INTEGRATED SANITARY MASTER PLAN
Municipal Class Environmental Assessment –
Volume 2 (Technical Memorandums)

May 2, 2024

Prepared for:
City of Kitchener

Prepared by:
Stantec Consulting Ltd.

Project Number: 165640334

Revision	Description	Author	Quality Check
Draft	Draft MP	HB / SM	JP / DE
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Technical Memo 5 – Design Criteria & Level of Service

City of Kitchener Integrated Sanitary Master Plan – Technical Memo #2: Hydraulic Analysis

Final

February 2, 2024

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Sign-off Sheet

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Glossary

ADWF	Average Dry Weather Flow
ASF	Average Sewage Flow
C of A	Certificate of Approval
DEM	Digital Elevation Model
DN	Disconnected Node
DNP	Disconnected Node & Pipe
DWF	Dry Weather Flow
EA	Environmental Assessment
ECA	Environmental Compliance Approval
EMP	Employment
FM	Flow Monitor
FS	Flow Split
GIS	Geographic Information Systems
GWI	Groundwater Infiltration
HGL	Hydraulic Grade Line

HP	High Point
ICI	Industrial-Commercial-Institutional (Land Use)
ICM	Integrated Catchment Modelling
I/I	Infiltration and Inflow
IPI	Inconsistent Profile Based on Inverts
ISAN-MP	Integrated Sanitary Master Plan
MH	Maintenance Hole
MDSI	Missing Downstream Invert
MDSN	Missing Downstream Node
MUSI	Missing Upstream Invert
MUSN	Missing Upstream Node
PAG	Pipe Above Ground
PLUM	Region of Waterloo’s Population and Land Use Model
PPJ	Parcel-People-Jobs Data
PS	Pumping Station
RDII	Rainfall-Derived Infiltration and Inflow
RES	Residential

RG	Rain Gauge
ROP	Regional Official Plan
SA	Area-Based Sanitary Subcatchment
SAN	Sanitary
SCADA	Supervisory Control and Data Acquisition
SP	Parcel-Based Sanitary Subcatchment
SPS	Sewage Pumping Station
SQL	Structured Query Language
TM	Technical Memorandum
WWF	Wet Weather Flow
WWTP	Wastewater Treatment Plant

1.0 INTRODUCTION

The City of Kitchener (City) has retained Stantec Consulting Ltd. (Stantec) to complete the Integrated Sanitary Master Plan (ISAN-MP). The purpose of the ISAN-MP is to develop an overall master plan to guide the future needs of the City with respect to growth development and infrastructure renewal to account for updated population and employment growth projections to the 2051 planning horizon, building on the work/studies previously completed and integrating available information from ongoing studies/programs. Following the Class Environmental Assessment (EA) Process, priority and strategic projects will be evaluated to continue to efficiently and effectively operate the system, implement best management practices (including growth tracking and digital innovation), and practice sustainable staging and funding of capital projects.

The following tasks will be carried out for the completion of the ISAN-MP, including a series of Technical Memoranda (TM) that will comprise the content of the final Master Plan document:

- Task 1: Background Data Review (TM#1)
- **Task 2: Hydraulic Analysis (TM#2)**
- Task 3: Sanitary Servicing Analysis (TM#3)
- Task 4: Capital Infrastructure Funding and Risk Analysis (TM#4)
- Task 5: Design Criteria, Level of Service & Sensitivity Analysis (TM#5)
- Task 6: Growth Management and Implementation Plan (TM#6)
- Task 7: Communications and Community Engagement
- Task 8: Sanitary Servicing Master Plan / Innovation Strategy

Task 2 involves the review, assessment, and re-development of the sanitary hydraulic model, which forms the basis of the collection system assessment. This TM#2 was broken out into four submissions to help facilitate information exchange and decision-making throughout the model development, as follows:

- TM2a: Model Assessment and Software Recommendation
- TM2b: Modelling Plan
- TM2c: Flow Monitoring, Model Calibration and Validation
- TM2d: Modeling Scenarios

This memo is TM#2 which compiles the four submissions into one final deliverable, and includes the following:

- a review of the City's modelling needs, a review of available software platforms, and outlines the recommended modelling platform that will meet the City's current and future needs;
- the modelling plan, which covers the general approach to specific model elements based on the available data (from TM#1) and assessment/software selection;
- a review of the flow monitoring and rainfall data collection and analysis, including a summary of the calibration process and results for dry weather flow (DWF) and wet weather flow (WWF) calibration; and,
- a summary of the proposed modelling scenarios for sanitary sewer system assessments under existing and future conditions, to be completed in Task 3.

1.1 OVERVIEW

The work of the preceding Technical Memoranda #1, #2a, #2b, and #2c come together to define the preferred approach for the Kitchener Integrated Sanitary Master Plan model update.

Through the development of TM#1, relevant background reports, GIS data, populations and land use, natural heritage data, GIS sewer network data, and flow monitoring and rain gauge data were reviewed and assessed for data gaps and quality. Pumping station data and statuses were also reviewed, revealing wet well and pump data for all existing pumping stations, and updated condition assessment reports (2020/2021) for 20 of the 25 stations. Notably, it was identified that the Bleams Sewage Pumping Station (SPS) recently underwent decommissioning, while the Old Mill SPS is currently being rebuilt (now the New Old Mill SPS), and the Nathalie SPS was reconstructed (in operation in early 2022). Since the submission of TM#1, two additional condition assessment reports were provided for the Bridgeport and Spring Valley Pumping Stations, which are both Regional pumping stations.

In TM#2a, a general overview of the existing hydraulic model was conducted, which was developed in InfoSWMM in 2011 and was later updated in 2019 using 2016 sewer flow monitoring data. The model data was compared to the provided GIS data and assessed for general completeness and validity. The following conclusions were made:

- There are over 230 pipes (1.8%) where unusual sewer depths or negative offsets were found, which affect the certainty of the sewer data;
- A total of 5 sewers have connectivity issues, including being unconnected to an outfall, both ends connected to the same node, or an invalid slope;
- There are over 600 MHs with incoming sewer inverts lower than the outgoing sewer invert (inconsistent profiles based on inverts), and 1,000 MHs with upstream sewer diameters greater

than downstream sewer diameters (inconsistent profiles based on diameters, potentially indicating incorrect diameters); and,

- Approximately 450 MHs with possible connectivity issues (isolated, or close to other nodes or pipes but not connected to them).

Also documented and discussed in TM#2a was the modelling software selection. Relevant programs were evaluated and ranked for suitability for the Kitchener Integrated Sanitary Master Plan model update. As concluded in TM#2a, InfoWorks ICM was proposed for use for the following reasons:

- The City already owns and maintains the program/licenses for stormwater modelling purposes;
- ICM has an excellent data management/auditing data structure (one database) and strong documentation and flagging system; and,
- Its robust features improve efficiency, including advanced query / geospatial / visualization tools, ArcGIS compatibility without requiring a GIS license, stable computational engine, advanced core computing options for improved processing speed, and, powerful data sharing through compact transportable databases.

The next TM, TM#2b, outlined the modelling plan for the ISAN-MP project regarding both model updates and calibration, which included discussions of the following:

- New infrastructure and developments integration;
- The detailed engineering validation error assessment and fixes applied to the original model network and new network elements added to the model;
- The methodology followed to implement fixes to the errors/warnings identified;
- Subcatchment delineation and parameter development;
- Pumping station updates; and,
- Boundary conditions.

The updated model was used in the calibration process outlined in TM#2c. TM#2c also documented the flow monitoring and rainfall data quality and review, the resulting DWF and WWF calibration fits, and the final metershed flow generation parameters. Based on the calibration, the sanitary system was found to have relatively low GWI and RDII contributions and reasonable per capita rates throughout. Metersheds with higher or lower than average rates were discussed. The model is considered calibrated and deemed appropriate for the upcoming system assessments.

Lastly, TM#2d outlined the proposed modelling scenarios to be completed as part of Task 3, for the purposes of assessing the sanitary sewer system responses under existing and future conditions and constraints. A total of 17 scenarios are recommended, capturing the Existing, Future 2031, and Future

2051 DWF, 5-year, 10-year and 25-year storm event system response, in addition to a Future 2051 Climate Change scenario, and four (4) critical failure scenarios.

2.0 EXISTING HYDRAULIC MODEL

2.1 GENERAL OVERVIEW

The City updated and calibrated their wastewater hydraulic InfoSWMM model in 2016 to conduct a capacity assessment under existing and future-build out conditions. Since that time, a detailed asset management plan for the Sanitary Utility was completed in 2019 for the City's sanitary infrastructure, which is desired to be incorporated into the hydraulic model for continuity and future connectivity to the asset database.

It is evident from the initial review that there have been some changes to specific asset IDs to replace the existing ones which are the basis of the current model. In addition, there have been modifications to the database since the original asset download used for the model which was cited in the 2019 Model Calibration Update Report (AECOM) circa May 2016. **Table 2-1** provides a summary of the model build characteristics included in the 2016 InfoSWMM model.

Table 2-1: 2016 InfoSWMM Model Build Characteristics

Model Elements	No. of Elements
Pipe	13,142
Junction	12,208
Pump	60
Wet Well	26
Rain Gauge	43 (Permanent:2; Temporary: 5; Virtual Rain Gauge:36)
Outfall	15

2.1.1 Modelled Sewers Review

The modelled sewer attributes from the existing InfoSWMM model were compared against the provided GIS database, including the asset ID, diameter, and invert elevations. The findings of the comparison included:

- 208 pipes (1.6%) were identified with asset ID differences where the sewers have the same upstream and downstream invert elevation and same construction year;
- 283 pipes (2.2%) with the same asset ID had upstream invert differences;
- 169 pipes (1.3%) with the same asset ID had downstream invert differences; and,
- 152 pipes (1.2%) with the same asset ID had different diameters.

Additionally, 1,129 sewers are present in the provided GIS database but not in the 2016 model. These new sewers were further reviewed prior to adding them to the model.

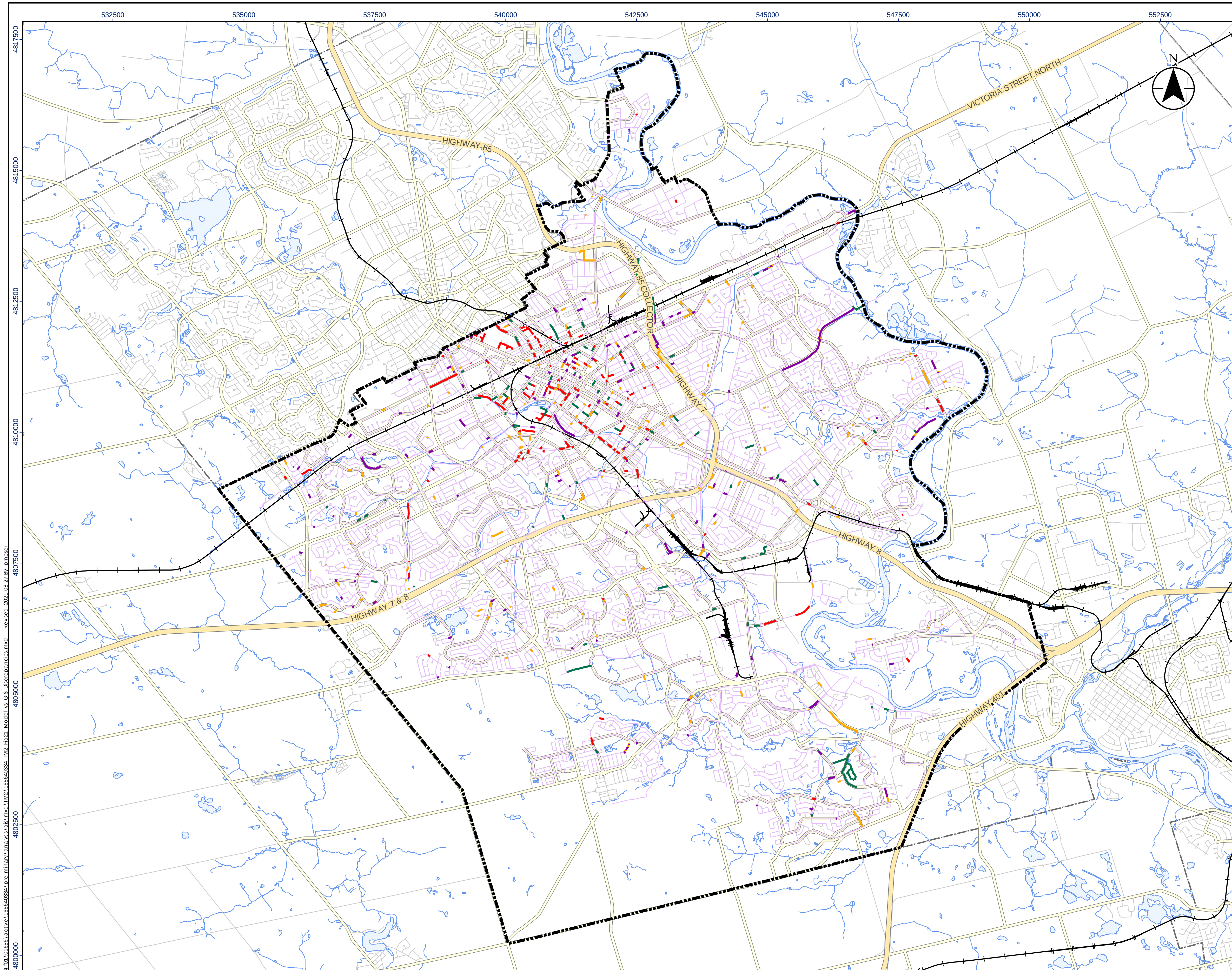
Figure 2.1 presents the pipe differences in the model compared to the new asset information by ID, while **Figure 2.2** shows the new sewers to be included in the model update.

2.1.1.1 Engineering Validation Review

To facilitate review and to evaluate the potential for model migration to the ICM platform, the InfoSWMM model was imported into InfoWorks through a new feature available in version 10.5. Both InfoSWMM and InfoWorks ICM have built-in Engineering Validation tools to assist with identifying data gaps/inconsistencies, missing or erroneous data, and pipe connectivity issues. Before converting to ICM, the validation tools in InfoSWMM were used to identify the following:

- 180 pipes (1.4%) with depth issues;
- 54 pipes (0.4%) with negative offsets (i.e. inconsistent profile);
- 3 pipes unconnected to an outfall;
- 1 pipe where the upstream and downstream node was the same; and,
- 1 pipe with an invalid slope.

There are over 230 pipes (1.8%) where unusual sewer depths or negative offsets were found, which affect the certainty of the sewers. A total of 5 sewers have connectivity issues, including being unconnected to an outfall, both ends connected to the same node, and an invalid slope.



Stantec

Legend

- City of Kitchener Boundary
- Sanitary Sewer
- D/S Invert Mismatch (169)
- Pipe Diameter Mismatch (151)
- U/S Invert Mismatch (283)
- Pipe Asset ID Mismatch (208)
- Expressway / Highway
- Major Road
- Minor Road
- Railway
- Watercourse
- Waterbody
- Municipal Boundary

0 2 4 km

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Notes

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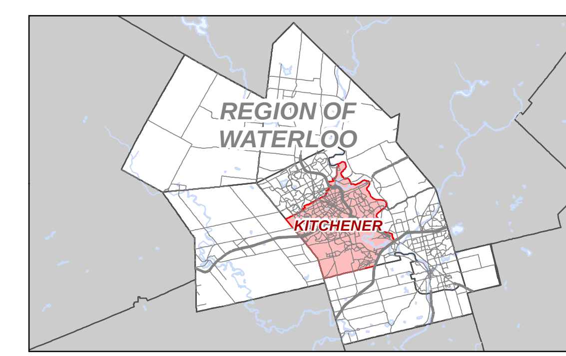


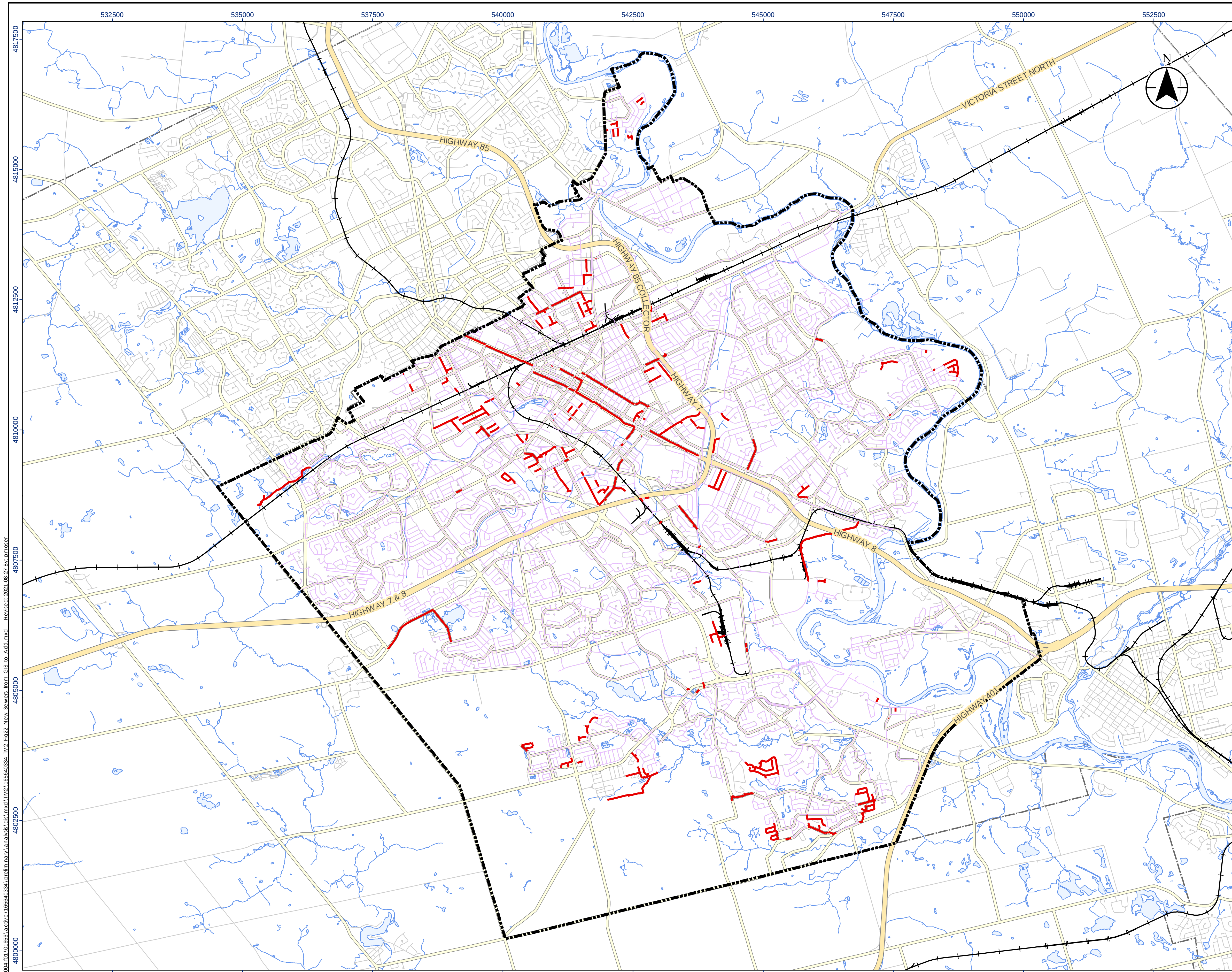
Project Location
City of
Kitchener

165640334 REVA
Prepared by PRM on 2021-08-27
Technical Review by FB on 2021-08-27

Client/Project
CITY OF KITCHENER
INTEGRATED SANITARY MASTER PLAN

Figure No.
2.1

Title
Model vs GIS Data Sewer Discrepancies



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Legend

- City of Kitchener Boundary
- New Pipe
- Sanitary Sewer
- Expressway / Highway
- Major Road
- Minor Road
- Railway
- Watercourse
- Waterbody
- Municipal Boundary

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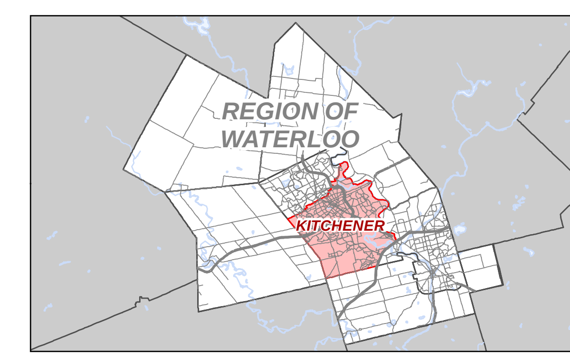

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Figure No.
2.2

Title
New Sewers from GIS Data to be Added

2.1.2 Modelled Maintenance Holes Review

The modelled maintenance hole (MH) attributes from the existing InfoSWMM model were also compared against the provided GIS database. The attributes compared included the asset ID, MH depth, and ground elevations. A total of 12,208 MHs are represented in the model. **Figure 2.3** presents the node differences in the model compared to the new asset information by ID, while **Figure 2.4** shows the new MHs to be included in the model update.

The findings of the comparison included:

- 96 MHs (0.8%) with asset ID differences where the locations, depths, and construction year are the same;
- 15 MHs (0.1%) where the asset IDs are the same but there are depth differences; and,
- 1,441 MHs (11.8%) where the asset IDs are the same but there are ground elevation differences.

Additionally, 964 MHs (7.9%) are present in the provided GIS database but not in the 2016 model. These new MHs will be further reviewed prior to adding them to the model.

2.1.2.1 Engineering Validation Review

The built-in Engineering Validation tools were also used to assess the MH databases. This initial process identified the following:

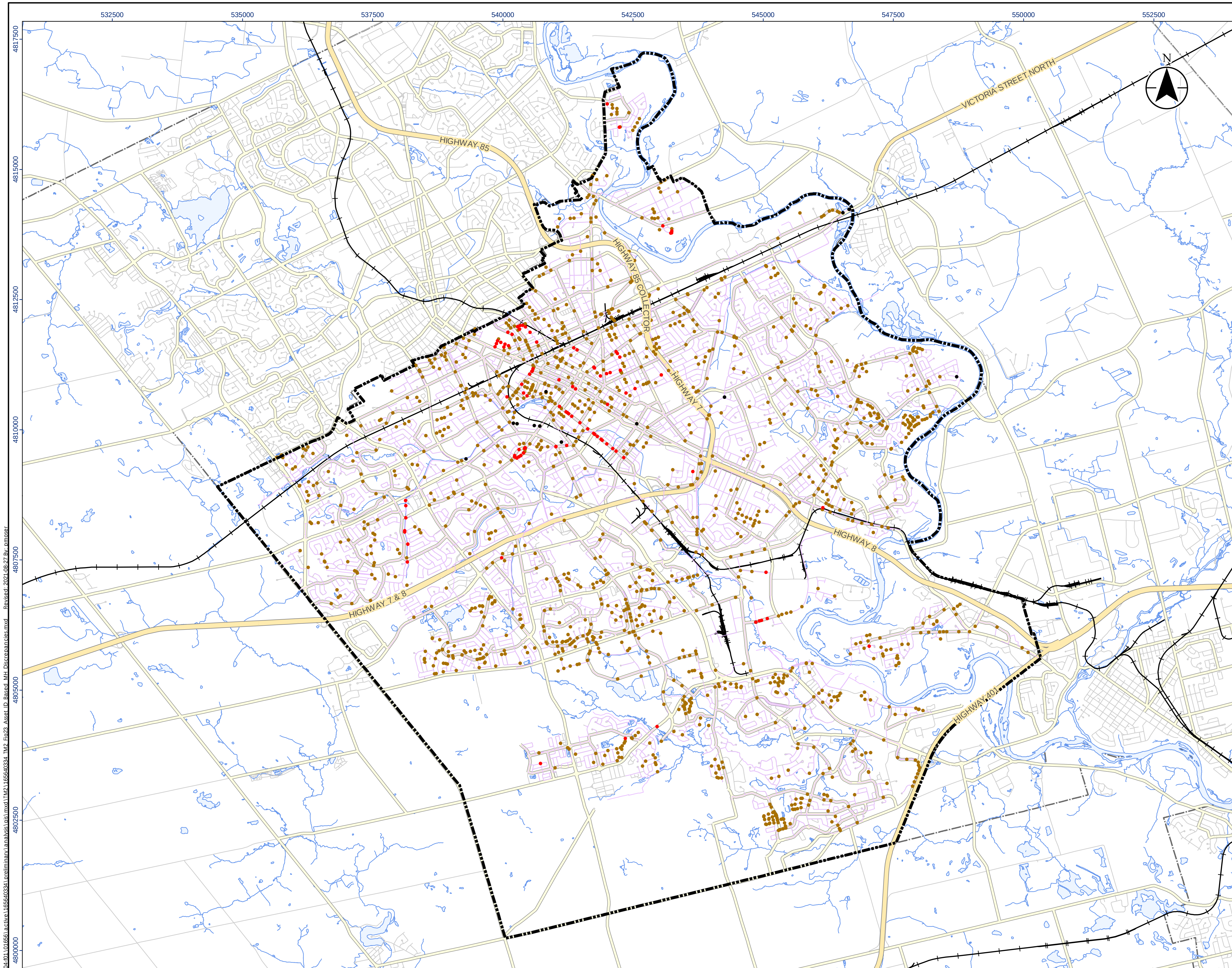
- 3,040 MHs (24.9%) have the outgoing sewer invert higher than the incoming; and,
- 452 MHs (3.7%) have unusual settings (irregular drops, MH floor above roof, orphan MH etc.).

2.1.3 Pump Station Review

The modelled pump station attributes were compared against those identified in the available pump station assessment reports. These assessment reports were obtained for many of the pump stations in 2012, while newer ones at 19 locations were updated in 2020/2021. Considering the last model update was completed in 2016, it is expected that updates based on the newer assessments are warranted. Refer to **Table 2-2** for the comparison.

2.2 SUMMARY

The City's existing InfoSWMM model is already established, but will require some updates based on new GIS asset data, corrections to remaining engineering validation errors, updated recalibration based on 2021 rainfall and flow monitoring, and newer pump station condition assessments / SCADA information.



Stantec

Legend

- City of Kitchener Boundary
- MH ID Mismatch (96)
- MH Depth Mismatch (15)
- MH Ground Elevation Mismatch (1441)
- Sanitary Sewer
- Expressway / Highway
- Major Road
- Minor Road
- Railway
- Watercourse
- Waterbody
- Municipal Boundary

0 2 4 km

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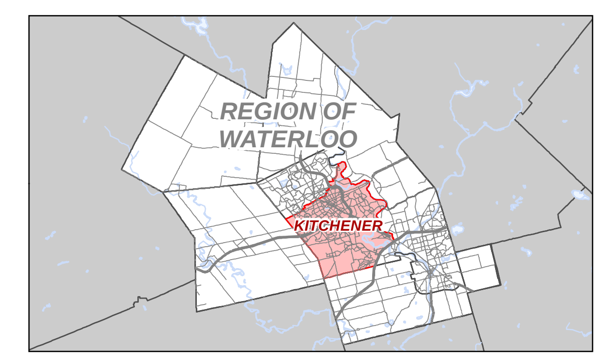

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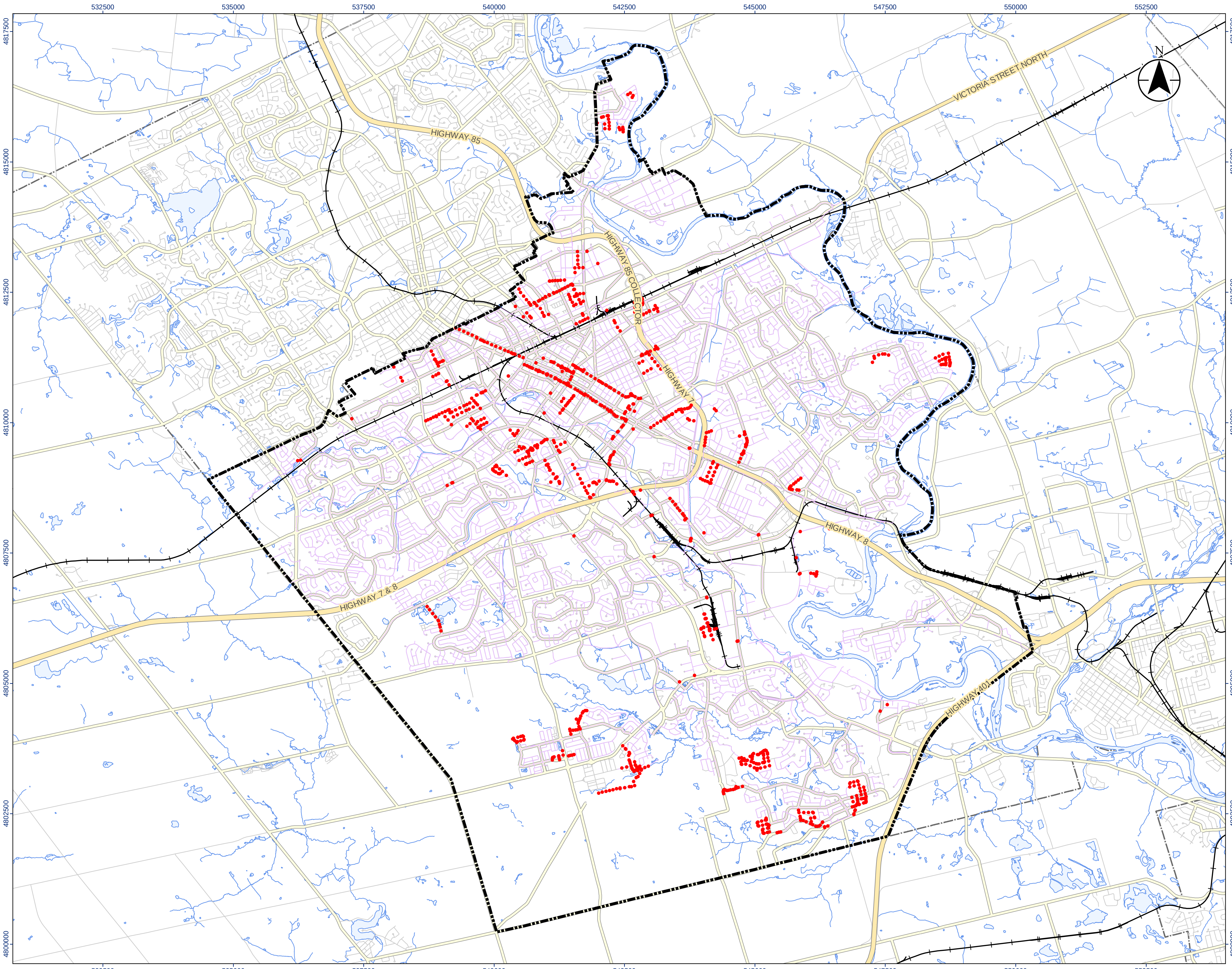
Figure No.
2.3

Title
Asset ID Based MH Discrepancies



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Legend

- City of Kitchener Boundary
- New MH (964)
- Sanitary Sewer
- Expressway / Highway
- Major Road
- Minor Road
- Railway
- Watercourse
- Waterbody
- Municipal Boundary

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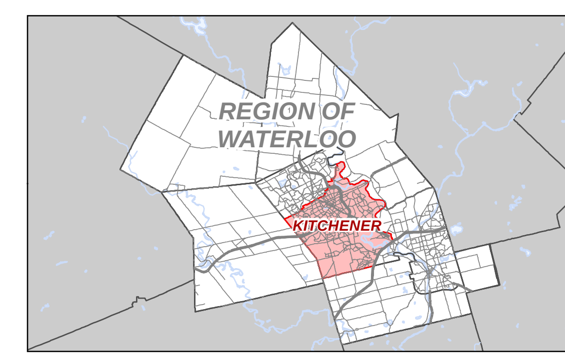

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Figure No.
2.4

Title
New MH Inclusion

Table 2-2: Pump Station Attribute Comparisons (Model vs. Assessment Reports)

Name		Wet Well		No. of Pumps	Pump 1		Pump 2		Pump 3		Pump Capacity (L/s)		
		Area (m2)	Depth (m)		Start (m)	Stop (m)	Start (m)	Stop (m)	Start (m)	Stop (m)	P1	P1+P2	P1 + P2 + P3
Bleams	Existing Model	4.5	10.0	2	2.00	0.60	2.20	0.60	-	-	24.3	33.4	-
	No recent Assessment available	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*
Manheim	Existing Model	4.5	6.7	3	0.70	0.45	0.90	0.45	1.10	0.45	1.2	2.4	3.5
	No recent Assessment available	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*
Stoke	Existing Model	23.4	9.1	3	1.44	1.00	1.60	1.00	1.70	1.00	192.7	257.5	293.9
	2020 Assessment	*17.7*	*9.4*	*2*	*1.60*	*1.00*	*1.60*	*0.93*	-	-	*126.5*	*186.8*	*-*
Patricia	Existing Model	7.5	4.2	2	1.20	0.55	1.30	0.55	-	-	23.4	37.6	-
	2021 Assessment	*7.5*	*4.0*	*2*	*0.75*	*0.30*	*0.75*	*0.60*	-	-	*9.4*	*33.7*	*-*
Moore	Existing Model	1.8	12.0	2	1.60	1.10	1.65	1.00	-	-	18.3	21.4	-
	2021 Assessment	*1.8*	*Not Provided*	*2*	*1.65*	*1.00*	*1.65*	*1.00*	*-*	*-*	*17.1*	*18.2*	*-*

Name		Wet Well		No. of Pumps	Pump 1		Pump 2		Pump 3		Pump Capacity (L/s)		
		Area (m2)	Depth (m)		Start (m)	Stop (m)	Start (m)	Stop (m)	Start (m)	Stop (m)	P1	P1+P2	P1 + P2 + P3
Oxford	Existing Model	3.1	7.3	2	1.50	0.95	1.55	0.95	-	-	46.2	48.8	-
	2020 Assessment	*3.1*	*7.6*	*2*	*1.50*	*0.90*	*1.50*	*0.90*	-	-	*35.7*	*43.5*	*-*
Falconridge	Existing Model	21.0	10.7	2	1.50	0.85	1.65	0.85	-	-	51.4	58.9	-
	2020 Assessment	*21.0*	*10.7*	*2*	*1.53*	*1.04*	*1.50*	*0.85*	-	-	*52.9*	*62.6*	*-*
Shirley (Originally Victoria)	Existing Model	33.0	8.3	2	2.50	1.50	2.75	1.50	-	-	242.0	313.0	-
	2021 Assessment	*32.9*	*4.8*	*2*	*2.00*	*1.47*	*2.05*	*1.60*	-	-	*165.6*	*242.0*	*-*
Breslau	Existing Model	7.1	13.9	2	1.00	0.30	1.25	0.30	-	-	61.0	102.0	-
	No Assessment available	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*
Carson	Existing Model	11.5	7.5	2	1.30	0.50	1.40	0.50	-	-	62.3	79.3	-
	2021 Assessment	*11.3*	*6.4*	*2*	*1.30*	*0.70*	*1.30*	*0.70*	-	-	*66.9*	*86.4*	-
Manchester	Existing Model	45.0	8.0	2	1.50	0.30	2.00	0.30	-	-	197.0	-	-
	2021 Assessment	36.6	5.2	2	-	-	-	-	-	-	-	-	-

Name		Wet Well		No. of Pumps	Pump 1		Pump 2		Pump 3		Pump Capacity (L/s)		
		Area (m2)	Depth (m)		Start (m)	Stop (m)	Start (m)	Stop (m)	Start (m)	Stop (m)	P1	P1+P2	P1 + P2 + P3
Otterbein	Existing Model	27.1	4.2	3	2.00	1.40	2.20	1.40	2.30	1.40	51.7	75.6	85.9
	2021 Assessment	*6.7*	*3.1*	*3*	*2.00*	*1.20*	*2.00*	*1.20*	*2.00*	*1.20*	*58.7*	*88.7*	*N/A*
Springmount	Existing Model	22.2	7.9	3	2.00	0.85	2.25	0.90	2.40	0.95	98.2	143.0	171.7
	2021 Assessment	*22.2*	*7.9*	*3*	*1.70*	*0.95*	*1.35*	*0.90*	*1.30*	*0.76*	*74.7*	*112.1*	*N/A*
Bancroft	Existing Model	4.5	6.6	2	1.00	0.50	1.20	0.50	-	-	6.5	6.9	-
	2020 Assessment	*4.5*	*6.6*	*2*	*1.00*	*0.50*	*1.00*	*0.50*	-	-	*6.0*	*6.4*	-
Apple Tree	Existing Model	10.2	8.5	3	1.75	0.75	1.95	0.85	2.15	0.95	32.3	44.4	55.2
	2020 Assessment	*10.2*	*8.5*	*3*	*1.75*	*0.85*	*1.75*	*0.75*	*1.75*	*0.75*	*27.8*	*40.8*	*N/A*
Woolner (Originally Zeller)	Existing Model	103.3	9.1	3	2.25	1.85	2.35	1.85	2.85	1.85	47.7	69.5	88.5
	2021 Assessment	*14.4*	*3.6*	*3*	*2.25*	*2.00*	*2.25*	*1.85*	*2.25*	*1.85*	*96.4*	*143.9*	*N/A*
Chandos	Existing Model	4.5	11.2	2	1.40	0.50	1.50	0.50	-	-	26.1	31.6	-
	2021 Assessment	*4.5*	*11.3*	*2*	*1.40*	*1.25*	*1.40*	*0.40*	-	-	*26.0*	*31.1*	*-*

Name		Wet Well		No. of Pumps	Pump 1		Pump 2		Pump 3		Pump Capacity (L/s)		
		Area (m2)	Depth (m)		Start (m)	Stop (m)	Start (m)	Stop (m)	Start (m)	Stop (m)	P1	P1+P2	P1 + P2 + P3
King St (Originally Freeport)	Existing Model	12.4	4.2	2	2.85	1.40	2.95	1.45	-	-	-	-	-
	2021 Assessment	*57.0*	*5.9*	*3*	*2.50*	*1.93*	*2.50*	*1.92*	*2.41*	*1.94*	*159.3*	*N/A*	*N/A*
River Birch	Existing Model	4.5	5.3	2	1.70	0.60	1.90	0.60	-	-	25.3	27.1	-
	2021 Assessment	*4.5*	*7.6*	*2*	*1.40*	*0.60*	*1.55*	*0.85*	-	-	*23.4*	*28.7*	-
Pioneer Tower	Existing Model	20.7	6.7	2	1.50	0.75	1.60	0.80	-	-	73.1	101.2	-
	2021 Assessment	*20.7*	*6.7*	*2*	*1.50*	*1.00*	*1.50*	*1.30*			*62.0*	*88.7*	
Old Mill	Existing Model	7.8	5.6	2	1.75	1.10	1.85	1.10	-	-	21.9	40.0	-
	No Assessment available	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*
Homer Watson	Existing Model	36.0	9.2	2	1.40	0.85	1.50	0.85	-	-	-	-	-
	2021 Assessment	*36.0*	*3.1*	*3*	*1.40*	*0.85*	*1.40*	*0.85*	*1.4*	*0.85*	*140.5*	*272.9*	*N/A*
Conestoga (Originally New Dundee)	Existing Model	10.2	6.8	2	1.10	0.60	1.20	0.60	-	-	-	-	-
	2021 Assessment	*10.2*	*6.9*	*2*	*1.10*	*0.60*	*1.10*	*0.75*	-	-	*40.4*	*50.6*	-

Name		Wet Well		No. of Pumps	Pump 1		Pump 2		Pump 3		Pump Capacity (L/s)		
		Area (m2)	Depth (m)		Start (m)	Stop (m)	Start (m)	Stop (m)	Start (m)	Stop (m)	P1	P1+P2	P1 + P2 + P3
New Dundee (Originally Doon South)	Existing Model	21.7	3.6	2	1.60	1.00	2.20	1.00	-	-	40.0	-	-
	2021 Assessment	*30.4*	*10.8*	*2*	-	-	-	-	-	-	-	-	-
Spring Valley	Existing Model	50.4	6.8	3	2.90	1.30	3.05	1.30	3.20	1.30	149.6	207.7	325.7
	No Assessment available	-	-	-	-	-	-	-	-	-	-	-	-
Bridgeport	Existing Model	39.0	5.7	3	0.75	0.45	0.95	0.65	1.15	0.85	81.3	70.0	104.0
	No Assessment available	-	-	-	-	-	-	-	-	-	-	-	-

3.0 MODEL PLATFORM REVIEW

The City of Kitchener previously undertook a software selection review as part of the 2009 Systemwide Capacity Study, which resulted in the selection of the InfoSWMM platform. Since that time, the City has also invested in the InfoWorks ICM platform for the stormwater utility. As part of the Master Plan update, the model platform is being re-reviewed to confirm the current selection or to recommend migration to another platform.

The selected model software and development strategy is dependent on several factors. In some applications, additional modeling functionality is required to efficiently complete assessments and summarize information, warranting a larger investment in software and resources to complete and maintain datasets. In other cases, a high-level analysis is adequate, allowing organizations to reduce the required resources to develop and maintain the model. Potential applications for sanitary hydraulic models can be classified into four main categories, and include several specific uses as follows:

1. Growth Planning
    - Master Planning/Master Servicing Capacity Assessments
    - Development Reviews
    - Capacity Assurance and Impact Assessment
2. Program Management
    - Asset Management (Capital Program Forecasting/Renewal)
    - Wet Weather Flow Management (Flooding, Overflows, Regulatory Compliance)
    - Infiltration and Inflow (Quantification, Rehabilitation)
3. Functional and Detailed Design
    - Pipe/Storage Sizing (Dimensions, Alignments)
    - Pump Station Design (Wet Well, Pump Operation, Forcemain Sizing)
4. Operational Review and Support
    - Level of Service Assessments
    - Emergency Planning and Risk Assessment (Climate Change, Flood Forecasting)

Depending on the intended use, a high level of software functionality (e.g., time-varying vs. static), infrastructure data, or loading data may be warranted to ensure the model can be used to complete the assigned task accurately and efficiently. As such, the intended use dictates the overall collection system model approach. In the case of Kitchener, the model use has primarily focused on Growth Planning and Functional Design support, to date; however, there is an interest to potentially expand its use beyond these functions.

3.1 STATE OF INDUSTRY PRACTICES

To inform the recommendation, a review of the state of industry practice was conducted. **Figure 3.1** provides an overview of the sanitary hydraulic model softwares in use in the surrounding municipalities. Three programs dominate the local markets: InfoWorks ICM, PCSWMM, and InfoSWMM.

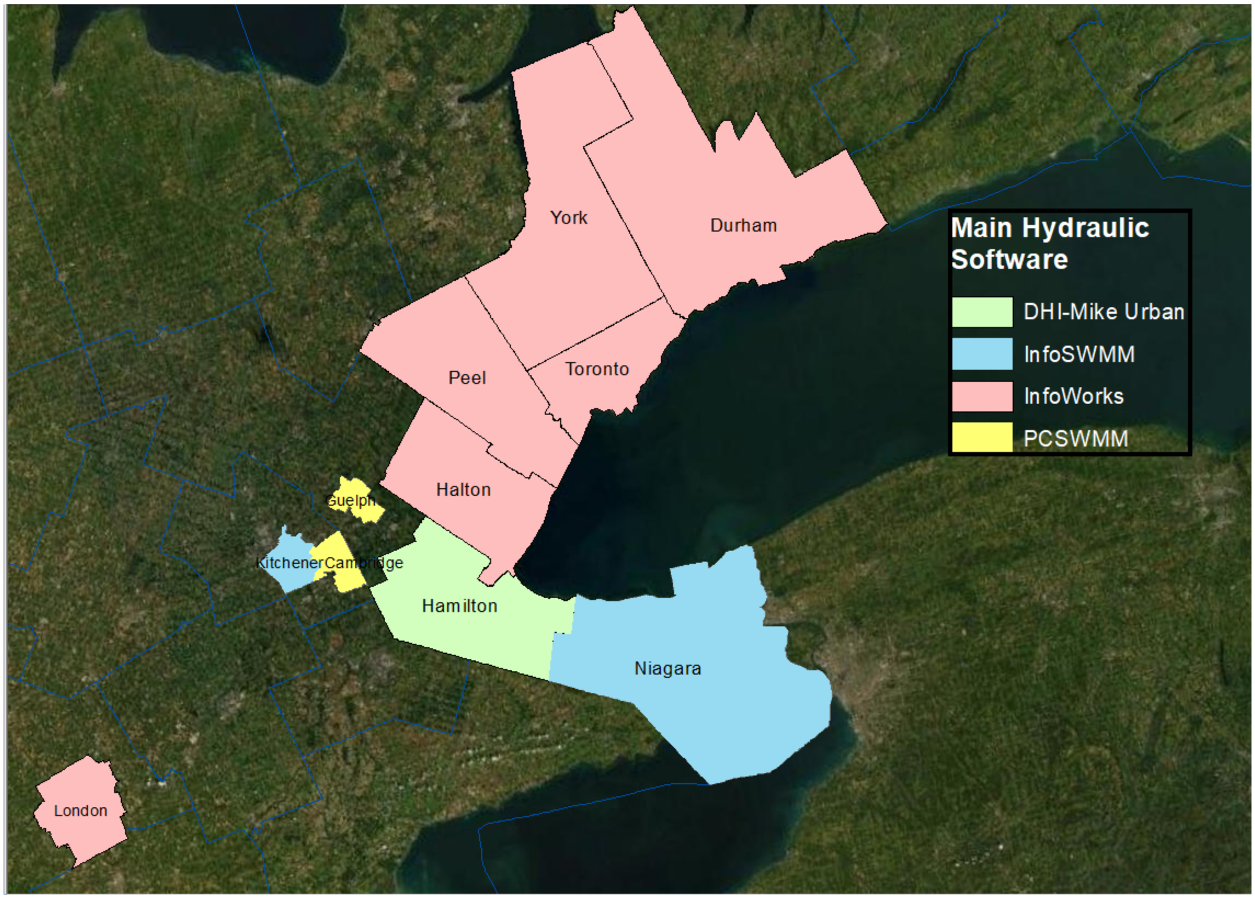


Figure 3.1: Local Municipal Sanitary Software Use

Each municipality's use of the software varies depending on their unique circumstances in terms of model needs. Within southern Ontario, there is a variety of model scale and usage, with InfoWorks ICM dominating the major municipalities in the Greater Toronto Area (GTA).

3.2 PLATFORM EVALUATION

Several sanitary collection system software options commonly used in the industry were identified and vendors contacted to obtain the product information necessary to evaluate the software with respect to the City's needs (see **Table 3-1**).

Table 3-1: Software Vendor Contact Details

Vendor	Software	Contact
Environmental Protection Agency (EPA)	EPASWMM 5	Website: http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/
Computational Hydraulics Int. (CHI)	PCSWMM	Meghan Korman Phone: 519-767-0197 ext. 1001 Email: meghan@chiwater.com
DHI	MIKE URBAN/MOUSE	Patrick Delaney Phone: 519 650 4545 Email: pad@dhigroup.com
Bentley	SewerGEMS	Bruce Thomas Phone: 403-221-9370 ext. 817814 Email: Bruce.Thomas@bentley.com
Innovyze	InfoWorks ICM InfoSWMM XPSWMM	Christopher W. Baxter Phone: 604-639-7167 Email: cwbaxter@watsyn.ca

3.2.1 Short-List Screening

The short-list screening was based on the following criteria:

- Ability to conduct dynamic and static modeling as per City's needs;
- Prevalence of software use locally, incorporating municipal experience;
- Adequacy of vendor software support; and,
- Potential for future regional and inter-municipal coordination.

5. All vendors provide support, except EPASWMM, and thus this option was screened out. SewerGEMS and MIKE URBAN are not used extensively locally, with only the City of Hamilton using MIKE URBAN. Conversely, PCSWMM, InfoWorks ICM and InfoSWMM are widely used locally. These three (3) packages thus form the short-list for further consideration.

Short-list screening results are provided in **Table 3-2**.

Table 3-2: Software Short-Listing

Software	Local Municipal Use	Vendor Support	Other	Carry Forward
EPASWMM 5	Low	None	Software engine basis for all SWMM-based models	No
PCSWMM	Moderate	Yes	Local provider (Guelph); used by Cambridge and Guelph	Yes
MIKE URBAN/ MOUSE	Low	Yes	Limited use in Ontario	No
SewerGEMS	Low	Yes	Limited use in Ontario	No
InfoWorks ICM	High	Yes	Used extensively in GTA	Yes
InfoSWMM	High	Yes	Used by Kitchener	Yes

3.2.2 Evaluation Criteria

Criteria are provided in **Table 3-3** which were reviewed while assessing the short-listed software options.

Table 3-3: Evaluation Criteria

Criteria	Description
Hardware Requirements	Hardware requirements to install and run the model, including additional software or platforms that must be run in conjunction with the modeling software, if any.
Graphics Capabilities	Ability to graphically display input and output information, as well as manipulate graphics to suit the needs for specific analyses.
Data Review and Validation	Tools and options to review and validate input data to identify potential data gaps or errors.
Vendor/Model Support	Availability, extent and speed of vendor, hard copy or on-line support.
Simulation Time and Stability	Ability for the model to complete simulations efficiently and without simulation errors (provided the data input is correct).
Hydrology/Flow Generation	Methodology and flexibility for generating inflow/infiltration inputs.
Calibration Capabilities	Available tools and methodology for calibrating the model.
Scenario Management	Ability to create and manage multiple modeling scenarios and track modifications or links between scenarios.
GIS Integration/Data Exchange	Ability to exchange input/output information, manipulate layers, and create graphics.
Database Management	Ability to track/document changes, manipulate information, and reporting capabilities.
Ease of Use/Need for Training	Complexity of the tool and degree of training requirements.
Inter-Municipal Coordination	Use of a common software can aid in data transfer between models/municipalities.
Capital Cost	Relative cost of initial software purchase.

Criteria	Description
Maintenance Cost	Relative cost of annual maintenance.
Training Costs	Relative cost of on-site vendor-provided training.

3.2.3 Evaluation of Short-listed Software

The following summarizes the key findings and comparisons for the 3 softwares considered:

- **Hardware Requirements**: Each requires approximately equivalent computer speed, memory, graphics capabilities. PCSWMM generally requires less physical memory
- **Graphics Capabilities**: All have the same basic graphical user interface capabilities, allowing graphs, tables, hydraulic profiles, and GIS-integrated mapping. InfoWorks ICM has the added built-in capability of dynamic 3-dimensional imagery of the collection system and the ability to interact between multiple window views simultaneously (tables, map, profile plots) and is considered superior.
- **Data Review and Validation**: All platforms have built-in tools for assessing data input validation (tracing tools, engineering validation queries, etc.). InfoWorks SQL query toolset and 'selection set' saving capabilities within the model environment, along with the individual data field flagging function, are considered superior.
- **Vendor/Model Support**: Based on experience utilizing the support systems of each provider, a preference was given to the smaller, local firm of CHI who have put a strong emphasis on client support, including proactively responding to recommendations for model enhancements. Innovyze is based out of the United States with no local support office; however, their global presence does offer a larger pool of support staff across multiple time zones. Software documentation for all is primarily through an in-model help dialogue that is updated with each version release. Innovyze also hosts several free Webinars with their technical staff, publish online blogs and social media posts with supporting technical information.
- **Simulation Time and Stability**: All models generally operate with decent run times depending on the complexity of the network. User experience indicates some instabilities and performance issues with InfoSWMM on larger networks, with episodes of model 'crashes'. Although based on the same underlying SWMM5 engine, PCSWMM experiences have been more favorable than InfoSWMM. InfoWorks ICM is considered superior due to its proprietary computational engine that is reportedly more robust with limited stability issues, which our experience confirms.
- **Hydrology/Flow Generation**: All of the short-listed software equally provides flexibility for inputting and computing hydrologic response and load input. Both PCSWMM and InfoSWMM offer dry weather flow allocation routines, however only PCSWMM includes this in the base software. InfoWorks allows for a specific separation of residential and employment (called "Trade") inputs, however the trade flow input is limited requiring external processing of the values before input.

- **Calibration Capabilities**: All three programs include graphical functions for conducting model calibrations, including comparative graphs with simulated vs. observed datasets. The InfoWorks ICM tools are robust, provide direct quantification summaries, and is easily saved/ viewed within the model environment. InfoSWMM is similar with a slightly more cumbersome interface and external data file saving requirement, however at extra cost there is an additional Calibrator tool which uses genetic algorithms. PCSWMM also has a genetic algorithm-based sensitivity, calibration and error analysis tool as part of their base product, which also ties in a parameter uncertainty and confidence tracking tool.

- **Scenario Management**: All software have a dedicated scenario management functionality, whereby combinations of various input data sets and simulation options can be easily selected and results compared. InfoWorks ICM has a fundamentally different database structure which stores all network data together thus enabling more robust file management and internal documentation of scenarios, without the risk of disconnection from model folder files.

- **GIS Integration/Data Exchange**: All platforms offer a completely integrated GIS interface. In the case of InfoSWMM, this version sits as an ESRI ArcGIS extension thereby requiring a separate license. Both InfoWorks ICM and PCSWMM are stand-alone GIS interfaces, with both having the ability to connect to enterprise GIS systems. InfoWorks has the ability to use an ArcGIS license for improved integration and use of geodatabases. InfoWorks and PCSWMM offer greater import functionality and analytical tools for manipulating spatial data, with PCSWMM providing a few more advanced topological operations (intersections, joining, area-weighting, buffering).

- **Database Management**: The structure of InfoWorks ICM is a relational database, housing all data in a master database allowing for controlled management of files, data documentation and auditing, and user access rights. Both PCSWMM and InfoSWMM save in an open structure with less control of file integrity on a common network. While each have decent data structures, PCSWMM has a better file management interface. InfoWorks by far has the superior data management structure with the one-source database and built-in auditing mechanisms such as date/user stamps and multiple documentation fields.

- **Ease of Use/Need for Training**: Inherently, all three programs will require some level of training for ultimate end-users. Ease of use is subjective and user-dependent; however, InfoWorks reportedly has a larger training need due to its unique data structure, but there are a variety of training materials available on-line and a comprehensive help menu embedded in the software that updates each release.

- **Inter-Municipal Coordination:** Within southern Ontario, there is a variety of model scales and usage, with InfoWorks ICM dominating the major municipalities in the Greater Toronto Area (GTA). While other municipalities could change their selected software at any time, the use of a common software will likely aid in any data transfer needed. Additionally, frequency of use in nearby areas can imply program quality.

- **Relative Capital Cost**: The InfoWorks platform has the most expensive up-front capital cost. PCSWMM is subscription-based therefore only requiring the annual subscription fee (covered under maintenance cost). However, if an enterprise license was required for PCSWMM, it would still be the most economical up-front cost depending on number of users.
- **Relative Maintenance Cost**: Each provider requires an annual maintenance fee to cover model updates and user support. InfoWorks ICM is the most expensive, followed by InfoSWMM, and as mentioned PCSWMM is the most economical with only an annual subscription cost.
- **Relative Training Cost**: In a similar vein, InfoWorks and InfoSWMM by Innovyze has more expensive training, while PCSWMM located in nearby Guelph, is the most economical.

The software specific descriptions are attached to this document as **Appendix A**.

3.3 RECOMMENDED SOFTWARE

Based on a review of the preceding criteria, it is recommended that the City migrate the existing sanitary model to the InfoWorks ICM software. This recommendation considers that the City already owns and maintains the InfoWorks ICM product which is considered superior to those short listed in many ways:

- Excellent data management / auditing data structure (one database) and strong documentation / flagging;
- Robust features including advanced query/geospatial/visualization tools;
- Does not require ArcGIS license (but is more powerful with ArcGIS v10.7 or earlier);
- Stable computational engine, advanced core computing options for improved processing speed; and,
- Powerful data sharing through compact transportable databases.

Additionally, this recommendation to abandon the existing InfoSWMM license will reduce the annual maintenance fees with no cost to transition to ICM. Migrating to InfoWorks also allows alignment with the Stormwater Utility and provides a common asset/model management process.

4.0 MODELLING PLAN

4.1 MODEL COMPONENTS

The following subsections outline the specific model components, existing methodology used to model them, and the proposed ISAN-MP approach.

4.1.1 Original Pipe Network

TM#1 and **Section 2.0** above provide a high-level review of the data gaps associated with the physical pipe network. To facilitate further reviews and based on the software selection, the network was converted from InfoSWMM into InfoWorks ICM to perform additional engineering validation checks and utilize the flagging and tagging (user text fields) features within ICM. While there are relatively few gaps in the model network data, the engineering validation exercise revealed several issues associated with pipe profile continuity and erroneous values. The ICM environment has built-in checks that prevent the model from 'initializing'; a process by which the network is 'wetted' in advance of performing hydraulic calculations to reveal potential instabilities or input errors. The converted model revealed over 600 profile continuity inconsistencies, resulting primarily from reversed pipe direction and invert input error (typos). **Appendix B** presents some sample profile issues, including dead-end pipes, inconsistent profiles, and pipes above the ground level.

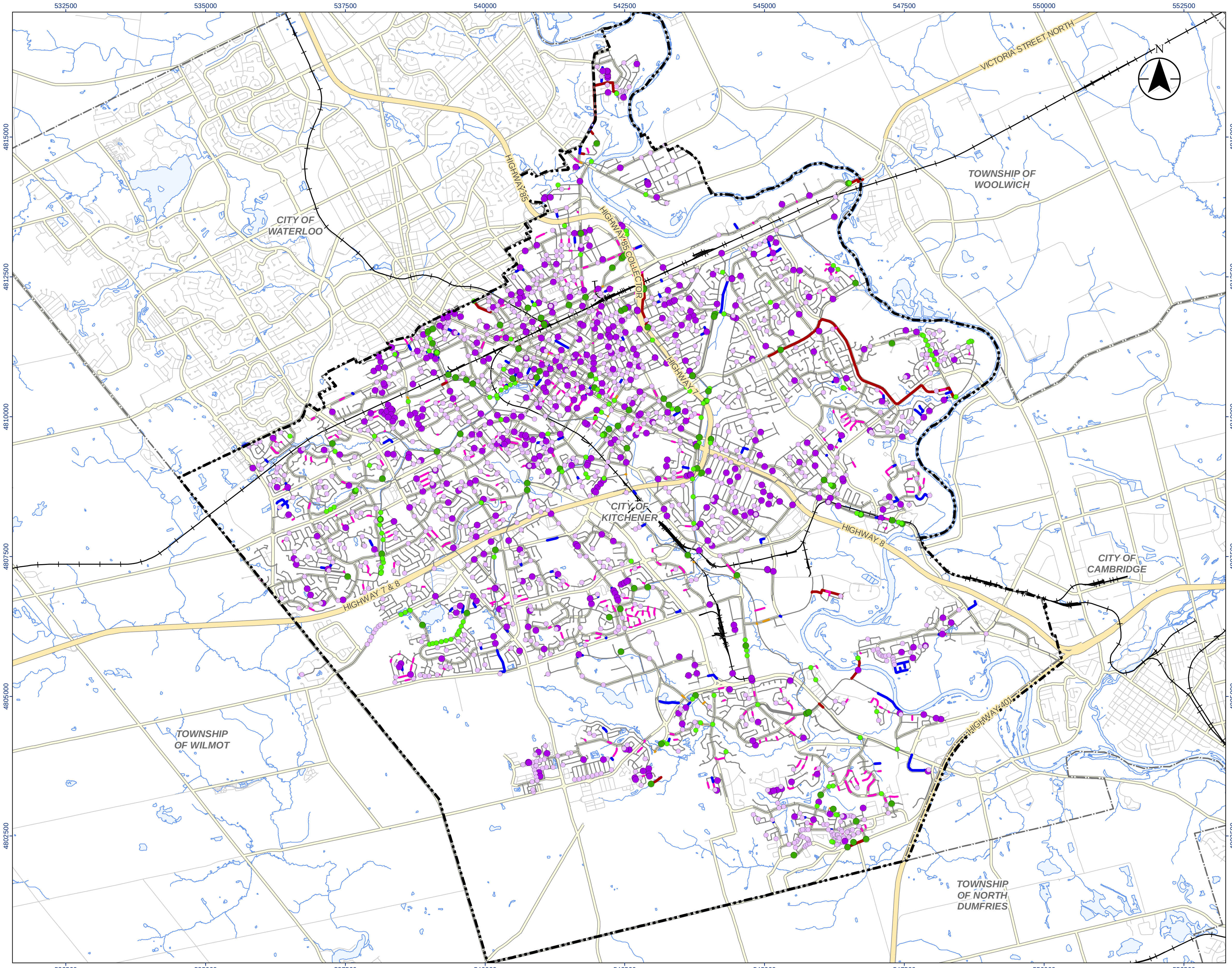
Given the challenges in the model network set-up, a series of data inferences were required to improve the model stability and ability to generate reliable flow and level results. The following sub-sections outline the actions that were therefore undertaken to resolve the necessary issues, in order.

4.1.1.1 Engineering Validation Error Assessment

Using built-in tools and custom-developed SQLs, a series of engineering validation errors are flagged and tagged. Some errors will not require fixes, but rather offer a warning regarding the confidence and quality of the data.

"Focus areas" were established within the model to help quantify the significance of the errors found. Focus areas include hydraulically significant system features, such as trunk sewers, pumping stations, newly constructed areas, and, the downstream infrastructure that is relevant to each focus areas' operation.

Table 4-1 presents the list of engineering validation errors identified, their severity, and the representative error code/tag applied in the model. It also presents the quantity of each error identified within the original model network; in focus and non-focus areas. The Engineering Validation flag ("EV") is applied to all identified errors. **Figure 4.1** presents the extent of errors identified in the existing model, and outlines the suggested focus areas.



Stantec

Legend

- City of Kitchener Boundary
- Original Model Sanitary Pipe Network
- Expressway / Highway
- Major Road
- Minor Road
- Railway
- Watercourse
- Waterbody
- Municipal Boundary

Focus Area Nodes with Errors
- Severity: Error
- Severity: Warning

Non-Focus Area Nodes with Errors
- Severity: Error
- Severity: Warning

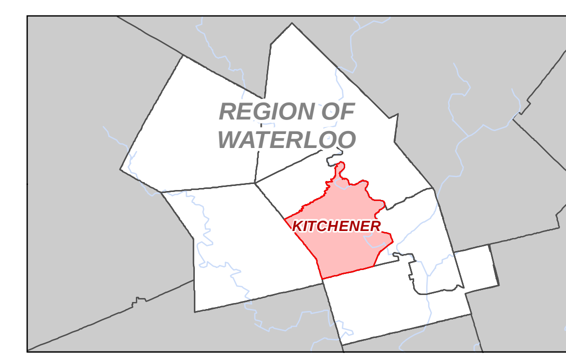
Non-Focus Area Links with Errors
- Severity: Error
- Severity: Warning

Focus Area Links with Errors
- Severity: Error
- Severity: Warning

0 2 4 km

1:70,000 (At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2021.
3. Contains information licensed under the Open Government Licence - The Corporation of the City of Kitchener, 2021.



Project Location
City of Kitchener

165640334 REVA
Prepared by EH on 2021-11-19
Technical Review by AL on 2021-11-19

Client/Project
CITY OF KITCHENER
INTEGRATED SANITARY MASTER PLAN

Figure No.
4-1

Title
Original Network Focus Area & Non-Focus Area Errors

V:\01656\active\165640334\preliminary\analysis\gis\mxd\TM2b\165640334_TM2b_Fig2-1_OG_Network_Focus_NonFocus_Errors.mxd Revised: 2021-11-19 By: vbassan

Table 4-1: Engineering Validation Errors

Error	Description	Applied To	Error Severity	Error Severity Rationale	Error Code	Focus Area		Non-Focus Area	
						Quantity of Errors	% Model Elements w/ Error	Quantity of Errors	% Model Elements w/ Error
Adverse Slope	Negative sloped pipe	Links	Warning	May be valid; however, could be indicative of incorrect inverts or a reversed pipe.	AS	1	0.0%	2	0.0%
Bifurcation Node - Flow Split	Flow split (2+ outgoing pipes)	Nodes	Warning	Helps to identify where flow splits may affect the contributing drainage areas used in calibration.	BNFS	61	0.5%	113	0.9%
Bifurcation Node - High Point	System high point w/ 2+ outgoing pipes	Nodes	Warning	Helps to identify where backwater over high points may affect the contributing drainage areas used in calibration.	BNHP	62	0.5%	723	5.9%
Isolated Node	Orphan node (not connected)	Nodes	Error	Node should either be removed if irrelevant, or connectivity issues fixed to integrate into system.	DN	0	0.0%	1	0.0%
Partially Connected Network	Connectivity issues, no outfall	Links	Error	Disconnected system should either be removed if irrelevant, or connectivity issues fixed to integrate into system.	DNP	3	0.0%	10	0.1%
Flat Slope	Pipe w/ 0% slope	Links	Warning	May be valid; however, may result in capacity constraints.	FS	6	0.0%	0	0.0%
Inconsistent Profile based on Diameter	Downstream diameter < upstream diameter	Node	Warning	May be valid; however, could indicate that surrounding diameter(s) may be incorrect.	IPD	115	0.9%	438	3.6%
Inconsistent Profile based on Inverts	Downstream invert > upstream invert	Node	Error	Typically not valid and indicates surrounding invert(s) are incorrect.	IPI	93	0.8%	509	4.2%

Error	Description	Applied To	Error Severity	Error Severity Rationale	Error Code	Focus Area		Non-Focus Area	
						Quantity of Errors	% Model Elements w/ Error	Quantity of Errors	% Model Elements w/ Error
Missing Diameter	Diameter = 0	Links	Error	Pipe diameter must be inputted.	MD	0	0.0%	0	0.0%
Missing Downstream Invert	Downstream invert = 0	Links	Error	Pipe inverts must be inputted.	MDSI	5	0.0%	0	0.0%
Missing Downstream Node	Connectivity issue, no downstream node	Links	Error	Connectivity must be provided; all pipes must have an upstream and downstream node.	MDSN	0	0.0%	0	0.0%
Missing Ground Elevation	Ground elevation = 0	Nodes	Error	Node ground elevations must be inputted.	MGE	2	0.0%	0	0.0%
Missing Pump	Existing pump not modelled	Pumps	Error	Pumps must be properly accounted for in the model, if considered hydraulically significant. Note that pump modelling can sometimes be simplified, but the station's capacity should be properly represented.	MPMP	0	0.0%	0	0.0%
Missing Pump On/Off	Pump missing set points	Pumps	Error	Pumps must be properly accounted for in the model, if considered hydraulically significant. Note that pump modelling can sometimes be simplified, but the station's capacity should be properly represented.	MPMP-ON-OFF	0	0.0%	0	0.0%

Error	Description	Applied To	Error Severity	Error Severity Rationale	Error Code	Focus Area		Non-Focus Area	
						Quantity of Errors	% Model Elements w/ Error	Quantity of Errors	% Model Elements w/ Error
Missing Pump Discharge Rate	Pump missing discharge rate or head-discharge curve	Pumps	Error	Pumps must be properly accounted for in the model, if considered hydraulically significant. Note that pump modelling can sometimes be simplified, but the station's capacity should be properly represented.	MP-Q	0	0.0%	0	0.0%
Missing Upstream Invert	Upstream invert = 0	Links	Error	Pipe inverts must be inputted.	MUSI	6	0.0%	0	0.0%
Missing Upstream Node	Connectivity issue, no downstream node	Links	Error	Connectivity must be provided; all pipes must have an upstream and downstream node.	MUSN	0	0.0%	1	0.0%
Pipe Above Ground	Pipe obvert (and possibly invert) above ground elevation	Links	Error	Ground levels and/or pipe inverts are incorrect and must be adjusted.	PAG	50	0.4%	205	1.6%
Steep Slope	Pipe slope > 5%	Links	Warning	May be valid; however, may result in model instabilities.	SS	44	0.3%	487	3.7%

4.1.1.2 Engineering Validation Fixes

The following process was used to resolve the issues identified from the previous error assessment. Errors with only warning-level severity do not require adjustments at this time. These locations can be reviewed if necessary during the calibration/solutions stages.

- Complete the connectivity in areas where isolated nodes (DN), partially connected networks (DNP), or missing upstream or downstream nodes (MUSN/MDSN) are identified.
- Use LiDAR data to compare existing model node rim elevations to the DEM elevations and assess the variance. For MHs identified with a variance greater than 0.3 m, the original ground level can be maintained, but flagged accordingly (Check flag, "CK"). This provides context later when reviewing system results. If the original ground level is zero, or lower than the connected pipe obverts and/or inverts, then a Pipe Above Ground (PAG) error is indicated and can be fixed by applying the DEM value as the ground level. If this does not resolve the PAG error, it is indicative that the inverts of the pipe are instead the issue and should be adjusted.
- For all invert or diameter-based errors, inferences are used when possible. For instance, they are used to resolve inconsistent profile errors based on inverts (IPI), or missing upstream or downstream inverts (MUSI/MDSI), based on the following hierarchy. A similar approach can be applied for missing pipe diameters.
    - Infer based on upstream or downstream pipe inverts, where surrounding profile continuity is acceptable. Establish an obvert-to-obvert connection, or if not plausible, an invert-to-invert connection.
    - Infer based on surrounding pipe slopes. Equivalent or similar slopes as the upstream or downstream system can be used, if plausible (i.e., not excessively flat or steep, and cultivates a reasonable overall profile).
- If the upstream and/or downstream system information is also inconsistent and little confidence in the surrounding area is present, assumptions are made to resolve the remaining errors based on relevant design standards (minimum slopes or diameters, cover requirements, etc.).
- If, during calibration it is observed that previous inferences or assumptions may be resulting in variations between the modelled and observed data, relevant infrastructure underwent drawing review. Drawing review was be prioritized for focus areas over non-focus areas, where needed.

4.1.2 New and Upgraded Pipe Infrastructure

The original network model was last updated in 2016 and thus, does not include newly constructed infrastructure or infrastructure upgrades that were ongoing or completed since that time. These upgrades were documented within the GIS data set however, and were provided for integration into the updated ICM model. Upon import of this data into ICM, a similar process to that outlined above for the original data set is proposed to identify the profile and connectivity issues within the new data. Identified errors can be fixed using the same methodology discussed under **Section 4.1.1.2**, with emphasis on drawing review for hydraulically significant network components, such as pumping stations. Some additional drawing review may be required in focus areas if severe profile or connectivity issues persist, or if calibration challenges for certain metersheds arise.

4.1.3 Subcatchments

There are multiple ways to set up subcatchments in a hydraulic model. Subcatchments tie the visual representation of the contributing area for each receiving maintenance hole (MH) to the overall approach of flow generation. The original InfoSWMM model was set up with a subcatchment layer, but no attributes were associated. While the flow generation was informed by the subcatchment geometry, the flow parameters are applied at the node only, which removes the overall context of the base parameters that comprise the average flow input. The following subsections document the breakdown of the dry and wet weather flow generation approach used in the original InfoSWMM model and discusses the relevant opportunities that exist in ICM associated to each component.

4.1.3.1 Dry Weather Flow

For representing Dry Weather Flow (DWF), the InfoSWMM model allows for the allocation of the following flows to nodes based on a population/land-use distribution:

- a constant baseflow representing groundwater infiltration (GWI);
- a residential flow with a weekday diurnal pattern; and,
- an industrial-commercial-institutional (ICI) flow with a weekday diurnal pattern.

The original Kitchener model included only one DWF allocation per node however, which represented all DWF components including the GWI, residential and ICI flow contributions.

ICM has the flexibility to assign flow generation values via a subcatchment. To generate sewage flow, these subcatchments require population values in conjunction with a Wastewater Profile, which houses a per capita rate and diurnal pattern. The subcatchment also contains a Total and Contributing Area (ha) field, and has additional input allowances for direct flows as required, such as a Baseflow (typically used for dry weather groundwater infiltration, or GWI), Trade Flow that can be assigned a separate diurnal pattern, and a generic Additional Flow. The base setup for sewage generation is reliant on data based on physical attributes (area, population), and parameters that are modified during calibration (per capita rate, groundwater infiltration, diurnal pattern shape).

Population Data

Some population data was provided, including two separate sources; the Parcels-Persons-Jobs (PPJ) shapefiles provided by the City's Planning Department, and the Region of Waterloo's Population and Land Use Model (PLUM) data. The PPJ data is proposed for use in baseline (existing conditions) calibration and consists of the existing population and number of jobs per parcel. It also includes what is understood to be an indication of the 50%, 75% and 100% build-out population and job numbers per parcel. The projected values provided as part of this data source is currently in draft format, and thus, were not used for future conditions model updates. The PLUM data was also provided and consists of zones with current 2021 and projected (2026, 2031, 2036, and 2041) residential (RES) populations. It does not appear to include employment (EMP) population distributions.

It is understood that these projections are subject to change as part of the Province's Growth Plan for the Greater Golden Horseshoe (2019) and the Regional Official Plan (ROP) Review that will fulfill the requirements of a Municipal Comprehensive Review of the Growth Plan and inform Kitchener's policies. The existing condition data for 2021 will be used, and review of the draft future growth projections from the Region were reviewed by the City to establish the ISAN-MP growth horizon scenarios. Updated projected residential and non-residential equivalent populations were provided by the City's Planning Department for use in future growth scenario modelling, as discussed in **Section 8.2**.

The City also provided Water Billing records per address point which were used as a cross-reference for calibrated sanitary per capita rates. The Water Billing records can also be used for distributing larger PLUM Zone information to the address point scale, if required, however the PPJ data is proposed for use in the model set-up.

4.1.3.2 Wet Weather Flow

To represent the Wet Weather Flow (WWF) response, the existing InfoSWMM model uses the RTK Unit Hydrograph method. It is comprised of three characteristic triangular unit hydrographs representing the fast response (inflow), moderate response (foundation drains), and slow response (groundwater leakage). The 9 RTK parameters (fast, moderate and slow response R, T and K values) were determined for each of the fifteen calibrated metersheds and applied to the corresponding nodes. The RTK values, in conjunction with the effective or contributing area, are used to generate the Rainfall Derived Infiltration and Inflow (RDII) in the model, or the wet weather response.

ICM also has the capability of using the RTK method, but rather than applying the parameters to the nodes as required in InfoSWMM, the 9 RTK parameters are applied to subcatchments. The contributing area associated to each subcatchment is then used to generate the wet weather response. Both the dry weather parameters discussed above, and the wet weather RTK parameters can be applied to the same subcatchment. Alternatively, these parameters can be applied to separate, overlapping subcatchments to improve visual correlation with the generated flows.

4.1.3.3 Proposed Approach

Thinking towards the longer term primary use of the model, subcatchments allow for an intuitive means of visually representing model inputs that can easily tie back to the underlying parcel fabric and be associated with the City's Planning department data for development applications. With this in mind, the following multi-subcatchment approach is proposed for the City of Kitchener's ISAN-MP model:

- Parcel-based subcatchents; and,

- Area-based subcatchments.

These subcatchments will be visually layered, as presented in **Figure 4.2** below, which illustrates the concept of the proposed approach.

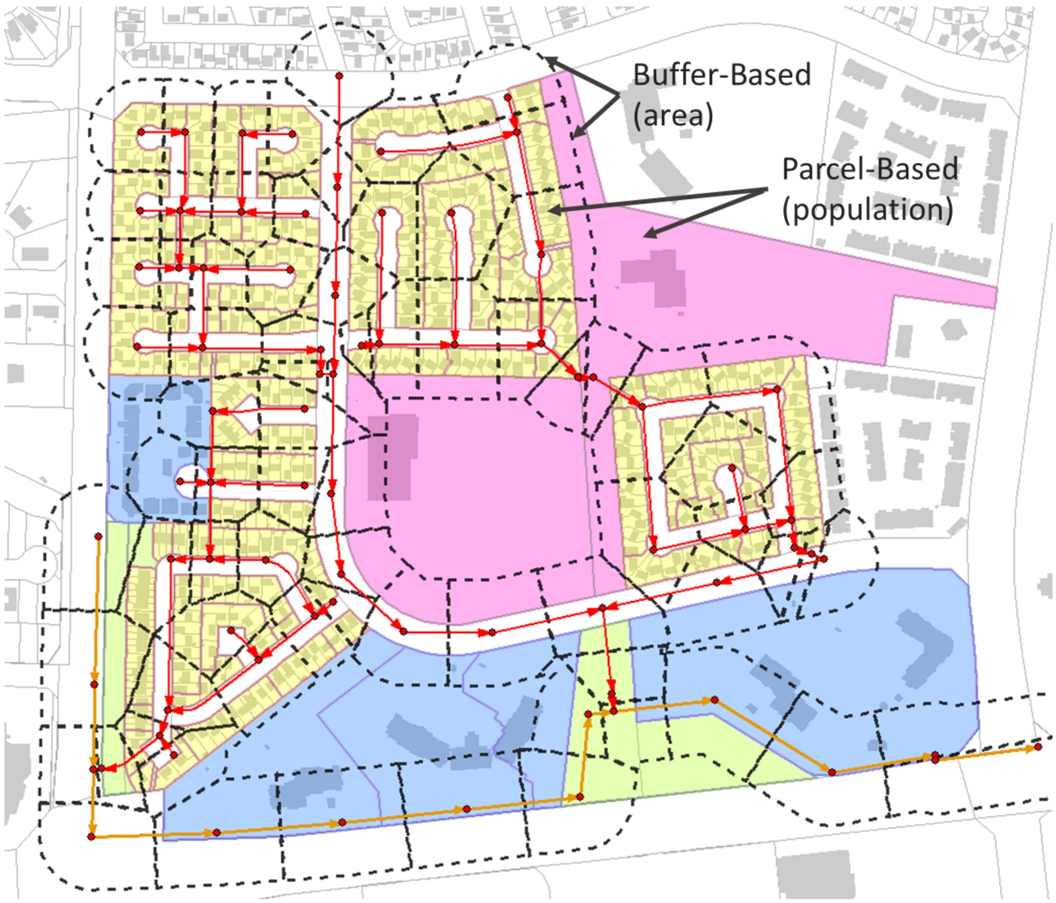


Figure 4.2: Proposed Subcatchment Delineation Approach

These parcel and area-based subcatchments will be applied separately to represent existing conditions. This multi-subcatchment approach is further explained in the subsections below.

Existing Conditions

Parcel-Based Subcatchments

Parcel-based subcatchments, or "SP" subcatchments, represent a collection of existing parcels that drain to the same sewer. They are generally developed on a MH-to-MH basis and are allocated to the upstream MH of the receiving sewer. Parcel-based subcatchments represent the population-derived sewage generated from the buildings within the collection of parcels. These parameters are generated based on the existing conditions parcel fabric information provided by the City's Planning department and the flow monitoring DWF data. The basis of the parcel-based subcatchments remains the original

InfoSWMM model subcatchment layer in terms of receiving MH, but the geometry will be restructured based on recent parcel data. The original subcatchment IDs are included in the User Text fields for linkability. To generate these subcatchments, the provided PPJ parcels were spatially joined to the original model's subcatchments in GIS, linking the original subcatchment's attributes, including its receiving node ID, to each of the new parcels. The parcels were then merged based on the receiving node ID, aggregating the parcels' individual populations. Corrections to allocations were made as necessary. For areas missing subcatchments in the original model, a receiving node ID was manually attributed to the parcels and then similarly merged in GIS. The following parameters are used to define the subcatchments and their DWF sewage generation:

- Subcatchment ID based on receiving MH, including a "SP_" prefix for discernability;
- Total Area (ha), which is equivalent to the aggregated parcel area;
- Contributing Area set to 0 ha to indicate no area-based flow;
- Equivalent population (residential + employment), which can be directly associated with the Planning Department's Parcel-People-Jobs (PPJ) layer; used for tracking existing and future growth scenarios; and,
- Wastewater Profile to define the diurnal pattern and per capita rates (obtained from the previous model update (2016) and adjusted where needed based on recent flow monitoring).

Neither the Total or Contributing Areas are used to generate flow in these parcel-based subcatchments. The total area is provided for informational purposes only.

Area-Based Subcatchments

Area-based subcatchments, or "SA" subcatchments, are not tied to the parcel fabric, but instead represent the effective, or contributing area, that contributes to the infiltration and inflow (I/I) within the system in both dry and wet weather conditions (GWI and RDII, respectively). The geometry of these subcatchments is developed based on a 45 m buffer around the municipal sanitary sewers, which is then split and allocated to the nearest MH using the Thiessen polygon method. This 45 m buffer approach is commonly used in sanitary system modelling, as it provides a consistent means for measuring the contributing area that factors out large parcels and non-residential land use, allowing for a uniform basis from which to assess groundwater infiltration and RDII unit rates across sewersheds. The following parameters will be used to define the area-based subcatchments and their GWI and RDII generation:

- Subcatchment ID based on receiving MH, including a "SA_" prefix for discernability;
- Total Area (ha), which is based on the 45 m pipe buffer area;
- Contributing Area (ha) equivalent to the Total Area;

- Baseflow (m^3/s), which represents the calibrated GWI based on the unit rate derived from flow monitoring (L/s/ha) and the contributing area per subcatchment (ha). In non-monitored areas, baseflows are generated using the a GWI rate found to be representative of the sytem;
- Rain Gauge Profile to define the associated rain gauge; and,
- RTK Hydrograph ID, which defines the associated RTK parameters per metershed.

Future Conditions

Future conditions growth horizons and subcatchment set-up was initially conceptualized but further evaluated after receiving the updated PPJ shapefile and through additional discussions with the City. The 2031 and 2051 horizons were selected for focus within this study and were noted to correspond approximately to the PPJ's 50% and 75% buildout populations. Please refer to **Section 8.2** for more details on the proposed future conditions modelling scenarios and their set-up.

Development Application Assessments

Considering the long-term primary use of the model, the subcatchment set up must allow for flexbility and ease-of-use for redevelopment or development application assessments. With this parcel-based subcatchment approach and the Planning Department's PPJ data, there is a direct visual correlation between each property and their existing or proposed flow generation. Since the underlying SP subcatchments are derived from aggregating parcels based on receiving MH, it is recommended that the corresponding PPJ data be incorporated in the model as a selectable background layer, to allow for detailed review of the existing populations per parcel. The proposed approach for development application assessments will be further established in TM#6 (Growth Management and Implementation Plan).

4.1.4 Pumping Stations

The existing conditions modelling approaches for both original network pumping stations and newly (post-2016) constructed or upgraded stations are outlined in the subsections below. These updates were completed for calibration purposes in order to offer the best correlation to the monitored flows within the system. Pumping station configuration was further adjusted for existing and future conditions modelling scenarios, as discussed in **Sections 8.1.3.1**, **8.2.3.3** and **8.2.4.3**.

4.1.4.1 Original Network Pumping Stations

There are 26 pumping stations included within the original InfoSWMM model. The base pump station data in the InfoSWMM model was converted into InfoWorks ICM input, which differs slightly between the models. There is no appreciable difference to how the two model engines operate, and the same base input (included wet well diameter, depth, pumps start and stop level and pump curves) is applicable to both modelling programs. From InfoSWMM to ICM, the following conversion variances were observed.

- InfoSWMM Type 2 pumps are automatically assigned a Fixed pump type in ICM and the maximum discharge rate from the pump curve applied in InfoSWMM was applied as the constant pump rate in ICM;
    - Type 2 pumps operate based on pump curves, where flow varies incrementally with upstream water depth and are independent of downstream conditions,
    - Fixed discharge pumps convey flow at a constant rate and are independent of head.
- InfoSWMM Type 3 pumps are automatically assigned a Rotodynamic pump type in ICM, but no other adjustments occurred;
    - Type 3 pumps convey flow based on a head-discharge pump curve using the head differential defined by the upstream and downstream water levels.
    - Rotodynamic pumps in ICM convey flow in the same manner.
- InfoSWMM Type 4 pumps are automatically assigned a Screw pump type in ICM upon conversion. Minor adjustments were observed in the pump curve, zeroing out the first depth value and adjusting all succeeding depths by the subtracted difference.
    - Type 4 SWMM pumps operate based on pump curves similarly to Type 2, however, flow varies continuously with upstream water depth rather than incrementally. Type 2 pumps are also independent of downstream conditions.
    - Screw pumps in ICM convey flow in the same manner.

No adjustments were made to the pump types in ICM once the import was complete.

Due to their hydraulic significance within the collection system, all pumping stations were reviewed for correlation to previous documented station operation (Table 4-2 of AECOM's *City of Kitchener Sanitary Sewer System Model Update Final Report*, dated December 12, 2019) and recent (post-2016) condition assessment reports. Review of the provided data identified several discrepancies. All inconsistencies were flagged to the City and were updated where applicable based on the most recent Condition Assessment Reports.

4.1.4.2 New and Upgraded Pumping Stations

Information from the post-2016 pump station assessment reports is used as the basis for hydraulic model input updates. New and recently upgraded pumping stations include Nathalie Pumping Station and New Old Mill Pumping Station, which were not integrated in the existing conditions model for calibration however, as their upgrades/construction were not implemented before the calibration period (i.e. operational at time of the flow monitoring program's selected events). These pumping stations will be included in the model for the existing conditions and future conditions system assessments. Other future proposed pumping stations and/or upgrades are also considered in the growth scenario modelling if details are known.

The City has indicated that the following 22 sanitary pumping stations have recent wet well levels and/or pump on/off SCADA data. The quality of this data can be reviewed and assessed for practicality in validation, specifically in areas where flow monitoring-based model calibration indicates inaccuracies in the upstream parameters/operation.

- Stoke
- Patricia
- Moore
- Oxford
- Falconridge
- Shirley
- Carson
- Manchester (Pump On/Off data only)
- Otterbein
- Springmount
- Bancroft
- Apple Tree
- Woolner
- Chandos
- King St
- River Birch
- Pioneer Tower
- Old Mill (Wet well level data only)
- Homer Watson
- Conestoga College
- New Dundee

4.1.5 Boundary Conditions

Boundary conditions help to define the operation of an area or feature that is decidedly excluded from the model for simplification or due to municipal boundaries. They are often used at points of discharge into adjacent systems/municipalities and watercourses, or where the modelled system is receiving inflows from adjacent areas. Boundary conditions can also be used to define downstream hydraulic grade line (HGL) conditions in complex facilities, such as WWTPs, that are not typically modelled in detail at this scale. The boundary condition at a discharge point represents the water level in the downstream system to which the Kitchener model is draining. Applying a downstream water level better reflects system hydraulics such as backwater conditions that propagate upstream. An inflow point can receive an incoming ‘inflow’ hydrograph representative of each modelled event, or a constant inflow, if applicable. Boundary conditions are often obtained from data sources such as background documents or reports, adjacent area models, pipe obverts, SCADA, or facility drawings.

In the Kitchener ISAN-MP model, there are several discharge and inflow points into and from adjacent systems. The Cross-Border agreements for each of these locations were reviewed and used to assess the impact of these connections. Based on this review and if the adjacent system’s conditions are determined to be influential to the Kitchener system, the corresponding water levels or inflows are obtained and used in the model. If adjacent water levels are unknown, a conservative boundary condition equivalent to pipe obvert is applied and assessed for sensitivity during calibration. If inflow hydrographs from adjacent areas are not available, high-level subcatchments with estimated flow generation parameters are applied. If the adjacent system’s water levels or inflows are found to be negligible in magnitude, they are excluded from the model.

There are also 11 pumping station overflows that discharge to nearby watercourses or storm systems. Since these overflows are meant to relieve the system when inundated, it is initially assumed that the downstream water levels do not impact the overflows. The validity of this assumption was assessed during calibration. There is also one potential boundary condition at the WWTP. Based on WWTP drawing review and discussions with the facility operators, the hydraulic drop between the sewer system and the WWTP is substantial and not anticipated to generate backwater conditions in the upstream system. Thus, a free-flowing outfall is applied at this location in the model (i.e., no water level boundary applied).

4.1.6 Calibration Process

The City has undertaken multiple flow monitoring activities since the last hydraulic model calibration, which was completed with 2016 data. There have been 10 flow monitoring programs in the last 5 years for the purposes of development reviews, I/I investigations, and pump station studies; and one proposed as part of this scope. The current program consists of 20 flow meters installed on trunk or sub-trunk sewers within the Kitchener sanitary sewer system. Data from these monitors is assessed for quality and use in the model calibration. As touched upon in **Section 4.1.3**, this data is used to establish the Dry Weather Flow (DWF) and Wet Weather Flow (WWF) parameters, including the per capita sewage generation rates, diurnal patterns, groundwater infiltration (GWI) rates and resulting baseflows, and rainfall derived infiltration and inflow (RDII). Areas without monitor coverage will use relevant 2021 parameters from areas with similar land use, density, and age of system. A total of 2 DWF and 3 - 4 WWF events were selected for calibration.

The process of comparing and adjusting model parameters to correlate results with observed data is commonly referred to as model calibration. A high-level summary of the calibration process is described below.

1. Delineate and characterize the flow metersheds, including area, land use, population, water billing records, and flow meter schematic;
2. Completion of a macro-level review of flow monitoring and rain gauge data looking for DWF periods and significant rainfall events correlating to good data quality for the majority of the meters;
3. Establish average DWFs, minimum nighttime flows, and diurnal patterns per meter, including extracting the GWI component (% of minimum nighttime flows);
4. For the chosen rainfall events, extract the DWFs from the metered data to obtain the RDII and the RTK parameters per meter (see **Section 7.3.1** for more details on the RTK method);
5. Import the metered data, rainfall, DWF and WWF parameters and run both the DWF and WWF periods/events, comparing the metered data to the modelled data visually and with percent fit calculations based on appropriate dry and wet weather targets; and finally,
6. Iteratively adjust parameters accordingly to better the fits and visual representation of the modelled data.

We have adopted dry and wet weather targets in accordance with *CIWEM Urban Drainage Group Code of Practice for the Hydraulic Modelling of Urban Drainage Systems*, ver. 1, dated November 3, 2017 (formerly the *Wastewater Planning Users Group (WAPUG) Code of Practice for the Hydraulic Modelling of Sewer Systems,* ver. 3.001, dated November 2002). The following guidelines will be considered throughout the model calibration process.

4.1.6.1 Dry Weather Flow

The dry weather flow (DWF) calibration should be carried out for at least two full dry weather days (48 hrs) and the modeled average and peak flows, as well as depths, compared to the observed values. In addition to tracking the overall general shape, the flow hydrographs should meet the following criteria/goodness-of-fit:

- The alignment of the peaks and valleys of the time series should be within 1 hour;
- The peak flows should be within ± 10% of each other; and,
- The 48-hour volume should be within ± 10%. Care should be taken to exclude periods of missing or inaccurate data.

Other Considerations

DWF is generated from a combination of flow components. These components include the contributing population, industrial/commercial/institutional (ICI) land area, and groundwater infiltration (GWI) areas whose rates can vary depending on several factors. The following is considered and reviewed during DWF calibration:

- The upstream contributing area and associated populations and ICI flows (or equivalent populations) are correct and up to date, and are allocated to the appropriate sewers.
- The residential average wastewater flow rates applied are within standard ranges for the area of interest. Generally the per capita flow rate is within 200-400 L/c/d. Rates above and below this range are possible, but the observed data and upstream contributing subcatchments' characteristics should be confirmed in these instances.
- The residential diurnal pattern typically has an early-morning and early-evening peak with a slight late-morning dip and late-night/early-morning drop. This pattern corresponds with the sleep and work schedule of the majority of the general population. However, this may vary in the flow monitoring completed between 2020 - 2022, as affects from the COVID-19 pandemic and working-from-home initiatives may be evident. The overall peak factor from this diurnal pattern is typically in the range of 1.5 to 4.
- The ICI wastewater flow rate can vary considerably depending on the type of commerce, industry, or institution present. ICI flow rates can vary from as low as 1,500 L/ha/d to as high as 75,000 L/ha/d. Water consumption records can sometimes be used to validate wastewater flows where calibration proves challenging due to potential upstream ICI contributions.

- The ICI diurnal pattern also varies considerably depending on the type of commerce, industry, or institution present. A blended residential and ICI rate can sometimes be helpful to account for the flow fluctuation seen due to ICI contributions.

- Groundwater infiltration rates can vary substantially depending on the soil condition, climate, location, and season. It is important to consider the DWF period over which the calibration is being completed. If this period is during a dry summer month, the rate may be less than that possibly seen during a spring melt event. Typical GWI rates can range anywhere from 0.02 to 0.12 L/ha/s (approx. 1,000 L/ha/d to 11,000 L/ha/d). Higher or lower rates are also possible. A revision of the observed data and upstream contributing subcatchment characteristics should be confirmed in these instances, however high GWI rates can also help identify leaky pipes in need of repair.

4.1.6.2 Wet Weather Flow

The wet weather flow (WWF) calibration should be carried out for the selected events from the flow survey. These events are often the top 3-5 events recorded while considering depth, intensity, and volume. Smaller events are sometimes selected for wet weather flow calibration as these are subject to different inflow characteristics when compared to the larger events. It is proposed to conduct flow monitoring calibration based on 3 - 4 WWF events, to be selected during flow monitoring and rain gauge data review and dependent on data quality.

The modeled flow rates and depths should be compared to the observed values from the corresponding rainfall event. The hydrographs should closely follow each other both in shape and in magnitude, until the flow has substantially returned to DWF conditions. In addition to the shape, the observed and modelled hydrographs should meet the following criteria for the majority of the events considered:

- The timing of the peaks and valleys should be similar for the duration of the event;

- The peak flow rates at each significant peak should be in the range of -15% to +25%;

- The volume of flow should be within -10% to +20%;

- The surcharge depths should be in the range of -0.1 m to +0.5 m; and,

- Where data of high confidence is available, the un-surcharged depths at key points should be within the range ±0.1 m.

Other Considerations

Beyond the targets mentioned above, several other factors should be considered during the WWF calibration process.

- The sewer system is generally taxed during large rainfall events; however these types of events also tend to occur simultaneously due to power outings at pump stations, backwater conditions (caused by sewer or downstream facility capacity constraints), infrastructure failures (i.e. sewer collapses), sewer blockages, or silted/damaged flow monitoring equipment – all of which can result in questionable observed data.

- Should there be deemed a benefit to running several events back-to-back during the same model run as a continuous simulation, to better account for soil transitions between saturated and unsaturated states, this will be presented to the City for consideration of additional calibration effort. The need for this approach will be assessed during the calibration process.
- When reliably available, flooding records may be used for validation of extreme model results; however, flooding can be caused by sewer surcharging, blocked/collapsed pipes, and/or surface drainage issues, and must always be interpreted with caution.

5.0 FLOW MONITORING PROGRAM

AMG Environmental (AMG) was engaged to collect data for the 2021 flow monitoring program. This consisted of 20 flow meters installed across the City in late-July of 2021 and remained operational through to late-November. The flow monitoring data is available on AMG's portal online. Data from the 20 flow meters is used for the sanitary model calibration, in conjunction with the relevant rain gauge data.

5.1 FLOW METER LOCATIONS

The 20 flow meters (FMs) were installed predominantly in local or sub-trunk sewers and provided monitoring coverage for the majority of the City. The following **Table 5-1** details the meter locations, pipe sizes, and contributing area characteristics. **Figure 5.1** illustrates the geospatial distribution of these monitors and rain gauges.

Table 5-1: Flow Meter & Metershed Characteristics

FM ID	FM Name and Location	Rain Gauge ID	Pipe Size (mm)	Total[1] Parcel-Based[2] Contributing Area (ha)	Incremental[3] Parcel-Based Contributing Area (ha)	Total[1] % RES[4] Population	Incremental[3] % RES[3] Population	Land Use Classification[5]
FM1	308300-KW-Highland Rd W*	RG3	675	246	206	94%	93%	RES
FM1b	309484-KW-Highview Dr	RG3	300	40	40	97%	97%	RES
FM2	304470-KW-West Ave*	RG3	1050	655	409	89%	87%	RES
FM2b	304819-KW-Sandrock Creek	RG4	675	283	283	69%	69%	Mixed
FM3	311165-KW-Victoria St S*	RG1	900	159	128	65%	61%	Mixed
FM3b	2091740-KW-Moore Ave PS	RG1	450	31	31	87%	87%	RES
FM4	303786-KW-David St	RG1	600	32	32	28%	28%	ICI
FM5b	311440-KW-Activa Ave	RG6	525	115	115	99%	99%	RES
FM6	301110-KW-Borden Ave S	RG1	600	87	87	52%	52%	Mixed
FM7	306584-KW-Hoffman St*	RG1	900	727	612	91%	90%	RES
FM9	301182-KW-Ottawa St N	RG4	675	420	420	90%	90%	RES
FM10	300305-KW-Shelley Dr*	RG2	1200	1,213	794	85%	81%	RES

FM ID	FM Name and Location	Rain Gauge ID	Pipe Size (mm)	Total[1] Parcel-Based[2] Contributing Area (ha)	Incremental[3] Parcel-Based Contributing Area (ha)	Total[1] % RES[4] Population	Incremental[3] % RES[3] Population	Land Use Classification[5]
FM11	302989-KW-Manitou Dr	RG2	450	165	165	35%	35%	ICI
FM12	300575-KW-Balzer Creek Trail	RG2	750	165	165	95%	95%	RES
FM13	303564-KW-Black Walnut Dr*	RG2	1050	559	346	74%	55%	Mixed
FM13b	2001421-KW-Huron Rd	RG6	675	214	214	98%	98%	RES
FM15	303238-KW-Homer Watson PS	RG7	600	249	249	95%	95%	RES
FM18	306550-KW-Hanson Ave	RG2	300	71	71	52%	52%	Mixed
FM19	311719-KW-Falconridge PS	RG1	450	46	46	98%	98%	RES
FM20	303424-KW-King St E	RG7	375	40	40	1%	1%	ICI

Notes:
1. Total Contributing Area and % RES includes area/populations draining to upstream FMs (FM in series).
2. Parcel-Based area refers to the area of all parcels draining to each meter; includes non-effective areas like parking lots, parks, etc.
3. Incremental area and % RES refers to only the area between the upstream FM and the FM of focus.
4. Percent (%) RES Population is based on total population (RES population / Total population).
5. Land Use Classification is generalized based on % RES;
   - < 50% is considered ICI,
   - Between 50% and 70% is considered Mixed, and,
   - > 50% is considered Residential.
- FM is downstream of one or more other FMs (FM in series)

All flow meters are installed in trunk or sub-trunk sewers within the City and provide representative coverage for master planning purposes. With 25 pumping stations distributed across the City, many meters experience fluctuations in flow patterns consistent with the presence of nearby pumps. The most significant influences are observed at FM2, FM3b, FM5b, FM9, and FM15. Meters FM2 and FM5b are located downstream of Patricia Sewage Pumping Station (SPS) and Mannheim SPS, respectively. Meter FM9 is located downstream of several pumping stations, including Otterbein SPS, Springmount SPS, and Woolner SPS. Meters FM3b and FM15 are located immediately upstream of Moore SPS and Homer Watson SPS, respectively. Refer to **Figure 5.1** for the pumping station distribution in relation to the flow metersheds.

General land use classifications are designated to each metershed based on the percentage of residential population within the area. Most of the metersheds predominantly consist of residential populations and are therefore considered residential in nature. Only three metersheds include less than

50% residential population, and are thus classified as Industrial/Commercial/Institutional (ICI), including FM4, FM11, and FM20. Five metersheds (FM2b, FM3, FM6, FM13, and FM18) are comprised of 50% to 70% residential population and are thus considered mixed land use. **Table 5-1** documents these general land use classifications.

A summary of the characteristics of the flow monitors and their metersheds can be found in **Appendix C**. Future monitoring program considerations, including use for future model updates, will be discussed in the final Master Plan document.

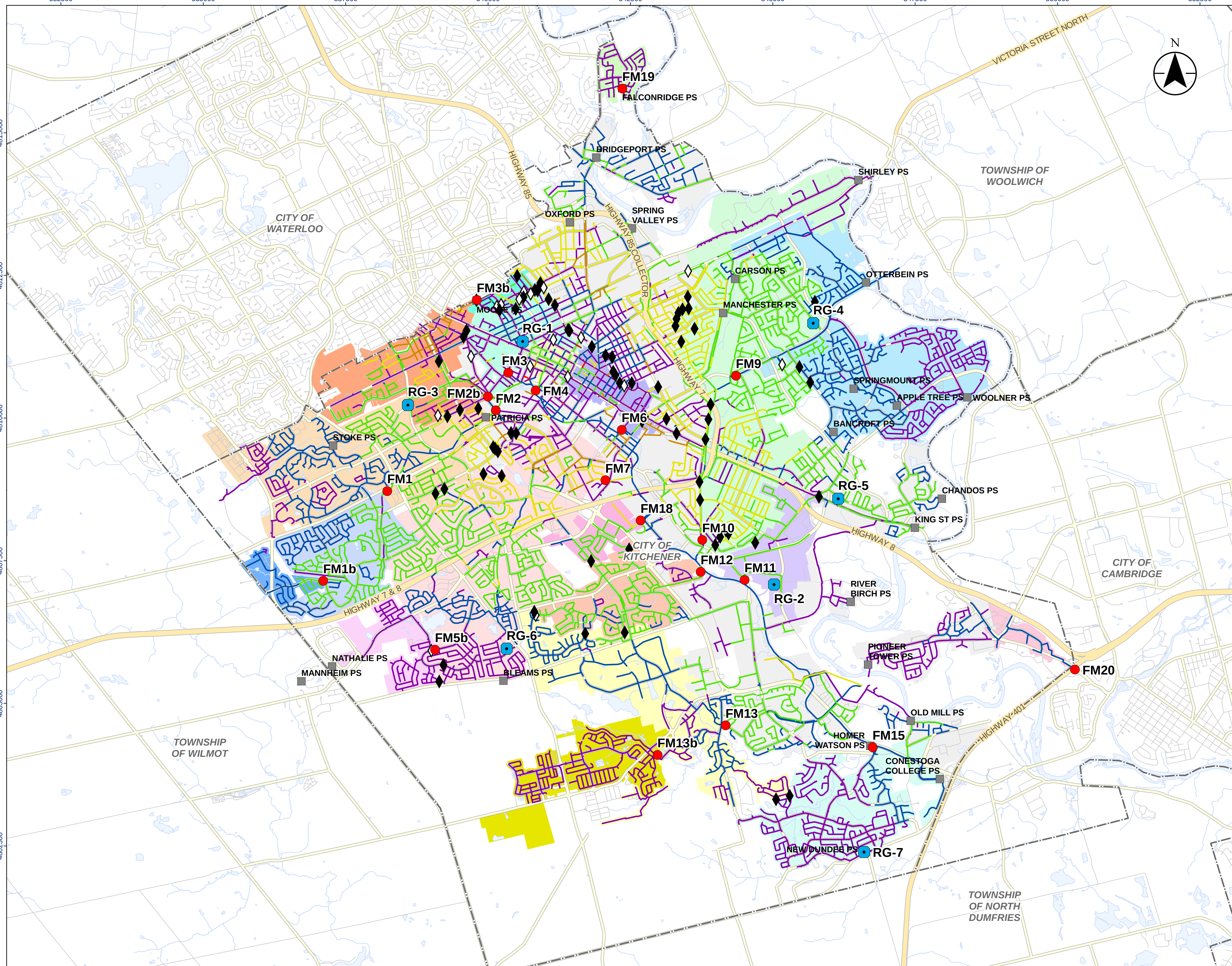
5.2 RAIN GAUGE LOCATIONS

There are two (2) permanent rain gauges (RGs) located at City Hall and the Kitchener Operations Facility which were installed prior to this project. To supplement the City's 2 permanent rain gauges, an additional five (5) temporary rain gauges were recommended for install as per the 2016 recalibration, to provide a reasonable spatial resolution and improve model calibration. Due to the location of these seven (7) rain gauges and each gauge's corresponding Thiessen polygon, only six (6) are required for use in this analysis. The coverage of RG5 is significantly smaller than the other rain gauges and has thus been used for validation of the other gauges only. **Table 5-2** presents a summary of the proposed rain gauges, while. **Figure 5.1** illustrates their locations.

Table 5-2: Available 2021 Rain Gauge Network

ID	Location	Notes
RG1	City Hall	Existing Permanent Gauge
RG2	Kitchener Operations Facility	Existing Permanent Gauge
RG3	Victoria Hill Community Centre	Temporary Gauge
RG4	Grand River Arena	Temporary Gauge
RG5	Centreville Chicopee Community Centre	Temporary Gauge
RG6	Williamsburg	Temporary Gauge
RG7	New Dundee Pump Station	Temporary Gauge

The Grand River Conservation Authority (GRCA), Region of Waterloo and University of Waterloo rain gauges are not used in this analysis.



Stantec

Legend

- Flow Meter
- Rain Gauge
- Sanitary Pumping Station

Metershed Spill Points

- Major Flow Split
- Minor Flow Split

Sanitary Sewer Installation

- 2000 - 2021
- 1980 - 1999
- 1960 - 1979
- 1940 - 1959
- 1920 - 1939
- 1907 - 1919
- Not Stated

Flow Metershed

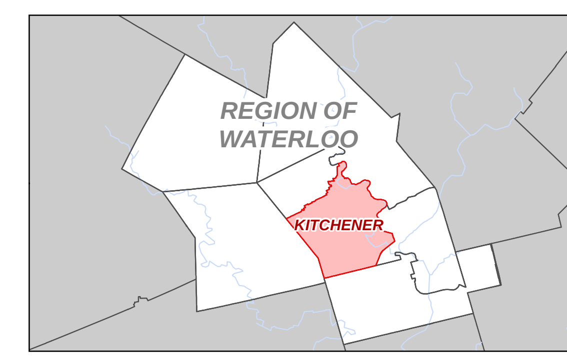
FM1	FM5b	FM13
FM1b	FM6	FM13b
FM2	FM7	FM15
FM2b	FM9	FM18
FM3	FM10	FM19
FM3b	FM11	FM20
FM4	FM12	Unmonitored

0 2 4 km

1:70,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2021.
3. Contains information licensed under the Open Government Licence - The Corporation of the City of Kitchener, 2021.



Project Location
City of Kitchener

165640334 REVA
Prepared by KB on 2022-10-05
Technical Review by AL on 2022-10-05

Client/Project
CITY OF KITCHENER
INTEGRATED SANITARY MASTER PLAN

Figure No.
5.1

Title
2021 Flow Monitoring Program Meter & Rain Gauge Locations

5.3 FLOW METER SCHEMATIC AND SYSTEM CONNECTIVITY

The ICM model was used to trace the contributing metersheds and create a schematic illustrating the 2021 flow meters, their connectivity, and their Average Dry Weather Flow (ADWF), as shown in **Figure 5.2**.

There are several meters in series within the study area, including:

- FM1b, FM1, and FM2;
- FM3b and FM3;
- FM5b and FM7;
- FM13b and FM13; and,
- FM9 and FM10.

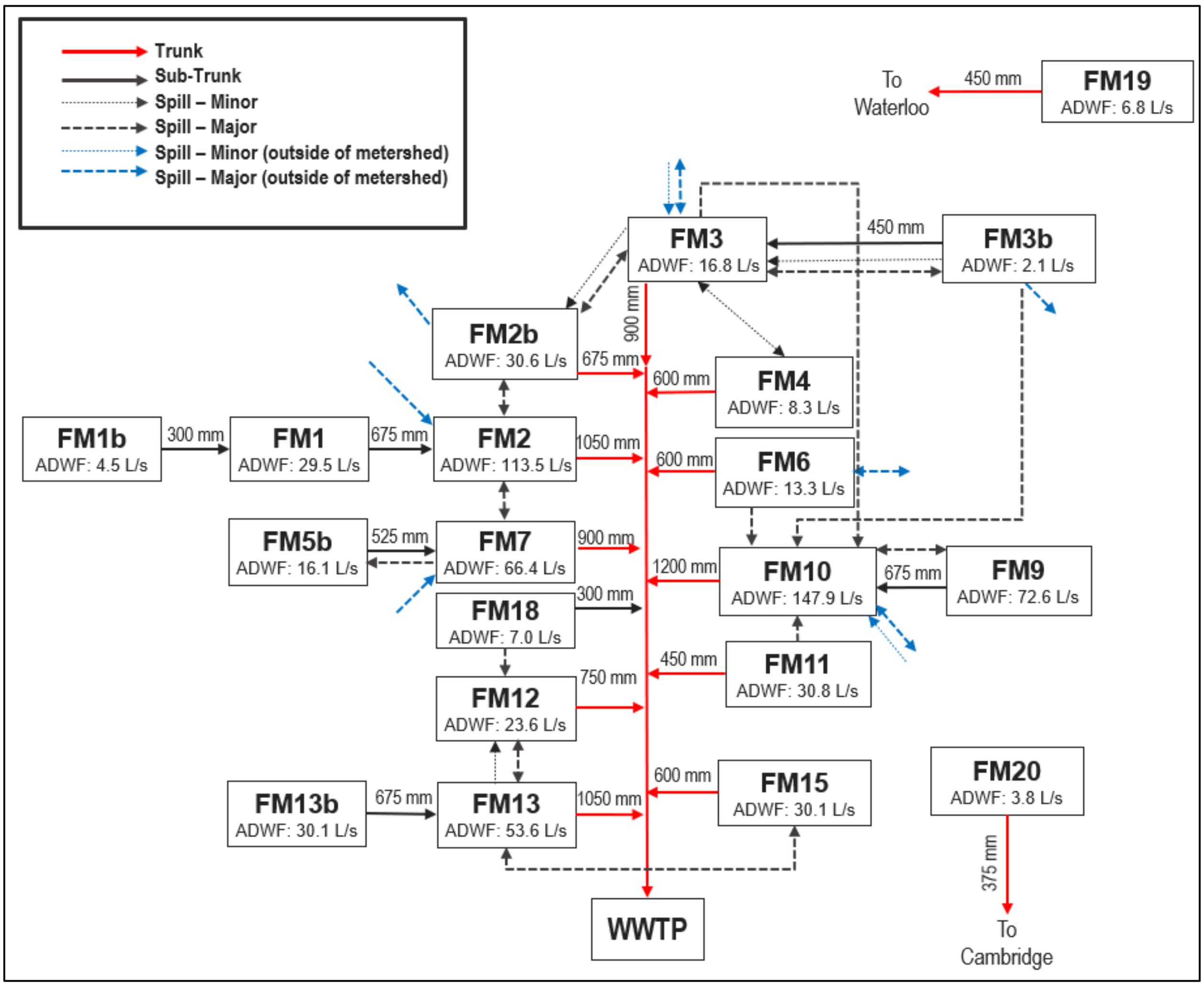


Figure 5.2: 2021 Flow Meter Schematic

FM19 drains through the Falconridge trunk sewer to Waterloo and FM20 drains through the Gateway Park trunk sewer to Cambridge. All other FMs eventually drain through to the Balzer, Doon South, Fairway, Henry Sturm, Lower Downtown, Lower Schneider, Montgomery, Shoemaker, Strasburg, Upper Downtown, and Upper Schneider trunk sewers to the Kitchener Wastewater Treatment Plant (WWTP) located in the south-central portion of the City.

Many metersheds include bifurcations manholes (more than 1 outgoing pipe) that define flow splits (FSs) or high points (HPs) within the system. If located along the metershed boundary, these bifurcations can result in hydraulic connectivity between sub-systems depending on the chamber and pipe orientation, and the flow conditions observed. The flow schematic indicates the presence of major spill points between metersheds, where the upstream inverts of the outgoing pipes from the FS or HP are similar in elevation, thus resulting in frequent or consistent hydraulic connectivity, potentially even during low flow conditions. The minor spill points denote bifurcations where a larger offset is observed between the upstream inverts of the outgoing pipes, and hydraulic connectivity with the system of higher elevation likely occurs less frequently and potentially only during higher flow conditions. With the number of minor and major spill points identified between metersheds, calibration can prove challenging due to the contributing upstream area varying with fluctuating flow conditions. It is noted that the basis of invert and connectivity data is the hydraulic model based on GIS, which at the local level may have erroneous data (see **Section 7.4**).

As noted in **Section 5.1**, FM2, FM3b, FM5b, FM9, and FM15 are located either just upstream or downstream of pumping stations (Patricia SPS, Moore SPS, Mannheim SPS, Otterbein SPS, Springmount SPS, Woolner SPS, and Homer Watson SPS).

5.4 FLOW METER DATA AVAILABILITY

Flow monitoring data is available at each monitor between August 1st and November 30th, 2021. Though there is data available throughout the entirety of the flow monitoring program, there are periods of variable data, including velocity dropouts and the effects of silt, debris, or connectivity issues. Please refer to **Section 5.5** for more details on data variability.

5.5 FLOW METER DATA QUALITY REVIEW

The meter data for all flow meters between August 2021 and November 2021 was reviewed on a macro-level to identify periods of missing data, questionable readings (depth/velocity), backwater, and surcharge. This review is the first step in identifying the most appropriate periods of data for the selection of the dry weather flow (DWF) periods and wet weather flow (WWF) events.

A total of 20 flow monitors were installed as part of the flow monitoring program. There are six (6) FMs which are noted to have variable data quality due to connectivity, installation, or silt/debris issues, resulting in data dropouts, and/or fluctuations that may be challenging to calibrate to. These monitors include FM2, FM3b, FM4, FM5b, FM6, and FM19. The following 14 monitors are noted to have good quality data overall.

- FM1
- FM1b
- FM2b
- FM3
- FM7
- FM9
- FM10
- FM11
- FM12
- FM13
- FM13b
- FM15
- FM18
- FM20

The 6 meters with variable data are used in calibration only for the periods where their data is deemed reliable. Data from the remaining periods is used for validation purposes. Of the 14 meters noting overall good quality, it is possible that occasional meter dropouts or minor variations in flow response are observed, therefore resulting in the potential for event exclusions or reduced periods of review. Key observations from this macro data review are listed below, which are considered in the selection of calibration periods and the evaluation of subsequent calibration results.

- **Two flow meters had significant periods of questionable data quality –** FM3b experienced questionable data due to site conditions and silt buildup in the pipes, resulting in changes in the flow pattern and decreased velocity readings. Additionally, FM19 experienced a questionable flow variation between October 2nd to October 18th, which consisted of an increase in velocity readings and a decrease in depth. The velocity and depth scatterplot also clearly indicates two different trends observed. Refer to **Figure 5.3** and **Figure 5.4** for the questionable data observed at FM3b and FM19, respectively.

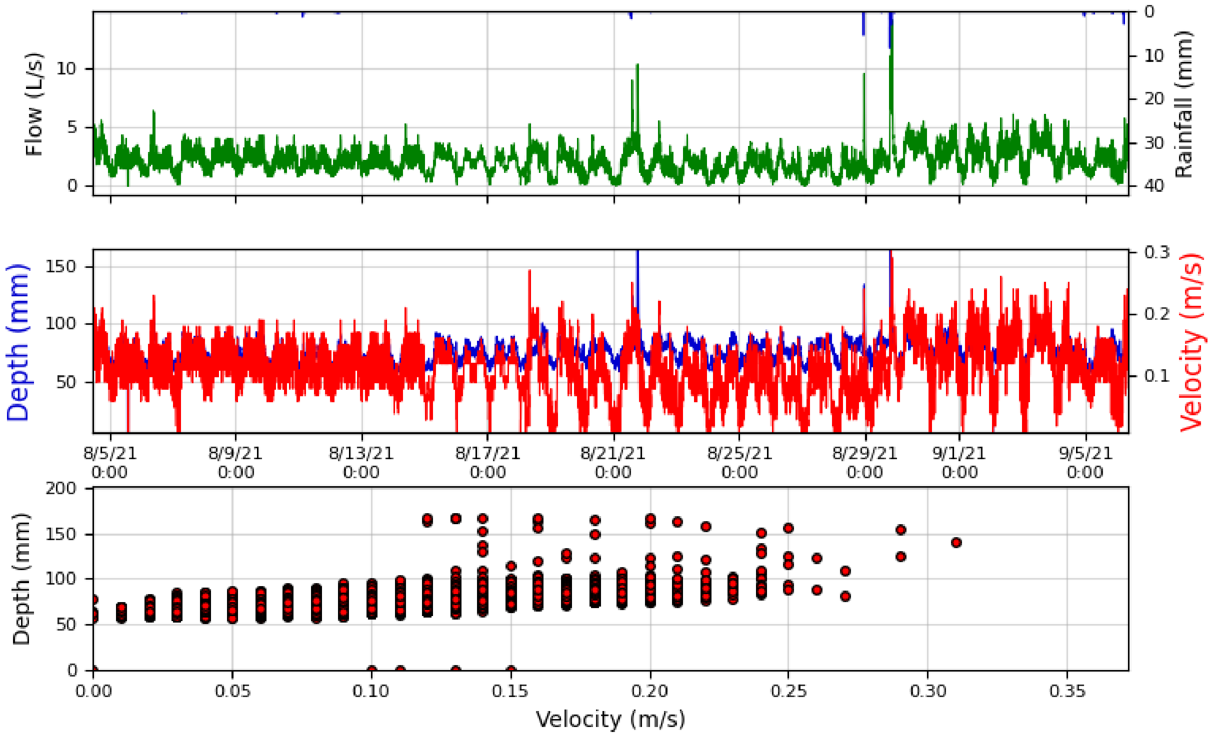


Figure 5.3: FM3b Flow, Depth and Velocity Data

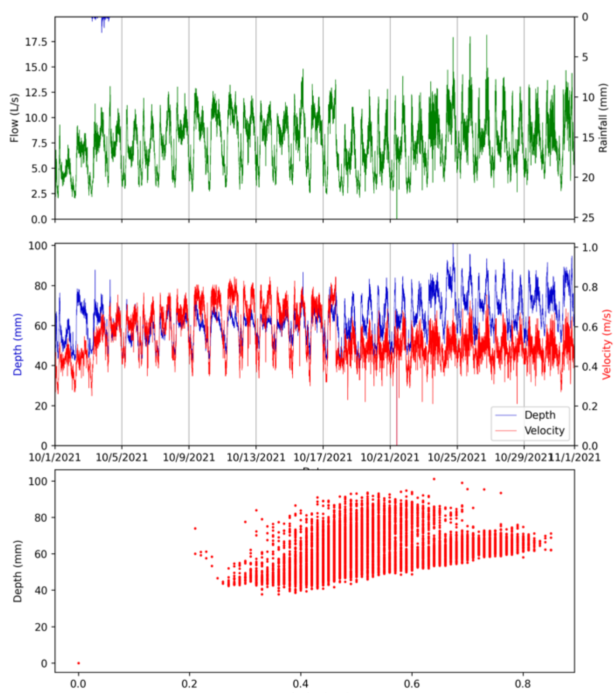


Figure 5.4: FM19 Flow, Depth and Velocity Data

- **FM6 experienced substantial connectivity issues** - FM6 had a 10-day period of velocity dropout in late August, which resulted in adjustments to the meter sensors and a change in depth and velocity readings. See **Figure 5.5** for the referenced velocity dropout.

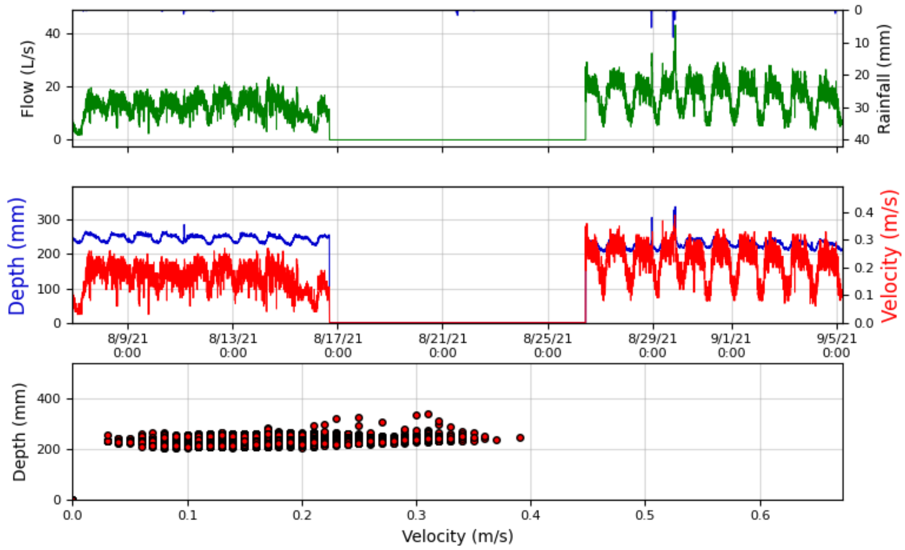


Figure 5.5: FM6 Flow, Depth and Velocity Data

- **Three meters recorded variable data** – While the flow meter data shows no missing data periods for FM2, FM4, and FM5b, a variation in the velocity and depth measurements is observed. For FM2, an abrupt jump in velocity is observed on October 1st, 2021, which persists for the remaining duration of the monitoring period (see **Figure 5.6**). AMG confirmed that there is higher confidence in the data collected after this date and noted considerable rocks and debris at this site, along with underestimated velocity readings. FM4 and FM5b see more gradual variations in readings with sporadic changes to flow patterns inconsistent with rainfall response.

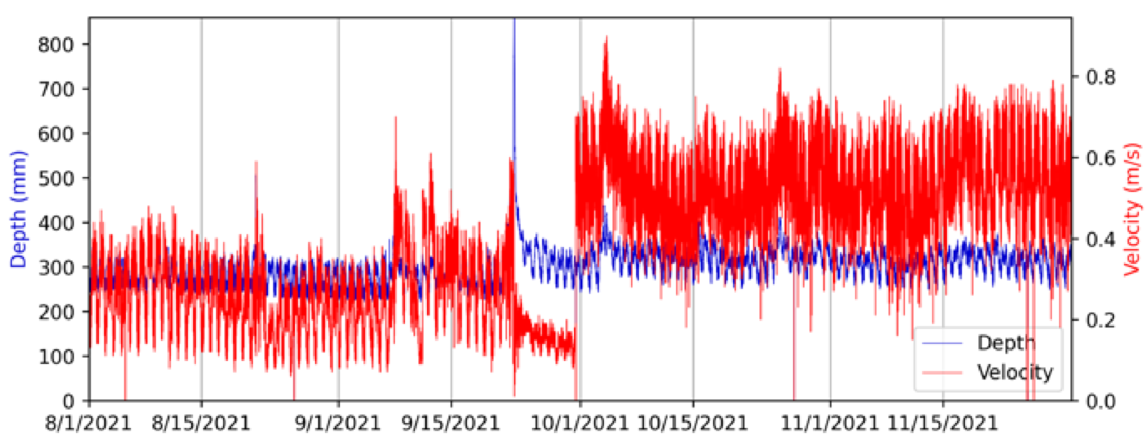


Figure 5.6: FM2 Velocity and Depth Results

- **Pump station influence** – As discussed in **Section 5.1**, there are five (5) FMs that experience notable fluctuations in flow patterns consistent with the presence of nearby pumps (FM2, FM3b, FM5b, FM9, and FM15). Pump station influence can present challenges in calibration, as operational changes occurring in the pumping stations can be difficult to represent in the model. The modelled pumping stations were updated prior to calibration using the latest Condition Assessment Reports. In some cases however, specific details required for model input were either not available or contradictory in nature. The information provided in the Condition Assessment Reports was used when available. In some cases, where the information taken from the Condition Assessment Report did not correlate with data obtained from multiple other sources, additional details were requested from the City and implemented in the model.
- **Two meters experience backwater conditions** – FM1 and FM1b both experience backwater conditions during the September 21st to 23rd rainfall event. Backwater conditions can present challenges during calibration as measurements can be less accurate when the pipe is surcharging. This response suggests that there may be some undersized pipes within this area.
- **The flow meter data quality is acceptable for calibration** – The majority of the flow meters showed reasonable response to the WWF events and presented generally consistent data for DWF calibration.

A summary of the flow meter locations, characteristics, data, and their metersheds can be found in **Appendix C**.

6.0 RAINFALL DATA COLLECTION AND ANALYSIS

The rainfall data collected from the six (6) applicable rain gauges was assessed and used to select the two (2) dry weather flow (DWF) periods and four (4) wet weather flow (WWF) events used for calibration. The following sections detail the assessment findings and selected periods.

6.1 RAINFALL DATA QUALITY AND QUANTITY REVIEW

Figure 6.1 presents the cumulative rainfall measured at each of the RGs during the flow monitoring program period from August 2021 to November 2021. RG3 and RG7 observed the largest amounts of rainfall over the monitoring period and RG2 and RG6 observed the lowest amount of rainfall. RG1 and RG4 observed similar amounts of rainfall throughout the flow monitoring period. Between August 1st and October 5th, RG2 and RG3 experienced a difference of 150 mm in cumulative rainfall.

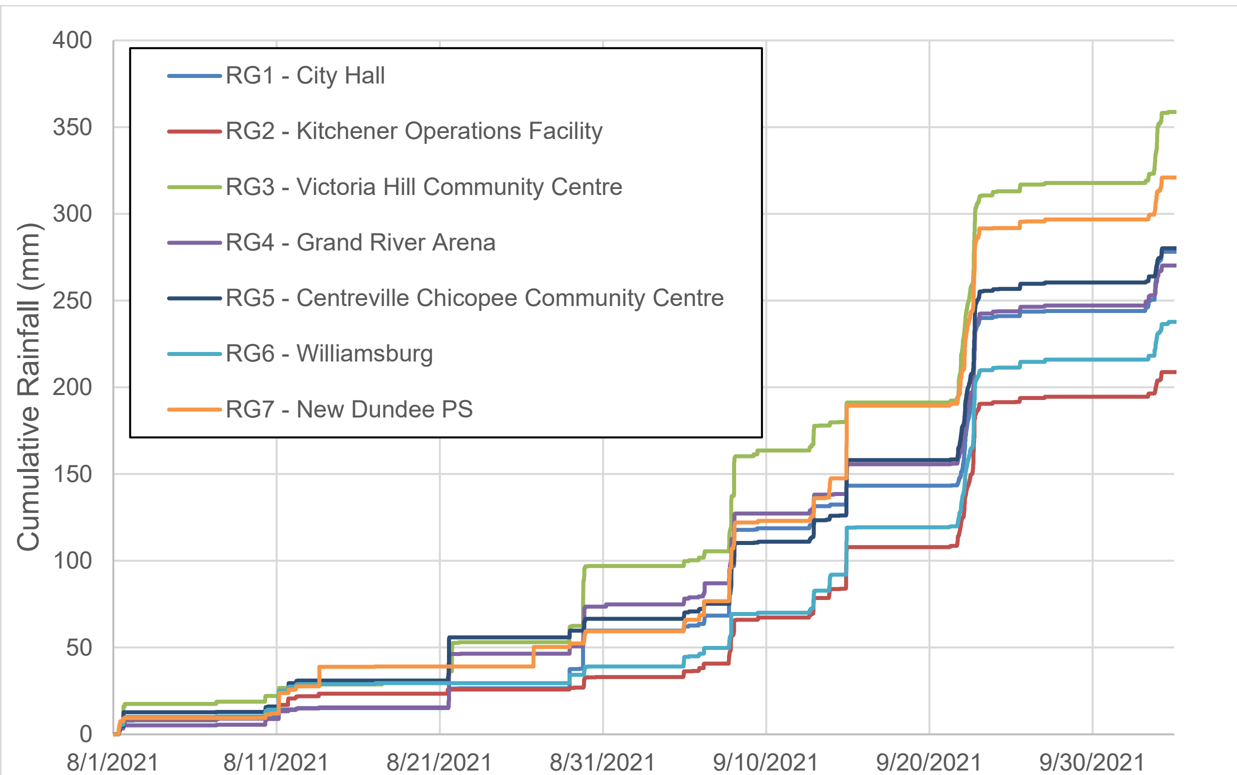


Figure 6.1: Cumulative Rainfall Volume

This demonstrates the spatial variability of rainfall across the City in that wet weather is not always uniform per flow monitor metershed or event.

6.2 DRY WEATHER FLOW CALIBRATION PERIODS

Periods of DWF were defined by no more than 1 mm of rain in the previous two days, no more than 2.5 mm of rain in the previous three days, and no more than 50 mm of rain in the previous 7 days. Ideally a period of five days of dry weather was to be selected for calibration. There was an average of 19 DWF days per rain gauge between August 2021 and early October 2021. Most of these DWF days fall within three separate periods. Only two of these periods allowed for five consecutive days with DWF conditions, and were therefore selected for calibration. These DWF periods are as follows:

- DWF Period 1: August 15th, 2021 (00:00) to August 20th, 2021 (00:00); and,
- DWF Period 2: September 28th, 2021 (00:00) to October 3rd, 2021 (00:00).

Consideration was also given in selecting the DWF periods to account for the flow variation observed at FM2 (October 1st, 2021). Thus, one period was selected before, and the other during this variation. Periods of 5 days of dry weather were few; none of which occurring entirely after the October 1st variation. Additionally, the DWF periods were chosen to include a variety of weekday and weekend days for a more representative calibration.

6.3 STORM EVENTS SUMMARY

As described in **Section 5.2**, six (6) primary rain gauges were processed for storm event identification. Storm events were defined by a minimum duration of 6 hours and 15 mm of rainfall. Peak intensities were also considered when identifying potential events for use in calibration. An average of 24 rainfall events were observed per rain gauge between August 2021 and early October 2021. **Table 6-1** presents a summary of the six (6) most significant rainfall events which were common across multiple rain gauges.

Table 6-1: Storm Event Characteristics

Start Time	End Time	Duration (hr)	Average Depth (mm)	Average Peak Intensity (mm/hr)
8/21/2021 11:40	8/21/2021 20:55	9.2	10.99[1]	25.70[1]
8/29/2021 18:45	8/30/2021 1:10	6.4	16.11	64.96
9/7/2021 16:55	9/9/2021 01:35	32.6	39.11	63.21
9/14/2021 21:35	9/15/2021 23:55	26.3	20.93	56.13
9/21/2021 16:35	9/23/2021 20:45	52.2	95.76	41.76
10/3/2021 5:30	10/5/2021 11:50	54.3	26.41	16.38

Notes:

1. The August 21st rainfall event was not observed at RG6 or RG7 and thus, the average depth and peak intensity for this event is affected.

It should be noted that RG6 and RG7 did not experience the rainfall event on August 21st, thus reducing the average depth and peak intensity presented in the above table and resulting in the exclusion of this event for calibration.

6.4 WET WEATHER FLOW CALIBRATION EVENTS

The objective for calibration was to define four (4) WWF events with at least 15 mm of rainfall depth where possible. As noted, the August 21st event was excluded as it was spatially not observed in all rain gauges. Though the August 29th storm observed a higher peak intensity than other storms, it was excluded due to its short duration and subsequent lower rainfall volume and system response.

Consequently, the wet weather events selected for calibration are as follows (see accurate start and ends times in **Table 6-1**):

- WWF Event 1: September 7th, 2021 to September 9th, 2021;
- WWF Event 2: September 14th, 2021 to September 15th, 2021;
- WWF Event 3: September 21st, 2021 to September 23rd, 2021; and,
- WWF Event 4: October 3rd, 2021 to October 5th, 2021.

Similar to the DWF period selection, the WWF event selection objective was to include at least one event in October to provide a basis of calibration for FM2. WWF Event 4 occurred after October 1st and therefore satisfies the calibration needs of FM2.

The selected WWF events were plotted against the City's Intensity-Duration-Frequency (IDF) curves, with most gauges measuring rainfall events with a 1:2-year return period or less. In WWF Event 2 however, RG7 (New Dundee Pump Station) experienced a 1:10-year return period, while all other rain gauges observed less than a 1:2-year event. While WWF Event 3 generated the most significant response in the system, it still classifies as only a 1:2-year storm. Therefore, there were limited significant events captured in the shortened monitoring period from which to base the wet weather flow calibration. See **Appendix D** for the IDF curves for the 4 selected WWF events at all 6 rain gauges.

7.0 SANITARY SYSTEM CALIBRATION AND VALIDATION

The selected 2021 flow monitoring periods/events are used to establish the DWF and WWF parameters, including the per capita sewage generation rates, diurnal patterns, groundwater infiltration (GWI) rates, resulting baseflows, and rainfall derived infiltration and inflow (RDII). Areas without monitor coverage are allocated an average of the derived 2021 parameters. A total of 2 DWF and 4 WWF events have been selected for calibration.

Once the model updates were complete and the flow monitoring had been analyzed for data quality and DWF and WWF event selection, the monitoring (or observed) data and the rain gauge data were imported into InfoWorks as Flow Surveys for comparison to the modelled results. This initial review is considered model validation, to observe how well the original model parameters meet current monitoring data. The process of adjusting model parameters to better correlate results with observed data is referred to as model calibration. This calibration process was achieved using an iterative approach until an acceptable fit to the observed flow was obtained. Dry and wet weather targets have been adopted in accordance with the *Wastewater Planning Users Group (WAPUG, now CIWEM) Code of Practice for the Hydraulic Modelling of Sewer Systems,"* ver. 3.001, dated November 2002. The target guidelines are outlined in **Section 7.2.1** and **Section 7.3.1**.

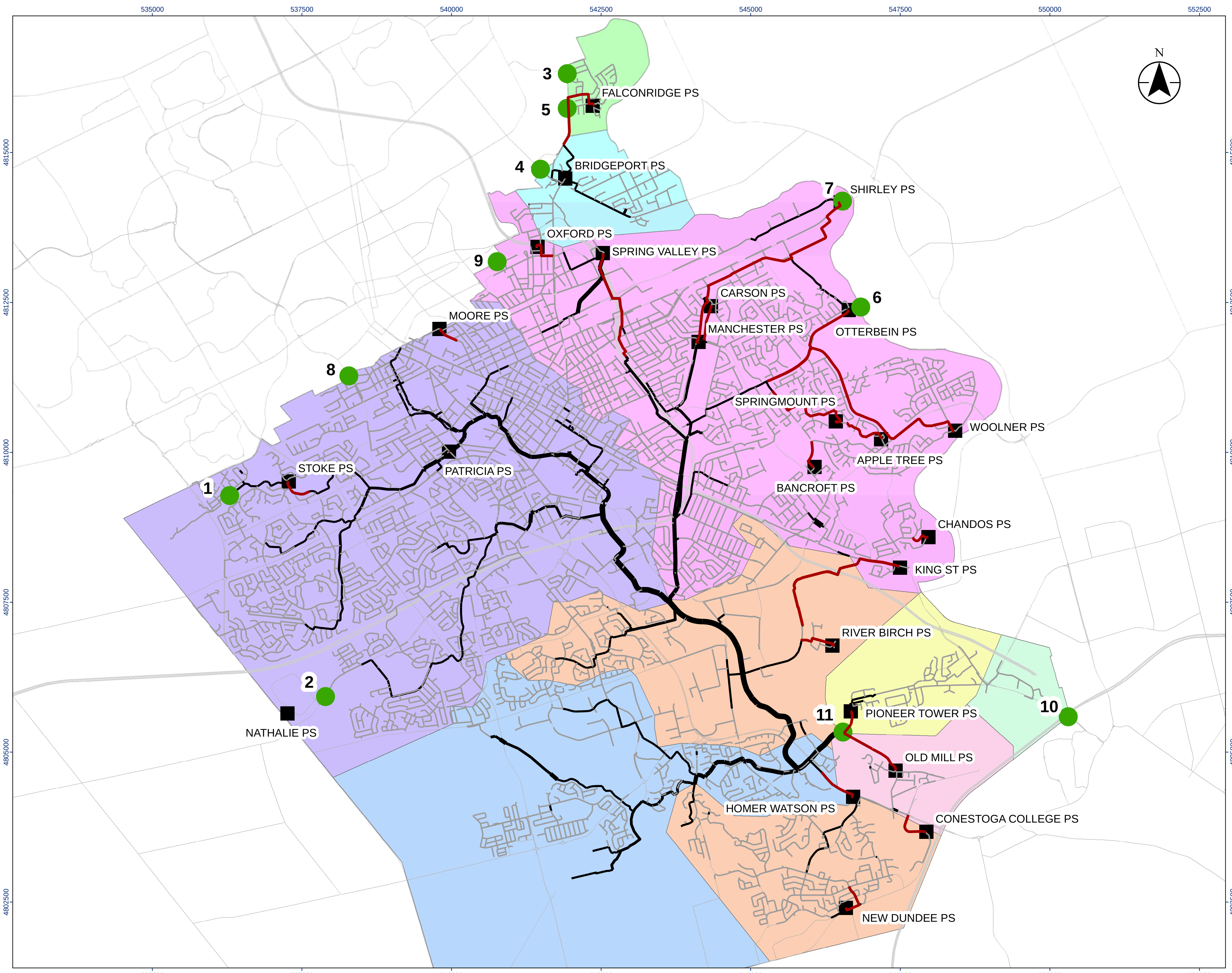
7.1 BOUNDARY CONDITIONS

In the Kitchener ISAN-MP model, there are several discharge and inflow points into and from adjacent systems, as discussed in **Section 4.1.5**. The Cross-Border Agreements for each of these locations have been reviewed and used to assess the impact of these sources. Based on this review and the adjacent system's conditions, a total of seven (7) inflow locations and 13 discharge points were identified. Of the 7 inflow locations, only four (4) have a maximum acceptable discharge flow rate explicitly stated in the agreements. Thus, only 4 inflows are applied in the model; the remaining three (3) receive an inflow of 0 L/s, but are instead compensated for by the GWI rate attributed to the FM19 and unmonitored metershed, as no inflow data was provided. As only the maximum flow rate is provided in the agreements at the 4 inflow locations where information is available, this maximum discharge rate is applied as a constant inflow at each location, with the exception of the Breslau inflow into the Shirley SPS. The Cross-Border Agreement for this location indicated a maximum allowable discharge into the Kitchener system just upstream of the Shirley SPS of 189 L/s. This value was originally applied as the inflow boundary condition in the model; however, through calibration, it was determined that this value was overly conservative and was reduced based on the average weekly flows observed through the 2021 metered data provided from the Victoria SPS. These 4 inflows are applied to the upstream ends of the FM2, FM5b, FM9, and FM10 sewersheds.

In addition to these inflow points, two areas residing within the City of Waterloo contribute to the City of Kitchener sanitary sewer system based on the Cross-Border Agreement review. These areas are located along the north-central border of the City of Kitchener and include approximately 11 ha of residential properties. These areas have been integrated into the Kitchener ISAN-MP model using high-level parcel-based subcatchments defining the total and contributing areas, with estimated populations based on unit counts and the 3.5 persons per unit (ppu) design rate.

One level boundary condition is applied to the discharge location into Cambridge where FM20 is located. The downstream obvert elevation is applied as a constant boundary condition at this location, representing the conservative assumption that the downstream system is full. There are also 11 pumping station overflows that discharge to nearby watercourses or storm systems. Since these overflows are meant to relieve the system when inundated, it can be initially assumed that the downstream water levels do not impact the overflows. The validity of this assumption was reviewed during calibration and did not suggest any required adjustments. There is also one potential boundary condition at the WWTP. Based on WWTP drawing review and discussions with the facility operators, the hydraulic drop between the sewer system and the WWTP is substantial and not anticipated to generate backwater conditions in the upstream system. Thus, a free-flowing outfall was initially applied at this location in the model (i.e., no water level boundary applied) and verified during calibration.

Figure 7.1 and **Table 7-1** present the boundary conditions applied in the model.



Stantec

Legend

- Boundary Condition Location
- Sewage Pumping Station
- Sanitary Sewer
- ForceMain

Sewershed

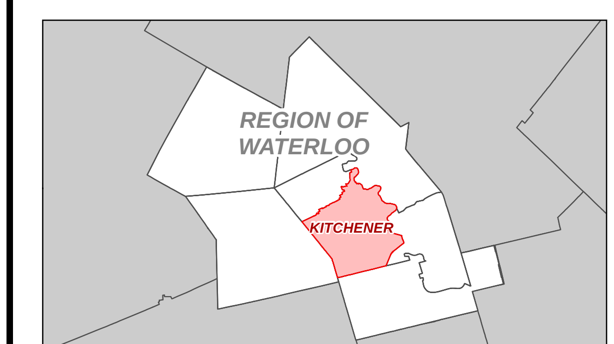
- Bridgeport
- Gateway Park
- Lower Schneider
- Melitzer
- Montgomery
- New Dundee
- Pioneer Tower West
- Strasburg
- Upper Schneider

0 10 20 km

1:65,355 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2021.
3. Contains information licensed under the Open Government Licence - The Corporation of the City of Kitchener, 2021.



Project Location
City of Kitchener

165640334 REVA
Prepared by HB on 2022-10-05

Client/Project
CITY OF KITCHENER
INTEGRATED SANITARY MASTER PLAN

Figure No.
7.1

Title
Boundary Condition Locations

Table 7-1: Boundary Conditions

Location No.	Location (Sewershed)	MH/ Modelled Node ID	Second Party in Cross Border Agreement	Boundary Condition Type	FM Metershed	Value Applied
1	Upper Schneider - Henry Sturm Direct	310088	Waterloo	Inflow	FM2	30.00 L/s
2	Upper Schneider - Borden	311511	Wilmot	Inflow	FM5b	7.05 L/s
3	Melitzer	311933	Waterloo	Inflow	FM19	Accounted for in GWI Rate
4	Bridgeport	JCT-236	Waterloo	Inflow	Unmonitored	Accounted for in GWI Rate
5	Melitzer	JCT-736	Waterloo	Inflow	FM19	Accounted for in GWI Rate
6	Montgomery - Kolb	JCT-88	Safety Kleen	Inflow	FM9	38.00 L/s (2 am to 5 am)
7	Montgomery - Kolb	Shirley-Dummy-Inflow	Woolwich	Inflow	FM10	12.70 L/s
8	Upper Schneider Westmount Direct	306155	Waterloo	External Subcatchment	FM2b	61 Units x 3.5 PPU
9	Montgomory – Spring Valley North	JCT-256	Waterloo	External Subcatchment	Unmonitored	38 Units x 3.5 PPU
10	Gateway Park	303424	Cambridge	Level	FM20	294.93 m (Pipe Obvert)
11	Lower Schneider – Direct	WWTP	N/A	Level	Unmonitored	Free Flowing

It is important to note that the boundary conditions used may be conservative as the maximum allowable flow value is applied as a constant inflow, and may result in overestimation of downstream flows. Additionally, for the other 3 locations where the inflow data was not provided, downstream modelled flows may be underestimated. This could include underestimations of GWI, per capita flow rates and RTK parameters, which may affect the calibration downstream of these locations.

7.2 DRY WEATHER CALIBRATION

7.2.1 Approach

The DWF parameters (sewage rate, GWI, average diurnal pattern) were determined for each sanitary flow meter using the USEPA flow monitoring data analysis software SSOAP. The GWI was derived using 85% of the average of the 7 lowest minimum nighttime flows, and was subtracted from the average sewage flow observed to determine the average DWF per meter. This represents the dry weather infiltration into the sewer and is applied as a constant base flow.

Parameters extracted from the flow monitoring data analysis are initially applied to the parcel-based and area-based subcatchments within the hydraulic model. The parcel-based subcatchments represent the flow generation based on population (diurnals, per capita sewage rates, etc.), while the area-based subcatchments represent the constant GWI. The flow hydrographs produced by the model at each meter site is compared to the monitored, or observed flow. The parameters (per capita rate, GWI, diurnal pattern) are then varied in a systematic manner within a reasonable range until an acceptable fit to the observed flow is obtained. This is completed for the two separate periods, both consisting of five full dry weather days (120 hrs). In addition to matching the overall general response, the flow hydrographs should meet the CIWEM criteria for goodness-of-fit, as defined in **Section 4.1.6.1**.

Calibration is intended to establish a representative model of the system, but often does not perfectly reflect real-life conditions. Slight differences can be observed for various reasons, including varying system hydraulics, as well as inconsistent field conditions (e.g. sediment depth, minor defects and obstructions, and/or differences between the actual pipe condition, size, or slope and the available record-drawing data applied in the model). As discussed in **Section 7.1**, boundary condition assumptions may also result in variations observed between modelled and monitored data, as does variable facility operation (i.e., pump stations) and ongoing maintenance activities such as flushing.

In some cases, the available flow monitoring data was considered reliable for only portions of the selected 5-day periods, and thus, the calibration was completed for a reduced DWF window, as necessary. Refer to **Section 7.2.3** for more details.

7.2.2 Calibration Challenges and Assumptions

The following notes outline challenges and assumptions encountered during DWF calibration:

- In dry weather flow, the magnitude of the flows tend to be small. With smaller flows, under- or overestimating the peak flows in the model by even a few L/s can result in percent fits that fall outside of the targeted range. The magnitudes should be considered to provide context for the suitability of the DWF calibration fits presented;
- The Condition Assessment Reports for all Pumping Stations incorporated in the model were reviewed and where necessary, the model was updated with the latest PS data. In some cases and as discussed with the City, some information provided in the Condition Assessment Reports contradicted that of other sources (previously modelled operation/attributes or previously documented attributes). The data provided in the latest (2020/2021) Condition Assessment Report was taken in these instances, when possible, or supplemented by additional information provided by the City. This should be considered in the interpretation; specifically for flow meters where PS influence is observed, including FM2, FM3b, FM5b, FM9, FM10 and FM15 (as discussed in **Section 5.5**). As the Condition Assessment Reports represent the most up-to-date information for each pumping station, pump operation was not generally tweaked as part of calibration, unless the calibration suggested information from another source was better suited. It should be noted that the information compiled for the Condition Assessment Reports does not always have a direct relation to the required model inputs, and can thus result in a reasonable

estimation of pump station operation in the model, but not a perfect representation. Additionally, actual pump station operation is not consistent, adding another layer of uncertainty;

- GWI rates can vary substantially depending on the soil condition, climate, location, and season. It is important to consider the DWF period over which the calibration is being completed. Since the calibration period extends from August to November, the GWI rates are anticipated to be less than those possibly seen during wetter seasons, such as the spring melt. Typical GWI rates can range anywhere from 0.02 to 0.12 L/s/ha (approx. 1,000 L/ha/d to 11,000 L/ha/d). Higher or lower rates are also possible; and,
- The ICI wastewater flow rate can vary considerably depending on the type of commerce, industry, or institution present. ICI flow rates can vary from as low as 1,500 L/ha/d to as high as 75,000 L/ha/d. Water consumption records were used as a reference to validate wastewater flows. These water consumption rates are reported in **Table 7-2**.

7.2.3 Results

Table 7-2 presents the final DWF parameters derived through model calibration for each metershed.

Table 7-2: Final Dry Weather Flow Parameters

Flow Monitor		Metershed Characteristics				Calibrated Parameters					
		Total[1] Area-Based[2] Tributary Area	Total[1] Existing Population	Water Consumption Rates[3]		Average Dry Weather Flow		Groundwater Infiltration		Average Sewage Flow	
		(ha)		(L/s)	(L/c/d)	(L/s)	(L/c/d)	(L/s)	(L/s/ha)	(L/s)	(L/c/d)
FM1	308300-KW-Highland Rd W	307	13,213	23.2	152	29.5	193	8.5	0.028	21.1	138
FM1b	309484-KW-Highview Dr	48	1,984	4.2	183	4.5	196	1.0	0.021	3.4	147
FM2	304470-KW-West Ave	703	37,628	65.2	150	113.5	261	17.6	0.025	96.0	220
FM2b	304819-KW-Sandrock Creek	217	15,073	32.1	184	30.6	175	12.8	0.059	17.8	102
FM3	311165-KW-Victoria St S	168	12,532	15.6	108	16.8	116	0.8	0.005	16.1	111
FM3b	2091740-KW-Moore Ave PS	33	1,810	2.4	115	2.1	100	0.1	0.003	2.0	95
FM4	303786-KW-David St	44	6,663	9.3	121	8.4	109	2.2	0.050	6.3	82
FM5b	311440-KW-Activa Ave	81	4,522	11.6	222	16.1	308	0.8	0.010	15.3	292
FM6	301110-KW-Borden Ave S	92	9,174	12.6	119	13.3	125	1.0	0.011	12.3	116

Flow Monitor		Metershed Characteristics				Calibrated Parameters					
		Total[1] Area-Based[2] Tributary Area	Total[1] Existing Population	Water Consumption Rates[3]		Average Dry Weather Flow		Groundwater Infiltration		Average Sewage Flow	
		(ha)		(L/s)	(L/c/d)	(L/s)	(L/c/d)	(L/s)	(L/s/ha)	(L/s)	(L/c/d)
FM7	306584-KW-Hoffman St	780	40,466	73.1	156	66.4	142	9.3	0.012	57.1	122
FM9	301182-KW-Ottawa St N	486	18,841	45.2	207	72.6	333	20.4	0.042	52.2	239
FM10	300305-KW-Shelley Dr	1,210	51,964	80.8	134	147.9	246	35.3	0.029	112.6	187
FM11	302989-KW-Manitou Dr	62	9,802	18.7	165	30.8	271	5.2	0.084	25.5	225
FM12	300575-KW-Balzer Creek Trail	172	11,463	24.7	186	23.6	178	4.9	0.028	18.7	141
FM13	303564-KW-Black Walnut Dr	456	21,118	24.0	98	53.6	219	16.5	0.036	37.0	151
FM13b	2001421-KW-Huron Rd	175	9,495	20.9	190	30.1	274	3.8	0.022	26.3	239
FM15	303238-KW-Homer Watson PS	289	10,340	30.6	256	30.1	252	8.7	0.030	21.4	179
FM18	306550-KW-Hanson Ave	51	3,220	5.2	140	7.0	188	1.0	0.020	6.0	161
FM19	311719-KW-Falconridge PS	60	1,960	5.5	242	6.8	300	1.7	0.028	5.2	229
FM20	303424-KW-King St E	26	1,159	1.9	142	3.8	283	0.7	0.027	3.1	231
Average		***-***	***-***	***-***	***155***	***-***	***216***	***-***	***0.028***	***-***	***170***
Total		***5,459***	***282,426***	***507***	***-***	***708***	***-***	***152***	***-***	***555***	***-***

Notes:

1. Total Area-Based Tributary Area and Total Existing Population includes all area/population draining to upstream FMs (FM in series).
2. Area-Based Tributary area refers to the area draining to each meter, based on the buffer-derived “SA” subcatchments only. “SA” subcatchments are defined by a 90 m buffer around all pipes and are meant to represent the effective area contributing groundwater and rainfall derived I/I to each sewer segment.
3. The Water Consumption Rates presented are based on 100% of the average water consumption rates for August, September, and October 2020.

The GWI rates range between 0.003 L/s/ha and 0.084 L/s/ha, with an average of 0.028 L/s/ha. Metersheds such as FM3, FM3b, FM5b, FM6 and FM7 exhibit lower GWI values, which generally correspond to areas containing newer residential sanitary systems (2000’s or newer). In theory, newer systems have better seals resulting in less infiltration into the piping network. Higher GWI rates (0.050 - 0.084 L/s/ha) are applied in the FM4, FM2b, and FM11 metersheds, which generally align with smaller mixed/ICI land use areas comprised of mostly older pipes (1960 – 1980). Refer to **Figure 5.1** and **Table**

5-1 in **Section 5.1** for sewer age and land use classifications, respectively. All GWI rates applied are relatively low when compared to typical rates and design rates used for other municipalities. These lower rates correlate with a relatively new and tight overall sanitary system. Details for each FM metershed can also be found in **Appendix C**.

The per capita flow rates range between 82 L/c/d and 292 L/c/d, with an overall average of 170 L/c/d. All derived per capita rates are lower than the design rate used for new developments (305 L/c/d), which is expected as design rates are considered conservative. Lower per capita rates (< 100 L/c/d) are observed in the north-central portion of the City (metersheds FM3b, and FM4). These areas generally correspond to those that were determined to have lower per capita rates in the previous calibration (Table 3-4 of AECOM's Sanitary Sewer System Model Update Report, dated 2019). These low per capita rates may be explained by overestimated residential and/or employment populations within this portion of the City, and may be further affected by population fluctuations experienced throughout the school year, or due to overly-conservative employment populations as a result of the COVID-19 pandemic. FM3b is predominantly residential (87% of the population is residential), whereas FM4 represents the downtown core of Kitchener and is predominantly comprised of ICI area, with only 24% of the population considered residential. FM3b and FM4 have relatively small tributary areas (30 - 45 ha).

The population densities for the metersheds with low per capita rates were calculated using the total population within the metershed (residential and employment) to help inform these values. The population density for FM3b is representative of typical residential areas, with 59 persons/ha. FM4 however, has a relatively high population density of 211 persons/ha, which further emphasizes the possibility of the overestimation of populations resulting from impacts from the pandemic.

As mentioned in **Section 7.2.2**, water consumption rates are used to validate the DWF per capita rates established through calibration. As shown in **Table 7-2**, the water consumption per capita rates generally align with the dry weather flow rates, with a total average water consumption rate of 155 L/c/d; only 15 L/c/d lower than the total average DWF per capita rate (170 L/c/d). The three ICI metersheds (FM4, FM11, and FM20) account for some of the more significant differences between water consumption and average dry weather flow rates, typically resulting in higher DWF per capita rates than water consumption rates. Additionally, FM2 (residential), FM2b (mixed land use), FM10 (residential), and FM15 (residential) also experience considerable variations; generally exhibiting lower DWF per capita rates than water consumption rates. These differences may be due to industrial processes within the ICI areas, or lawn watering practices in residential and mixed areas**.** The average dry weather per capita rates of the remaining metersheds generally align with the water consumption rates reported in **Table 7-2**. It should be noted that the water consumption rates are derived from 2020 water billing data and while offering an opportunity to validate the DWF rates established through calibration, may not accurately reflect the water consumption observed during the calibration period in 2021.

Table 7-3 and **Table 7-4** present the resulting calibration fits between the modelled and observed data for DWF Period 1 (August 15th – 20th, 2021) and DWF Period 2 (September 28th - October 3rd, 2021), respectively. The peak flow and volume percent fits are colour-coded in green if it falls within the targeted range of ± 10%, yellow if it extends up to the ± 15% range, and red if it exceeds the ± 15% range. These tables also include details regarding reduced calibration periods, which can be found in the 'Reduced

Data Window Presented' columns. The 'Data Quality Notes' column briefly explains why the period was unsuitable for calibration for the entirety of the 5 days, if applicable. In general, data variability and velocity dropouts were the cause of the reduced periods of calibration. FM6 and FM19 were reduced to less than 48 hours in DWF Period 1. All other flow monitors had a suitable calibration period of at least 48 hours for both DWF periods. Refer to **Appendix E** for the corresponding DWF calibration graphs.

Generally, the fits reported in **Table 7-3** and **Table 7-4** show low peak flow calibration fits, but good fits with respect to volume. The majority of the peak flows fall outside the targeted range except for four (4) FMs in the DWF Period 1, which will be further discussed below. As for the volume fits, 11 fall within the targeted volume percent fits in the DWF Period 1, and 14 fall within the targeted volume percent fits in DWF Period 2. Key observations regarding the monitored data that help to explain where the targeted calibration fits were not met are described below:

- There is noise observed in the monitored data during DWF conditions for many of the meters, which can often be attributed to the low flows observed and corresponding measurement inaccuracies that can occur in these conditions. In some cases, this noise can also be due to nearby pumping station influence. This noise results in several instantaneous elevated readings for many of these metered locations. In order to generate the diurnal patterns for calibration, the hourly flows are averaged, essentially smoothing out the flow pattern and reducing the noise generated in the modelled response. If the observed peak flow is adjusted to account for removal of this noise, the observed and modelled peak flows are closer than **Table 7-3** and **Table 7-4** suggest and generally fall within the targeted fits. These adjustments however, are not included in the above-presented tables and therefore, the majority of peak flows are reported as exceeding the targets. An example of this noise can be seen in **Figure 7.2** (FM3 in DWF Period 1), where the smoothed simulated results essentially average the highs and lows of the observed flow fluctuations. In this example, the volumetric calibration fit is good, and the peak flow fit falls just below of the targeted range (at -10.4% fit);

Table 7-3: 2021 Dry Weather Calibration Results for Period 1 – Peak Flow & Volume

FM ID	FM Name	Link ID	Reduced Data Window Presented	Data Quality Notes	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Volume (m^3)	Modelled Volume (m^3)	Volume Percent Fit
FM1	308300-KW-Highland Rd W	308299.1			0.049	0.043	-10.8%	11,326	13,338	17.8%
FM1b	309484-KW-Highview Dr	309486.1			0.009	0.006	-24.5%	1,837	1,968	7.2%
FM2	304470-KW-West Ave	304472.1		Before Oct 1st unreliable, PS influence	0.097	0.158	63.9%	21,572	51,094	136.9%
FM2b	304819-KW-Sandrock Creek	304821.1			0.040	0.037	-7.6%	12,104	13,457	11.2%
FM3	311165-KW-Victoria St S	311167.1			0.029	0.026	-10.4%	6,841	6,851	0.1%
FM3b	2091740-KW-Moore Ave PS	2091735.1	Day 1-2 only	Questionable data	0.004	0.004	-4.2%	349	383	9.7%
FM4	303786-KW-David St	303748.1		Variable data	0.015	0.010	-33.9%	3,442	3,581	4.0%
FM5b	311440-KW-Activa Ave	311440.1	Day 3-4 only	Velocity dropouts	0.025	0.024	-3.0%	2,883	3,545	22.9%
FM6	301110-KW-Borden Ave S	2130010.1	First 36h only	Variable data, velocity dropouts	0.020	0.017	-14.0%	1,225	1,499	22.4%
FM7	306584-KW-Hoffman St	306527.1			0.143	0.104	-27.2%	31,312	32,805	4.8%
FM9	301182-KW-Ottawa St N	301207.1	Day 1-3 only	Velocity dropouts, PS influence	0.184	0.147	-20.0%	17,819	19,956	12.0%
FM10	300305-KW-Shelley Dr	300304.1		PS influence	0.356	0.281	-21.1%	60,026	81,082	35.1%
FM11	302989-KW-Manitou Dr	302987.1			0.051	0.037	-27.6%	11,910	12,969	8.9%
FM12	300575-KW-Balzer Creek Trail	307136.1			0.044	0.035	-19.3%	9,694	10,551	8.8%
FM13	303564-KW-Black Walnut Dr	303563.1			0.075	0.077	3.0%	21,006	23,317	11.0%
FM13b	2001421-KW-Huron Rd	2001420.1			0.057	0.047	-18.9%	11,282	12,333	9.3%

FM ID	FM Name	Link ID	Reduced Data Window Presented	Data Quality Notes	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Volume (m^3)	Modelled Volume (m^3)	Volume Percent Fit
FM15	303238-KW-Homer Watson PS	303239.1		PS influence	0.064	0.041	-35.5%	12,367	12,732	3.0%
FM18	306550-KW-Hanson Ave	306551.1			0.016	0.010	-37.2%	3,076	2,950	-4.1%
FM19	311719-KW-Falconridge PS	311920.1	First 44h only	Variable data	0.014	0.009	-34.0%	1,187	1,040	-12.4%
FM20	303424-KW-King St E	303425.1			0.007	0.006	-18.5%	1,571	1,670	6.3%

Table 7-4: 2021 Dry Weather Calibration Results for Period 2 – Peak Flow & Volume

FM ID	FM Name	Link ID	Reduced Data Window Presented	Data Quality Notes	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Volume (m^3)	Modelled Volume (m^3)	Volume Percent Fit
FM1	308300-KW-Highland Rd W	308299.1			0.062	0.043	-30.4%	14,987	13,341	-11.0%
FM1b	309484-KW-Highview Dr	309486.1	Day 2-3 only	Velocity dropouts	0.011	0.006	-48.7%	899	787	-12.4%
FM2	304470-KW-West Ave	304472.1	After Sept 30th at noon	Before Oct 1st unreliable, PS influence	0.186	0.158	-15.2%	25,399	25,961	2.2%
FM2b	304819-KW-Sandrock Creek	304821.1			0.047	0.037	-21.1%	13,673	13,458	-1.6%
FM3	311165-KW-Victoria St S	311167.1			0.035	0.026	-25.3%	7,271	6,851	-5.8%
FM3b	2091740-KW-Moore Ave PS	2091735.1	Day 1-2 only	Variable data	0.005	0.003	-37.4%	380	383	0.7%
FM4	303786-KW-David St	303748.1		Variable data	0.015	0.010	-32.5%	3,595	3,581	-0.4%
FM5b	311440-KW-Activa Ave	311440.1	Day 4-5 only	Variable data	0.029	0.025	-14.3%	3,047	3,545	16.3%
FM6	301110-KW-Borden Ave S	2130010.1		Variable data	0.024	0.017	-28.4%	4,807	5,241	9.0%

FM ID	FM Name	Link ID	Reduced Data Window Presented	Data Quality Notes	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Volume (m^3)	Modelled Volume (m^3)	Volume Percent Fit
FM7	306584-KW-Hoffman St	306527.1			0.139	0.105	-24.5%	28,484	32,798	15.1%
FM9	301182-KW-Ottawa St N	301207.1		PS influence	0.198	0.145	-26.5%	32,332	33,211	2.7%
FM10	300305-KW-Shelley Dr	300304.1		PS influence	0.380	0.283	-25.5%	67,087	81,084	20.9%
FM11	302989-KW-Manitou Dr	302987.1			0.048	0.037	-22.8%	12,183	12,972	6.5%
FM12	300575-KW-Balzer Creek Trail	307136.1			0.049	0.035	-28.4%	9,980	10,552	5.7%
FM13	303564-KW-Black Walnut Dr	303563.1			0.086	0.077	-11.0%	22,945	23,316	1.6%
FM13b	2001421-KW-Huron Rd	2001420.1			0.058	0.047	-19.5%	11,820	12,334	4.3%
FM15	303238-KW-Homer Watson PS	303239.1		PS influence	0.062	0.041	-33.3%	13,442	12,731	-5.3%
FM18	306550-KW-Hanson Ave	306551.1			0.015	0.010	-32.0%	3,160	2,950	-6.7%
FM19	311719-KW-Falconridge PS	311920.1	First 48h only	Variable data	0.012	0.009	-20.2%	1,033	1,138	10.2%
FM20	303424-KW-King St E	303425.1			0.016	0.006	-63.4%	1,720	1,670	-2.9%

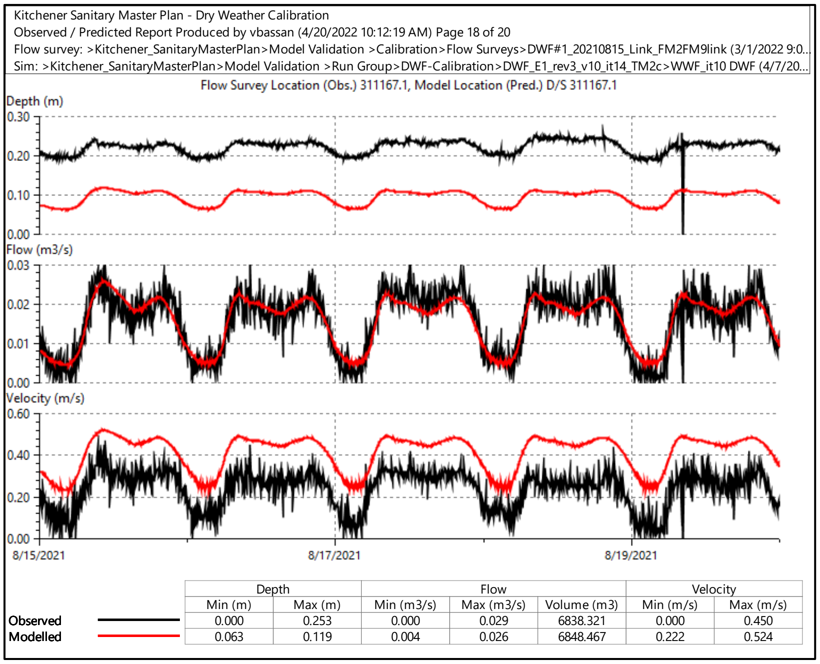


Figure 7.2: DWF Period 1 FM3 Modelled vs Observed Results

- In addition to some of the 6 FMs noted to have variable data in **Section 5.5** (FM2, FM3b, FM4, FM5b, FM6, and FM19), FM1b and FM9 require a reduction in one of the DWF periods for calibration to account for variable data observed during that specific DWF period;
- As many of these meters see low-magnitude DWFs (<50 L/s), even a small discrepancy of only 5 L/s or less between the modelled and observed flows can result in calibration fits that fall outside of the targeted range, which is a contributing factor to the low peak flow calibration fits observed, but is not a significant difference at the master planning metershed parameter scale;
- The differences in the volumetric percent fit can sometimes be attributed to variations in the diurnal pattern over the flow monitoring period. Only one diurnal flow pattern is generated per meter and represents the average pattern observed over the monitoring period, excluding any questionable days. This may result in a slightly better fit in one period than the other. Diurnal pattern variations could be attributed to impacts observed with the start of the school year, or varying COVID-related limited contact recommendations;
- In addition to the diurnal pattern, most meters observe higher flows during DWF Period 2 (end of September to early October), than in DWF Period 1 (mid- to late-August). This is likely attributable to the influx of student population for the start of the school year and return from summer holiday season. This is always a challenge for calibration, where the best balance of parameters are applied given the number of inherent contributing variables;
- FM1, FM1b, FM2b and FM19 experience volumetric calibration fits that fall outside of the targeted range in one of the DWF periods, and experience a fit lower than the targeted range in the other

period. Due to the differences observed in the monitored data, the calibration was completed to sit between both extremes to produce an overall average within the targeted volume percent fit;

- FM5b, FM6, FM7, FM9, FM10 and FM13 have higher modelled volumes than observed in one or both of the DWF periods. FM5b and FM6 are noted in **Section 5.5** to experience data variability over the monitoring period, including a gradual increase and pump station influence observed at FM5b, and an extended velocity dropout at FM6 that resulted in a change in depth and velocity readings after coming back online. The pump station influence observed in FM5b is caused by the Mannheim SPS located at the upstream end of the metershed. This pumping station is not included in the model however, and is instead replaced by a constant inflow boundary condition. This can help to explain the peak flow and volumetric differences observed between modelled and monitored data at this location. FM7, FM9, and FM13 see higher volumes in the model than observed for both DWF periods, but experience good volume fits for one of the DWF Periods, and fits that are slightly high for the other period; thus resulting in an acceptable calibration. FM9 also sees additional inflow between the hours of 2 am and 5 am daily from the Safety Kleen facility, represented by a constant inflow boundary condition during this time period. Because this inflow is assumed based on the limited data available, the DWF parameters were not further reduced to account for this additional flow/volume. FM10's volumetric calibration fits are high in both events, but this meter resides downstream of FM9 and thus the exaggerated volumes observed in FM9 are propagated downstream and cannot be reduced further due to restrictive lower limit per capita rates observed in FM10. Additionally, as most of the modelled peak flows are lower than the monitored data, the GWI and/or per capita rates may have been increased in an attempt to better match the peak flows, resulting in higher volumes; and,

- FM2 was considered to have more reliable data after October 1st, 2021. This would exclude DWF Period 1 from the calibration and explains the exceedances reported in **Table 7-3**.

7.3 WET WEATHER CALIBRATION

7.3.1 Approach

The WWF event-based calibration was carried out for the four (4) selected events discussed in **Section 6.4**. These events fall within the top six (6) events recorded while considering depth, intensity, and volume. WWF Event 3 was considered the largest event as it consisted of the greatest amount of rainfall observed over one of the longest event durations. Ideally, one set of WWF calibration parameters would produce perfect fits in all four events, but this is not likely due to the variance in rain, as well as other model limitations. Therefore, when there is a large response difference between WWF Event 3 and the other WWF events, the calibration focused on matching WWF Event 3 over than the other events as to produce a more conservative model.

Upstream monitors were calibrated first, with the process systematically working downstream. This iterative process continued, with due consideration given to the flow data quality and model assumptions and uncertainties, until a reasonable representation of the various captured storm events was achieved.

The modelled flow rates, volumes, and depths are compared to the observed values from the corresponding rainfall event to determine the calibration fits. The hydrographs should closely follow each other both in shape and in magnitude, until the flow has substantially returned to DWF conditions. In addition to matching the overall general response, the flow hydrographs should meet the CIWEM criteria for goodness-of-fit, as defined in **Section 4.1.6.2**.

The RDII in a sanitary system is often estimated using the RTK method, where the "R" is the percentage of rainfall in a given metershed that is observed in the sewer, the "T" is the time it takes to see the peak flow response to a rainfall occurrence (Time to Peak), and the "K" is the ratio of the Time to Peak to the recession time. **Figure 7.3** shows how these parameters work together to create three distinct unit hydrograph responses, representing the fast initial inflow response (R1, T1, K1), moderate infiltration response (R2, T2, K2) and slow infiltration response (R3, T3, K3). The fast response is attributed to cross-connections such as roof downspouts or catchbasins; the moderate response is associated with foundation drains or low-lying MHs; and the slow response is via migrating surface water through the ground into cracks and pipe/MH deficiencies.

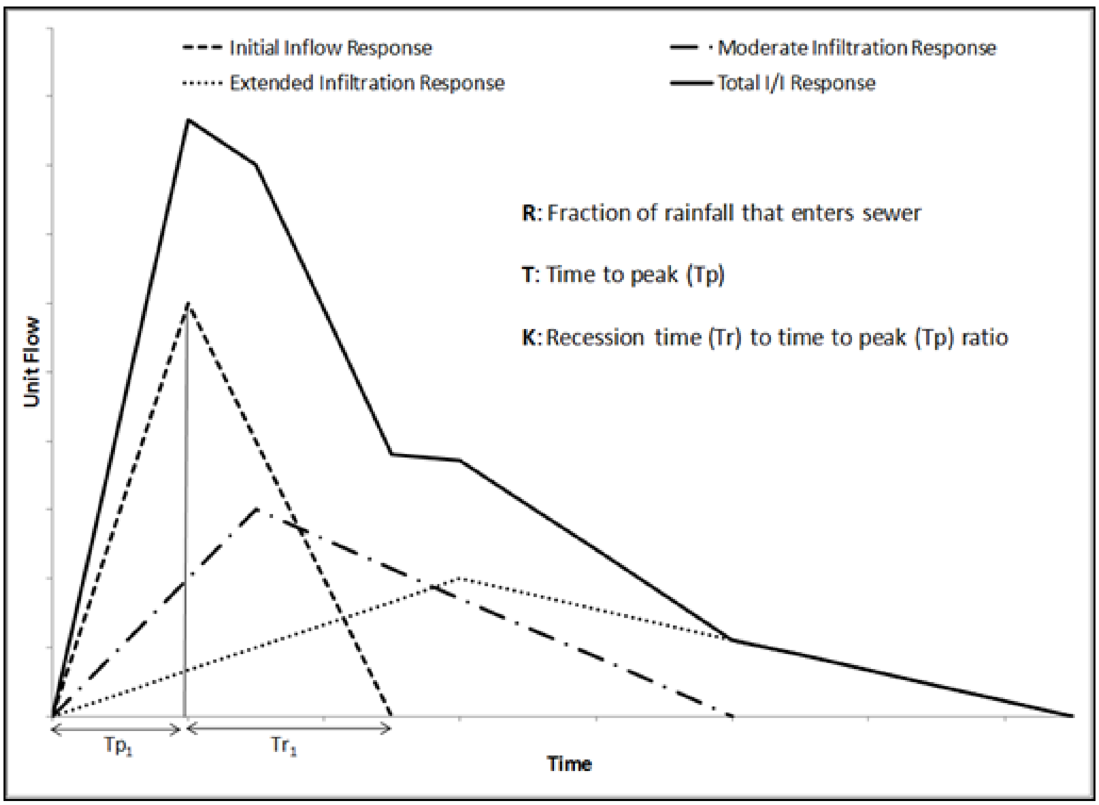


Figure 7.3: Definition of RTK Parameters

InfoWorks ICM requires these 9 RTK parameters to be applied to subcatchments. The rainfall applied on the contributing area associated to each subcatchment is used to generate the wet weather response. Both the dry weather flow parameters and the wet weather RTK parameters can be applied to the same subcatchment. For the Kitchener ISAN-MP model however, the GWI and RTK parameters are applied to the area-based sanitary subcatchments, while the other DWF parameters are applied to the parcel-based sanitary subcatchments.

RTK parameters are derived from monitoring data and applied on a metershed basis. Through hydrograph separation, the wet weather hydrograph is isolated per rain event. The volume under the curve represents the wet weather volume, which is compared to the total rainfall depth over the effective tributary area to the FM (i.e., total rainfall volume) to generate the Total R, or volumetric runoff coefficient. The value becomes the target for distributing the R1, R2 and R3 parameters per unit hydrograph. The combination of RTKs is adjusted within a range per characteristic response to generate the overall RDII response. Generally, the "R" values are adjusted to match the shape/volumes of the WWF events, and the "T" and "K" values adjusted to improve peaks timing.

Separated sewer areas are expected to have Total R values typically below 4 % to 6%, while partially separated areas are expected to have R values up to 20%, depending on the magnitude of the storm event. As the magnitude of the storm event increases, a maximum capture rate (R value) will be reached as there is a limitation on the infiltration rate of the soil, and there are capacity restrictions of the sewers.

7.3.2 Calibration Challenges and Assumptions

Beyond the targets mentioned in **Section 7.3.1**, several other factors should be considered during the WWF calibration process:

- The presence of surcharging makes calibration more difficult. It is crucial that the correct diameters, slopes, and materials are being applied in the model to be able to replicate the same backflow conditions at the same time as the monitored data. This is not unique to the pipe where the flow monitor is located, but also the pipes upstream and downstream which may be contributing to the surcharged conditions. Multiple FMs experience surcharging during this calibration period, which will be further discussed in **Section 7.3.3**;
- As discussed in **Section 7.3.1**, WWF Event 3 was selected as the primary event due to its magnitude and duration. When there is a large response difference between WWF Event 3 and the other WWF events, the calibration focuses on matching WWF Event 3 over the other events as to produce a more conservative model;
- Calibration challenges experienced for FM1 triggered a drawing review for the stretch of sewers just upstream and downstream of the flow meter. This review identified that pipe upgrades completed in 2009 had not been integrated into the model network. At the onset of this project, the previous (2016) existing conditions model was updated with recent infrastructure (2016 or newer), however, upgrades dating back to the 2000s were not evaluated. These changes were made in the model once identified, which improved the calibration fits at this location and allowed for a reduction in RTK parameters;
- The calibration focuses on matching peak flow. When an event has a long duration, such as WWF Event 3, it can consist of multiple rainfall peaks. This presents an opportunity for volume

discrepancies due to attempting to meet the largest peak flow values and over or under-estimating smaller peaks observed earlier or later in the event; and,

- In select circumstances where the data is identified as variable or questionable during the primary event (WWF Event 3), calibration is completed focusing on one or all of the other, smaller events. Calibrating to a smaller event can result in a less conservative calibration, however. This is considered in these cases by allowing slightly higher calibration fits for WWF Events 1, 2 and/or 3, where appropriate.

7.3.3 Results

The final RTK parameters for the WWF calibration are presented in **Table 7-5** and the final Total R distribution is shown per metershed in **Figure 7.4.**

Table 7-5: Final Wet Weather RTK Calibration Parameters

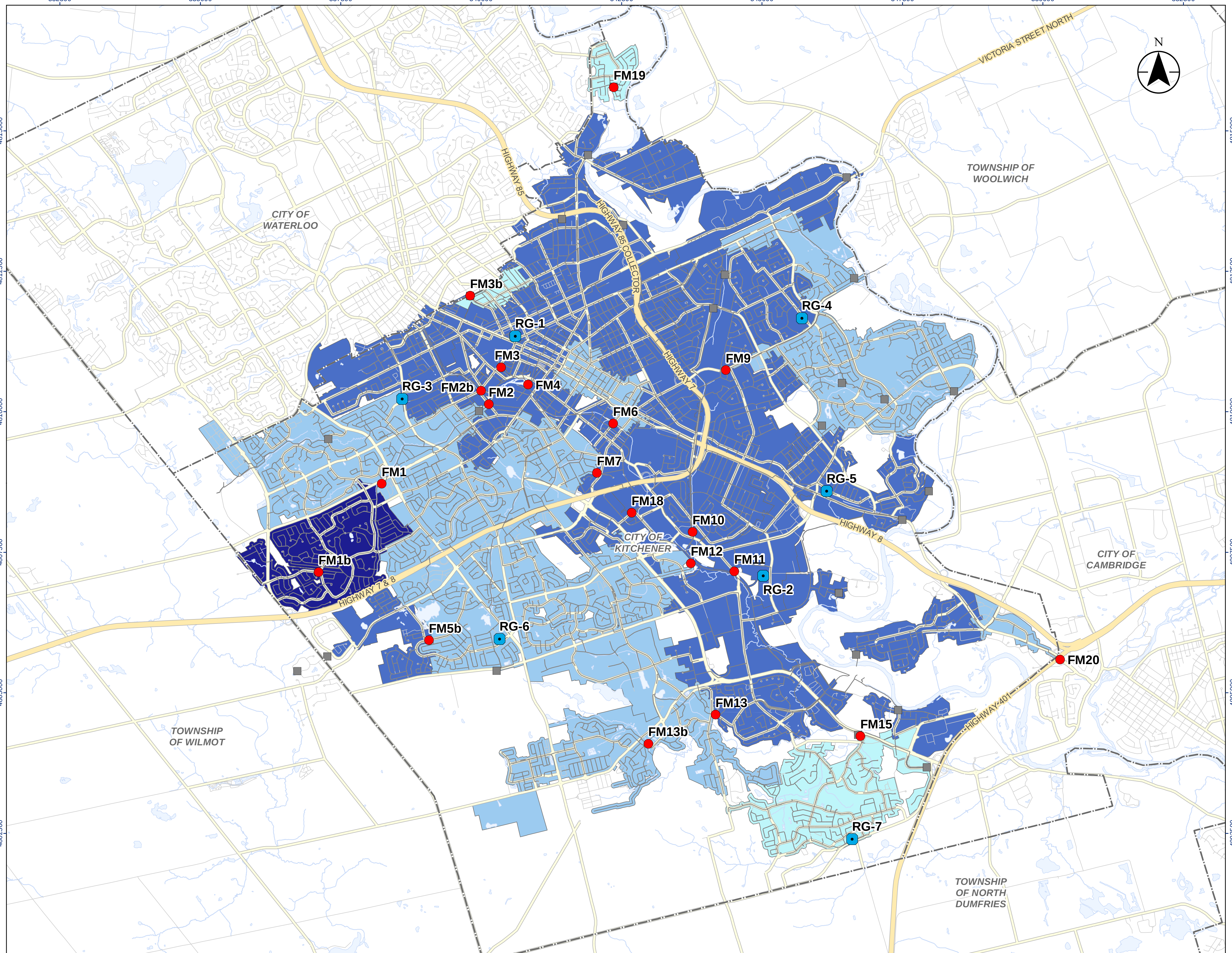
FM ID	FM Name	Total R	R1	T1	K1	R2	T2	K2	R3	T3	K3
FM1	308300-KW-Highland Rd W	8.80%	4.00%	0.9	3.0	4.80%	4.5	6.0	0	0.0	0.0
FM1b	309484-KW-Highview Dr	6.50%	2.90%	0.8	0.7	3.60%	2.9	7.0	0	0.0	0.0
FM2	304470-KW-West Ave	1.42%	0.40%	1.0	1.0	0.90%	7.0	3.0	0.12%	10.0	10.0
FM2b	304819-KW-Sandrock Creek	2.02%	1.00%	0.6	2.0	0.90%	3.0	7.0	0.12%	6.0	6.0
FM3	311165-KW-Victoria St S	4.20%	2.35%	0.5	4.0	1.40%	4.3	4.0	0.45%	10.0	8.0
FM3b	2091740-KW-Moore Ave PS	0.51%	0.28%	0.5	0.1	0.20%	0.6	1.0	0.03%	5.0	10.0
FM4	303786-KW-David St	2.76%	1.76%	0.5	1.0	1.00%	1.0	4.0	0	0.0	0.0
FM5b	311440-KW-Activa Ave	2.08%	2.08%	1.1	2.0	0	0.0	0.0	0	0.0	0.0
FM6	301110-KW-Borden Ave S	1.50%	0.40%	1.0	1.0	1.10%	5.0	1.0	0	0.0	0.0
FM7	306584-KW-Hoffman St	1.40%	0.80%	1.2	0.9	0.50%	2.0	3.0	0.10%	6.0	10.0
FM9	301182-KW-Ottawa St N	1.46%	0.74%	1.0	1.0	0.70%	4.0	6.0	0.02%	8.0	10.0
FM10	300305-KW-Shelley Dr	2.23%	1.20%	1.0	1.2	1.00%	2.5	4.0	0.03%	10.0	10.0
FM11	302989-KW-Manitou Dr	2.83%	1.30%	0.6	3.0	1.00%	6.0	3.0	0.53%	8.0	8.0
FM12	300575-KW-Balzer Creek Trail	1.06%	0.70%	0.9	1.0	0.30%	3.0	5.0	0.06%	6.0	10.0
FM13	303564-KW-Black Walnut Dr	1.01%	0.57%	1.3	1.0	0.40%	4.0	5.0	0.04%	5.0	10.0
FM13b	2001421-KW-Huron Rd	1.04%	0.80%	1.1	1.6	0.24%	5.0	5.0	0	0.0	0.0
FM15	303238-KW-Homer Watson PS	0.46%	0.29%	0.7	1.0	0.17%	3.2	2.0	0	0.0	0.0
FM18	306550-KW-Hanson Ave	3.10%	1.90%	1.1	0.5	1.20%	2.5	4.0	0	0.0	0.0
FM19	311719-KW-Falconridge PS	0.43%	0.30%	1.0	1.0	0.13%	5.0	3.0	0	0.0	0.0
FM20	303424-KW-King St E	1.11%	0.71%	0.5	1.0	0.40%	1.0	1.5	0	0.0	0.0

The total R's range from 0.43% to 8.80%, with an overall average of 2.30%. Lower R values, as observed in FM3b, FM15 and FM19, represent systems with less RDII. Generally, the lower Total R values are established in smaller metersheds with newer developments (pipe ages 1980 +), which in theory results in less infiltration to the piping network and likely employs newer design guidelines that prevent roof and foundation drain connections to sanitary sewers. The highest total R values were established in metersheds FM1 and FM1b, where the system is noted to have generally older pipes (1960 – 1980) with a greater possibility of having roof and foundation connections to the sanitary system. Refer to **Figure 5.1** or details on pipe age.

Generally, the total R increases as you move towards the center of the City, with the exception of FM1 and FM1b, as discussed above. This trend was anticipated as it generally aligns with the older, downtown areas within the City.

Table 7-6, **Table 7-7**, **Table 7-8** and **Table 7-9** show the resulting calibration fits between the modelled and monitored data for WWF Event 1 (September 7th, 2021), WWF Event 2 (September 14th, 2021), WWF Event 3 (September 21st, 2021), and WWF Event 4 (October 3rd, 2021), respectively. These calibration fits are colour-coded based on the following:

- Peak flow:
  - Green: if it falls within the targeted range of -15% to +25%;
  - Yellow: if it falls within -25% to -15% or +25% to +35%; and,
  - Red: if it is less than -25% or greater than +35%.
- Depths:
  - Green: if it is in the targeted depth range of ±0.1 m;
  - Yellow: if it is within -0.2 m to -0.1 m or +0.1 m to +0.6 m; and,
  - Red: if it is less than -0.2 m and greater than 0.6 m.
- Volume:
  - Green: if it falls within the targeted range of -10% to +20%;
  - Yellow: if it falls within -20% to -10% or +20% and +30%; and,
  - Red: when it is less than -20% and greater than 30%.



Stantec

Legend

- Sanitary Pumping Station
- Sanitary Sewer
- Rain Gauge
- Flow Meter

Total R by Flow Metershed

- ≤ 1.00 %
- 1.01 - 2.00 %
- 2.01 - 5.00 %
- > 5.00 %

0 2 4 km

1:70,000 (At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2021.
3. Contains information licensed under the Open Government Licence - The Corporation of the City of Kitchener, 2021.

REGION OF WATERLOO
KITCHENER

Project Location
City of Kitchener

165640334 REVA
Prepared by KB on 2022-04-26
Technical Review by AL on 2022-04-26

Client/Project
CITY OF KITCHENER
INTEGRATED SANITARY MASTER PLAN

Figure No.
7.4

Title
Total R Per Metershed

Table 7-6: 2021 Wet Weather Calibration Results for Event 1

FM ID	FM Name	Link ID	Data Quality Notes	Modelled Surcharge (Y/N)	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Depth (m)	Modelled Depth (m)	Depth Fit (m)	Monitored Volume (m^3)	Monitored Volume (m^3)	Volume Percent Fit
FM1	308300-KW-Highland Rd W	308299.1		N	0.244	0.485	98.9%	0.31	0.44	0.14	7,657	17,671	130.8%
FM1b	309484-KW-Highview Dr	309486.1		Y	0.041	0.091	120.9%	0.17	0.70	0.52	1,311	2,249	71.6%
FM2	304470-KW-West Ave	304472.1	Before Oct 1st unreliable, PS influence	N	0.249	0.633	153.6%	0.47	0.45	-0.03	10,360	30,844	197.7%
FM2b	304819-KW-Sandrock Creek	304821.1		N	0.109	0.136	24.8%	0.28	0.29	0.01	4,323	5,822	34.7%
FM3	311165-KW-Victoria St S	311167.1		N	0.135	0.147	8.5%	0.37	0.26	-0.11	3,199	4,540	41.9%
FM3b	2091740-KW-Moore Ave PS	2091735.1	Variable data	N	0.009	0.013	56.8%	0.16	0.09	-0.07	272	383	40.8%
FM4	303786-KW-David St	303748.1	Variable data	N	0.086	0.070	-18.0%	0.24	0.17	-0.07	1,555	1,559	0.3%
FM5b	311440-KW-Activa Ave	311440.1	Velocity dropouts	N	0.030	0.054	77.8%	0.19	0.18	0.00	1,458	2,748	88.5%
FM6	301110-KW-Borden Ave S	2130010.1	Velocity dropouts	N	0.029	0.039	33.9%	0.41	0.14	-0.26	1,326	2,127	60.4%
FM7	306584-KW-Hoffman St	306527.1		N	0.173	0.284	63.6%	0.44	0.36	-0.08	8,681	13,713	58.0%
FM9	301182-KW-Ottawa St N	301207.1	PS influence	N	0.217	0.236	8.9%	0.32	0.23	-0.09	10,284	11,761	14.4%
FM10	300305-KW-Shelley Dr	300304.1	PS influence	N	0.683	0.801	17.3%	0.48	0.50	0.02	24,645	36,642	48.7%
FM11	302989-KW-Manitou Dr	302987.1		N	0.051	0.046	-9.3%	0.28	0.13	-0.15	3,551	3,965	11.7%
FM12	300575-KW-Balzer Creek Trail	307136.1		N	0.059	0.054	-8.4%	0.15	0.14	-0.01	2,880	3,349	16.3%

FM ID	FM Name	Link ID	Data Quality Notes	Modelled Surcharge (Y/N)	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Depth (m)	Modelled Depth (m)	Depth Fit (m)	Monitored Volume (m^3)	Monitored Volume (m^3)	Volume Percent Fit
FM13	303564-KW-Black Walnut Dr	303563.1		N	0.109	0.113	4.1%	0.21	0.19	-0.03	6,475	7,542	16.5%
FM13b	2001421-KW-Huron Rd	2001420.1		N	0.066	0.062	-4.8%	0.16	0.14	-0.01	3,676	3,791	3.1%
FM15	303238-KW-Homer Watson PS	303239.1	PS influence	N	0.058	0.071	22.9%	0.19	0.17	-0.02	3,751	4,097	9.2%
FM18	306550-KW-Hanson Ave	306551.1		N	0.027	0.029	5.2%	0.08	0.12	0.04	826	1,172	41.9%
FM19	311719-KW-Falconridge PS	311920.1	Variable data	N	0.020	0.014	-27.9%	0.10	0.09	-0.01	875	900	2.9%
FM20	303424-KW-King St E	303425.1		Y	0.008	0.014	85.6%	0.07	0.38	0.31	336	594	76.6%

Table 7-7: 2021 Wet Weather Calibration Results for Event 2

FM ID	FM Name	Link ID	Data Quality Notes	Modelled Surcharge (Y/N)	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Depth (m)	Modelled Depth (m)	Depth Fit (m)	Monitored Volume (m^3)	Monitored Volume (m^3)	Volume Percent Fit
FM1	308300-KW-Highland Rd W	308299.1		N	0.186	0.238	27.6%	0.27	0.29	0.02	5,280	5,729	8.5%
FM1b	309484-KW-Highview Dr	309486.1		N	0.023	0.053	133.7%	0.14	0.18	0.04	849	777	-8.4%
FM2	304470-KW-West Ave	304472.1	Before Oct 1st unreliable, PS influence	N	0.157	0.366	133.4%	0.41	0.34	-0.08	7,166	14,640	104.3%
FM2b	304819-KW-Sandrock Creek	304821.1		N	0.052	0.081	54.9%	0.19	0.22	0.03	2,997	3,419	14.1%
FM3	311165-KW-Victoria St S	311167.1		N	0.087	0.079	-8.7%	0.31	0.19	-0.11	1,964	2,073	5.6%

FM ID	FM Name	Link ID	Data Quality Notes	Modelled Surcharge (Y/N)	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Depth (m)	Modelled Depth (m)	Depth Fit (m)	Monitored Volume (m^3)	Monitored Volume (m^3)	Volume Percent Fit
FM3b	2091740-KW-Moore Ave PS	2091735.1	Variable data	N	0.009	0.008	-18.1%	0.13	0.07	-0.06	220	235	6.8%
FM4	303786-KW-David St	303748.1	Variable data	N	0.039	0.041	3.3%	0.18	0.13	-0.05	990	913	-7.8%
FM5b	311440-KW-Activa Ave	311440.1	Velocity dropouts	N	0.050	0.081	62.0%	0.21	0.23	0.02	1,730	2,397	38.6%
FM6	301110-KW-Borden Ave S	2130010.1	Velocity dropouts	N	0.022	0.020	-4.9%	0.32	0.11	-0.21	1,063	1,295	21.8%
FM7	306584-KW-Hoffman St	306527.1		N	0.186	0.229	23.0%	0.48	0.32	-0.15	7,355	8,634	17.4%
FM9	301182-KW-Ottawa St N	301207.1	PS influence	N	0.229	0.201	-12.4%	0.33	0.21	-0.12	7,317	8,440	15.4%
FM10	300305-KW-Shelley Dr	300304.1	PS influence	N	0.514	0.701	36.4%	0.42	0.46	0.05	16,643	23,280	39.9%
FM11	302989-KW-Manitou Dr	302987.1		N	0.060	0.051	-14.6%	0.31	0.14	-0.17	2,790	3,114	11.6%
FM12	300575-KW-Balzer Creek Trail	307136.1		N	0.065	0.065	-0.4%	0.16	0.15	-0.01	2,475	2,594	4.8%
FM13	303564-KW-Black Walnut Dr	303563.1		N	0.155	0.141	-8.8%	0.27	0.21	-0.06	5,409	6,058	12.0%
FM13b	2001421-KW-Huron Rd	2001420.1		N	0.082	0.077	-6.7%	0.16	0.15	-0.01	3,099	3,172	2.3%
FM15	303238-KW-Homer Watson PS	303239.1	Variable data, PS influence	N	0.070	0.109	55.8%	0.21	0.21	0.00	3,015	3,337	10.7%
FM18	306550-KW-Hanson Ave	306551.1		N	0.037	0.042	16.1%	0.09	0.17	0.08	641	886	38.3%
FM19	311719-KW-Falconridge PS	311920.1	Variable data	N	0.013	0.010	-25.3%	0.09	0.08	-0.01	660	639	-3.2%
FM20	303424-KW-King St E	303425.1		Y	0.035	0.032	-11.0%	0.12	0.38	0.26	464	491	5.7%

Table 7-8: 2021 Wet Weather Calibration Results for Event 3

FM ID	FM Name	Link ID	Data Quality Notes	Modelled Surcharge (Y/N)	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Depth (m)	Modelled Depth (m)	Depth Fit (m)	Monitored Volume (m^3)	Monitored Volume (m^3)	Volume Percent Fit
FM1	308300-KW-Highland Rd W	308299.1		Y	0.751	0.584	-22.2%	2.19	0.86	-1.33	35,239	36,073	2.4%
FM1b	309484-KW-Highview Dr	309486.1		Y	0.092	0.083	-9.5%	1.23	1.11	-0.12	4,296	4,533	5.5%
FM2	304470-KW-West Ave	304472.1	Before Oct 1st unreliable, PS influence	N	0.351	0.771	119.7%	0.86	0.51	-0.35	17,594	58,046	229.9%
FM2b	304819-KW-Sandrock Creek	304821.1		N	0.143	0.144	1.2%	0.34	0.30	-0.04	9,748	10,097	3.6%
FM3	311165-KW-Victoria St S	311167.1		N	0.178	0.167	-5.9%	0.40	0.28	-0.12	9,682	8,329	-14.0%
FM3b	2091740-KW-Moore Ave PS	2091735.1	Variable data	N	0.011	0.013	22.2%	0.16	0.08	-0.07	609	672	10.3%
FM4	303786-KW-David St	303748.1	Variable data	N	0.061	0.058	-3.9%	0.19	0.15	-0.04	2,772	2,720	-1.9%
FM5b	311440-KW-Activa Ave	311440.1	Velocity dropouts	N	0.037	0.080	116.9%	0.22	0.23	0.01	1,789	5,411	202.5%
FM6	301110-KW-Borden Ave S	2130010.1	Velocity dropouts	N	0.046	0.040	-13.1%	0.45	0.15	-0.30	2,709	3,721	37.4%
FM7	306584-KW-Hoffman St	306527.1	Velocity dropouts	N	0.421	0.415	-1.5%	0.71	0.44	-0.26	20,324	24,531	20.7%
FM9	301182-KW-Ottawa St N	301207.1	PS influence	N	0.262	0.274	4.6%	0.37	0.24	-0.12	20,661	20,628	-0.2%
FM10	300305-KW-Shelley Dr	300304.1	PS influence	N	1.086	1.117	2.8%	0.60	0.60	0.01	54,159	69,664	28.6%
FM11	302989-KW-Manitou Dr	302987.1		N	0.075	0.067	-10.9%	0.30	0.16	-0.14	6,191	7,069	14.2%
FM12	300575-KW-Balzer Creek Trail	307136.1		N	0.089	0.080	-10.1%	0.19	0.17	-0.02	5,589	6,193	10.8%
FM13	303564-KW-Black Walnut Dr	303563.1		N	0.173	0.184	6.6%	0.28	0.24	-0.04	13,493	14,298	6.0%

FM ID	FM Name	Link ID	Data Quality Notes	Modelled Surcharge (Y/N)	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Depth (m)	Modelled Depth (m)	Depth Fit (m)	Monitored Volume (m^3)	Monitored Volume (m^3)	Volume Percent Fit
FM13b	2001421-KW-Huron Rd	2001420.1		N	0.092	0.097	5.8%	0.18	0.18	-0.01	7,031	7,186	2.2%
FM15	303238-KW-Homer Watson PS	303239.1	PS influence	N	0.088	0.078	-11.7%	0.23	0.18	-0.05	6,693	6,895	3.0%
FM18	306550-KW-Hanson Ave	306551.1		N	0.055	0.048	-13.8%	0.12	0.20	0.08	2,176	2,574	18.3%
FM19	311719-KW-Falconridge PS	311920.1	Variable data	N	0.019	0.017	-10.8%	0.10	0.10	0.00	1,625	1,499	-7.7%
FM20	303424-KW-King St E	303425.1		Y	0.020	0.017	-16.8%	0.09	0.38	0.29	809	1,032	27.6%

Table 7-9: 2021 Wet Weather Calibration Results for Event 4

FM ID	FM Name	Link ID	Data Quality Notes	Modelled Surcharge (Y/N)	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Depth (m)	Modelled Depth (m)	Depth Fit (m)	Monitored Volume (m^3)	Monitored Volume (m^3)	Volume Percent Fit
FM1	308300-KW-Highland Rd W	308299.1		N	0.162	0.293	80.8%	0.26	0.33	0.07	12,128	16,726	37.9%
FM1b	309484-KW-Highview Dr	309486.1		N	0.018	0.051	176.6%	0.16	0.18	0.01	1,761	2,179	23.7%
FM2	304470-KW-West Ave	304472.1	PS influence	N	0.287	0.407	41.8%	0.44	0.36	-0.08	32,209	35,718	10.9%
FM2b	304819-KW-Sandrock Creek	304821.1		N	0.060	0.075	25.2%	0.20	0.21	0.01	7,587	7,574	-0.2%
FM3	311165-KW-Victoria St S	311167.1		N	0.101	0.073	-28.1%	0.33	0.19	-0.14	6,342	5,059	-20.2%
FM3b	2091740-KW-Moore Ave PS	2091735.1	Variable data	N	0.007	0.006	-18.8%	0.13	0.06	-0.06	414	528	27.6%
FM4	303786-KW-David St	303748.1	Variable data	N	0.036	0.032	-13.1%	0.15	0.11	-0.04	2,092	2,031	-3.0%

FM ID	FM Name	Link ID	Data Quality Notes	Modelled Surcharge (Y/N)	Monitored Peak Flow (m^3/s)	Modelled Peak Flow (m^3/s)	Peak Flow Percent Fit	Monitored Depth (m)	Modelled Depth (m)	Depth Fit (m)	Monitored Volume (m^3)	Monitored Volume (m^3)	Volume Percent Fit
FM5b	311440-KW-Activa Ave	311440.1	Variable data	N	0.033	0.033	-0.7%	0.20	0.14	-0.06	3,786	4,406	16.4%
FM6	301110-KW-Borden Ave S	2130010.1	Variable data	N	0.027	0.022	-17.8%	0.29	0.11	-0.18	2,558	2,904	13.5%
FM7	306584-KW-Hoffman St	306527.1		N	0.127	0.189	49.0%	0.43	0.30	-0.13	14,118	18,149	28.5%
FM9	301182-KW-Ottawa St N	301207.1	Variable data, PS influence	N	0.221	0.166	-25.0%	0.32	0.19	-0.13	16,449	16,573	0.8%
FM10	300305-KW-Shelley Dr	300304.1	Variable data, PS influence	N	0.379	0.412	8.5%	0.38	0.35	-0.03	34,989	45,729	30.7%
FM11	302989-KW-Manitou Dr	302987.1		N	0.047	0.039	-17.6%	0.25	0.12	-0.13	5,246	6,084	16.0%
FM12	300575-KW-Balzer Creek Trail	307136.1	Peak flow spike; unrelated to rainfall	N	0.058	0.040	-31.4%	0.14	0.12	-0.02	5,321	5,090	-4.3%
FM13	303564-KW-Black Walnut Dr	303563.1		N	0.083	0.081	-3.5%	0.19	0.16	-0.03	10,042	11,292	12.4%
FM13b	2001421-KW-Huron Rd	2001420.1		N	0.058	0.047	-19.2%	0.16	0.12	-0.03	6,210	5,993	-3.5%
FM15	303238-KW-Homer Watson PS	303239.1	PS influence	N	0.064	0.045	-29.0%	0.20	0.14	-0.06	6,388	6,066	-5.0%
FM18	306550-KW-Hanson Ave	306551.1		N	0.015	0.015	-2.9%	0.06	0.07	0.01	1,626	1,566	-3.7%
FM19	311719-KW-Falconridge PS	311920.1	Questionable data	N	0.013	0.012	-12.0%	0.09	0.08	-0.01	1,396	1,379	-1.2%
FM20	303424-KW-King St E	303425.1	Variable data	Y	0.009	0.007	-21.3%	0.07	0.38	0.30	765	819	7.0%

Due to its magnitude, WWF Event 3 is the primary focus for calibration. Peak flow calibration fits fall within the targeted range except for FM1, FM2, FM5b and FM20. There are 13 depth fits which fall within the targeted range. Volumetric calibration fits fall within the targeted range except for FM2, FM3, FM5b, FM6, FM7, FM10 and FM20. Key observations regarding the monitored data that help to explain where the calibration fits fall outside of the targeted ranges are described herein:

- Generally, WWF Event 1, WWF Event 2, and WWF Event 4 calibration fits are higher than the WWF Event 3 calibration fits, which typically fall within the targeted ranges. This is due to WWF Event 3 being the primary focus for calibration, as WWF Event 1, Event 2 and Event 4 are smaller events in volume and duration compared to this event. This results in a more conservative calibration. There are also instances of a delayed modelled response to observed rainfall in the smaller WWF events, yet no delay observed in WWF Event 3. Due to the volume of rainfall observed prior to the peak rain during WWF Event 3, the ground is likely saturated before the largest peak rain occurs, which results in a more instantaneous response to the rain in the latter half of the event. This same saturation is likely not present during the smaller, shorter WWF events;

- Overall, many depth fits fall outside of the targeted range, with most experiencing lower modelled depths than the observed. Assuming the GIS diameter and slope data is accurate, this is most likely due to the presence of sedimentation in the system, which is not replicated in the model;

- FM1, FM1b and FM20 experience surcharging in WWF Event 3 and matching the observed data can be challenging. Additionally, the surcharged depths should be compared to the target range of -0.1 m to +0.5 m instead of the un-surcharged target of ±0.1 m (currently represented by the colour-coded results in **Table 7-6**, **Table 7-7**, **Table 7-8** and **Table 7-9**). In all four WWF events where FM20 depths are shown as exceeding, the depths are within the surcharged targeted depth range. FM1 and FM1b still exceed surcharged depth fit targets in WWF Event 3. Depth fit targets can be challenging to achieve due to variable sediment, silt, and debris conditions in the field.

- Due to the higher RTK parameters and calibration challenges experienced at FM1 and FM1b, the contributing drainage area characteristics and sanitary sewer system connectivity were reviewed. Other than the diameter upgrades surrounding FM1 mentioned above, no additional discrepancies were identified that would contribute to the challenges experienced. While the peak flow fits are low for WWF Event 3, the other three events exhibit high peak flow fits, resulting in an overall acceptable calibration;

- As discussed in **Section 5.5**, FM2 observed an abrupt jump in velocity readings on October 1st, 2021, which persists for the remaining duration of the monitoring period. AMG confirmed that the data obtained for FM2 after this jump is more reliable, corresponding to only WWF Event 4. Therefore, WWF Event 4 is the focus for calibration at this meter; during which, FM2's peak flow calibration fit falls above the targeted range, but its volumetric target is met. WWF Event 4 is smaller than the primary event (WWF Event 3) and therefore, the peak exceedance in WWF Event 4 is intentionally conservative to account for this;

- FM5b has been deemed variable or questionable at a macro-level, which is evident in Event 1, 2 and 3. This FM's volume and peak flow fits fall within the targeted range in WWF Event 4. As the data for this meter was initially identified as variable or questionable, this calibration fit is considered reasonable;

- When reviewing the flow monitoring data from a macro-level perspective, FM6 data was initially deemed reliable for level-only calibration due a 10-day connectivity issue resulting in a data gap and variation in depth and velocity readings post-reconnection. In reviewing the data for each of the selected WWF events however, FM6 appears to have more reliable data for WWF Event 4. In this event, the peak flow and depth fits are slightly low, falling just outside the targeted range, but the volume fit is good. With only 27 L/s observed at this meter in WWF Event 4, even the small difference in flow (5 L/s) at this scale affects the ease at which targets are met. This calibration result is considered reasonable based on the data quality obtained;

- In addition to some of the 6 FMs noted to have variable data in **Section 5.5** and discussed previously in this section, dropouts and variable or questionable data observed during all or some of the selected WWF events result in calibration challenges for FM9, FM10, FM12, and FM15;

- FM3 experienced a slightly lower volume than the monitored data in WWF Event 3. The fit is generally a good match for shape. However, due to the duration of the event, matching the largest rainfall peak that occurs later in the event meant under-estimating the smaller peaks observed at the start of the event, thus a slightly lower total volume observed in the modelled data;

- FM7 experienced a slightly higher volume in WWF Event 3 due to some observed velocity dropouts during the largest peak of the rain event;

- FM10's volumetric calibration percent fits falls above the targeted range for all WWF calibration events, yet the depth fits fall within the targeted range. The peak flow fits are good for WWF Event 1, 3, and 4, but is high for WWF Event 2. In the primary calibration event (WWF Event 3), this meter did not experience much of a response during the start of the rainfall and therefore the model overestimates the volume at the beginning of the event in order to meet the peak flow during the peak of the event. Overall, the calibration for this meter is considered good; and,

- The boundary condition applied at FM20 results in modelled surcharging and higher depths within the pipe, which is not observed in the monitored data. This surcharging is not propagating upstream however, indicating minimal sensitivity to this boundary condition. Thus, this calibration is deemed acceptable.

With the calibration complete, the calibrated model results for the primary event (WWF Event 3) are presented in **Figure 7.5**, illustrating the resulting HGL exceedances and surcharged pipes. Exceedances are defined by peak HGLs within 1.8 m from surface or above, reflecting potential basement flooding risk.

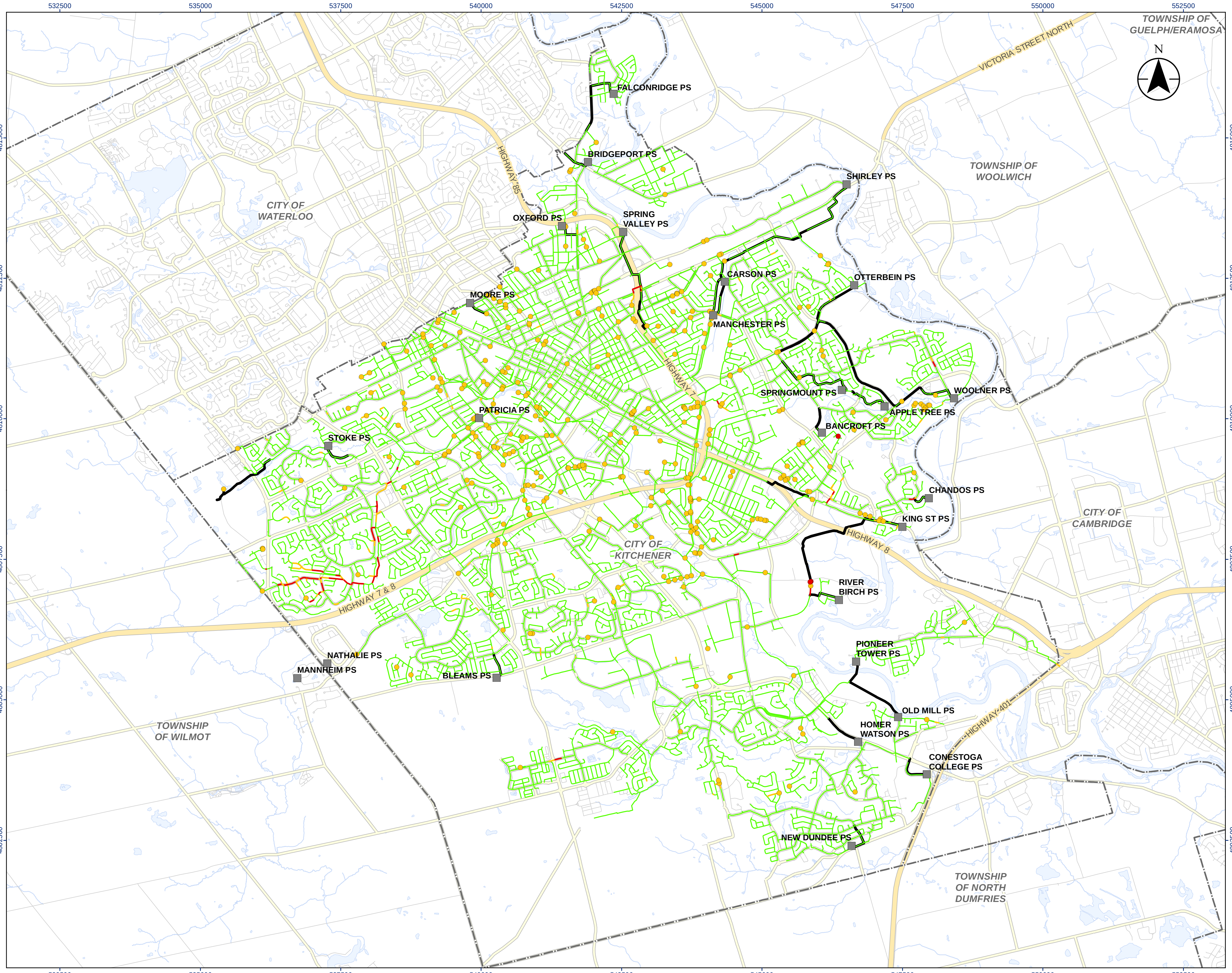
Though there are a few surcharged pipes and several HGL exceedances observed in the model during WWF Event 3, most exceedances are attributed to model Engineering Validation Errors such as shallow pipes or Inconsistent Profiles based on Inverts (IPIs), as previously discussed in **Section 4.1.1.1**. Surcharged pipes that are not related to Engineering Validation Errors are mainly located in the FM1 and FM1b metersheds, but do not result in HGL issues during this event.

These results generally correspond to the findings of the Sanitary Sewer System Model Update report completed by AECOM in 2019. The majority of pipes presented in the AECOM report as running at 85% full (d/D) or higher during the calibrated 1:25-year, 12hr AES design event are also located in the northwestern portion of the study area near FM1 (Upper Schneider - Sandrock) as shown in **Figure 7.5**. However, the 2019 findings also indicate low residual capacities in the FM3b (Upper Schneider - Victoria) and FM18 (Upper Schneider Direct) metersheds, as well as along the trunk sewer just downstream of FM2 (Upper Schneider Direct). HGL and surcharge issues are not replicated in these areas based on WWF Event 3 calibrated model results. It should be noted that the AECOM results are based on the d/D results during the 1:25-year event, while those presented in **Figure 7.5** represent the WWF Event 3 results and illustrate the surcharge state of the pipes (free-flowing, backwater conditions, or bottlenecked) and the HGL freeboard results. Additionally, WWF Event 3 has a 1:2-year return period (as discussed in **Section 6.4)**, and thus, this comparison provides only a high-level validation of the resulting capacity issues observed in the model.

7.4 MODEL LIMITATIONS

Notwithstanding the calibration challenges and assumptions discussion in the preceding sections, the model development is within the normal application of large-scale planning studies and therefore all subsequent results should be interpreted according to this level of detail currently available. The following describes limitations within the model in reference to the calibration:

- Uncertainty in the boundary conditions can impact the calibration. The boundary conditions applied generally represent the maximum discharge rates agreed to in the Cross-Border Agreements. This could produce higher modelled results than what was observed in the dry or wet weather flow period in question. Subsequently, the DWF parameters may have required additional reductions to account for the conservative boundary conditions applied. In the cases where no value was assigned to the inflow and thus, the inflows were not accounted for in the model, it is possible that the DWF parameters were artificially increased to account for missing inflow;
- The residential diurnal pattern typically has an early-morning and early-evening peak with a slight late-morning dip and late-night/early-morning drop. This pattern corresponds with the sleep and work schedule of the majority of the general population. However, this may vary in the flow monitoring completed between 2020 - 2022, as effects from the COVID-19 pandemic and working-from-home initiatives may be evident. Existing conditions populations may not account for recent and continual changes in residential and ICI-based habits due to the pandemic. The diurnal pattern could also vary from the start of the flow monitoring period (August) to the end (November) due to a potential response from the student population returning to school;



Stantec

Legend

- Sanitary Pumping Station
- Forcemain

HGL Freeboard

- At or Above Surface
- Within Basement Level (Within 1.8 m of Surface)

Pipe Surcharge State

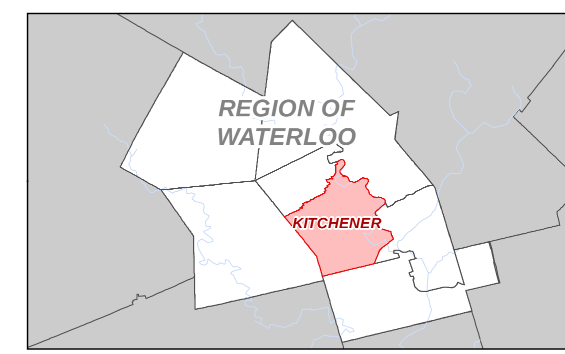
- Bottleneck (Undersized Sewer)
- Backwater Conditions
- Free-Flowing Conditions

0 2 4 km

1:70,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2021.
3. Contains information licensed under the Open Government Licence - The Corporation of the City of Kitchener, 2021.



Project Location
City of
Kitchener

165640334 REVA
Prepared by EH on 2022-04-27
Technical Review by AL on 2022-04-27

Client/Project
CITY OF KITCHENER
INTEGRATED SANITARY MASTER PLAN

Figure No.
7.5

Title
WWF Event 3 Calibrated Model Results

- The effects of the DWF calibration are carried forward into WWF calibration. Though the magnitude is minimal in comparison to heavy rainfall events, when the DWF calibration did not fall within the targeted fit, it is possible that poor fits carry over or influence the results of WWF calibration;
- Relatively small storm events were observed in the calibration period of August to October 2021 with return periods of 1:2-years or less in general. Linear extrapolation to larger events may not be fully reflective of the actual response to such events. Future model updates and recalibration are recommended to account for the magnitude of events observed during calibration. However, for this study, a sensitivity analysis will be employed to overcome any potential limitations in the baseline model and subsequent remediation measures due to insufficient rainfall capture;
- Though the model was updated with recent infrastructure (2016 or newer), it is possible that previous network upgrades have not been included. Additionally, it is also possible that the record drawings do not perfectly match the real site conditions, and thus do not completely capture the site hydraulics. There are remaining Engineering Validation Errors that are unresolved, such as inconsistent profile inverts (IPIs) in the model, as discussed with the City.
- While the IPIs and other Engineering Validation Errors that were deemed critical for the Master Plan work were resolved using inference, it is possible that the remaining local system IPIs could account for unrepresentative metershed traces, flow diversions, or flow attenuation that can affect the calibration; and,
- Sediment may be present in the pipes, which is not represented in the model. This can result in discrepancies between the modelled and observed depths, but is often temporary in nature due to flushing programs and large WWF events potentially dislodging debris and build-up. AMG did note on select occasions that silt or debris was found in the pipes and could cause some variation in the data. Providing frequent sewer flushing programs for City sewers can help to reduce sediment and its impact to flow conditions.

8.0 PROPOSED MODELLING SCENARIOS

Using the calibrated model detailed in **Section 7.0**, the existing and future conditions scenarios will be developed and assessed for system performance. The following sections outline the flow generation, infrastructure updates, and design criteria involved in these assessments. Additional analyses will be completed including climate change and critical failure, which are also described in the following sections. The results of these assessments will be presented during Task 3 of this project.

8.1 EXISTING CONDITIONS

Existing conditions modelling scenarios represents 2021 populations and infrastructure, which includes infrastructure updates completed since the calibration period in Summer/Fall of 2021.

8.1.1 Flow Generation

Existing populations are obtained from the draft Parcel-Person-Jobs (PPJ) file provided September 20th, 2021. These populations were used during the calibration of the model and in the derivation of the calibrated per capita flow rates used in DWF generation. These populations remain unchanged for the existing conditions modelling scenario.

Additionally, the other DWF and WWF parameters derived through calibration are maintained in the existing condition analysis. These parameters include the diurnal patterns, baseflows representing Groundwater Infiltration (GWI), and RTKs for Rainfall Derived Inflow and Infiltration (RDII) per metershed, as presented in **Section 7.0**.

8.1.2 Boundary Conditions

All inflow and level boundary conditions used during calibration are maintained for existing conditions, with the exception of the Woolwich inflow. In calibration, the average flow extracted from the 2021 measured data (12.7 L/s) was used as the inflow boundary condition. As per the Cross-Border Agreement, a maximum allowable inflow of 189 L/s can be discharged to the Shirley SPS from Woolwich. This value is conservatively applied as the Woolwich inflow in the existing conditions model to assess Kitchener’s sanitary sewer system performance. Refer to **Section 7.1** for the remaining boundary condition details.

8.1.3 Infrastructure Updates

The Middle Strasburg Trunk Sanitary Sewer (MSTSS), commissioned on October 29, 2021, conveys flows from the Middle Strasburg area to the South Strasburg area via gravity. Previously, the Bleams SPS pumped these flows north to the Upper Schneider drainage area. The Bleams SPS was decommissioned upon MSTSS commissioning. For calibration, these infrastructure updates were not included in the model as the calibration period preceded this transition. For existing conditions however, the MSTSS is considered operational, and the Bleams SPS is no longer online. Thus, these infrastructure updates are included in the existing conditions model. The MSTSS As-Constructed drawings were referenced as part of this update.

Additionally, the Nathalie SPS was recently commissioned and is thus included in the existing conditions infrastructure updates.

8.1.3.1 Pumping Stations

The remaining pumping stations are idealized in the existing conditions model; allowing all incoming flow to be pumped through the station without constraint (Qin = Qout). This provides a straightforward comparison of the unrestricted incoming peak flow during the design event to the pumping station’s firm and rated capacities to identify the need for upgrades. The firm capacity of a pumping station is defined as the maximum pumping capacity with the largest pump offline. The rated capacity is defined as the designed operational capacity of the pumping station and usually does not include the simultaneous operation of the standby pump(s). Both the firm and rated capacities were obtained for each pumping station from the most recent Condition Assessment Report. If available, the theoretical duty points from the system and pump curve analysis, and the known operation of the pumps (number of duty and standby pumps) informed the firm and rated capacities used in this analysis. While the current operating capacity of the pumps may be lower than the theoretical capacities due to deteriorating conditions, it is assumed that the theoretical capacity will be achieved through planned maintenance. If the operating capacity exceeds the theoretical, the theoretical is conservatively applied to account for future depreciation. These values may differ from the firm capacities noted in the pumping station Environmental Compliance Approval (ECA) (formerly the Certificate of Approval (C of A)) which can be less accurate based on pump and system performance.

If the total flow through the idealized pump is greater than that of the pumping station’s rated capacity, this value is applied to the ideal pump as a maximum pump rate. This allows for an evaluation of the upstream system response and the occurrence of overflows at the pumping station under maximum pumping conditions. The flow through the ideal pumps will also be compared to the firm capacity from the ECA to determine if the current approval is adequate for existing and future conditions flows or requires amendment. See **Section 8.1.4** for more details on the pumping station’s performance criteria. The following **Table 8-1** lists the pumping station’s firm and rated capacities used in this analysis, the ECA firm capacity, and provides additional relevant notes where applicable.

Table 8-1: Existing Pumping Station Firm & Rated Capacities Based on Theoretical Operation

Pumping Station	Firm Capacity (L/s)	Rated Capacity (L/s)	Rated Capacity Pump Operation	ECA Firm Capacity (L/s)	Additional Notes
Apple Tree SPS	66.0	66.0	2 Duty ON; 1 Standby OFF	50.0	
Bancroft SPS	7.7	7.7	1 Duty ON; 1 Standby OFF	7.7	
Bridgeport SPS	136.0	136.0	1 Duty ON; 1 Standby OFF; 1 Jockey for low flow conditions	136.0	The firm and the rated capacities correspond to the capacity of the duty pump only; jockey pump ignored for capacity assessment (likely cannot run simultaneously to duty pump)
Carson SPS	66.9	66.9	1 Duty ON; 1 Standby OFF	Not Available	The rated and the firm capacities are based on the drawdown test (operational capacities instead of theoretical), as no pump curve was provided in the Condition Assessment report Firm capacity not noted in ECA
Chandos SPS	27.0	27.0	1 Duty ON; 1 Standby OFF	30.0	
Conestoga College SPS	47.5	47.5	1 Duty ON; 1 Standby OFF	50.0	
Falconridge SPS	45.5	45.5	1 Duty ON; 1 Standby OFF	118.0	The pump's operational capacities are higher than the theoretical capacity; however, the theoretical capacity was conservatively used ECA firm capacity represents future conditions with two additional provisional pumps installed
Homer Watson SPS	314.0	314.0	2 Duty ON; 1 Standby OFF	310.0	The station normally operates with only 1 duty on at a time, alternating between the three pumps The ECA does not include the firm capacity; this value was instead obtained from the Operation and Maintenance Manual (as per the 2021 Condition Assessment Report)
King St SPS	176.0	176.0	1 Duty ON; 2 Standby OFF	290.0	The station normally operates with only 1 duty on at a time, alternating between the three pumps

Pumping Station	Firm Capacity (L/s)	Rated Capacity (L/s)	Rated Capacity Pump Operation	ECA Firm Capacity (L/s)	Additional Notes
Manchester SPS	240.0	240.0	1 Duty ON; 1 Standby OFF	240.0	No system/pump curves or drawdown test results provided in Condition Assessment report; assumed firm and rated capacity is equivalent to the rated capacity of a single pump
Moore SPS	21.5	23.5	1 Duty ON; 1 Standby OFF	Not Available	Two different pumps; pump 2 is larger than pump 1 resulting in different firm and rated capacities ECA not available
Nathalie SPS	94.0	94.0	2 Duty ON; 1 Standby OFF	Not Available	ECA not yet available
New Dundee SPS	56.0	56.0	1 Duty ON; 1 Standby OFF	56.0	No system/pump curves or drawdown test results provided in Condition Assessment report; assumed firm and rated capacity is equivalent to the rated capacity of a single pump, as per the ECA
Old Mill SPS	Unknown	Unknown	Unknown	Unknown	No information provided on existing Old Mill SPS; although this pumping station is present in existing conditions, it will soon be replaced by New Old Mill SPS. It is located immediately upstream of the WWTP, thus has very little impact on the downstream system Modelled as an unrestricted idealized pump station in existing conditions
Otterbein SPS	88.7	88.7	2 Duty ON; 1 Standby OFF	126.0	The rated and the firm capacities are based on the drawdown test (operational capacities instead of theoretical), as no pump curve was provided in the Condition Assessment report
Oxford SPS	49.0	49.0	1 Duty ON; 1 Standby OFF	Not Available	ECA not available
Patricia SPS	23.5	23.5	1 Duty ON; 1 Standby OFF	Not Available	ECA not available
Pioneer Tower SPS	70.0	70.0	1 Duty ON; 1 Standby OFF	41.7	The pump station was designed to accommodate two additional duty pumps in the future when additional capacity is required
River Birch SPS	19.0	19.0	1 Duty ON; 1 Standby OFF	17.3	The pump's operational capacities are higher than the theoretical capacity; however, the theoretical capacity was conservatively used

Pumping Station	Firm Capacity (L/s)	Rated Capacity (L/s)	Rated Capacity Pump Operation	ECA Firm Capacity (L/s)	Additional Notes
Shirley SPS	207.0	207.0	1 Duty ON; 1 Standby OFF	378.0	The Condition Assessment report indicates only two pumps, but the Certificate of Approval indicates three pumps. Only two pumps are assumed for conservatism
Spring Valley SPS	245.0	245.0	2 Duty ON; 1 Standby OFF	245.0	No pump/system curves or drawdown test results were provided in Condition Assessment report); therefore the noted firm capacity is assumed equivalent to the rated capacity and cannot be validated further Furthermore, the Wastewater Treatment Master Plan (2018) identified a future capacity requirement of 265 L/s to meet 2051 forecasts ECA not provided; however, Condition Assessment Report notes firm capacity (assumed from ECA)
Springmount SPS	162.0	162.0	2 Duty ON; 1 Standby OFF	205.5	No alternation between standby and duty pumps; standby pump is not used as a duty pump due to its age and condition
Stoke SPS	196.0	196.0	2 Duty ON; 1 Standby OFF	473.0	Pump/system curve for Pump 3 not provided; assumed equivalent to Pump 1 and 2 ECA notes initial design capacity of 164 L/s (completed in 1980) and future design capacity of 473 L/s; assumed future capacity is applicable to 2021 and beyond
Woolner SPS	136.0	136.0	2 Duty ON; 1 Standby OFF	115.2	The pump's operational capacities are higher than the theoretical capacity; however, the theoretical capacity was conservatively used

8.1.4 Design Event(s) & Criteria

Both the DWF and WWF conditions are reviewed as part of the sanitary sewer system performance assessment. The Hydraulic Grade Line (HGL) elevations at nodes are used as the main indicator of issues within the collection system. Elevated HGLs occur when a capacity constraint drives the upstream water levels to rise. Risk of basement flooding (or HGL issues) in this design event is considered if the HGLs are higher than 1.8 m below the surface elevation, which coincides with the assumed basement elevation for homes with direct or indirect basement connections to the sewer. The system is evaluated for HGL issues in DWF conditions and during the 1:25-year AES, 12-hour storm event. This 25-year event was used in the latest system assessment performed by AECOM in 2019.

Sewer performance is reviewed in conjunction with the elevated HGLs to determine the cause of the HGL issues observed and determine possible solutions. Sewer performance alone is generally not used to define the need to provide upgrades; however, surcharging observed in the 5-year AES, 12-hour storm event may warrant upgrades. Surcharge state is used in ICM to define sewer performance, which is defined by both the d/D (depth of flow over diameter) and q/Q (flow through pipe over full pipe capacity) ratios. When the surcharge state is less then 1, the pipe is considered free-flowing. When the surcharge state is 1 or 2, the pipe is considered under backwater (slope of the HGL is less than the slope of the pipe), or bottlenecked/undersized (slope of the HGL is greater than that of the pipe), respectively.

For shallow sewers that are within 1.8 m from the surface, HGL issues may be illustrated; however, if the water level remains within the pipe and the pipe is under free-flowing conditions, it is not considered for upgrades.

For pumping stations, the 1:10-year AES, 12-hour storm event is used to assess performance. As per the City of Kitchener Design Standards and Procedures Manual for Wastewater Pumping Facilities (dated July 2022), all sewage pumping facilities should be designed to pump the 10-year peak flow with the largest pump offline (herein referred to as ‘firm capacity’).

Thus, with the use of idealized pumps in the model, the peak flow conveyed through the pump station during the 10-year event is compared to the pumping station’s firm capacity, as described in **Section 8.1.3.1**. The pumping station’s performance is then based on this comparison; pumping stations receiving 10-year peak flows greater than the station’s firm capacity are considered to have capacity constraints. The 10-year peak flow through the ideal pumps will also be compared to the firm capacity from the ECA to determine if the current ECA is adequate for existing and future conditions flows or requires amendment.

Additionally, pumping station performance is evaluated with respect to overflows, in that overflows should not occur in events smaller than the 25-year. Using the simplified idealized pump setup, the pump station’s rated capacity (i.e., maximum pumping capacity) is used to limit outflow from the station in the model. The occurrence of an overflow in events smaller than the 25-year indicates inadequate pumping station capacity. Additionally, no physical damage to the pumping station should occur due to flooding during stress test events, which is evaluated as part of the climate change analysis described in **Section 8.3**.

In later stages of this project, solutions to the identified capacity constraints can be sized based on the following criteria, where feasible, as per the City of Kitchener Development Manual (Summer 2021) and discussed with the City:

- Depth of flow to diameter (d/D) ratio is no higher than 80% in DWF conditions (lower d/D ratios may be considered in trunks to facilitate maintenance activities);
- Full flow velocity is appropriate to provide scour and peak flow velocity is less than the maximum allowable (0.8 m/s > v > 3 m/s);
- No HGL issues observed due to capacity constraints in the 25-year AES design event;

- No surface flooding observed during stress test events; and,
- Pumping stations have adequate firm capacity to convey the 10-year AES peak flows, and do not experience overflows in events smaller than the 25-year AES storm event, or endure physical damage to the pumping station due to flooding during stress test events.

8.2 FUTURE CONDITIONS

Future conditions scenarios include the 2031 and 2051 horizons where growth is observed to occur as infill, intensification, and new developments. The modelling approach for these types of growth differ and are discussed in the following sections.

The following sections also discuss area-based and parcel-based flow generation parameters. As presented in **Section 4.1.3.3**, area-based parameters include baseflow (or Groundwater Infiltration, GWI) and Rainfall-Derived Inflow and Infiltration (RDII) generated from the applied RTKs. In the calibrated model, these parameters are applied to the area-based subcatchments only, which are generated based on a 45 m buffer surrounding the gravity pipes.

The parcel-based parameters include the per capita sewage generation rate and the diurnal pattern allocated by the Wastewater Profile assigned to each subcatchment. In the calibrated model, these parameters are applied to the parcel-based subcatchments only, which are created based on the aggregation of parcels draining to the same node.

8.2.1 Infill & Intensification

Within urban environments, infill is described as the redevelopment of land, and commonly includes the conversion of open space to new residential or ICI construction. Intensification includes the redevelopment of properties to accommodate higher densities of populations. Because the adjacent properties are often previously serviced by nearby municipal sanitary sewers, infill and intensification typically does not require additional City-owned infrastructure (i.e., only requires internal site servicing). For this reason, area-based flows (GWI and RDII) are already accounted for and do not require adjustments for infill development.

For infill and intensification for properties that reside within previously delineated subcatchments, the subcatchment's population is adjusted to represent the total future population, as per the provided PPJ file. The per capita rate and diurnal pattern applied to the subcatchment during calibration is maintained. For infill that occurs outside of a previously delineated subcatchment, the parcel is imported from the PPJ file with the future population and is used as the parcel-based subcatchment. Based on the land use type attributed to the parcel in the PPJ file, the representative per capita rate and diurnal pattern obtained through calibration for a similarly characterized metershed is applied. Based on a review of the flow generation rates and the metershed characteristics, parameters derived for the FM13b metershed (predominantly residential) is selected for application to residential infill and intensification, and parameters derived for the FM20 metershed (predominantly ICI) is used for ICI infill and intensification. If the parcel includes both residential and ICI populations, the overall parcel land use type is assigned based on the governing population distribution. **Table 8-2** outlines the flow generation parameters applied for infill and intensification growth.

Table 8-2: Infill & Intensification Flow Generation Parameters by Land Type

Land Use Type	Applicable FM Metershed	Land Use	FM Per Capita (L/cap/d)	Wastewater Profile[1]
Residential	FM13b	98% RES	225	16
ICI	FM20	99% ICI	232	20

NOTES:
1. Wastewater profile defines the per capita rate, and weekend and weekday diurnal patterns applicable to the flow metershed. See **Appendix F** for the applicable diurnal patterns.

8.2.2 New Developments

Differing from infill, new developments are generally situated in undeveloped areas within the study area and often require new City-owned sanitary infrastructure for servicing. Parcels for these new developments are imported into the model and used as subcatchments, with both the parcel-based and area-based parameters applied for flow generation (i.e., one subcatchment used to define the population, per capita rate, diurnal pattern, baseflow (GWI), and RTKs for RDII). Area-based contributions (GWI and RDII) are included in subcatchments representing new developments as they are not previously accounted for by surrounding subcatchments. The total area of the parcel is assumed equivalent to the contributing area, which is then used to generate the area-based flow contributions. Similarly to the infill parcels in areas outside of existing subcatchments, the new development's land use, as derived from the population distribution per parcel, is used to define the flow generation parameters. **Table 8-3** outlines the flow generation parameters applied for new development growth.

Table 8-3: New Development Flow Generation Parameters by Land Type

Land Use Type	Applicable FM Metershed	Land Use	FM Per Capita (L/cap/d)	Wastewater Profile[1]	GWI Rate (L/s/ha)	RTK Hydrograph[2]	Total R (%)
Residential	FM13b	98% RES	225	16	0.0219	New-RES(FM13b)	1.04%
ICI	FM20	99% ICI	232	20	0.0255	New-ICI(FM20)	1.11%

NOTES:
1. Wastewater profile defines the per capita rate, and weekend and weekday diurnal patterns applicable to the flow metershed. See **Appendix F** for the applicable diurnal patterns.
2. RTK Hydrograph defines the R, T and K values used to generate RDII. See **Appendix F** for the applicable RTKs.

8.2.3 2031 Horizon

8.2.3.1 Flow Generation

For the 2031 modelling scenarios, the City has recommended the use of the 50% build-out populations provided in the PPJ file, as they are noted to best correlate to the 2031 horizon. These populations are used to update existing subcatchments, while new subcatchments are added to represent infill, intensification, or new developments, as discussed in **Sections 8.2.1** and **8.2.2**. Existing parcels with significant future population increases in areas currently not serviced by the City's sanitary sewer system were evaluated and imported into the model if conservatively anticipated to be serviced in the future.

The City's projected 2031 population forecast is approximately 419K in total, including both residential and employment populations, as provided by the City's Planning department.

Refer to **Appendix G** for the correspondence from the Planning department detailing these forecasts. The total population included in the model for the 2031 horizon based on the 50% build-out populations in the provided PPJ file is ~566K in total, including both residential and employment equivalents. The suggested approach of utilizing the 50% build-out populations to represent the 2031 horizon is considered conservative, as this population is higher than that forecasted for the City.

8.2.3.2 Boundary Conditions

The boundary conditions applied in the existing conditions model scenario are maintained for the 2031 horizon, including the Shirley SPS inflow from Woolwich (189 L/s).

8.2.3.3 Infrastructure Updates

Infrastructure updates incorporated in the 2031 model scenarios include the addition of the New Old Mill SPS and the decommissioning of the current Old Mill SPS. The Future Biehn Drive Sanitary Trunk Sewer extension is also anticipated for construction prior to the 2031 horizon. Information regarding the final proposed alignment and sewer profile is required for integration in the model.

The City has indicated the potential for growth in the Hidden Valley area and noted the probable River Road extension. To represent the proposed development in this area, the parcels with population growth as determined from the provided PPJ file are not included in the model, and are instead represented by a constant inflow of 91 L/s into the upstream end of the Wabanaki Trunk Sewer equivalent to the proposed peak flow rate outlined in the *Upper Hidden Valley Sanitary Pump Station and Forcemain Environmental Assessment (EA)* prepared by MTE Consultants Inc., dated May 25, 2022. The timeline of which has not been confirmed, but is assumed for the 2031 and 2051 scenarios.

Upgrades along the Wabanaki Trunk Sewer have also been identified and provided, and are included in the 2031 and 2051 scenarios.

Pumping Stations

As noted in the preceding section, the New Old Mill SPS is included in the 2031 model scenario. Similar to the existing conditions pumping stations, it is modelled as ideal with the following firm and rated capacity constraints considered (see **Table 8-4)**. The current Old Mill SPS is omitted from the 2031 model scenario, as it will be decommissioned during transition to the New Old Mill SPS.

Upgrades are proposed at the Otterbein SPS that should be considered for the 2031 and 2051 scenarios. The EA was provided and used to obtain the future conditions' capacities. All other pumping station setups are maintained from the existing conditions scenario.

Table 8-4: 2031 Pumping Station Firm & Rated Capacities Based on Theoretical Operation

Pumping Station	Firm Capacity (L/s)	Rated Capacity (L/s)	Rated Capacity Pump Operation	ECA Firm Capacity (L/s)	Additional Notes
New Old Mill SPS	150.0	150.0	2 Duty ON; 1 Standby OFF	Not Available	The firm capacity and pump/system curves are not provided in the Process Control Narrative (PCN); assume equivalent to rated capacity denoted in PCN ECA not yet available
Otterbein SPS	165.0	165.0	Unknown	165.0	EA for proposed upgrades provided; notes 165 L/s design capacity

Provisional additions to the pumping stations noted in their ECAs can be considered when evaluating solutions, if applicable.

8.2.4 2051 Horizon

8.2.4.1 Flow Generation

For the 2051 modelling scenarios, the City's Planning department has recommended the use of the 75% build-out populations provided in the PPJ file, as they are noted to best correlate to this horizon. The approach used to update the model with these populations is the same as detailed in **Section 8.2.3** above.

The City's projected 2051 population forecast ranges from approximately 579K to 588K in total, including both residential and employment populations, as provided by the Planning department. Refer to **Appendix G** for further information. The total population included in the model for the 2051 horizon based on the 75% build-out populations in the provided PPJ file is ~755K in total, including both residential and employment equivalents. The suggested approach of utilizing the 75% build-out populations to represent the 2051 horizon is considered conservative, as this population is higher than that forecasted for the City.

8.2.4.2 Boundary Conditions

The boundary conditions applied in the existing conditions model scenario are maintained for the 2031 and 2051 horizons, including the Shirley SPS inflow from Woolwich (189 L/s).

8.2.4.3 Infrastructure Updates

No additional infrastructure updates are confirmed for this horizon.

Pumping Stations

No additional pumping stations or pumping station upgrades are confirmed for this horizon. The pumping station details used in the 2031 model scenario are maintained for the 2051 horizon.

8.2.5 Design Event(s) & Criteria

The design events and criteria outlined in **Section 8.1.4** remain applicable for the 2031 and 2051 horizons.

8.3 CLIMATE CHANGE

Based on practices of local municipalities in Ontario with separated sanitary and storm sewer systems, the approach to climate change adaptation and mitigation is still evolving. For many, including Peel Region, York Region and the City of Toronto, the use of the 25-yr design storm itself for assessing level-of-service capacity is one of the means with which climate change is being accommodated in wastewater planning, in tandem with a suite of supporting multi-disciplinary programmatic measures to mitigate the impact on sanitary capacity, such as an I/I Strategy and/or ongoing improvements to the storm drainage system including implementation of green infrastructure. Once the factored rainfall hyetographs are established and applied in the model, the system is assessed for sensitivity, which can then be considered in solution development.

Climate change IDF curves from the available IDF CC Tool can be used to establish factors that increase the 25-year AES, 12-hour design storm rainfall intensities to account for climate change (herein identified as the 25-year + CC event). These factors are based on historical trends and widely accepted climate models included within the IDF CC Tool. Initially, the approach used the Waterloo Wellington A rain gauge with the Coupled Model Intercomparison Project 6 (CMIP6) Global Climate Models, with SSP5.85 providing the most conservative emissions predictions. Given the very conservative projected increase in volume and intensity of over 60%, it was discussed and recommended for Kitchener that the Master Plan be based on planning for infrastructure at the current 25-yr storm level, with indication of the sensitivity to the +20% Climate Change 'stress test' incorporated into project prioritization, allocation of funding, and prioritization for the complementary CCTV, I/I and Data Collection/Analytics programs to further inform the preliminary and detailed design stages.

8.4 CRITICAL FAILURE ANALYSIS

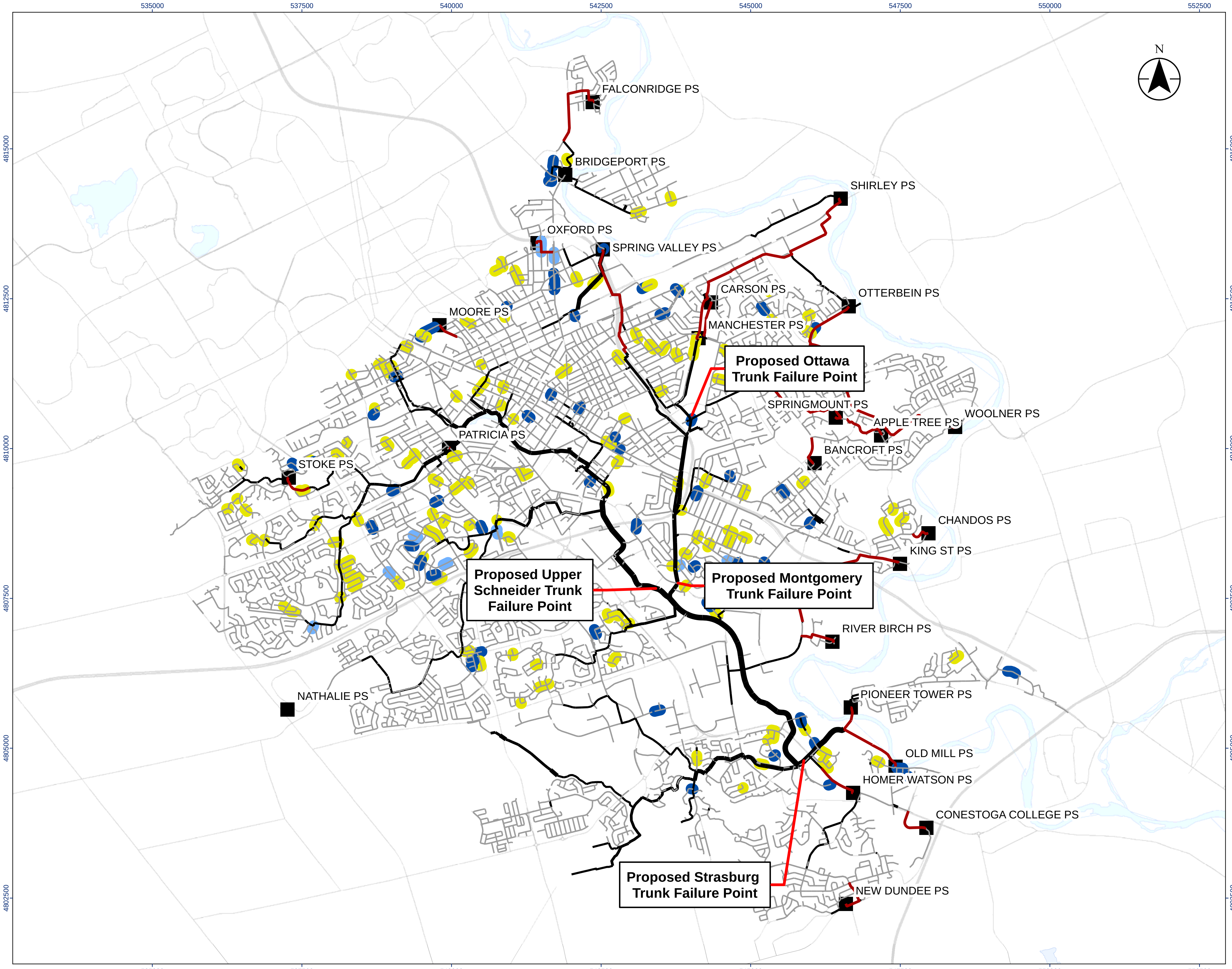
Failure of critical trunks within the system can result in severe flooding concerns. For this analysis, sediment is applied to represent pipe failures in the 2051 model scenario, to assess upstream system response and the current available redundancy in the 25-year + CC event, as derived based on **Section 8.3**. Four (4) locations were selected based on criticality within the system (i.e. significant drainage areas) and poor condition as per the CCTV scores provided in the *COK_SAN_Main_CCTV_Score* shapefile. Pipe conditions are defined by a score of 1 to 5, with 1 representing good conditions, and 5 representing poor. Refer to **Table 8-5** for a list of the proposed critical failure analysis locations and rationale. Refer to **Figure 8.1** illustrating the trunk system and the provided CCTV scores (scores 4 and higher). As some of these trunks are in series, the critical failure assessments are broken down into separate model scenarios to limit the impact of the upstream failures.

Additionally, all pumping stations are tested with complete pump failure to determine upstream system response. This is performed by applying a flow limit of 0 L/s to the idealized pump stations in the model. These pump stations are also denoted in **Figure 8.1**.

It is possible that flooding conditions are observed in these scenarios. The results can be used to inform potential redundancy options within the system to prevent severe flooding or property damage.

Table 8-5: Selected Critical Trunk Sewers for Failure Analysis

Trunk Sewer Name	Suggested Link ID for Failure Analysis	Rationale
Ottawa Direct	301192.1	Known sewer collapse; CCTV score of 5
Montgomery Direct	300583.1	Concern for sewer collapse noted by City; significant drainage area
Upper Schneider Direct	300579.1	Significant drainage area
Strasburg Direct	303094.1	Significant drainage area



Stantec

Legend

- ForceMain

Sewer Diameter

- 100 - 449
- 450 - 675
- 676 - 900
- 901 - 1350
- 1351 - 2500

CCTV Score (0 to 5)

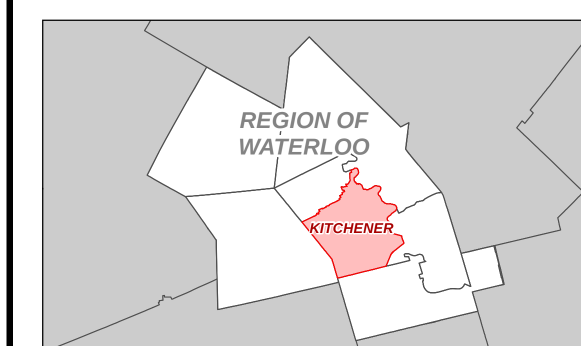
- Score = 4
- 4 < Score < 5
- Score = 5

0 2 4 km

1:65,355 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2021.
3. Contains information licensed under the Open Government Licence - The Corporation of the City of Kitchener, 2021.



Project Location
City of Kitchener

165640334 REVA
Prepared by HB on 2022-10-04

Client/Project
CITY OF KITCHENER
INTEGRATED SANITARY MASTER PLAN

Figure No.
8.1

Title
Sanitary Sewer Trunks & CCTV Scores

9.0 CONCLUSIONS

This technical memorandum (TM#2) outlines the previous hydraulic model and model platform selection, the proposed modelling approach, the flow monitoring and calibration process and results, and the proposed modelling scenarios to be assessed in Task 3 for the Kitchener ISAN-MP update. This TM includes the following discussions:

- A general overview of the previous model's sewers, maintenance holes and pumping stations (**Section 2.0**);
- Model platform review and recommendation (**Section 3.0**);
- Engineering validation fixes required for the original pipe network to improve model stability and system hydraulics (**Section 4.1.1**);
- Model updates required for new and upgraded infrastructure (post-2016) (**Section 4.1.2**);
- Subcatchment delineations, nomenclature, and parameters to define both DWF and WWF contributions (**Section 4.1.3**);
- Pumping Station reviews and updates (**Section 4.1.4**);
- Boundary conditions (**Section 4.1.5**);
- A high-level summary of the calibration process, including discussion on the DWF and WWF calibration strategy (**Section 4.1.6**);
- The flow monitoring program including the flow meter and rain gauge locations and related metershed characteristics (**Section 5.1 & Section 5.2**);
- The flow metershed schematic and system connectivity (**Section 5.3**);
- Flow meter data availability and quality (**Section 5.4** and **Section 5.5**, respectively);
- Rainfall data quality and quantity (**Section 6.0 & Section 6.1**);
- Dry weather flow calibration periods (**Section 6.2**);
- Rain gauge and storm event summary (**Section 6.3**);
- Wet weather flow calibration events (**Section 6.4**);
- Applicable boundary conditions and their potential affects in calibration (**Section 7.1**);
- Dry weather calibration approach, challenges, and results (**Section 7.2**);

- Wet weather calibration approach, challenges, and results (**Section 7.3**).
- Proposed existing conditions model setup and design criteria (**Section 8.1**);
- Proposed future conditions model setup and design criteria for both the 2031 and 2051 horizons (**Section 8.2**);
- Climate change considerations and assessment (**Section 8.3**); and the,
- Critical failure analysis approach (**Section 8.4**)

In general, the following main considerations result from the foregoing TM:

- The original pipe network provided was reviewed for data gaps and erroneous values, which identified over 900 pipes (6.8%) with unusual sewer depths or negative offsets, 5 sewers with connectivity issues, over 600 MHs with incoming sewer inverts lower than the outgoing sewer invert (inconsistent profiles based on inverts), 1,000 MHs with upstream sewer diameters greater than downstream sewer diameters (inconsistent profiles based on diameters), and, approximately 450 MHs with possible connectivity issues;
- Based on an evaluation of relevant modelling software, InfoWorks ICM was proposed for use in this ISAN-MP as the City already owns and maintains the program/licenses for stormwater modelling purposes, ICM has an excellent data management/auditing data structure (one database) and strong documentation and flagging system, and, its robust features improve efficiency and data sharing through compact transportable databases;
- The original InfoSWMM model was imported into InfoWorks ICM, where the model data was reviewed and further assessed for instabilities and continuity issues. Significant conflicts were identified in this review pertaining to those noted in the first bullet of this section that required adjustments in order to enable model simulations within ICM;
- New and upgraded pipe and pumping station infrastructure completed since 2016 was reviewed and assessed for discrepancies and flagged to the City for resolution approach. As presented in **Figure 4.1**, there are several issues in the model profile continuity that could create false capacity errors; therefore the degree of inference used could have impacts on future model interpretation. Additionally, there are discrepancies in the latest pump station assessment reports that required City input to reconcile the existing conditions;
- To improve the visual correlation of sanitary flow generation parameters to their contributing parcels, the dry and wet weather flow contributions are proposed to be represented using separate parcel-based and area-based subcatchments.
- Boundary conditions are also required in the model to represent incoming flows and downstream conditions for systems that are not included within the ISAN-MP model. Cross-border agreement information is used for these locations. If adjacent system information is not available, assumptions are made with the City and reviewed for validity and sensitivity during calibration;

- There are no major gaps in the collected flow or rainfall data. Most flow monitors have valid data for the flow monitoring period of interest. It should be noted that FM2 has more reliable data in the latter half of the flow monitoring program;

- Future monitoring program considerations, including use for future model updates, will be discussed in the final Master Plan document;

- Two five-day periods in 2021 were selected for DWF calibration, including August 15th to August 20th (DWF Period 1) and September 28th to October 3rd (DWF Period 2);

- Four storm events in 2021 were selected for WWF calibration, including September 7th to September 9th (WWF Event 1), September 14th to September 15th (WWF Event 2), September 21st to September 23rd (WWF Event 3), and October 3rd to October 5th (WWF Event 4). There was an emphasis on WWF Event 3 during calibration as it is the largest event, resulting in a more conservative model;

- Overall, there is a good fit for pattern and volume for both DWF periods. The modelled peak flows are generally lower than the observed, due to noise present in the monitored data;

- Generally, the WWF calibration for WWF Event 3 peak flows and volumes are within the targeted range and match the observed data well. The majority of the WWF Event 3 depths are within the target range as well;

- The established GWI rates, ranging from 0.003 L/s/ha and 0.084 L/s/ha, with an average of 0.028 L/s/ha, are comparatively low in general, indicating that the sanitary sewer system is relatively new and tight. The established per capita flow rates range between 82 L/c/d and 292 L/c/d, with an overall average of 170 L/c/d. These values are generally reasonable, with some falling below 100 L/c/d in the FM3b and FM4 metersheds, which may suggest overestimations of populations within these areas. The populations estimations may be influenced by student behaviors and COVID-19 related impacts. Populations in these areas should be confirmed;

- The final total R values, ranging from 0.43% to 8.80%, with an overall average of 2.30%, also suggest the system is newer in vintage and separated, with limited connections from roofs, foundation drains, and/or other instantaneous inflow sources.

It is our recommendation that the model parameters derived through the 2021 calibration be considered suitable for use in the establishment of system remediation measures. Sensitivity analyses can be completed when evaluating solutions that can further improve confidence with selected capital planning recommendations. It is recommended, however, that additional information continue to be collected by the City regarding network details and required model updates, population distributions, the performance of the existing system, and the condition of all assets, to further improve the resolution of this model in the future. The remaining Engineering Validation Errors identified should also be reviewed and updated when possible, and calibration results reconfirmed.

With the completion of the model calibration, remaining updates to the network can be implemented in the model to account for system upgrades that occurred between the calibration period and now; including the decommissioning of Bleams SPS and the commissioning of the Middle Strasburg Trunk Sanitary Sewer (MSTSS). Once completed, the existing conditions sanitary system performance can be assessed using design storm events. The growth scenarios can then be evaluated, incorporating future system upgrades such as the Biehn Dr Sanitary Trunk Sewer, Nathalie SPS, New Old Mill SPS commissioning and Old Mill SPS decommissioning, Otterbein SPS upgrades, Wabanaki Trunk Sewer upgrades, Hidden Valley proposed growth, and additional growth area servicing and intensification.

Table 9-1 summarizes the 17 proposed modelling scenarios for both existing and future conditions assessments. Results of these analyses will be presented as part of Task 3 of this project.

For future conditions modelling, relevant sanitary sewer infrastructure updates associated to the future Biehn Sanitary Trunk Sewer extension should be confirmed for inclusion.

Table 9-1: Proposed Existing & Future Conditions Model Scenarios

Scenario No.	Scenario ID	Conditions	Design Event	Scenario Purpose	Additional Details
1	Existing (DWF)	Existing	DWF	HGL issues due to capacity constraints observed in the DWF event are indicative of potentially severe flooding concerns during storm events	
2	Existing (5-year)	Existing	5-year AES, 12-hour Storm Event	Assess sewer surcharge to inform potential upgrades	
3	Existing (10-year)	Existing	10-year AES, 12-hour Storm Event	Assess adequacy of pump station's firm capacity	Apply flow limit to pump station (rated capacity) if less than pump station incoming flow; Check for overflows at pump stations
4	Existing (25-year)	Existing	25-year AES Storm Event	Assess trunk sewer capacity based on combination of HGLs and surcharge state	Apply flow limit to pump station (rated capacity) if less than pump station incoming flow; Check for overflows at pump stations
5	Future 2031 (DWF)	Future 2031	DWF	HGL issues due to capacity constraints observed in the DWF event are indicative of potentially severe flooding concerns during storm events	
6	Future 2031 (5-year)	Future 2031	5-year AES, 12-hour Storm Event	Assess sewer surcharge to inform potential upgrades	

Scenario No.	Scenario ID	Conditions	Design Event	Scenario Purpose	Additional Details
7	Future 2031 (10-year)	Future 2031	10-year AES, 12-hour Storm Event	Assess adequacy of pump station's firm capacity	Check for overflows at pump stations
8	Future 2031 (25-year)	Future 2031	25-year AES, 12-hour Storm Event	Assess trunk sewer capacity based on combination of HGLs and surcharge state	Check for overflows at pump stations
9	Future 2051 (DWF)	Future 2051	DWF	HGL issues due to capacity constraints observed in the DWF event are indicative of potentially severe flooding concerns during storm events	
10	Future 2051 (5-year)	Future 2051	5-year AES, 12-hour Storm Event	Assess sewer surcharge to inform potential upgrades	
11	Future 2051 (10-year)	Future 2051	10-year AES, 12-hour Storm Event	Assess adequacy of pump station's firm capacity	Check for overflows at pump stations
12	Future 2051 (25-year)	Future 2051	25-year AES, 12-hour Storm Event	Assess trunk sewer capacity based on combination of HGLs and surcharge state	Check for overflows at pump stations
13	Future 2051 (25-year + Climate Change)	Future 2051	25-year + CC Event	Assess sensitivity of system; inform solutions	Check for severe flooding at pump stations
14	Critical Failure – Ottawa & Upper Schneider Trunks	Future 2051	25-year + CC Event	Break/remove critical infrastructure to assess upstream system response and need for redundancy	Check for overflows at pump stations and severe flooding in upstream system
15	Critical Failure – Montgomery Trunk	Future 2051	25-year + CC Event	Break/remove critical infrastructure to assess upstream system response and need for redundancy	Check for overflows at pump stations and severe flooding in upstream system
16	Critical Failure – Strasburg Trunk	Future 2051	25-year + CC Event	Break/remove critical infrastructure to assess upstream system response and need for redundancy	Check for overflows at pump stations and severe flooding in upstream system
17	Critical Failure – Pumping Stations	Future 2051	25-year + CC Event	Break/remove critical infrastructure to assess upstream system response and need for redundancy	Check for overflows at pump stations and severe flooding in upstream system

APPENDIX A - SOFTWARE SUMMARY

	InfoWorks ICM (Innovyze)	InfoSWMM (Innovyze)	PCSWMM (CHI)
Relative License & Maintenance Cost	Most Expensive	Moderately Expensive	Least Expensive
Relative Cost Impact to City	City already owns 2 Licenses. No increase in annual maintenance fees. Net zero impact.	City already own License, but with migration to InfoWorks can abandon InfoSWMM and have net reduction in cost to City.	Would Require new Purchase of Licenses which are user-based. $4,000 Base (annually) + $480 per user (annually)
Alignment with City Initiatives / Departments	ICM is used for Stormwater Utility Work, and can be used for Sanitary Utility Work	ICM is Used for Sanitary Utility Work, and can be used for stormwater work	PCSWMM can do both stormwater and sanitary; not currently owned by City
Additional add-on modules	InfoWorks 2D	InfoSWMM 2D, InfoSWMM Suite, InfoSWMM Executive Suite	PCSWMM 2D
On-site training costs	$7,250 CAD + HST for up to 8 people including all manuals, licenses, and instructor expenses. These costs can be share with other local clients.		$3,500 + travel + HST
Available technical support	Included in annual maintenance fees. Phone support available from 8 AM EST to 5 PM PST. E-mail support available outside these hours as we have support staff around the world.		Included in Annual Maintenance Fee;
Hardware requirements	CPU Speed: 2.2 GHz minimum or higher; Hyper-threading (HHT) or Multi-core recommended Processor: Intel Pentium 4, Intel Core Duo, or Xeon Processors; SSE2 (or greater) Memory/RAM: 2 GB or higher Screen Resolution: 1024 x 768 recommended or higher at Normal size (96dpi) Disk Space: 500 MB of free space to accommodate a full setup installation and additional disk space - keep as much free disk space available as possible. Its virtual memory system needs additional free disk space when working on large projects Video/Graphics Adapter: 64 MB RAM minimum, 256 MB RAM or higher recommended. NVIDIA, ATI and INTEL chipsets supported Networking Hardware: Simple TCP/IP, Network Card or Microsoft Loopback Adapter is required for the License Manager	CPU Speed: 2.2 GHz minimum or higher; Hyper-threading (HHT) or Multi-core recommended Processor: Intel Pentium 4, Intel Core Duo, or Xeon Processors; SSE2 (or greater) Memory/RAM: 2 GB or higher Screen Resolution: 1024 x 768 recommended or higher at Normal size (96dpi) Disk Space: 500 MB of free space to accommodate a full setup installation and additional disk space - keep as much free disk space available as possible. Its virtual memory system needs additional free disk space when working on large projects Video/Graphics Adapter: 64 MB RAM minimum, 256 MB RAM or higher recommended. NVIDIA, ATI and INTEL chipsets supported Networking Hardware: Simple TCP/IP, Network Card or Microsoft Loopback Adapter is required for the License Manager	Requires the Microsoft 7, Vista, XP (SP2), or 2000 operating system, with the Microsoft .NET 4.0 framework installed. In addition, it requires a minimum screen resolution of 1600x768 pixels (XGA), a minimum of 2GB of physical memory and 100MB of disk space

	InfoWorks ICM	InfoSWMM	PCSWMM
Additional system/platform operating requirements	None	Requires a license of ArcGIS Desktop Pro	None
Graphics capabilities	Robust graphical rendering of input and output data, including the creation of tables, graphs, annotations, custom symbology, and contour maps. External GIS layers displayed and toggled with ease. Native 3D rendering of networks. Custom workspaces (dashboards) assist with data visualization.	Full ArcGIS Integration allows for use of ArcGIS symbology definitions. Robust graphical rendering of input and output data, including the creation of tables, graphs, annotations, custom symbology, and contour maps. External GIS layers displayed and toggled with ease.	Robust graphical rendering of input and output data, including the creation of tables, graphs, annotations, custom symbology, and contour maps. External GIS layers displayed and toggled with ease.
Data review and validation	User-defined flags for data review, connectivity review and fix tools, engineering (data) validation tools.	Comprehensive GIS-based data and network review toolset, engineering (data) validation tools.	Comprehensive GIS-based data and network review toolset, engineering (data) validation tools.
Computational engine	Fully dynamic proprietary engine	Modified SWMM 5 engine with full dynamic capabilities	Modified SWMM 5 engine with full dynamic capabilities
Hydrology/flow generation	Supports dry weather and wet weather inflows. Many different routines for sanitary and wet weather loading	Supports dry weather and wet weather inflows. Many different routines for sanitary and wet weather loading. Optional DWF Allocator allows for easy geospatial assignment of sanitary loads.	Supports dry weather and wet weather inflows. Many different routines for sanitary and wet weather loading
Calibration capabilities	Flow Survey (calibration) toolset allows for calibration of model to field observations	Calibrator, which uses genetic algorithms for network calibration is available as part of the Suite package. Real-time data connection allows for easy comparison of modelling results and field observations	Calibration tools as part of base package; sensitivity toolbar with uncertainty analysis
Hydraulic routing capabilities (i.e. complex flow structures, RTC, water quality, etc.)	Complex ancillary structures modelled directly. Comprehensive RTC module including PID control. Full water quality modelling	SWMM-based ancillaries (orifices, weirs, dividers) modelled directly. Rule-based control allows for comprehensive if-then-else logic. Water quality modelling for many key parameters.	SWMM-based. Completely capable of handling complex geometry, conditions
Simulation time and stability	Mature and stable engine with exceptionally fast run times (for a dynamic engine)	Widely-used stable SWMM 5 engine, with advanced simulation options to decrease run times	Widely-used stable SWMM 5 engine

	InfoWorks ICM	InfoSWMM	PCSWMM
Scenario management	Physical / attribute differences stored in individual networks. Parameter differences stored in groups. Drag and drop functionality allows for the quick and easy creation of any combination of networks and parameters. Simulations can be run individually or in batch, and results can be compared across multiple simulations	Comprehensive scenario manager allows for changes in the physical network, feature attributes, or simulation options. Scenarios can be run individually or in batch mode. Results can be reported on multiple scenarios simultaneously.	Comprehensive scenario manager allows for changes in the physical network, feature attributes, or simulation options. Scenarios can be run individually or in batch mode. Results can be reported on multiple scenarios simultaneously.
GIS integration/capabilities	GIS-based stand-alone modelling interface. Supports import and display of many common GIS data formats. Map Control functionality allows user to leverage existing GIS software (ArcGIS, MapInfo) for displaying GIS data	Fully-integrated into ArcGIS (sits as ArcGIS extension). Read/write capabilities from/to any popular GIS data source. Comprehensive GIS-centric modelling tool-set	GIS-based stand-alone modelling interface. Supports import and display of many common GIS data formats.
Database management	Proprietary relational database. Comprehesive tools for data review, editing, and querying.	Network schematic stored as Geodatabase. Attribute information stored in DBF files. Comprehesive tools for data review, editing, and querying.	Network schematic stored as Geodatabase. Attribute information stored in DBF files. Comprehesive tools for data review, editing, and querying.

APPENDIX B - SAMPLE PROFILE ISSUES IN ORIGINAL PIPE NETWORK

Review of Existing Model Gaps

Existing InfoSWMM Model

2011 Report Review

- Original model developed from scratch
- Based on GIS data
- Acknowledged requirement to resolve missing / incomplete GIS data
- Critical **gaps** filled - "edits/updates of the GIS data were performed during the process of calibrating and analyzing the model"
- Large number of area of erroneous capacity concern identified due to potential GIS errors

Appendix N

Sanitary Conduit ID	street	US Unique Junction ID	DS Unique Junction ID	Pipe Size (mm)	Remaining Capacity (l/s)	Status	q/Qcap	d/D	Cause
104251	WILHELM ST	303954	303955	200	17.961	Backwater	0.130	1.000	GIS Error
104255	AHRENS ST W	303980	303979	250	26.191	Backwater	0.562	1.000	GIS Error
104256	AHRENS ST W	303979	303978	250	15.090	Backwater	0.695	1.000	GIS Error
104257	AHRENS ST W	303978	304071	200	-15.845	Exceeds Capacity	1.664	1.000	GIS Error
104552	ONTARIO ST N	304120	304122	200	20.209	Backwater	0.080	1.000	GIS Error
104560	KING ST W	304123	304122	250	51.887	Backwater	0.089	1.000	GIS Error
104659	QUEEN ST N	304441	304247	250	52.722	Backwater	0.024	1.000	GIS Error

Executive Summary

In November 2009 the City of Kitchener retained AECOM to perform a City Wide Sanitary Sewer System Capacity Study. The purpose of the study being to evaluate available capacity within the existing sanitary sewer network, to facilitate best practice in infrastructure assess management now and in the future and to provide the City with a hydraulic computer model of the sanitary drainage system. Following completion of the study the City will use the model as a comprehensive planning tool which will enable them to evaluate the impact of development proposals and potential future zoning changes on the sanitary sewer network.

AECOM conducted a market review of available software and held an evaluation workshop to allow City staff to review software functionality relative to their needs. Through this evaluation process InfoSWMM was selected as the City's preferred modelling software.

Using the City's GIS data as the basis for the model AECOM developed the hydraulic model using the InfoSWMM software. A comprehensive data collection, review and cleansing exercise was carried out to resolve missing/incomplete data identified in the GIS records. All critical missing data issues were resolved by consolidating background information from previous studies and as-built drawings, interpolating from adjacent records and using information obtained through communications with the City's staff.

To ensure the hydraulic model provides a true representation of the sanitary sewer network a three month flow monitoring programme was undertaken to gather flow data at strategic points within the sewer system. The hydraulic model was calibrated against data collected from these 17 temporary in sewer flow monitors and the City's SCADA data.

The City's Planning Department provided an assessment of future growth within the City to enable future sanitary loading conditions to be evaluated. Sanitary loadings were calculated and applied to the model for the existing, 50% growth, 100% growth and build out up to maximum zoning capacity. To evaluate available capacity and identify potential restrictions to growth the model was run with a 25 year design storm.

From this analysis 18 specific locations were identified where capacity concerns may restrict future growth within the City. Mitigation measure to alleviate these concerns have been evaluated, costed and are presented for consideration.

During the analysis in addition to the 18 locations above a large number of areas of erroneous capacity concern were identified due to potential errors within the GIS, where insufficient data was available for accurate modelling, in areas not monitored by either the temporary flow monitoring programme or the City's SCADA system or where surcharge is by deisgn. i.e. at siphons and flow control devices. To improve confidence in the model in these areas and confirm available capacity it is recommended that as part of their asset management strategy the City carry out a comprehensive programme of asset surveys to gather missing information and additional flow monitoring to re-calibrate the model.

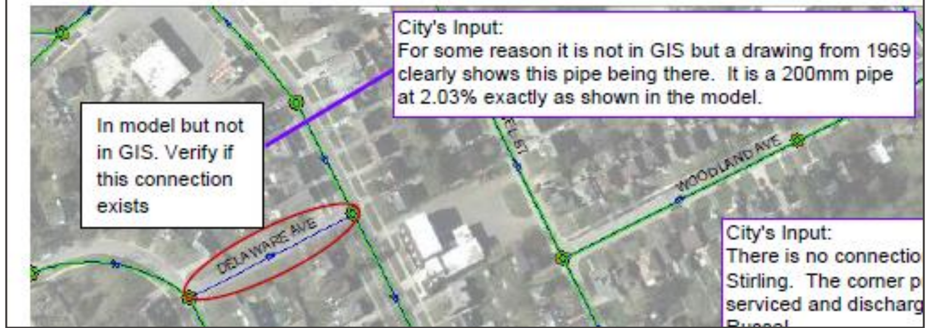
Review of Existing Model Gaps

Existing InfoSWMM Model

2019 Report Review

- Model was updated, which appears to have been primarily based on adding missing GIS data, not necessarily updating previously identified errors
- Appears most **gaps** were filled based on GIS data
  - Missing or zero entries for inverts, ground elevations, or diameters
  - Some plan view connectivity was confirmed with the City (App. B)

Verification #04



4.2 Model Update

The existing InfoSWMM model was updated to reflect the latest infrastructure as included in the latest GIS database provided by the City in May 2016. As-built drawings, field test reports and other relevant information was also utilized for updating the model. Table 4-1 presents a summary of model elements that are present in the updated model.

Table 4-1: Summary of Elements from the Updated Model

Model Feature	Updated Model*	Comment
No. of Pipes	13,050	# new pipes added = 913
No. of Manholes	12124	# new manholes added = 776
No. of Pump Stations	26	# pump stations added = 1

*based on latest GIS and other pertinent data provided by the City in May 2016

4.2.1 Conduits Update

As part of the model update, conduits were updated based on a review of the existing model and the latest GIS database provided by the City. A total of 913 pipe segments were added to the existing model. Connectivity, pipe diameters, invert elevations and lengths were based largely on City GIS data, and were refined through a review of record drawings where discrepancies or data gaps existed. Where not critical, discrepancies or data gaps were corrected by interpolation. Pipe roughness was initially assigned a Manning's "n" value of 0.013 based on standard practice for a typical sewer pipe (regardless of material).

The model review task identified a set of pipes, which were present in the model but not present in the GIS database. These pipes may have been updated in the latest GIS after the existing model was developed. These pipes were further reviewed and deleted from the model based on feedback received from the City. Pipes, which were present in both the model and the GIS were verified for pipe diameter and invert elevations. Pipe diameter and invert elevations were updated the model based on the GIS. However, when GIS information was not

ICM vs InfoSWMM Profile Comparison

- So what are we seeing now?
- On whole, the % of errors seem reasonable
- But not all errors are equal

Summary of Errors

Note: *Table includes original model data set and new assets (2016+).*

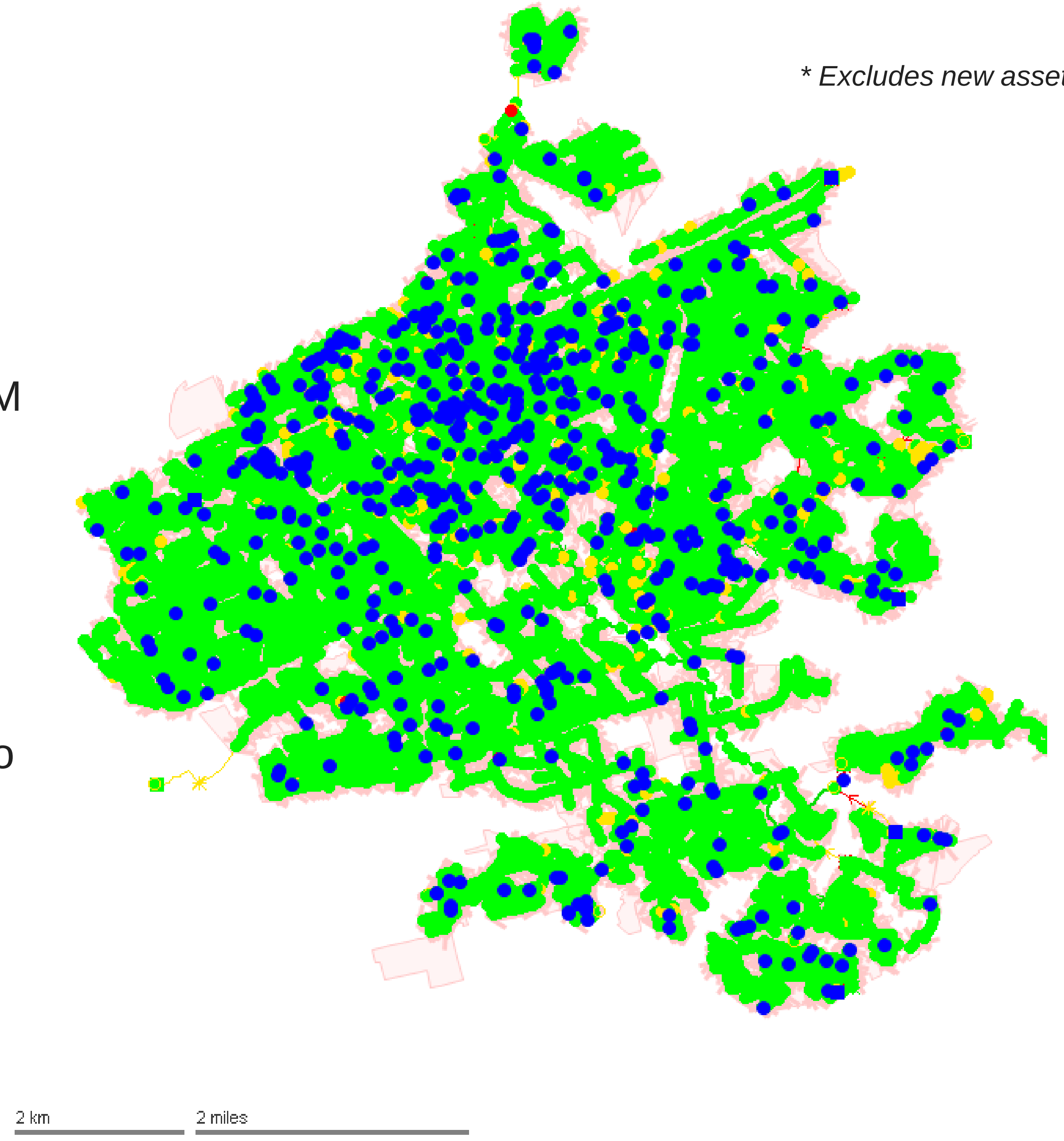
Error	Quantity of Errors in Study Area*	Number of Records*	% of Errors in Study Area*
Missing US Invert	33	13,142	0.3%
Missing DS Invert	33	13,142	0.3%
Missing Diameter	2	13,142	0.0%
Inconsistent Profile – Inverts**	**640**	**12,208**	**5.2%**
Pipe Above Ground	299	13,142	2.3%
Adverse Slope	19	13,142	0.1%
Flat Pipe	18	13,142	0.1%
Steep Slope	577	13,142	4.4%
Missing Ground Elevation	22	12,208	0.2%
Bifurcation Node - High Point	893	12,208	7.3%
Bifurcation Node - Flow Split	195	12,208	1.6%
Inconsistent Profile - Diameter	579	12,208	4.7%
Isolated Nodes	41	12,208	0.3%
Partially Connected Networks	350	13,142	2.7%
Missing Downstream Node	166	13,142	1.3%
Missing Upstream Node	35	13,142	0.3%
Unknown Shape ID	0	13,142	0.0%
Missing Pump On/Off	0	60	0.0%
Missing Pump Discharge Rate	39	60	65.0%

*** Excluding new assets (2016+), there are 600 Inconsistent Profiles - Inverts errors*

ICM vs
InfoSWMM
Profile
Comparison

Inconsistent Profiles - Inverts

- This is the ICM Model, converted from InfoSWMM
- Data checks confirm a seamless conversion of pipe / node attribute data
- But, the ICM model would not initialize when trying to simulate

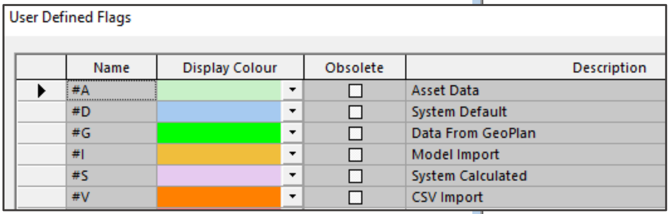


** Excludes new assets (2016+)*

- Blue Dots are nodes flagged as having an "Inconsistent Profile"
- Meaning, the pipes do not flow 'smoothly' from one sewer to the next

Example: Inconsistent Profiles - Inverts

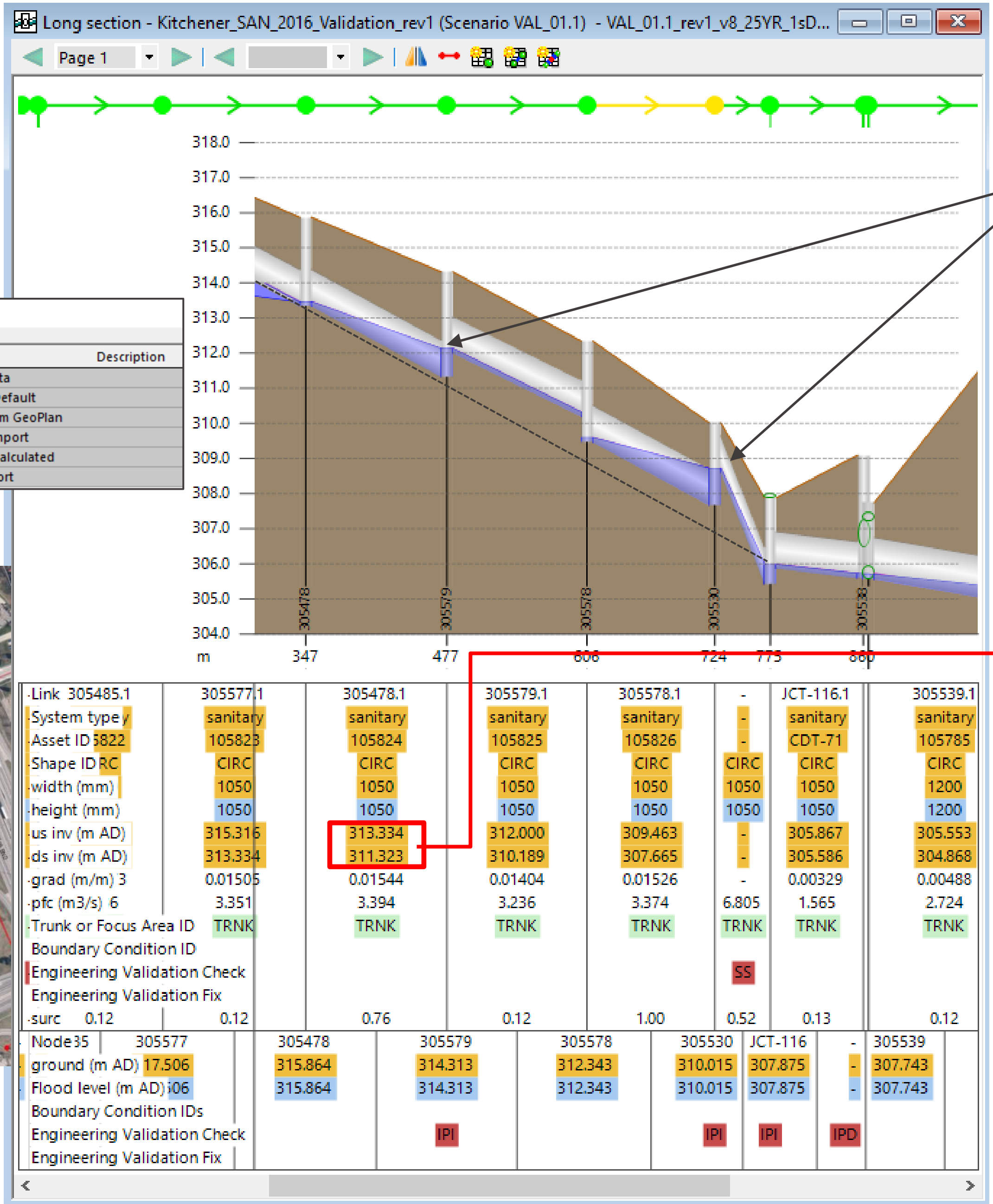
ICM vs InfoSWMM Profile Comparison



User Defined Flags

	Name	Display Colour	Obsolete	Description
▶	#A		☐	Asset Data
	#D		☐	System Default
	#G		☐	Data From GeoPlan
	#I		☐	Model Import
	#S		☐	System Calculated
	#V		☐	CSV Import

Spring Valley at Guelph St

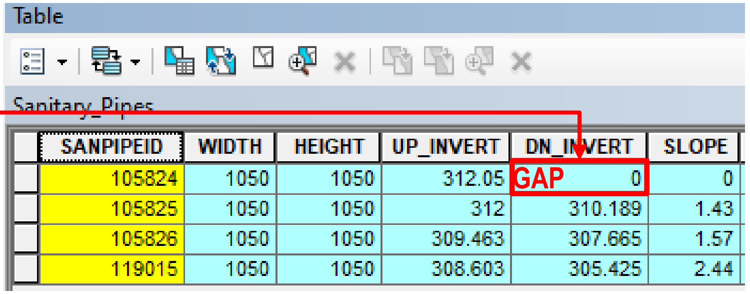


Link 305485.1	305577.1	305478.1	305579.1	305578.1	-	JCT-116.1	305539.1
System type y	sanitary	sanitary	sanitary	sanitary	-	sanitary	sanitary
Asset ID 5822	105823	105824	105825	105826	-	CDT-71	105785
Shape ID RC	CIRC	CIRC	CIRC	CIRC	CIRC	CIRC	CIRC
width (mm)	1050	1050	1050	1050	1050	1050	1200
height (mm)	1050	1050	1050	1050	1050	1050	1200
us inv (m AD)	315.316	313.334	312.000	309.463	-	305.867	305.553
ds inv (m AD)	313.334	311.323	310.189	307.665	-	305.586	304.868
grad (m/m) 3	0.01505	0.01544	0.01404	0.01526	-	0.00329	0.00488
pfc (m3/s) 6	3.351	3.394	3.236	3.374	6.805	1.565	2.724
Trunk or Focus Area ID	TRNK	TRNK	TRNK	TRNK	TRNK	TRNK	TRNK
Boundary Condition ID							
Engineering Validation Check					SS		
Engineering Validation Fix							
surc 0.12	0.12	0.76	0.12	1.00	0.52	0.13	0.12

Node 35	305577	305478	305579	305578	305530	JCT-116	-	305539
ground (m AD)	17.506	315.864	314.313	312.343	310.015	307.875	-	307.743
Flood level (m AD)	06	315.864	314.313	312.343	310.015	307.875	-	307.743
Boundary Condition IDs								
Engineering Validation Check			IPI		IPI	IPI	IPD	
Engineering Validation Fix								

- Downstream pipe higher than upstream pipe, resulting in ‘filling’ of the pipe before accessing the downstream sewer; flow still passes, but with incorrect levels and peak rates at higher flows

- Not always a “gap” – there is input in the model that comes from GIS



Table

Sanitary_Pipes

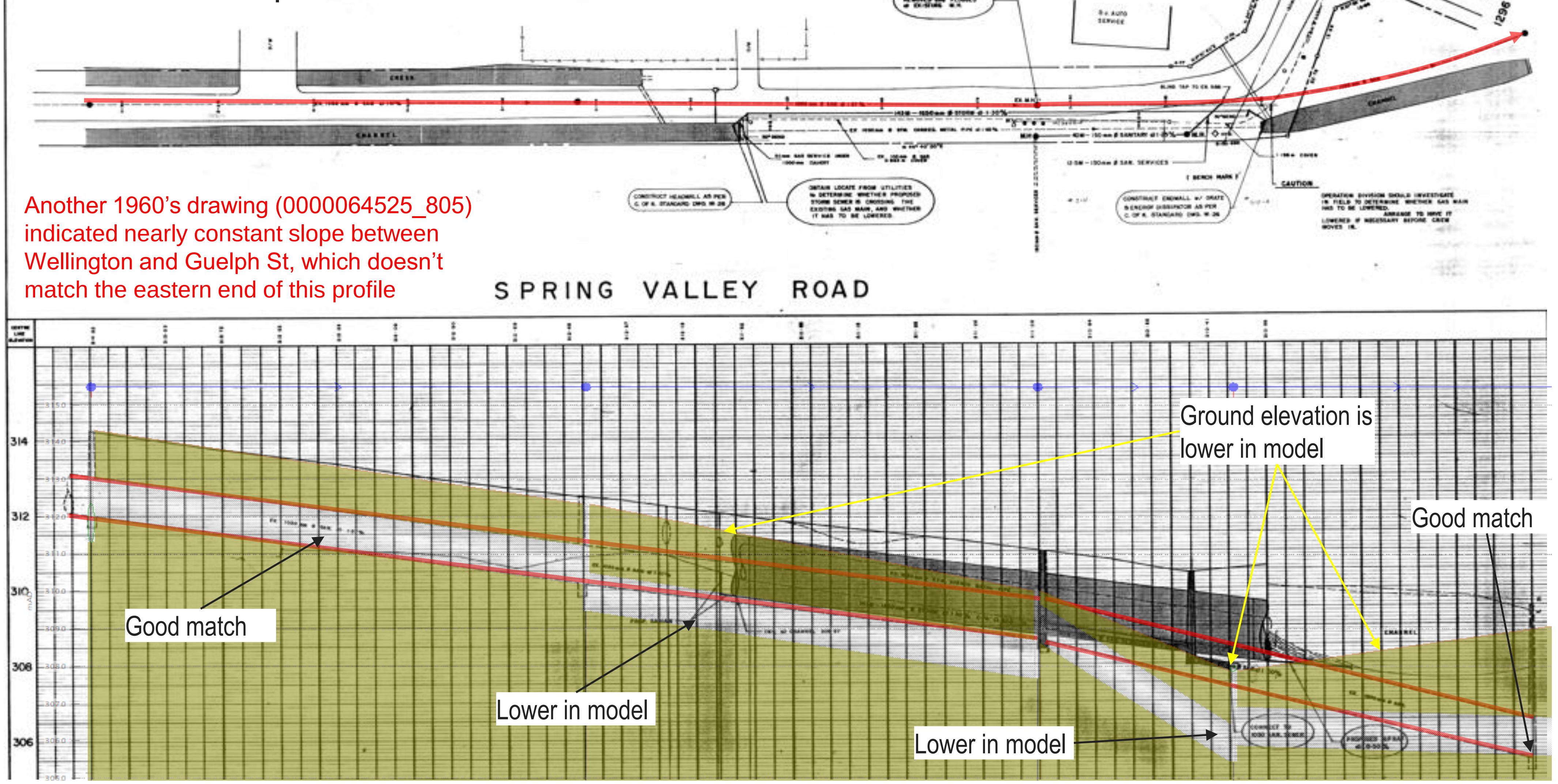
SANPIPEID	WIDTH	HEIGHT	UP_INVERT	DN_INVERT	SLOPE
105824	1050	1050	312.05	GAP 0	0
105825	1050	1050	312	310.189	1.43
105826	1050	1050	309.463	307.665	1.57
119015	1050	1050	308.603	305.425	2.44

- In this case, there is a gap in the GIS and a mismatch with the InfoSWMM input, so something was edited either in the original model-build, or in 2019 - inconsistency still remains, and model changes didn’t migrate back to GIS

Inconsistent Profile – Drawing Review

Model vs Drawing Profile Comparison

- Drawings can sometimes provide clarity – this was 5th drawing pulled (1988) (0000061357_805-1A)
- Can also open a can of worms



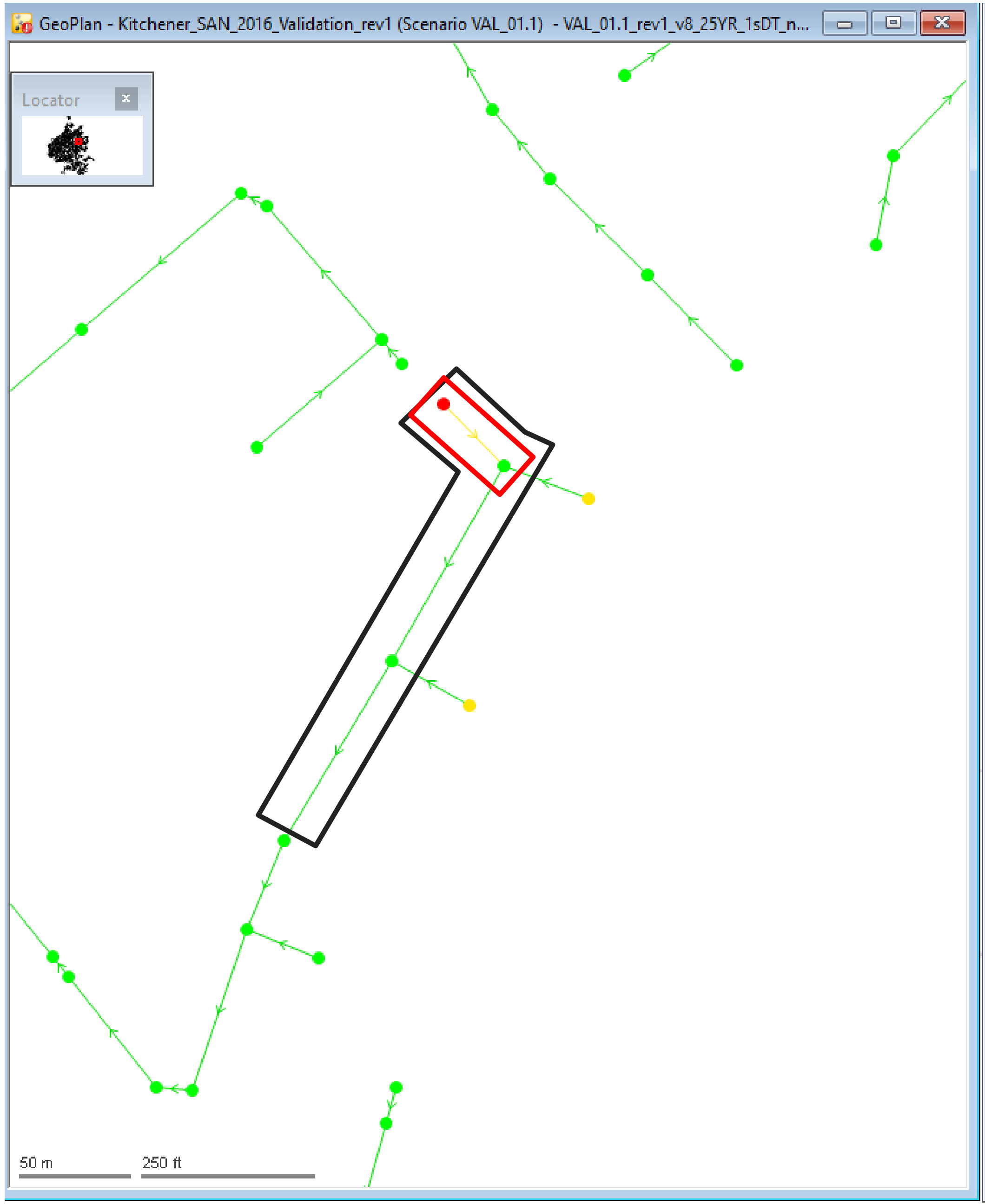
Superimposed model profile on record drawing

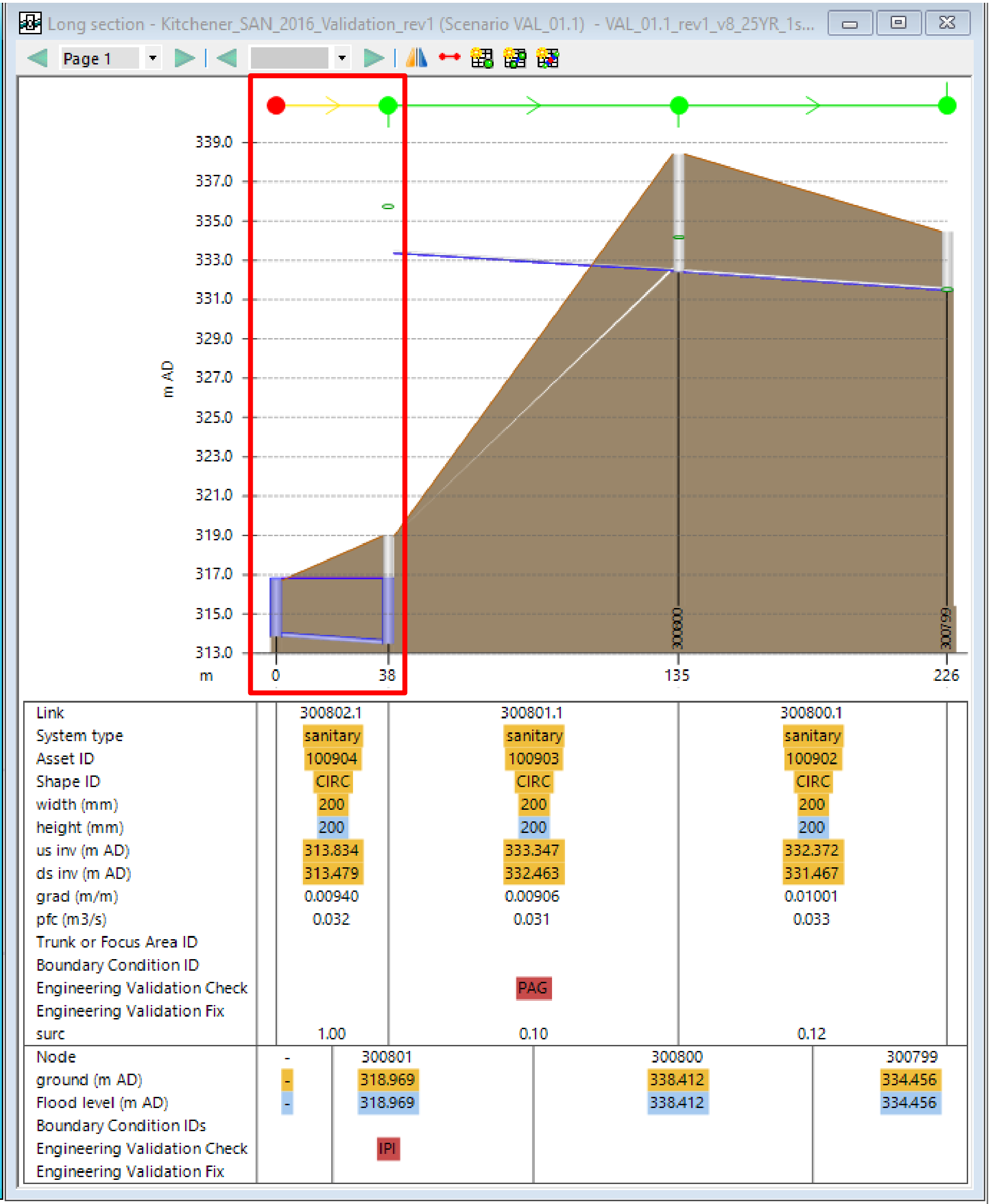
3 node elevations and 3 pipes need editing

Comparison 1: ICM - Asset ID: 100904

Pipe of Focus

Profile Extent



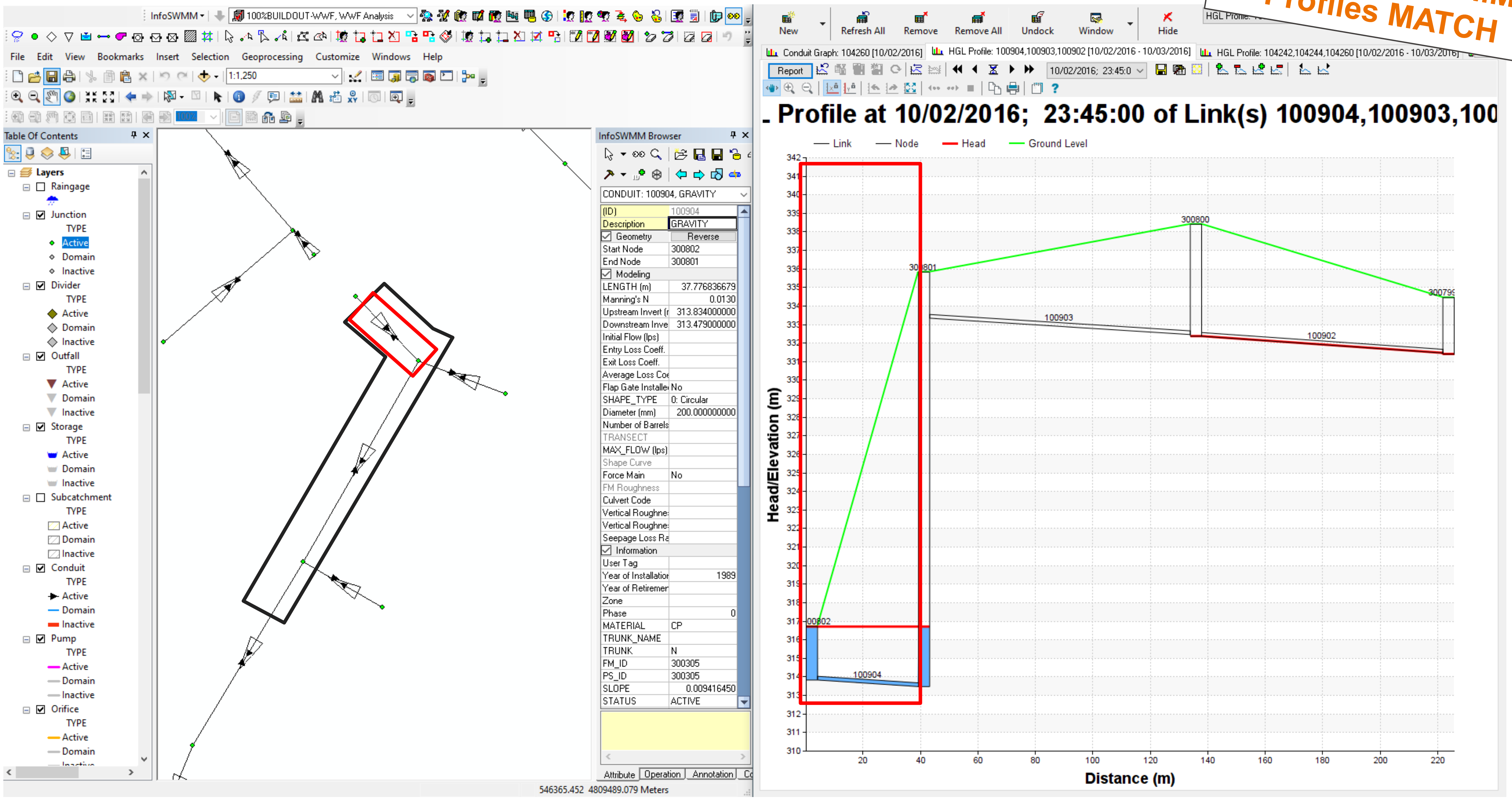


Comparison 1: InfoSWMM - Asset ID: 100904

** Base conduit set used for comparison*

ICM & InfoSWMM Profiles MATCH

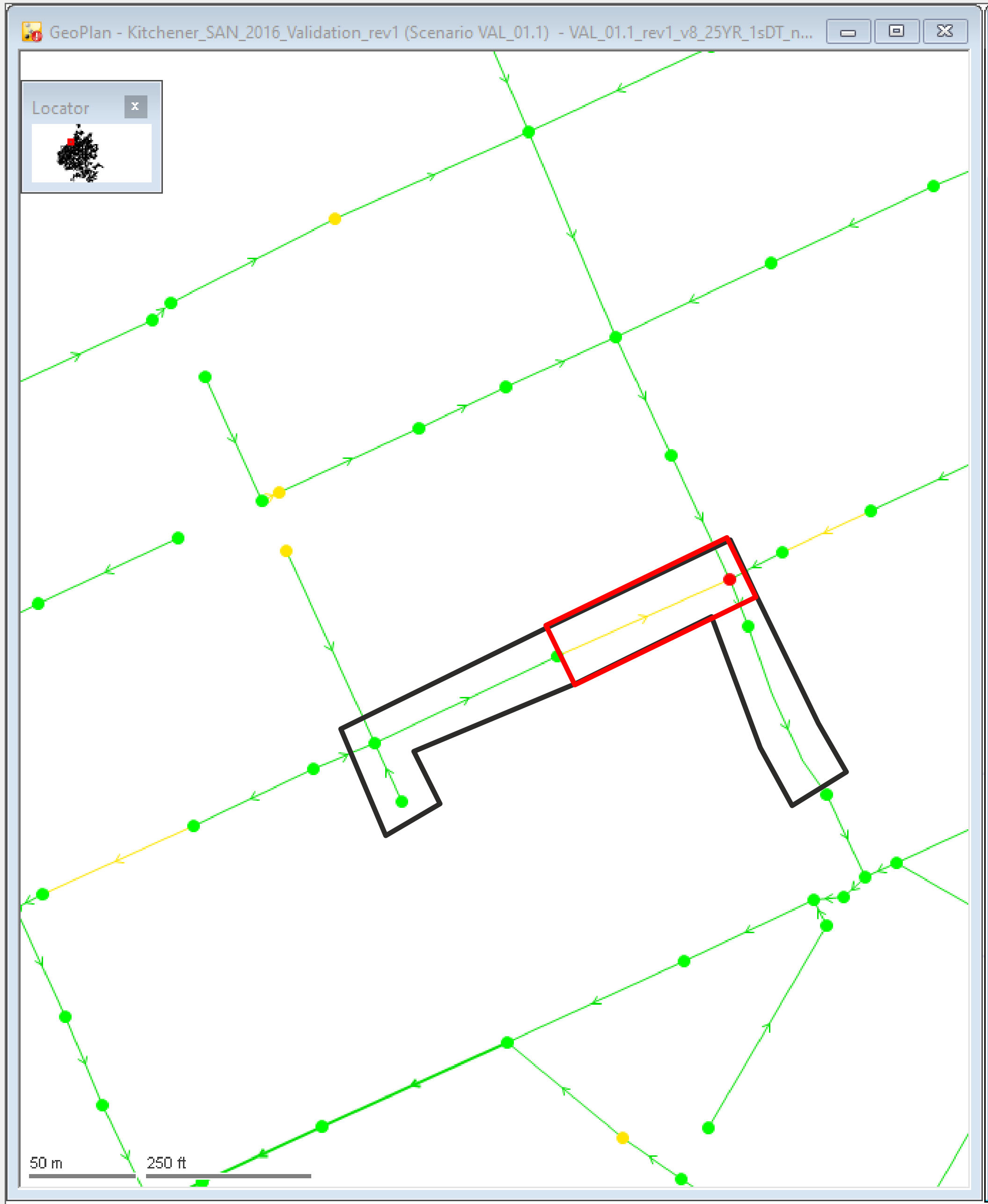
Pipe of Focus   Profile Extent

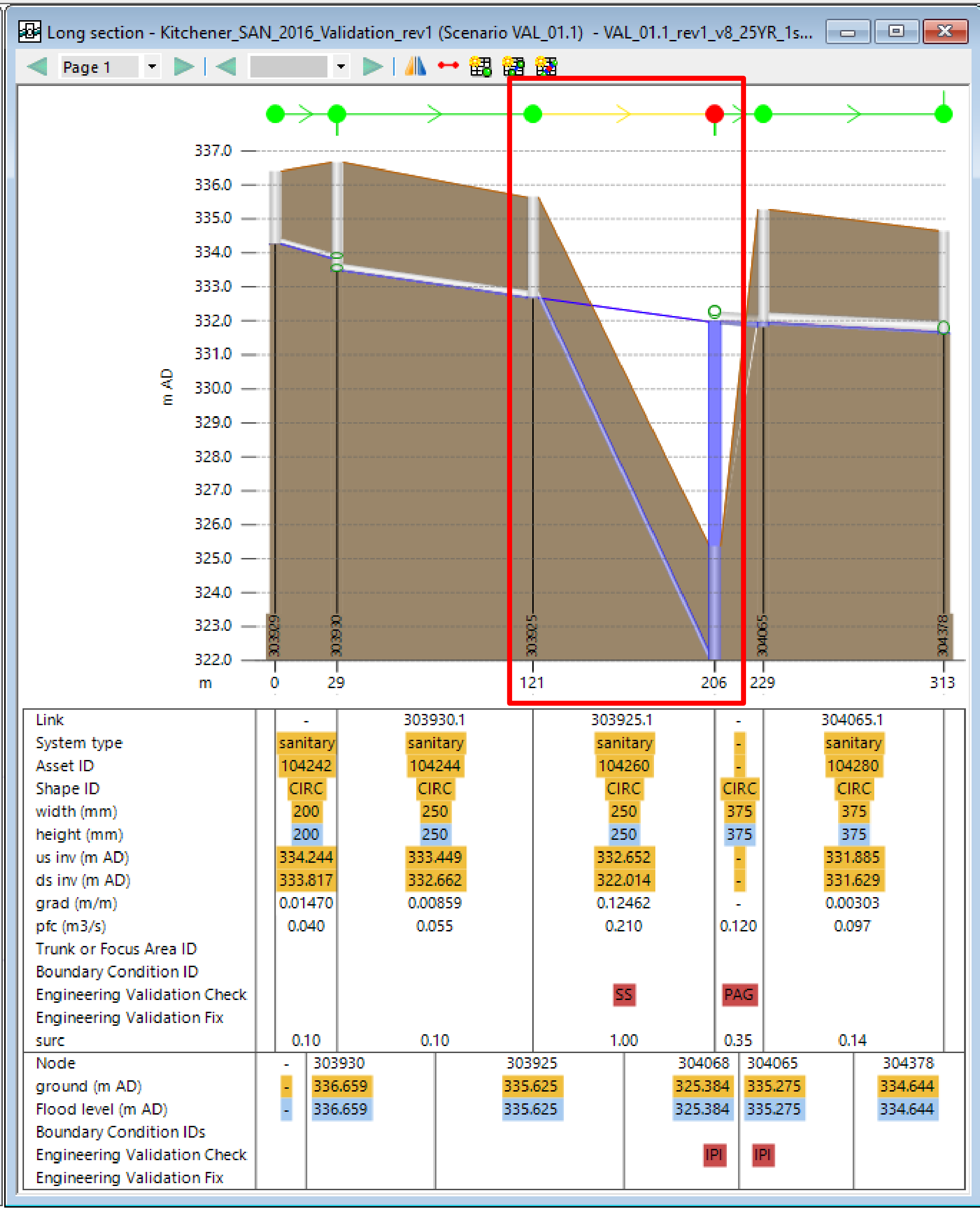


Comparison 2: ICM - Asset ID: 104260

Pipe of Focus

Profile Extent



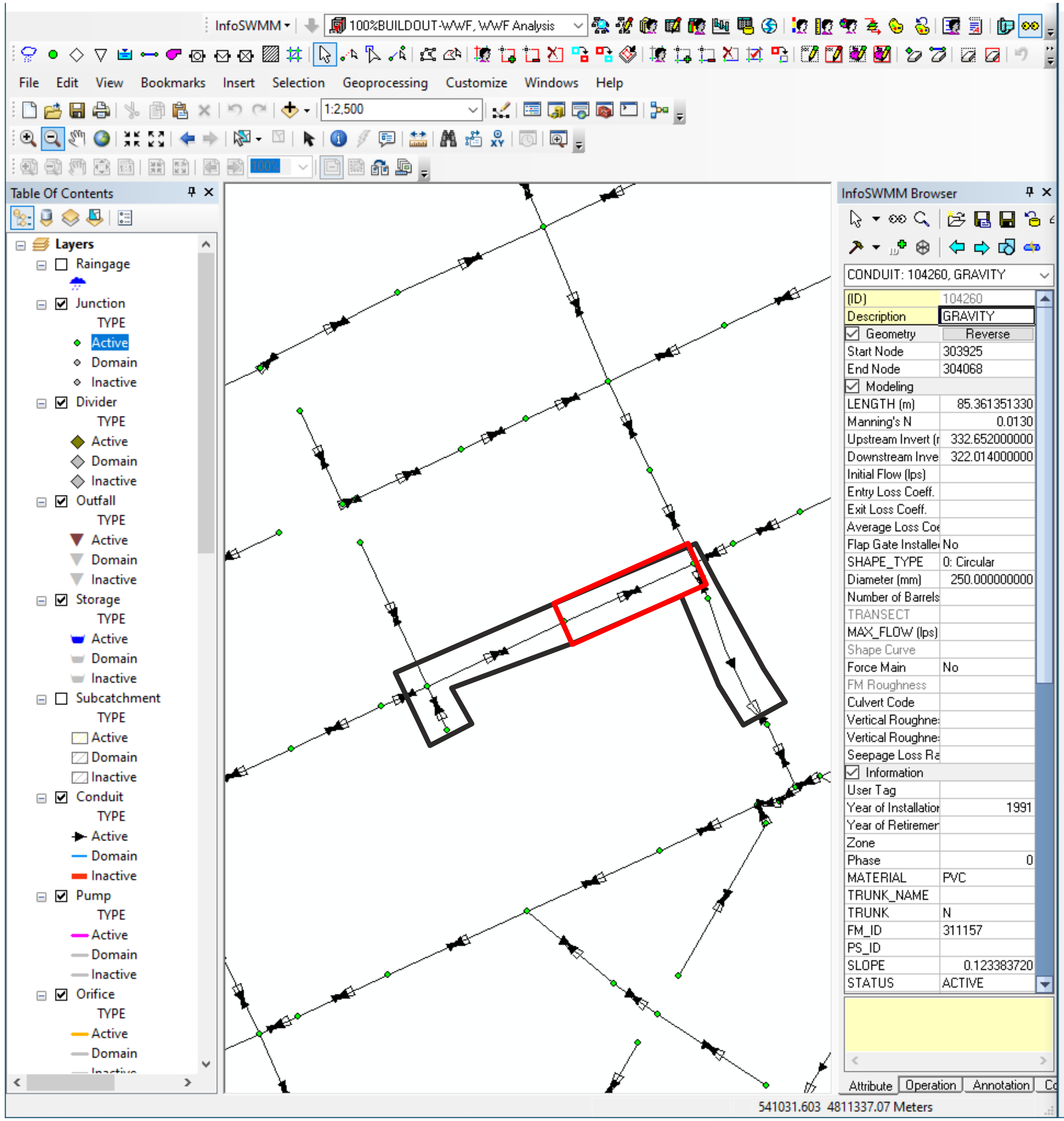


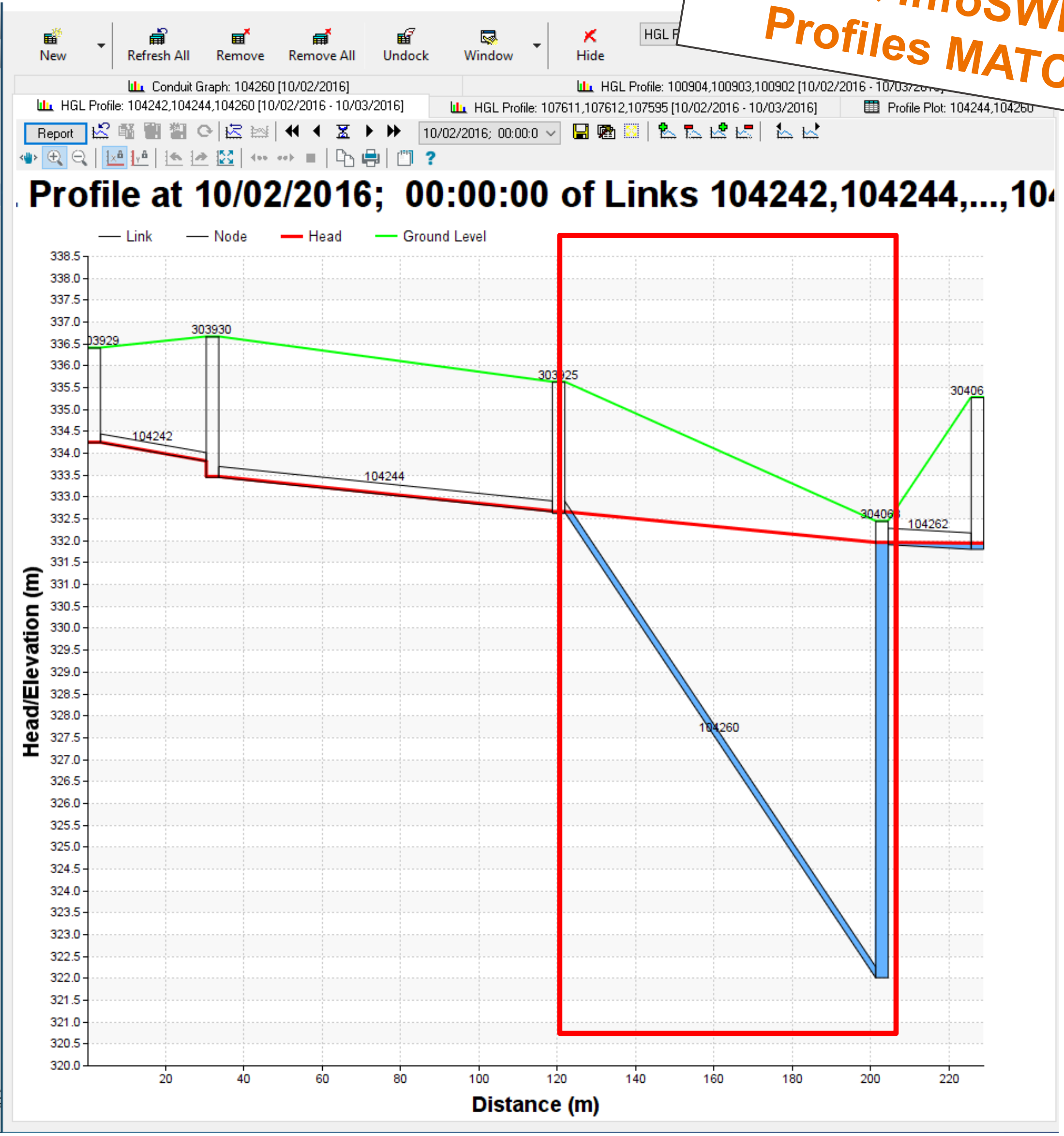
Base conduit set used for comparison

Comparison 2: InfoSWMM - Asset ID: 104260

Pipe of Focus   Profile Extent

ICM & InfoSWMM Profiles MATCH

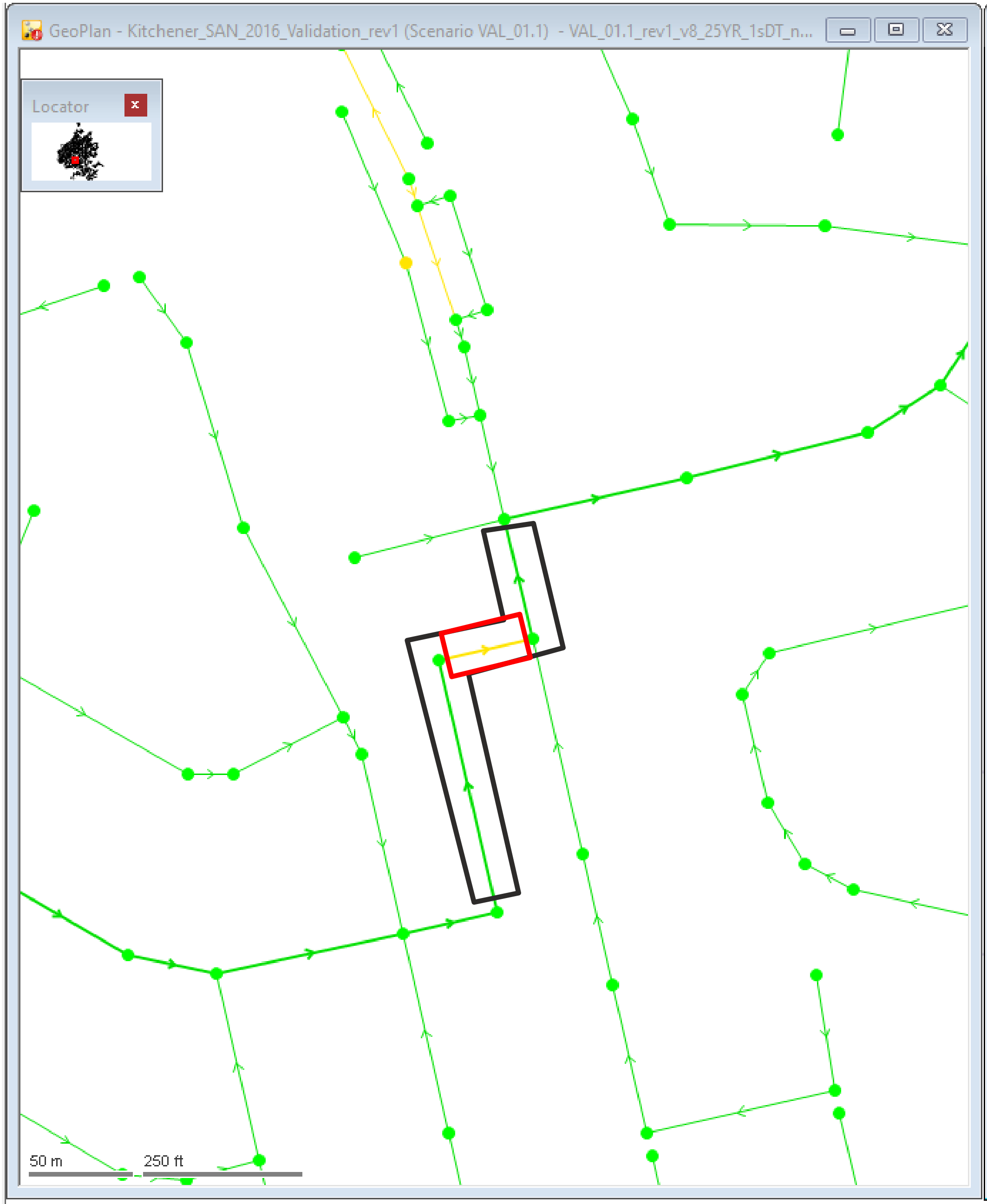


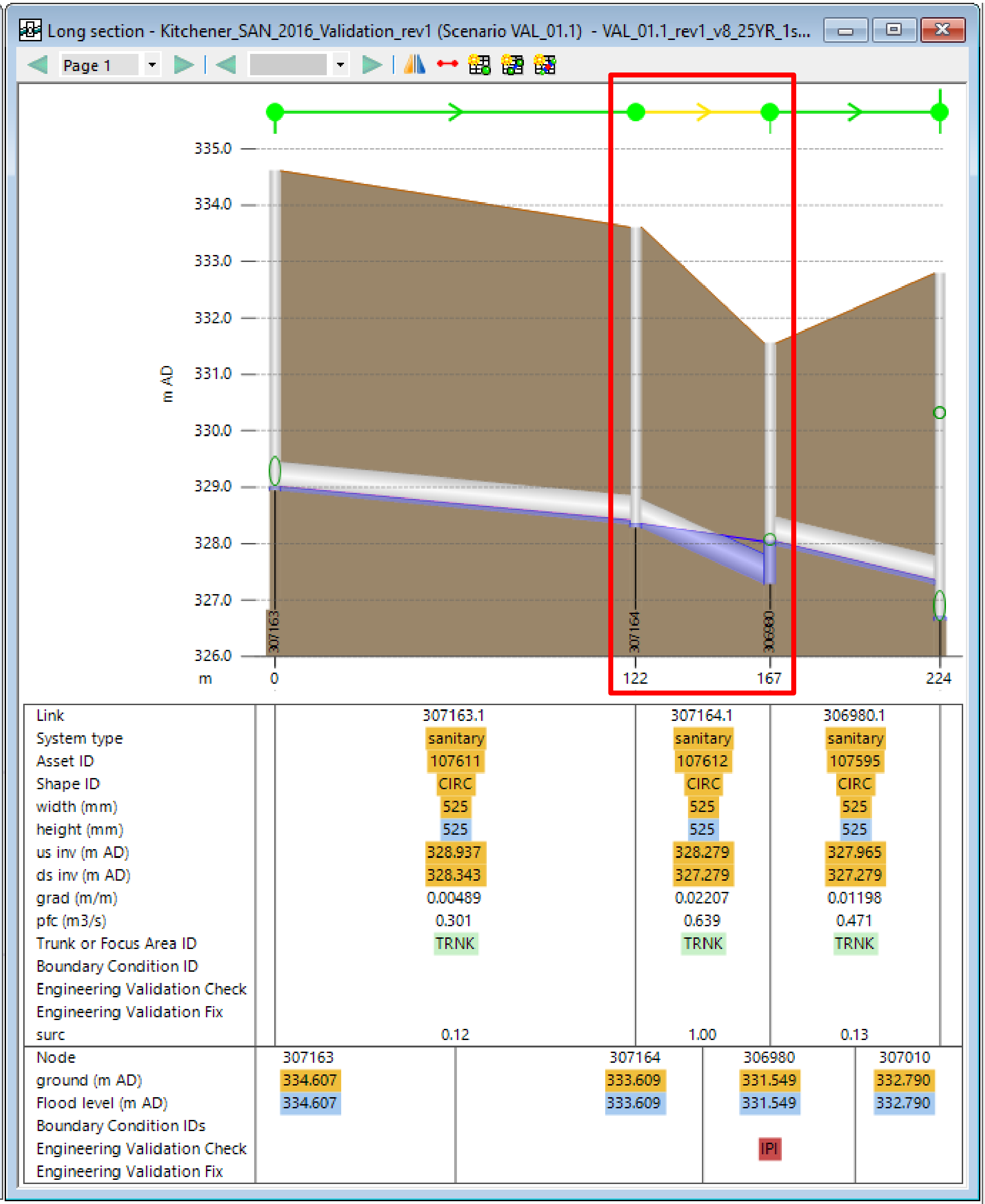


Comparison 3: ICM - Asset ID: 107612

Pipe of Focus

Profile Extent



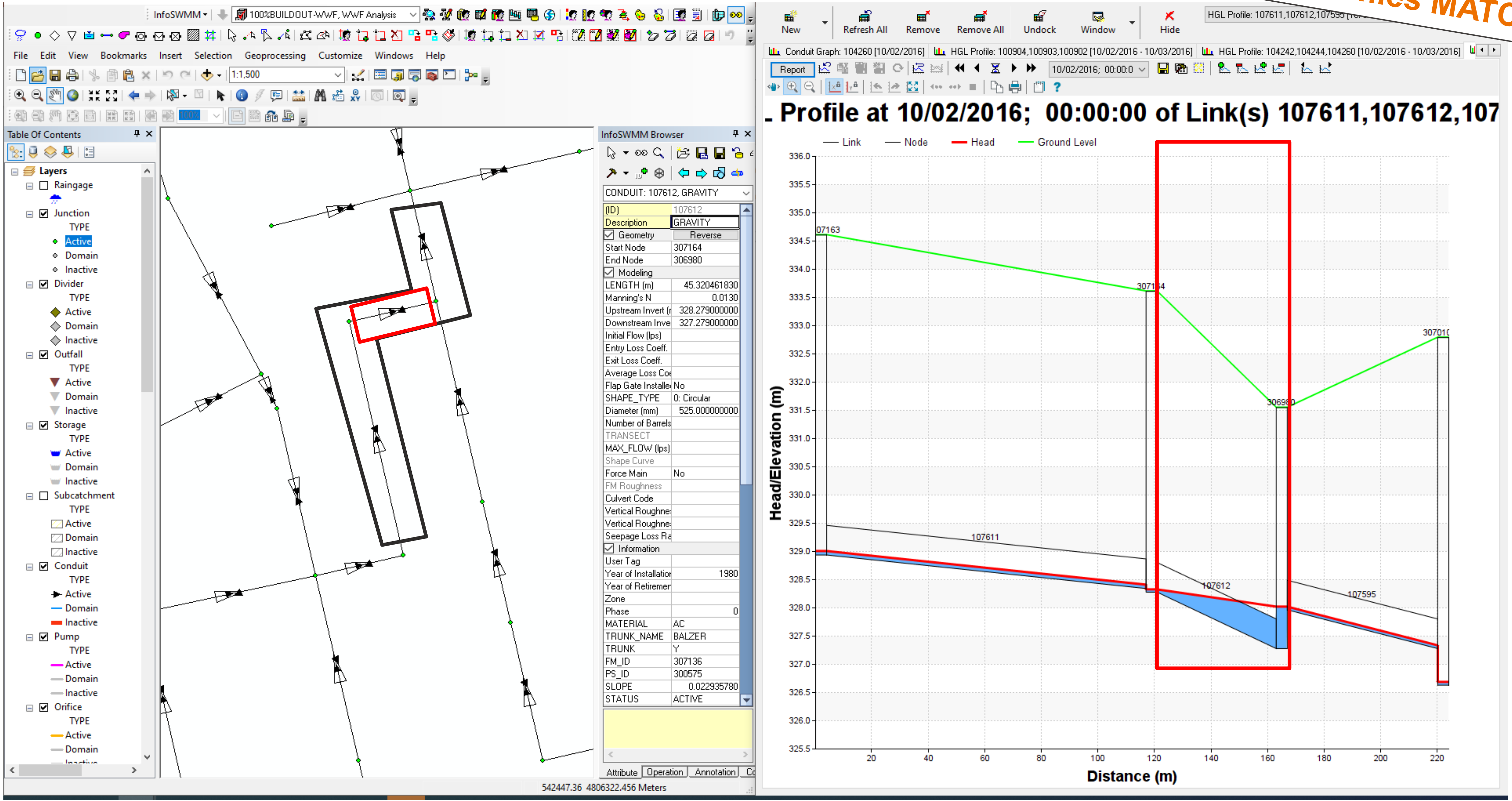


*** Base conduit set used for comparison**

Comparison 3: InfoSWMM - Asset ID: 107612

Pipe of Focus   Profile Extent

ICM & InfoSWMM Profiles MATCH



Implications

Inconsistent Profiles

- InfoWorks ICM internal checks will not allow the model to run, even though InfoSWMM can with limited continuity error – many warnings do exist
- This is the dry weather flow result from 2019 report – depth by diameter
- Many isolated pockets of capacity issues are not necessarily ‘real’
- Could influence calibration parameters
- Ultimately could influence capital planning decisions

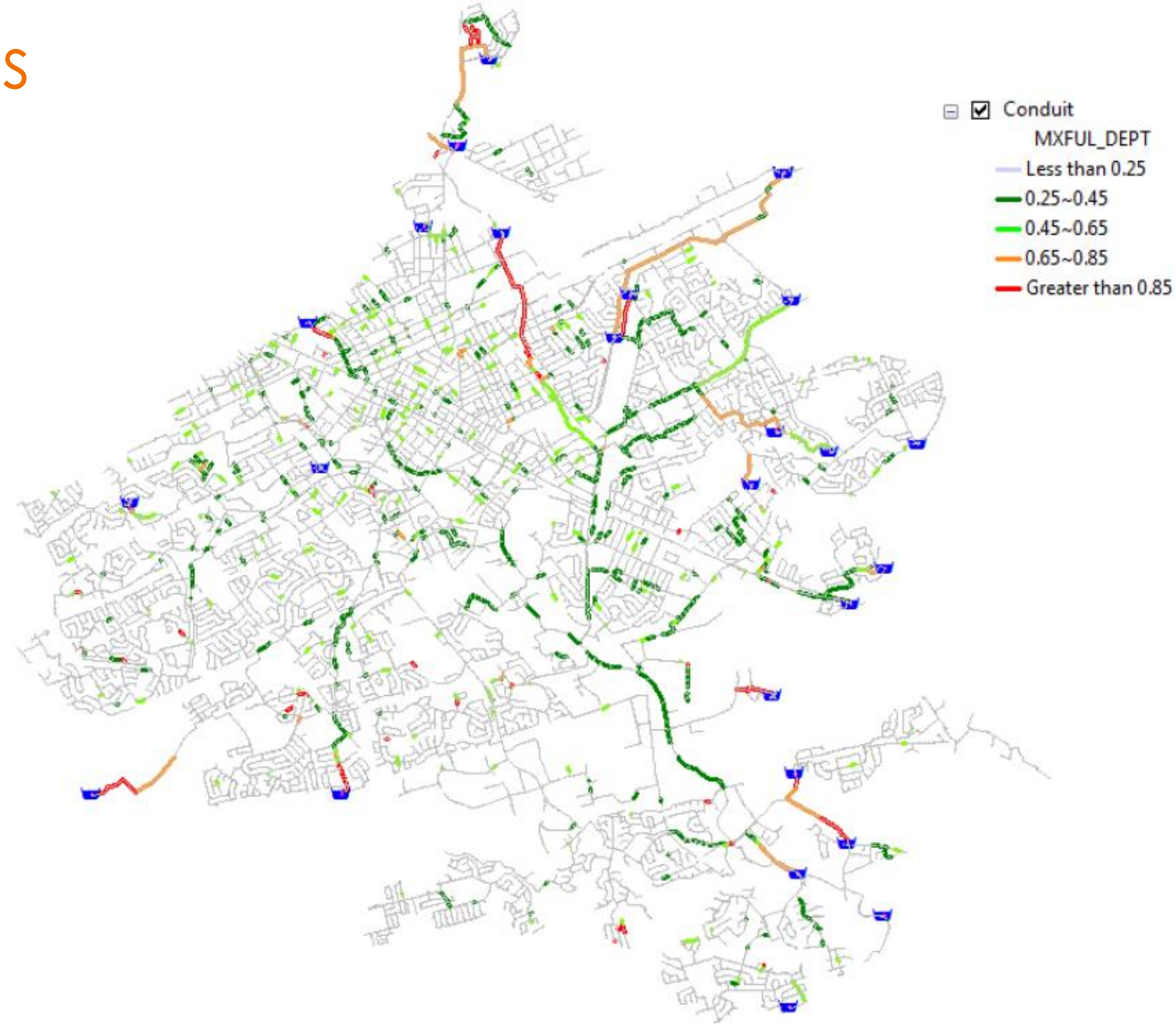
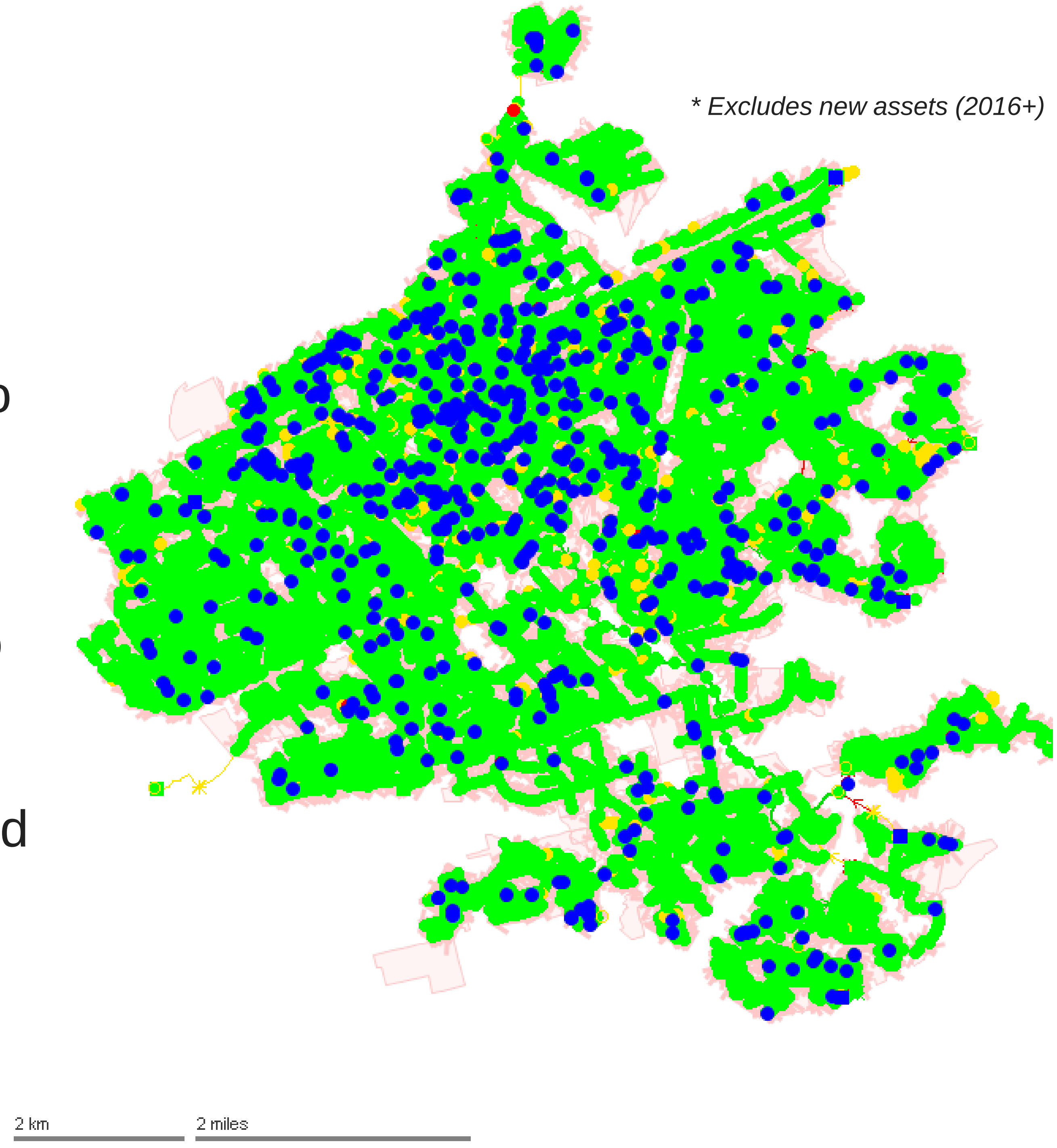


Figure 5-1: System Performance (d/D) under Existing DWF Condition

Decision

Inconsistent
Profiles

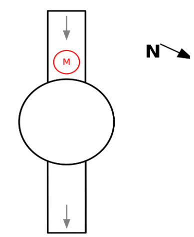
- The model requires adjustments to allow ICM to perform simulations
- This is a Master Plan – to what degree are these existing errors to be corrected?
- Over 600, geographically dispersed



APPENDIX C - FLOW MONITORING DATA REVIEW

MONITOR INFO			
Monitor ID	**FM1**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Highland Rd at Fischer-Hallman		
	GIS	**Model**	
MH ID	308300	308300	
Pipe ID	308299.1	308299.1	
Shape	ROUND	CIRC	
Height/Dia. (mm)	675	675	
Width (mm)	675	675	
Location Notes & Confirmation	The GIS and model meter location and diameter match.		

MONITOR INSTALLATION PLAN

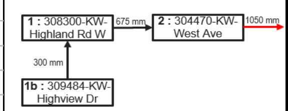


TRIBUTARY AREA CHARACTERISTICS

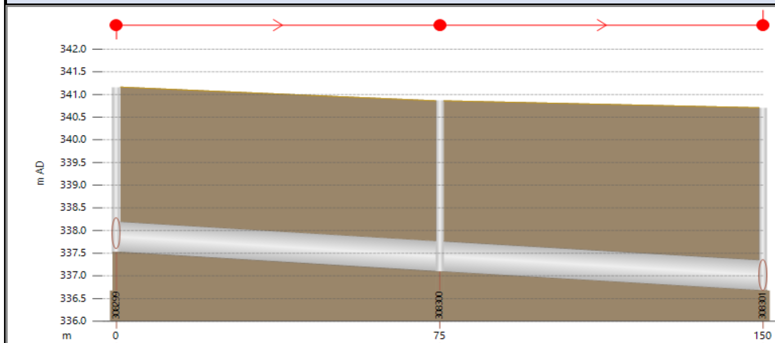
Monitors in Series?	Yes	
Bifurcations?	No	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	246.0	206.3
RES Area (ha)	223.8 (91%)	185.7 (90%)
ICI Area (ha)	22.3 (9%)	20.6 (10%)
Vacant Area (ha)	0.0 (0%)	0.0 (0%)
Total Population	13,213	11,229
RES Pop.	12,360 (94%)	10,434 (93%)
ICI Pop.	853 (6%)	795 (7%)
HD Pop.	N/A	N/A

Notes: FM1 is located upstream of FM2 and downstream of FM1b. The land use is residential.

MONITOR SCHEMATIC



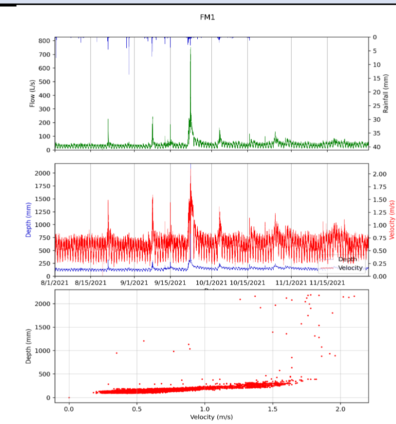
MODEL PROFILE



Link	308299.1	308300.1
System type	sanitary	sanitary
length (m)	75.0	75.0
Shape ID	CIRC	CIRC
width (mm)	675	675
us inv (m AD)	337.523	337.091
ds inv (m AD)	337.100	336.679
grad (m/m)	0.00564	0.00549
pfc (m3/s)	0.631	0.623

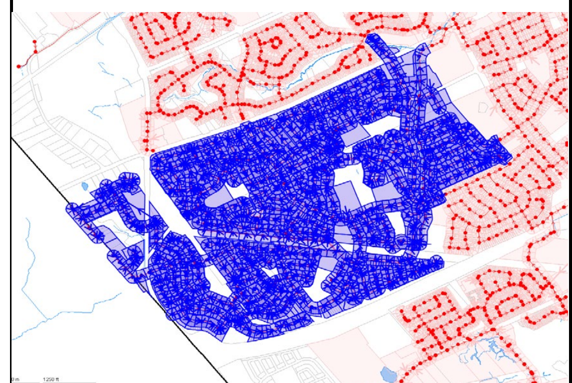
Node	308299	308300	308301
System type	sanitary	sanitary	sanitary
ground (m AD)	341.163	340.861	340.709

FLOW MONITOR DATA OVERVIEW



Notes: Backflow and generally good quality data observed.

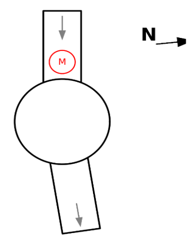
METERSHED CONTEXT



MONITOR INFO

Monitor ID	**FM1b**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Highview Dr at Driftwood Dr		
	GIS	**Model**	
MH ID	309484	309484	
Pipe ID	309486.1	309486.1	
Shape	ROUND	CIRC	
Height/Dia. (mm)	300	300	
Width (mm)	300	300	
Location Notes & Confirmation	The GIS and model meter location and diameter match.		

MONITOR INSTALLATION PLAN

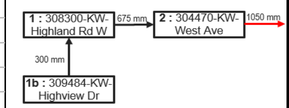


TRIBUTARY AREA CHARACTERISTICS

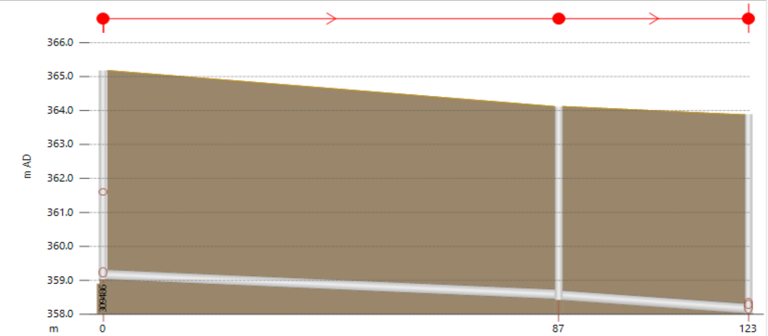
Monitors in Series?	Yes	
Bifurcations?	No	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	39.7	39.7
RES Area (ha)	38.0 (96%)	38.0 (96%)
ICI Area (ha)	1.6 (4%)	1.6 (4%)
Vacant Area (ha)	0.0 (0%)	0.0 (0%)
Total Population	1,984	1,984
RES Pop.	1,926 (97%)	1,926 (97%)
ICI Pop.	58 (3%)	58 (3%)
HD Pop.	N/A	N/A

Notes: FM1b is located upstream of FM1 and FM2. The land use is residential.

MONITOR SCHEMATIC



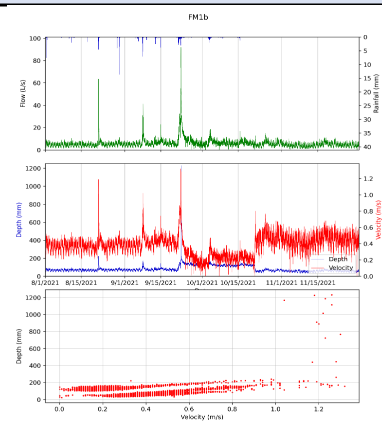
MODEL PROFILE



Link	309486.1	309484.1
System type	sanitary	sanitary
length (m)	86.6	36.2
Shape ID	CIRC	CIRC
width (mm)	300	300
us inv (m AD)	359.018	358.408
ds inv (m AD)	358.442	358.024
grad (m/m)	0.00665	0.01060
pfc (m3/s)	0.079	0.100

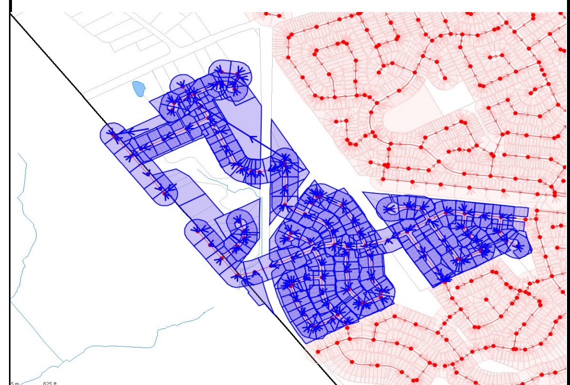
Node	309486	309484	309485
System type	sanitary	sanitary	sanitary
ground (m AD)	365.178	364.118	363.874

FLOW MONITOR DATA OVERVIEW



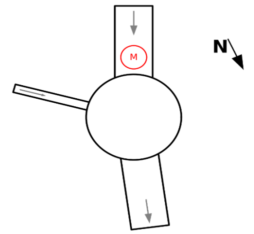
Notes: Backflow and two distinct trends in the velocity vs. depth scatterplot are observed.

METERSHED CONTEXT



MONITOR INFO			
Monitor ID	**FM2**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	West Ave		
	GIS	**Model**	
MH ID	304470	304470	
Pipe ID	304470.1	304472.1	
Shape	ROUND	CIRC	
Height/Dia. (mm)	1050	1050	
Width (mm)	1050	1050	
Location Notes & Confirmation	AMG notes confirmed different pipe than GIS data. AMG also confirmed that the initial installation had variable connectivity due to large rocks and debris.		

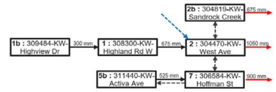
MONITOR INSTALLATION PLAN



TRIBUTARY AREA CHARACTERISTICS

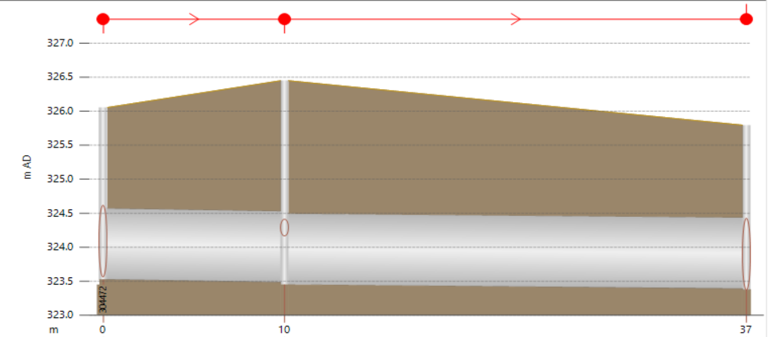
Monitors in Series?	Yes	
Bifurcations?	Bifurcations with FM2b; FM7	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	655.3	409.3
RES Area (ha)	528.8 (81%)	305.0 (75%)
ICI Area (ha)	85.8 (13%)	63.6 (16%)
Vacant Area (ha)	40.7 (6%)	40.7 (10%)
Total Population	37,628	24,415
RES Pop.	33,674 (89%)	21,314 (87%)
ICI Pop.	3,954 (11%)	3,101 (13%)
HD Pop.	N/A	N/A

MONITOR SCHEMATIC



Notes: FM2 is located downstream of FM1 and FM1b. The land use is residential. Major spill points from unmonitored sewers and to and from FM2b are present.

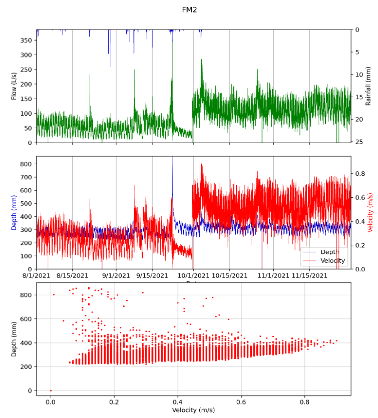
MODEL PROFILE



Link	304472.1	304470.1
System type	sanitary	sanitary
length (m)	10.4	26.4
Shape ID	CIRC	CIRC
width (mm)	1050	1050
us inv (m AD)	323.524	323.448
ds inv (m AD)	323.484	323.390
grad (m/m)	0.00386	0.00219
pfc (m3/s)	1.696	1.279

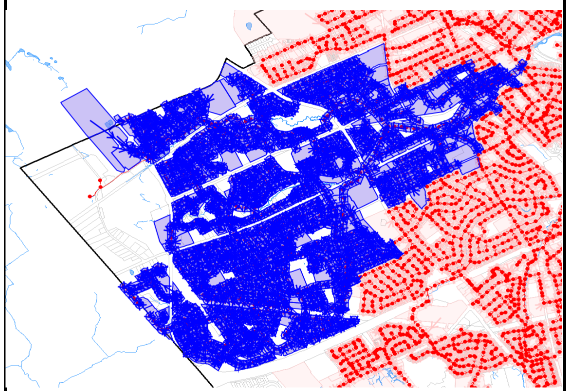
Node	304472	304470	304478
System type	sanitary	sanitary	sanitary
ground (m AD)	326.054	326.448	325.795

FLOW MONITOR DATA OVERVIEW



Notes: Data is noted as variable due to two distinct trends in the velocity vs. depth scatterplot observed. The velocity jumps halfway through the monitoring period; AMG noted more reliable data after October 1st, 2021. FM2 is downstream of Patricia SPS and its presence is noted in the data.

METERSHED CONTEXT



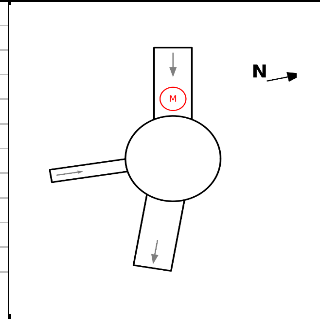
MONITOR INFO

Monitor ID	**FM2b**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Victoria St and West Ave		

	GIS	Model
MH ID	304819	304819
Pipe ID	304821.1	304821.1
Shape	ROUND	CIRC
Height/Dia. (mm)	675	675
Width (mm)	675	675

Location Notes & Confirmation: The GIS and model meter location and diameter match.

MONITOR INSTALLATION PLAN

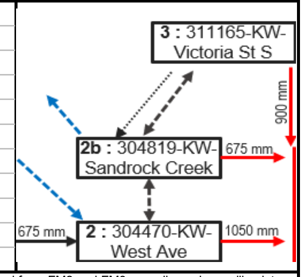


TRIBUTARY AREA CHARACTERISTICS

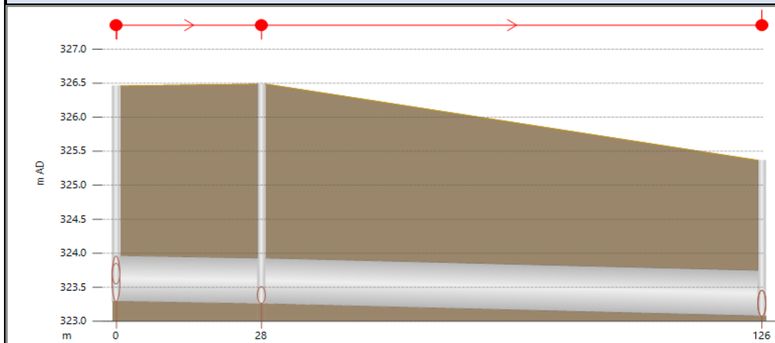
Monitors in Series?	No	
Bifurcations?	Bifurcations with unmonitored area; FM2; FM3	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	283.4	283.4
RES Area (ha)	196.9 (69%)	196.9 (69%)
ICI Area (ha)	75.4 (27%)	75.4 (27%)
Vacant Area (ha)	11.1 (4%)	11.1 (4%)
Total Population	15,073	15,073
RES Pop.	10,405 (69%)	10,405 (69%)
ICI Pop.	4,667 (31%)	4,667 (31%)
HD Pop.	N/A	N/A

Notes: The land use is mixed. Major spill points to unmonitored sewers to and from FM2 and FM3 as well as minor spill points from FM3 are present.

MONITOR SCHEMATIC



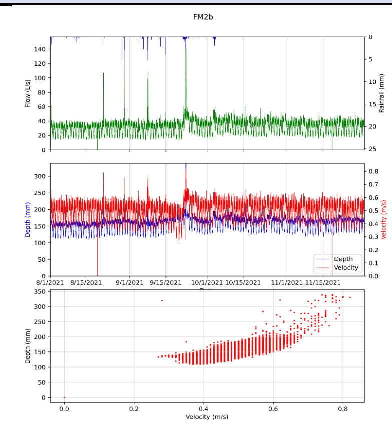
MODEL PROFILE



Link	304821.1	304819.1
System type	sanitary	sanitary
length (m)	28.3	97.5
Shape ID	CIRC	CIRC
width (mm)	675	675
us inv (m AD)	323.290	323.256
ds inv (m AD)	323.256	323.076
grad (m/m)	0.00120	0.00185
pfc (m3/s)	0.292	0.361

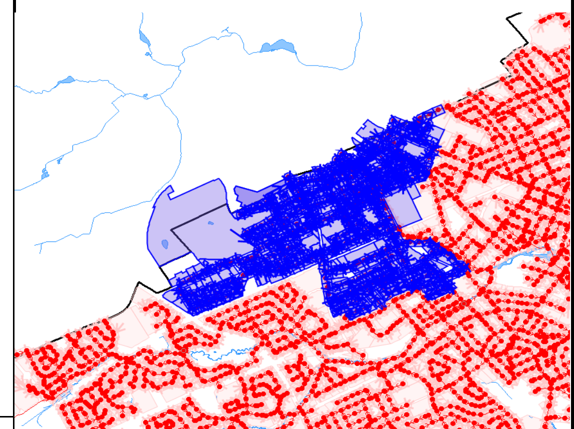
Node	304821	304819	303850
System type	sanitary	sanitary	sanitary
ground (m AD)	326.459	326.486	325.366

FLOW MONITOR DATA OVERVIEW



Notes: Good quality data observed.

METERSHED CONTEXT

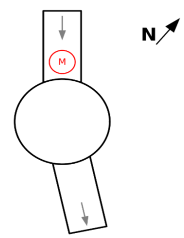


MONITOR INFO

Monitor ID	**FM3**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Victoria St S and Theresa St		

	GIS	**Model**
MH ID	311165	311165
Pipe ID	311167.1	311167.1
Shape	ROUND	CIRC
Height/Dia. (mm)	900	900
Width (mm)	900	900
Location Notes & Confirmation	The original model link size was 750mm and has since been updated. AMG noted silt and rocks upon installation.	

MONITOR INSTALLATION PLAN

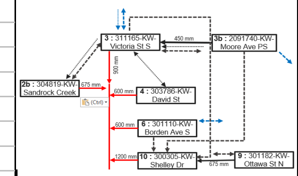


TRIBUTARY AREA CHARACTERISTICS

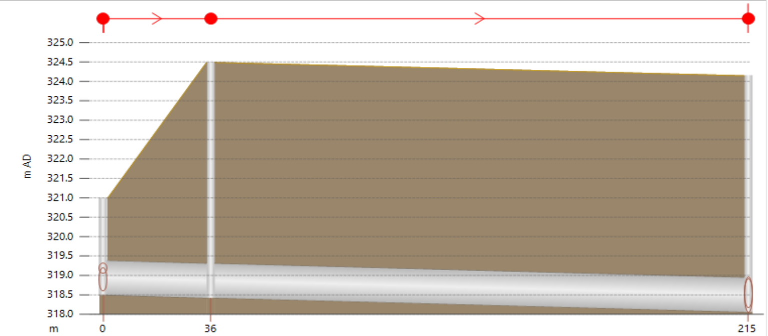
Monitors in Series?	Yes	
Bifurcations?	Bifurcations with unmonitored area; FM2b; FM3b; FM4; FM10	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	158.7	128.1
RES Area (ha)	106.7 (67%)	81.3 (63%)
ICI Area (ha)	50.4 (32%)	45.2 (35%)
Vacant Area (ha)	1.6 (1%)	1.6 (1%)
Total Population	12,532	10,723
RES Pop.	8,169 (65%)	6,589 (61%)
ICI Pop.	4,363 (35%)	4,134 (39%)
HD Pop.	N/A	N/A

Notes: FM3 is located downstream of FM3b. The land use is mixed. Major and minor spill points to and from FM2b, FM3b, FM4, FM10 and the unmonitored sewers are present.

MONITOR SCHEMATIC



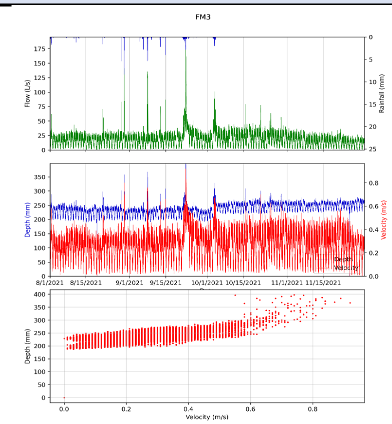
MODEL PROFILE



Link	311167.1	311165.1
System type	sanitary	sanitary
length (m)	35.8	179.6
Shape ID	CIRC	CIRC
width (mm)	900	900
us inv (m AD)	318.489	318.414
ds inv (m AD)	318.414	318.053
grad (m/m)	0.00209	0.00201
pfc (m3/s)	0.829	0.812

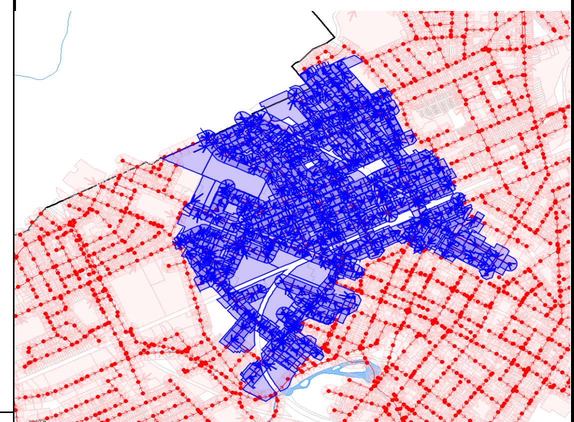
Node	311167	311165	311163
System type	sanitary	sanitary	sanitary
ground (m AD)	320.989	324.488	324.145

FLOW MONITOR DATA OVERVIEW



Notes: Good quality data observed.

METERSHED CONTEXT



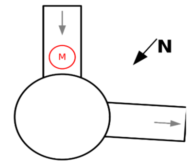
MONITOR INFO

Monitor ID	**FM3b**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0000577579_220		
Location	Moore Ave Pump Station		

	GIS	**Model**
MH ID	2091740	2091740
Pipe ID	2091735.1	2091735.1
Shape	ROUND	CIRC
Height/Dia. (mm)	0	450
Width (mm)	450	450

Location Notes & Confirmation: The GIS and model meter location and diameter match. AMG noted a diameter of 225 mm and later confirmed the 450 mm diameter.

MONITOR INSTALLATION PLAN

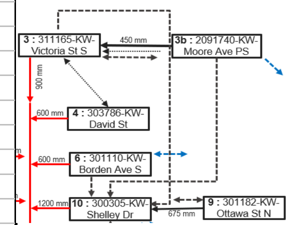


TRIBUTARY AREA CHARACTERISTICS

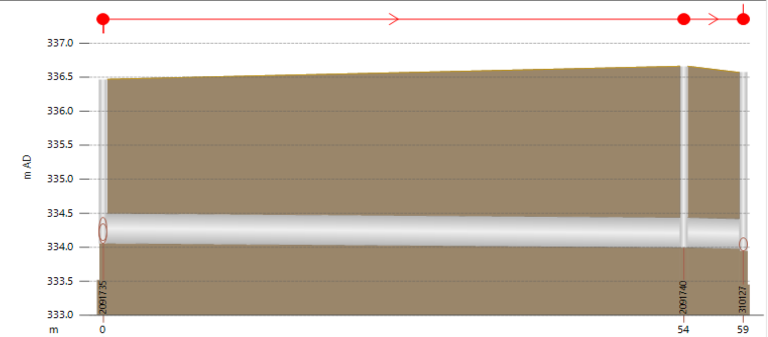
Monitors in Series?	Yes	
Bifurcations?	Bifurcations with unmonitored area; FM3; FM10	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	30.6	30.6
RES Area (ha)	25.4 (83%)	25.4 (83%)
ICI Area (ha)	5.2 (17%)	5.2 (17%)
Vacant Area (ha)	0.0 (0%)	0.0 (0%)
Total Population	1,810	1,810
RES Pop.	1,580 (87%)	1,580 (87%)
ICI Pop.	229 (13%)	229 (13%)
HD Pop.	N/A	N/A

Notes: FM3b is located upstream of FM3. The land use is residential. Major spill points to and from FM3 and to FM10 and the unmonitored sewers as well as minor spill points to FM3 are present.

MONITOR SCHEMATIC



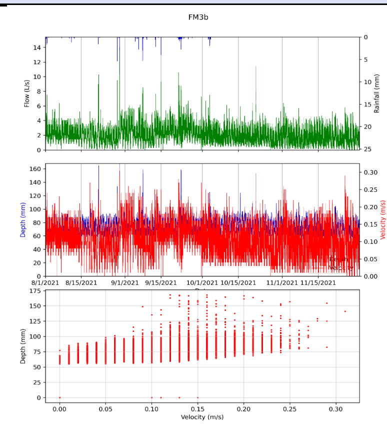
MODEL PROFILE



Link	2091735.1	2091740.1
System type	sanitary	sanitary
length (m)	53.9	5.5
Shape ID	CIRC	CIRC
width (mm)	450	450
us inv (m AD)	334.050	333.990
ds inv (m AD)	333.990	333.970
grad (m/m)	0.00111	0.00363
pfc (m3/s)	0.095	0.172

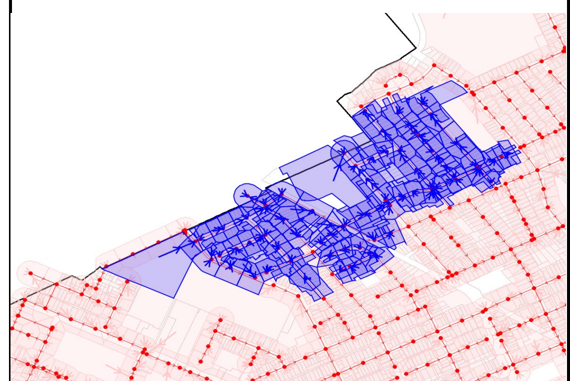
Node	2091735	2091740	-
System type	sanitary	sanitary	-
ground (m AD)	336.470	336.660	-

FLOW MONITOR DATA OVERVIEW



Notes: Data is noted as variable due to silt buildup causing fluctuation in flow and velocity. FM3b is located upstream of Moore Avenue SPS.

METERSHED CONTEXT



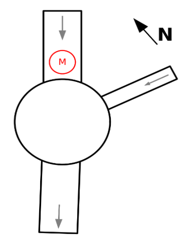
MONITOR INFO

Monitor ID	**FM4**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	David St/Victoria Park		

	GIS	Model
MH ID	303786	303786
Pipe ID	303748.1	303748.1
Shape	ROUND	CIRC
Height/Dia. (mm)	600	600
Width (mm)	600	600

Location Notes & Confirmation: The GIS and model meter location and diameter match.

MONITOR INSTALLATION PLAN

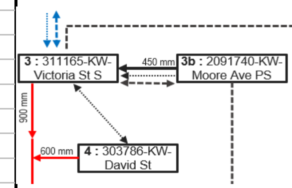


TRIBUTARY AREA CHARACTERISTICS

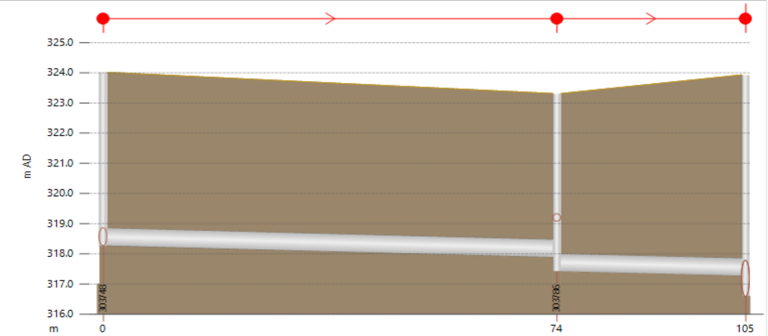
Monitors in Series?	No	
Bifurcations?	Bifurcations with FM3	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	31.6	31.6
RES Area (ha)	7.2 (23%)	7.2 (23%)
ICI Area (ha)	20.3 (64%)	20.3 (64%)
Vacant Area (ha)	4.1 (13%)	4.1 (13%)
Total Population	6,663	6,663
RES Pop.	1,840 (28%)	1,840 (28%)
ICI Pop.	4,823 (72%)	4,823 (72%)
HD Pop.	N/A	N/A

Notes: The land use is ICI. Minor spill points to and from FM3 are present.

MONITOR SCHEMATIC



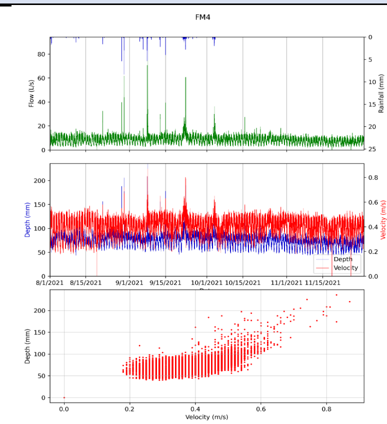
MODEL PROFILE



Link	303748.1	303786.1
System type	sanitary	sanitary
length (m)	74.4	31.0
Shape ID	CIRC	CIRC
width (mm)	600	600
us inv (m AD)	318.265	317.414
ds inv (m AD)	317.885	317.268
grad (m/m)	0.00511	0.00471
pfc (m3/s)	0.439	0.422

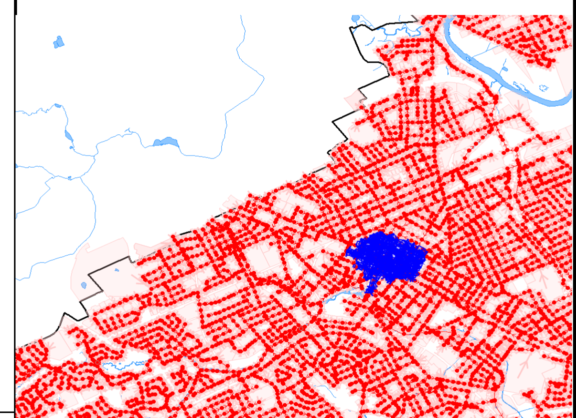
Node	303748	303786	303788
System type	sanitary	sanitary	sanitary
ground (m AD)	324.015	323.314	323.930

FLOW MONITOR DATA OVERVIEW



Notes: Data is noted as variable due to variations in readings and sporadic changes to flow patterns.

METERSHED CONTEXT



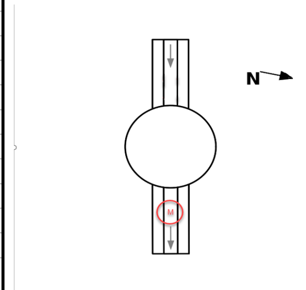
MONITOR INFO

Monitor ID	**FM5b**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Outgoing Pipe	**Duration**	122
Drawing Ref.	0		
Location	Activa Ave		

	GIS	Model
MH ID	311440	311440
Pipe ID	311439.1	311440.1
Shape	ROUND	CIRC
Height/Dia. (mm)	525	525
Width (mm)	525	525

Location Notes & Confirmation: AMG noted the meter was installed in the outgoing pipe due to the presence of a drop structure.

MONITOR INSTALLATION PLAN

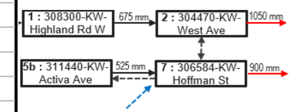


TRIBUTARY AREA CHARACTERISTICS

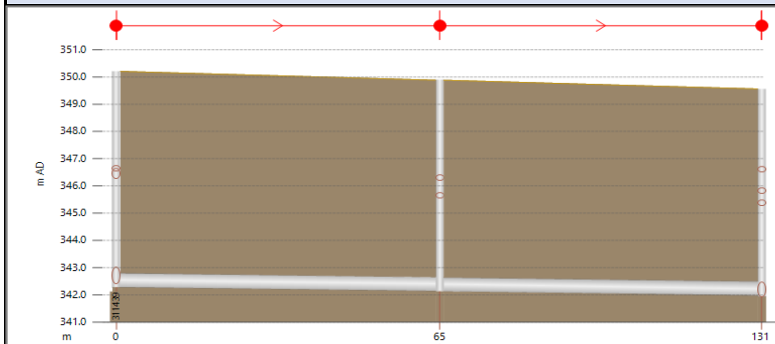
Monitors in Series?	Yes	
Bifurcations?	Bifurcations with FM7	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	114.8	114.8
RES Area (ha)	78.9 (69%)	78.9 (69%)
ICI Area (ha)	3.0 (3%)	3.0 (3%)
Vacant Area (ha)	32.9 (29%)	32.9 (29%)
Total Population	4,522	4,522
RES Pop.	4,471 (99%)	4,471 (99%)
ICI Pop.	50 (1%)	50 (1%)
HD Pop.	N/A	N/A

Notes: FM5b is located upstream of FM7. The land use is residential. Major spill points from FM7 are present.

MONITOR SCHEMATIC



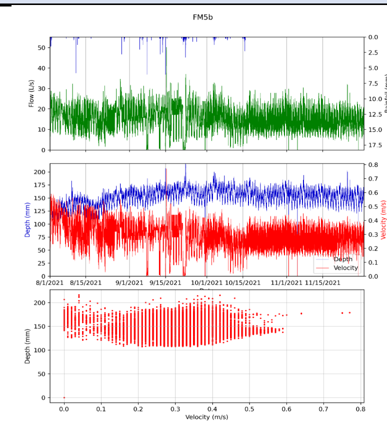
MODEL PROFILE



Link	311439.1	311440.1
System type	sanitary	sanitary
length (m)	65.5	65.2
Shape ID	CIRC	CIRC
width (mm)	525	525
us inv (m AD)	342.278	342.123
ds inv (m AD)	342.138	341.977
grad (m/m)	0.00214	0.00224
pfc (m3/s)	0.199	0.204

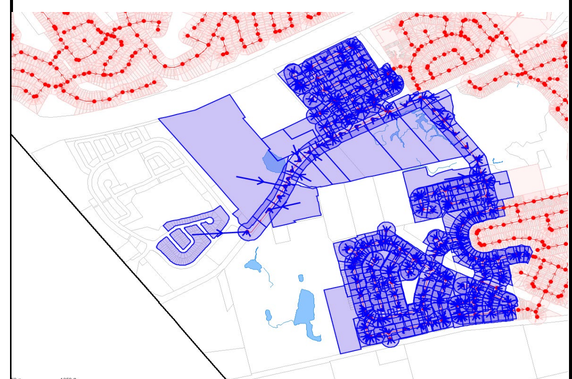
Node	311439	311440	311441
System type	sanitary	sanitary	sanitary
ground (m AD)	350.208	349.883	349.562

FLOW MONITOR DATA OVERVIEW



Notes: Data is noted as variable due to variations in readings and sporadic changes to flow patterns. FM5b is downstream of the Mannheim SPS, which is evident in the data.

METERSHED CONTEXT



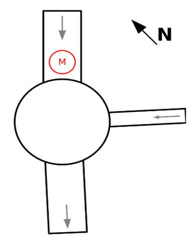
MONITOR INFO

Monitor ID	**FM6**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Borden Ave		

	GIS	**Model**
MH ID	301110	301110
Pipe ID	2130010.1	2130010.1
Shape	ROUND	CIRC
Height/Dia. (mm)	600	600
Width (mm)	600	600

Location Notes & Confirmation: The GIS and model meter location and diameter match. AMG noted silt and debris at the site.

MONITOR INSTALLATION PLAN

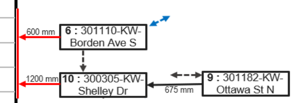


TRIBUTARY AREA CHARACTERISTICS

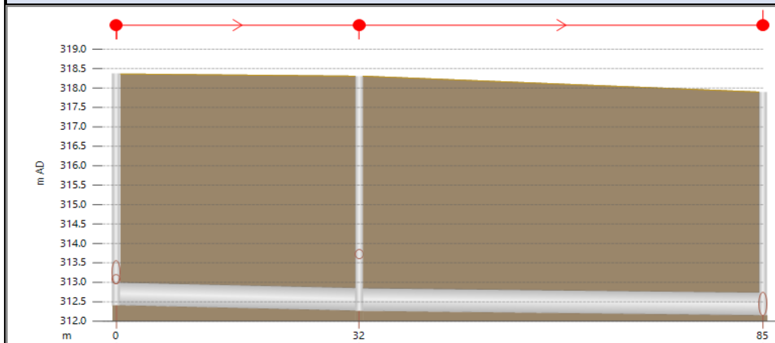
Monitors in Series?	No	
Bifurcations?	Bifurcations with unmonitored area; FM10	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	87.4	87.4
RES Area (ha)	47.3 (54%)	47.3 (54%)
ICI Area (ha)	38.0 (44%)	38.0 (44%)
Vacant Area (ha)	2.0 (2%)	2.0 (2%)
Total Population	9,174	9,174
RES Pop.	4,804 (52%)	4,804 (52%)
ICI Pop.	4,370 (48%)	4,370 (48%)
HD Pop.	N/A	N/A

Notes: The land use is mixed. Major spill points to FM10 and to and from the unmonitored sewers are present.

MONITOR SCHEMATIC



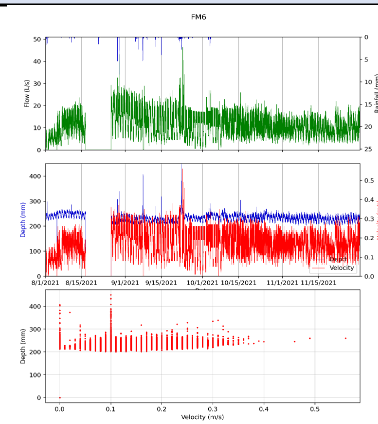
MODEL PROFILE



Link	2130010.1	301110.1
System type	sanitary	sanitary
length (m)	31.9	53.1
Shape ID	CIRC	CIRC
width (mm)	600	600
us inv (m AD)	312.403	312.255
ds inv (m AD)	312.265	312.147
grad (m/m)	0.00433	0.00203
pfc (m3/s)	0.404	0.277

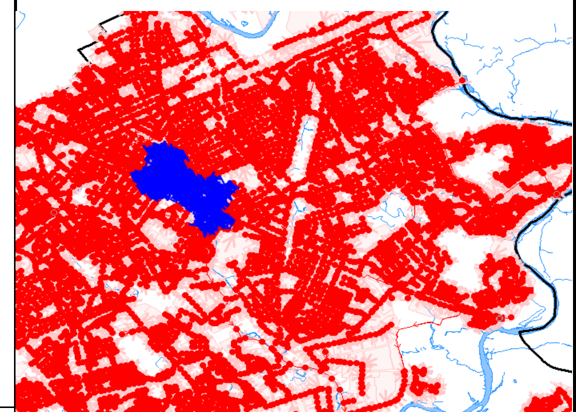
Node	2130010	301110	301115
System type	sanitary	sanitary	sanitary
ground (m AD)	318.361	318.305	317.897

FLOW MONITOR DATA OVERVIEW



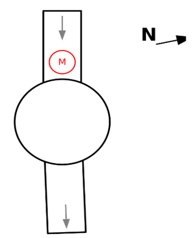
Notes: Data is noted as variable due to a 10 day velocity drop out, resulting in variations in velocity and depth readings.

METERSHED CONTEXT



MONITOR INFO			
Monitor ID	**FM7**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Hoffman / Ottawa		
	GIS	**Model**	
MH ID	306584	306584	
Pipe ID	306527.1	306527.1	
Shape	ROUND	CIRC	
Height/Dia. (mm)	900	900	
Width (mm)	900	900	
Location Notes & Confirmation	The GIS and model meter location and diameter match.		

MONITOR INSTALLATION PLAN

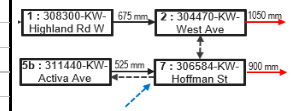


TRIBUTARY AREA CHARACTERISTICS

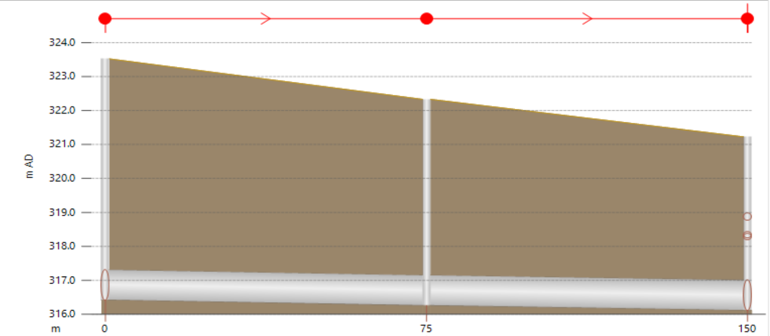
Monitors in Series?	Yes	
Bifurcations?	Bifurcations with FM2; FM5b	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	726.9	612.2
RES Area (ha)	580.6 (80%)	501.8 (82%)
ICI Area (ha)	110.0 (15%)	107.1 (17%)
Vacant Area (ha)	36.2 (5%)	3.3 (1%)
Total Population	40,466	35,944
RES Pop.	36,782 (91%)	32,311 (90%)
ICI Pop.	3,684 (9%)	3,633 (10%)
HD Pop.	N/A	N/A

Notes: FM7 is located downstream of FM5b. The land use is residential. Major spill points from FM5b and the unmonitored sewers as well as to and from FM2 are present.

MONITOR SCHEMATIC



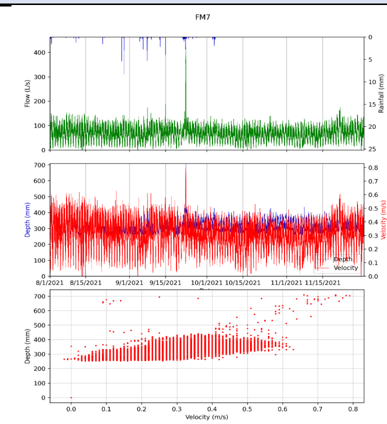
MODEL PROFILE



Link	306527.1	306584.1
System type	sanitary	sanitary
length (m)	75.0	75.0
Shape ID	CIRC	CIRC
width (mm)	900	900
us inv (m AD)	316.419	316.260
ds inv (m AD)	316.260	316.114
grad (m/m)	0.00212	0.00195
pfc (m3/s)	0.834	0.799

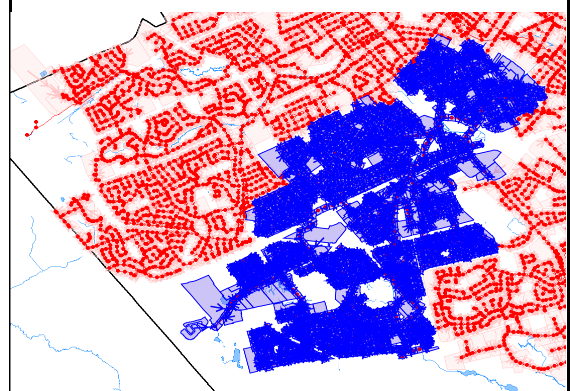
Node	306527	306584	306583
System type	sanitary	sanitary	sanitary
ground (m AD)	323.519	322.330	321.224

3



Notes: Good quality data observed.

METERSHED CONTEXT



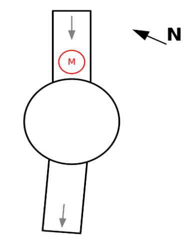
MONITOR INFO

Monitor ID	**FM9**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Ottawa St. N @ Franklin		

	GIS	Model
MH ID	301182	301182
Pipe ID	301181.1	301207.1
Shape	ROUND	CIRC
Height/Dia. (mm)	675	675
Width (mm)	675	675

Location Notes & Confirmation: The GIS and model diameter match however the GIS notes a different meter link location.

MONITOR INSTALLATION PLAN

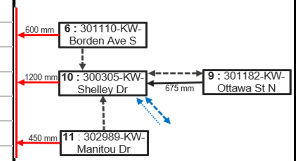


TRIBUTARY AREA CHARACTERISTICS

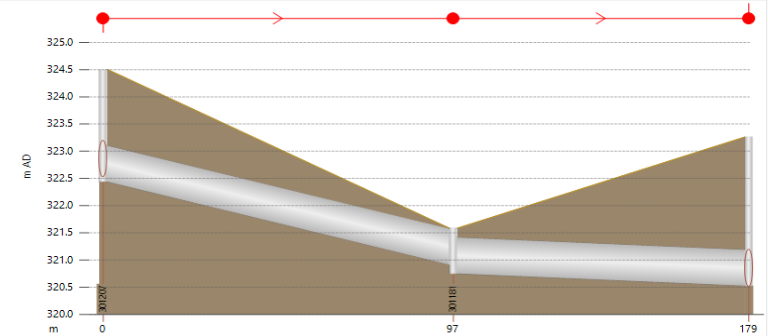
Monitors in Series?	Yes	
Bifurcations?	Bifurcations with FM10	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	419.7	419.7
RES Area (ha)	331.5 (79%)	331.5 (79%)
ICI Area (ha)	77.5 (18%)	77.5 (18%)
Vacant Area (ha)	10.7 (3%)	10.7 (3%)
Total Population	18,841	18,841
RES Pop.	16,944 (90%)	16,944 (90%)
ICI Pop.	1,897 (10%)	1,897 (10%)
HD Pop.	N/A	N/A

Notes: FM9 is located upstream of FM10. The land use is residential. Major spill points to and from FM10 are present.

MONITOR SCHEMATIC



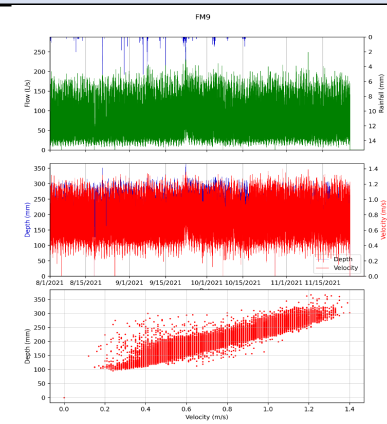
MODEL PROFILE



Link	301207.1	301181.1
System type	sanitary	sanitary
length (m)	96.9	81.8
Shape ID	CIRC	CIRC
width (mm)	675	675
us inv (m AD)	322.434	320.746
ds inv (m AD)	320.907	320.521
grad (m/m)	0.01576	0.00275
pfc (m3/s)	1.055	0.441

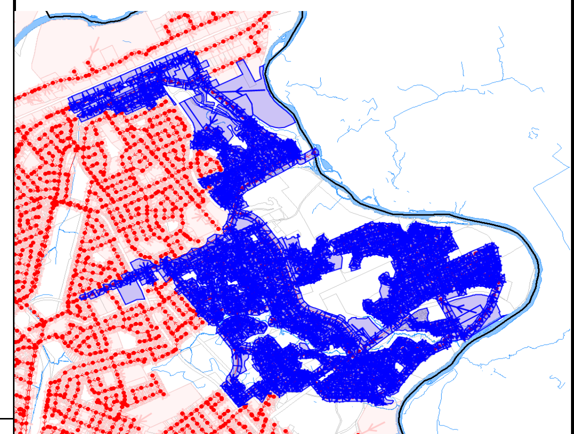
Node	301207	301181	301182
System type	sanitary	sanitary	sanitary
ground (m AD)	324.504	321.586	323.261

FLOW MONITOR DATA OVERVIEW



Notes: Good quality data observed. FM9 is located downstream of five PSs: Appletree SPS, Bancroft SPS, Otterbein SPS, Springmount SPS, and Woolner SPS, and their presence is reflected in the data.

METERSHED CONTEXT

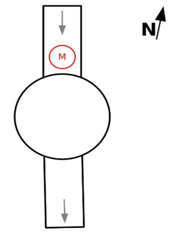


MONITOR INFO

Monitor ID	**FM10**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Shelley Dr/Hillmount		

	GIS	Model
MH ID	300305	300305
Pipe ID	300304.1	300304.1
Shape	ROUND	CIRC
Height/Dia. (mm)	1200	1200
Width (mm)	1200	1200
Location Notes & Confirmation	The GIS and model meter location and diameter match.	

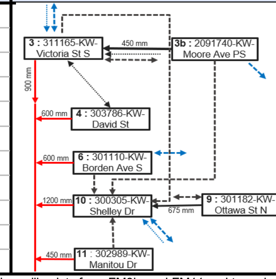
MONITOR INSTALLATION PLAN



TRIBUTARY AREA CHARACTERISTICS

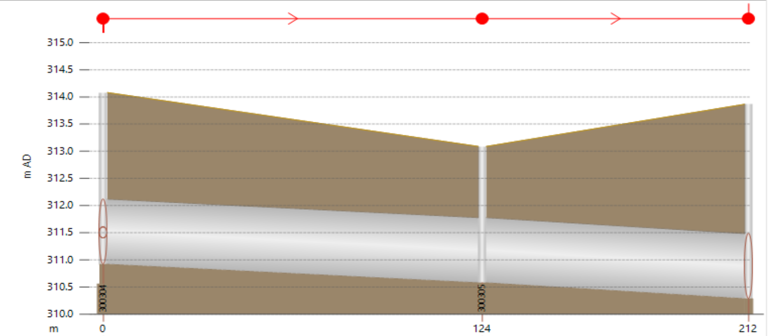
Monitors in Series?	Yes	
Bifurcations?	Bifurcations with unmonitored area; FM9	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	1213.2	793.6
RES Area (ha)	837.9 (69%)	506.5 (64%)
ICI Area (ha)	323.3 (27%)	245.7 (31%)
Vacant Area (ha)	52.0 (4%)	41.3 (5%)
Total Population	51,964	33,124
RES Pop.	43,911 (85%)	26,967 (81%)
ICI Pop.	8,053 (15%)	6,156 (19%)
HD Pop.	N/A	N/A

MONITOR SCHEMATIC



Notes: FM10 is located downstream of FM9. The land use is residential. Major spill points from FM3b, and FM11 and to and from FM9 and the unmonitored sewers exist. Minor spill points from the unmonitored sewers are present.

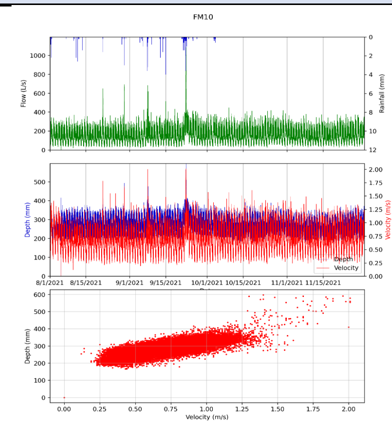
MODEL PROFILE



Link	300304.1	300305.1
System type	sanitary	sanitary
length (m)	124.3	87.4
Shape ID	CIRC	CIRC
width (mm)	1200	1200
us inv (m AD)	310.920	310.579
ds inv (m AD)	310.579	310.286
grad (m/m)	0.00274	0.00335
pfc (m3/s)	2.042	2.258

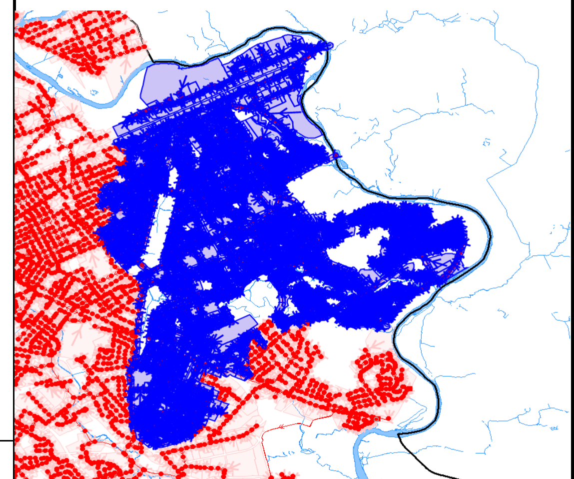
Node	300304	300305	2130028
System type	sanitary	sanitary	sanitary
ground (m AD)	314.080	313.089	313.865

FLOW MONITOR DATA OVERVIEW



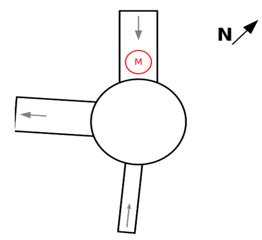
Notes: Good quality data observed. The data shows the impacts of upstream SPSs located in FM9 and Shirley SPS.

METERSHED CONTEXT



MONITOR INFO			
Monitor ID	**FM11**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Manitou Dr / Fairway		
	GIS	**Model**	
MH ID	302989	302989	
Pipe ID	302987.1	302987.1	
Shape	ROUND	CIRC	
Height/Dia. (mm)	450	450	
Width (mm)	450	450	
Location Notes & Confirmation	The GIS and model meter location and diameter match.		

MONITOR INSTALLATION PLAN

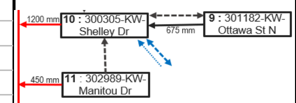


TRIBUTARY AREA CHARACTERISTICS

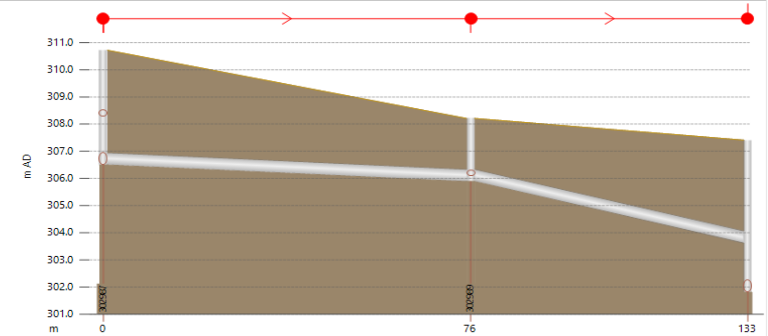
Monitors in Series?	No	
Bifurcations?	Bifurcations with FM10	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	165.0	165.0
RES Area (ha)	32.9 (20%)	32.9 (20%)
ICI Area (ha)	124.3 (75%)	124.3 (75%)
Vacant Area (ha)	7.8 (5%)	7.8 (5%)
Total Population	9,802	9,802
RES Pop.	3,408 (35%)	3,408 (35%)
ICI Pop.	6,393 (65%)	6,393 (65%)
HD Pop.	N/A	N/A

Notes: The land use is ICI. Major spill points to FM10 are present.

MONITOR SCHEMATIC



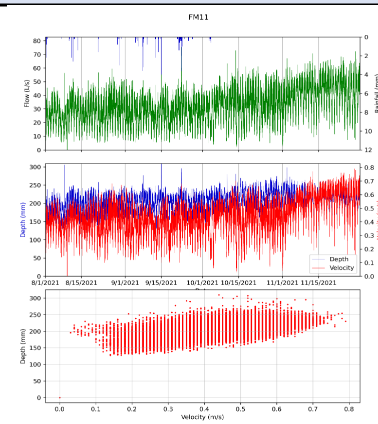
MODEL PROFILE



Link	302987.1	302989.1
System type	sanitary	sanitary
length (m)	75.6	57.1
Shape ID	CIRC	CIRC
width (mm)	450	450
us inv (m AD)	306.498	305.888
ds inv (m AD)	305.888	303.621
grad (m/m)	0.00807	0.03972
pfc (m3/s)	0.256	0.568

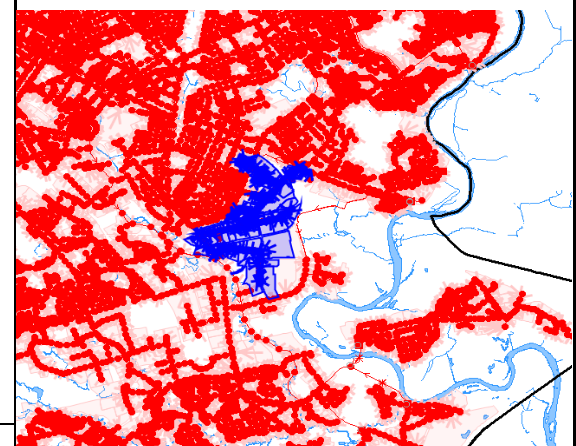
Node	302987	302989	302988
System type	sanitary	sanitary	sanitary
ground (m AD)	310.718	308.208	307.410

FLOW MONITOR DATA OVERVIEW



Notes: Good quality data observed.

METERSHED CONTEXT

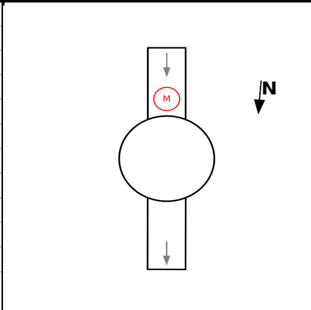


MONITOR INFO

Monitor ID	**FM12**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Balzer Creek Trail / Fallowfield Park		

	GIS	**Model**
MH ID	300575	300575
Pipe ID	307136.1	307136.1
Shape	ROUND	CIRC
Height/Dia. (mm)	750	750
Width (mm)	750	750
Location Notes & Confirmation	The GIS and model meter location and diameter match.	

MONITOR INSTALLATION PLAN

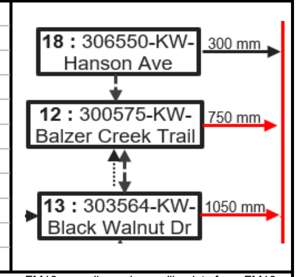


TRIBUTARY AREA CHARACTERISTICS

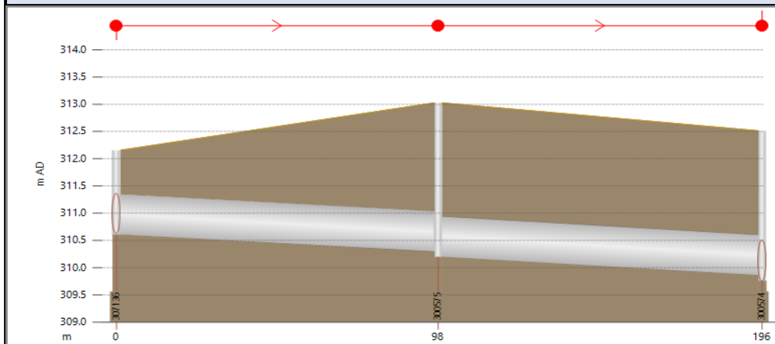
Monitors in Series?	No	
Bifurcations?	Bifurcations with FM13	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	165.1	165.1
RES Area (ha)	145.7 (88%)	145.7 (88%)
ICI Area (ha)	19.5 (12%)	19.5 (12%)
Vacant Area (ha)	0.0 (0%)	0.0 (0%)
Total Population	11,463	11,463
RES Pop.	10,850 (95%)	10,850 (95%)
ICI Pop.	613 (5%)	613 (5%)
HD Pop.	N/A	N/A

Notes: The land use is residential. Major spill points from FM18 and to and from FM13 as well as minor spill points from FM13 are present.

MONITOR SCHEMATIC



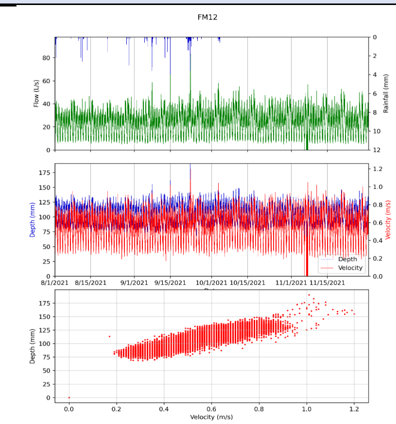
MODEL PROFILE



Link	307136.1	300575.1
System type	sanitary	sanitary
length (m)	97.5	98.2
Shape ID	CIRC	CIRC
width (mm)	750	750
us inv (m AD)	310.603	310.195
ds inv (m AD)	310.292	309.857
grad (m/m)	0.00319	0.00344
pfc (m3/s)	0.629	0.653

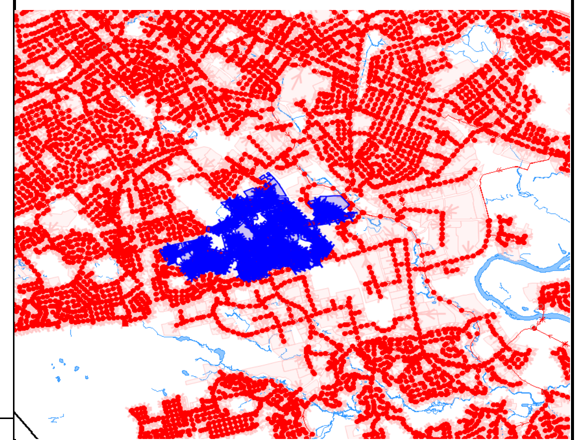
Node	307136	300575	300574
System type	sanitary	sanitary	sanitary
ground (m AD)	312.156	313.025	312.513

FLOW MONITOR DATA OVERVIEW



Notes: Good quality data observed.

METERSHED CONTEXT

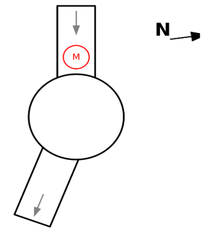


MONITOR INFO

Monitor ID	**FM13**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Black Walnut Dr/Biehn Dr		

	GIS	**Model**
MH ID	303564	303564
Pipe ID	303563.1	303563.1
Shape	ROUND	CIRC
Height/Dia. (mm)	1050	1050
Width (mm)	1050	1050
Location Notes & Confirmation	The GIS and model meter location and diameter match.	

MONITOR INSTALLATION PLAN

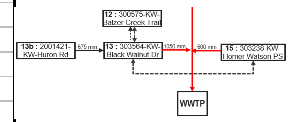


TRIBUTARY AREA CHARACTERISTICS

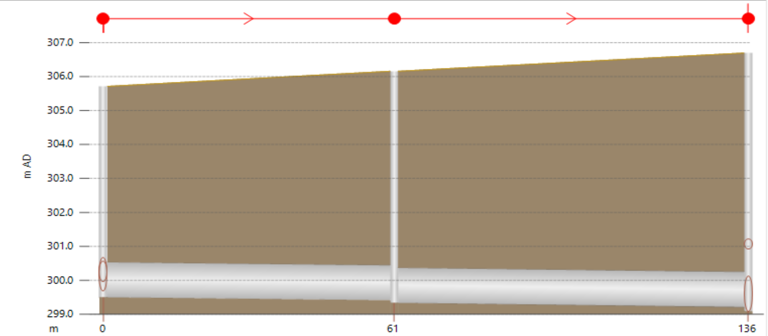
Monitors in Series?	Yes	
Bifurcations?	Bifurcations with FM12; FM15	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	559.4	345.7
RES Area (ha)	323.3 (58%)	139.6 (40%)
ICI Area (ha)	202.1 (36%)	173.2 (50%)
Vacant Area (ha)	34.0 (6%)	32.8 (10%)
Total Population	21,118	11,623
RES Pop.	15,674 (74%)	6,359 (55%)
ICI Pop.	5,444 (26%)	5,264 (45%)
HD Pop.	N/A	N/A

Notes: FM13 is located downstream of FM13b. The land use is mixed. Major spill points to and from FM15 and FM12 exist, as well as minor spill points to FM12 are present.

MONITOR SCHEMATIC



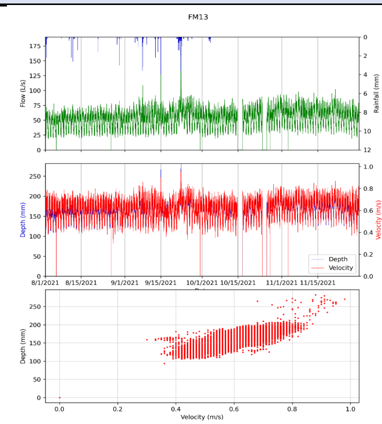
MODEL PROFILE



Link	303563.1	303564.1
System type	sanitary	sanitary
length (m)	61.2	74.5
Shape ID	CIRC	CIRC
width (mm)	1050	1050
us inv (m AD)	299.490	299.326
ds inv (m AD)	299.402	299.207
grad (m/m)	0.00144	0.00160
pfc (m3/s)	1.036	1.092

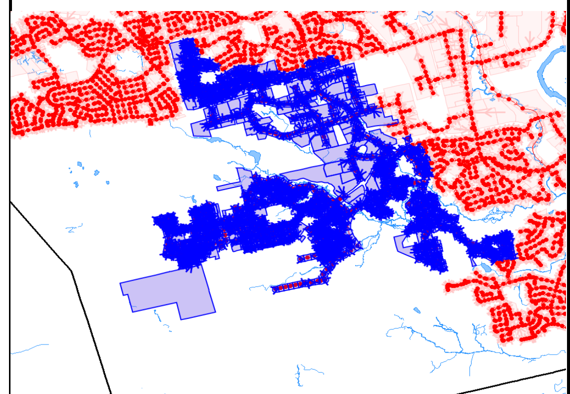
Node	303563	303564	303578
System type	sanitary	sanitary	sanitary
ground (m AD)	305.710	306.156	306.692

FLOW MONITOR DATA OVERVIEW



Notes: Some velocity dropouts observed, though not during the DWF periods and WWF periods selected. Generally good quality data observed.

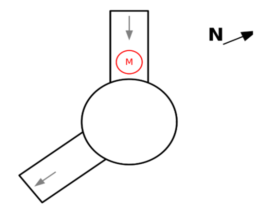
METERSHED CONTEXT



MONITOR INFO

Monitor ID	**FM13b**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Huron Rd, east of Newcastle		
	GIS	**Model**	
MH ID	2001421	2001421	
Pipe ID	2001420.1	2001420.1	
Shape	ROUND	CIRC	
Height/Dia. (mm)	675	675	
Width (mm)	675	675	
Location Notes & Confirmation	The GIS and model meter location and diameter match.		

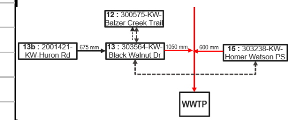
MONITOR INSTALLATION PLAN



TRIBUTARY AREA CHARACTERISTICS

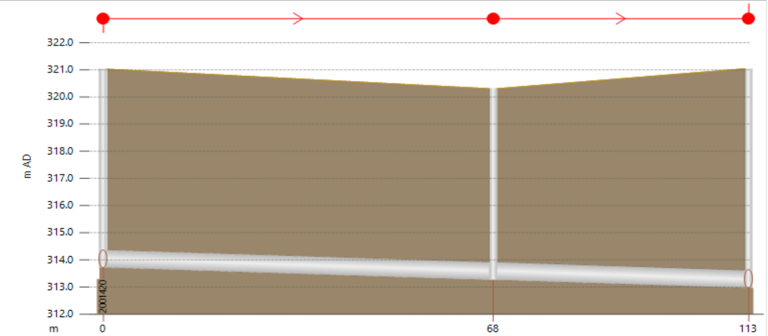
Monitors in Series?	Yes	
Bifurcations?	No	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	213.7	213.7
RES Area (ha)	183.6 (86%)	183.6 (86%)
ICI Area (ha)	28.9 (14%)	28.9 (14%)
Vacant Area (ha)	1.2 (1%)	1.2 (1%)
Total Population	9,495	9,495
RES Pop.	9,315 (98%)	9,315 (98%)
ICI Pop.	180 (2%)	180 (2%)
HD Pop.	N/A	N/A

MONITOR SCHEMATIC



Notes: FM13b is located upstream of FM13. The land use is residential.

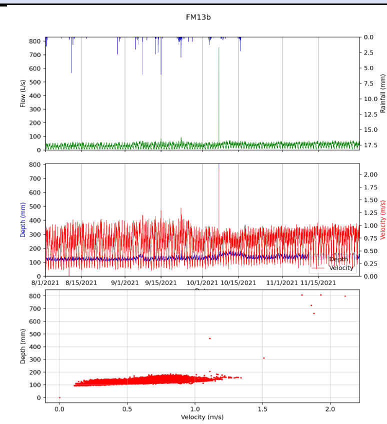
MODEL PROFILE



Link	2001420.1	2001421.1
System type	sanitary	sanitary
length (m)	68.2	44.7
Shape ID	CIRC	CIRC
width (mm)	675	675
us inv (m AD)	313.703	313.255
ds inv (m AD)	313.255	312.958
grad (m/m)	0.00657	0.00664
pfc (m3/s)	0.682	0.685

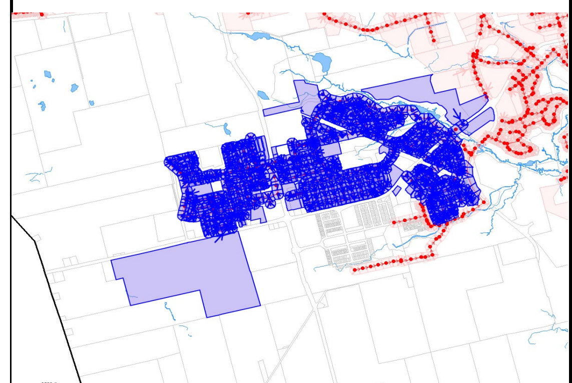
Node	2001420	2001421	2001422
System type	sanitary	sanitary	sanitary
ground (m AD)	321.023	320.305	321.038

FLOW MONITOR DATA OVERVIEW



Notes: Good quality data observed.

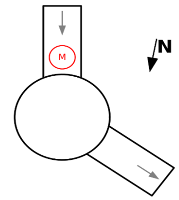
METERSHED CONTEXT



MONITOR INFO

Monitor ID	**FM15**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Homer Watson PS (near Doon S Dr)		
	GIS	**Model**	
MH ID	303238	303238	
Pipe ID	303239.1	303239.1	
Shape	ROUND	CIRC	
Height/Dia. (mm)	600	600	
Width (mm)	600	600	
Location Notes & Confirmation	The GIS and model meter location and diameter match. AMG noted the meter was installed inside the pump station.		

MONITOR INSTALLATION PLAN

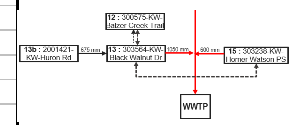


TRIBUTARY AREA CHARACTERISTICS

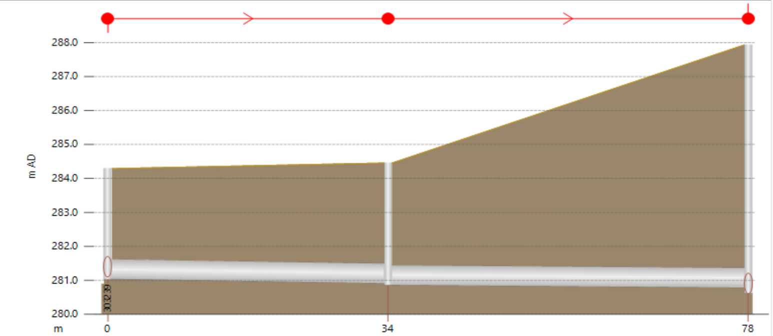
Monitors in Series?	No	
Bifurcations?	Bifurcations with FM13	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	249.0	249.0
RES Area (ha)	203.0 (82%)	203.0 (82%)
ICI Area (ha)	28.3 (11%)	28.3 (11%)
Vacant Area (ha)	17.6 (7%)	17.6 (7%)
Total Population	10,340	10,340
RES Pop.	9,859 (95%)	9,859 (95%)
ICI Pop.	481 (5%)	481 (5%)
HD Pop.	N/A	N/A

Notes: The land use is residential. Major spill points to and from FM13 are present.

MONITOR SCHEMATIC



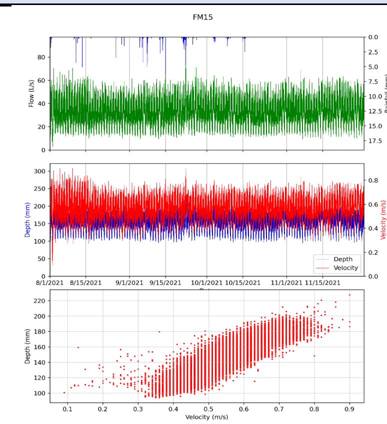
MODEL PROFILE



Link	303239.1	303238.1
System type	sanitary	sanitary
length (m)	34.2	44.0
Shape ID	CIRC	CIRC
width (mm)	600	600
us inv (m AD)	281.030	280.855
ds inv (m AD)	280.905	280.775
grad (m/m)	0.00365	0.00182
pfc (m3/s)	0.371	0.262

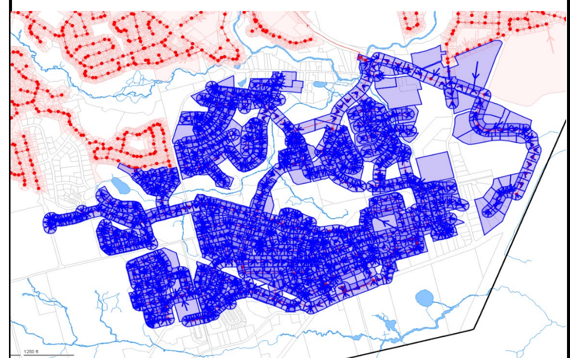
Node	303239	303238	303147
System type	sanitary	sanitary	sanitary
ground (m AD)	284.290	284.455	287.930

FLOW MONITOR DATA OVERVIEW



Notes: Good quality data observed. FM15 is located upstream of Homer Watson SPS and downstream of Conestoga SPS and their presence is reflected in the data.

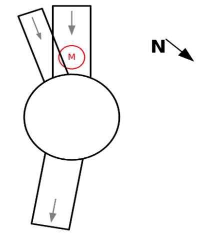
METERSHED CONTEXT



MONITOR INFO			
Monitor ID	**FM18**	Start	Aug 01, 2021
Sewer Type	Sanitary	End	Nov 30, 2021
Installed in	Incoming Pipe	Duration	122
Drawing Ref.	0		
Location	Hanson Ave, N. of Hayward		

	GIS	Model
MH ID	306550	306550
Pipe ID	306551.1	306551.1
Shape	ROUND	CIRC
Height/Dia. (mm)	300	300
Width (mm)	300	300
Location Notes & Confirmation	The GIS and model meter location and diameter match.	

MONITOR INSTALLATION PLAN

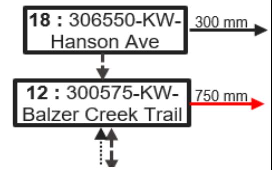


TRIBUTARY AREA CHARACTERISTICS

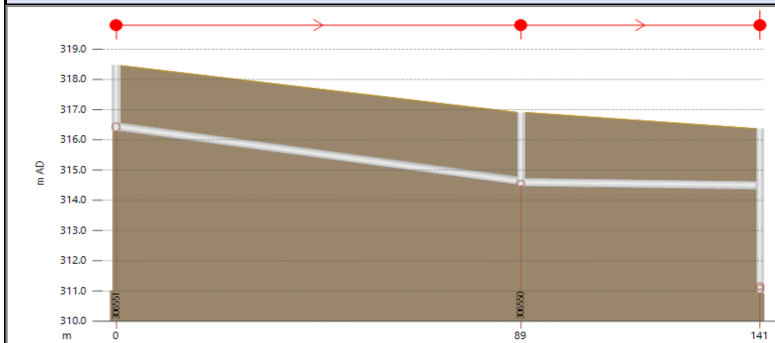
Monitors in Series?	No	
Bifurcations?	Bifurcations with FM12	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	70.6	70.6
RES Area (ha)	26.8 (38%)	26.8 (38%)
ICI Area (ha)	40.3 (57%)	40.3 (57%)
Vacant Area (ha)	3.5 (5%)	3.5 (5%)
Total Population	3,220	3,220
RES Pop.	1,664 (52%)	1,664 (52%)
ICI Pop.	1,556 (48%)	1,556 (48%)
HD Pop.	N/A	N/A

Notes: The land use is mixed. Major spill points to FM12 are present.

MONITOR SCHEMATIC



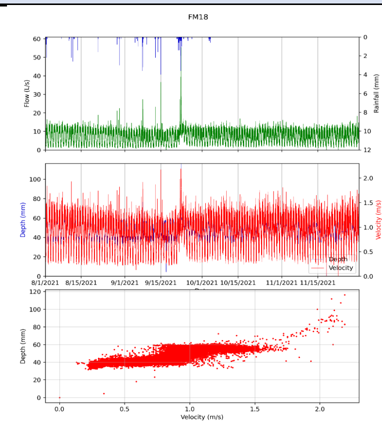
MODEL PROFILE



Link	306551.1	306550.1
System type	sanitary	sanitary
length (m)	88.8	52.5
Shape ID	CIRC	CIRC
width (mm)	300	300
us inv (m AD)	316.276	314.450
ds inv (m AD)	314.508	314.343
grad (m/m)	0.01990	0.00204
pfc (m3/s)	0.136	0.044

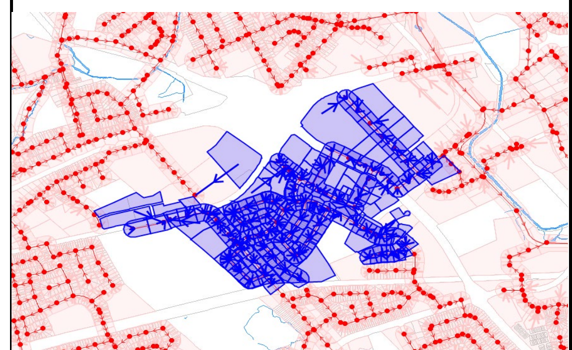
Node	306551	306550	307124
System type	sanitary	sanitary	sanitary
ground (m AD)	318.456	316.906	316.370

FLOW MONITOR DATA OVERVIEW



Notes: Good quality data observed.

METERSHED CONTEXT



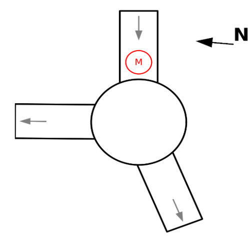
MONITOR INFO

Monitor ID	**FM19**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	Falconridge PS		

	GIS	**Model**
MH ID	311719	311719
Pipe ID	311920.1	311920.1
Shape	ROUND	CIRC
Height/Dia. (mm)	375	450
Width (mm)	375	450

Location Notes & Confirmation: The GIS and model meter location match. The diameters differ and the 450 mm diameter confirmed by AMG will be used.

MONITOR INSTALLATION PLAN



TRIBUTARY AREA CHARACTERISTICS

Monitors in Series?	No	
Bifurcations?	No	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	45.6	45.6
RES Area (ha)	43.3 (95%)	43.3 (95%)
ICI Area (ha)	1.0 (2%)	1.0 (2%)
Vacant Area (ha)	1.4 (3%)	1.4 (3%)
Total Population	1,960	1,960
RES Pop.	1,921 (98%)	1,921 (98%)
ICI Pop.	39 (2%)	39 (2%)
HD Pop.	N/A	N/A

Notes: The land use is residential. This metershed flows to Waterloo.

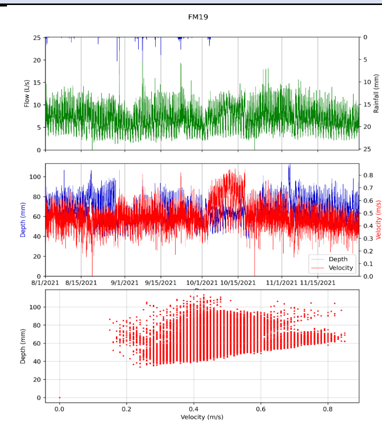
MONITOR SCHEMATIC

MODEL PROFILE

Link	311920.1	311719.1
System type	sanitary	sanitary
length (m)	14.7	5.8
Shape ID	CIRC	CIRC
width (mm)	450	450
us inv (m AD)	299.580	299.507
ds inv (m AD)	299.507	299.490
grad (m/m)	0.00495	0.00293
pfc (m3/s)	0.201	0.154

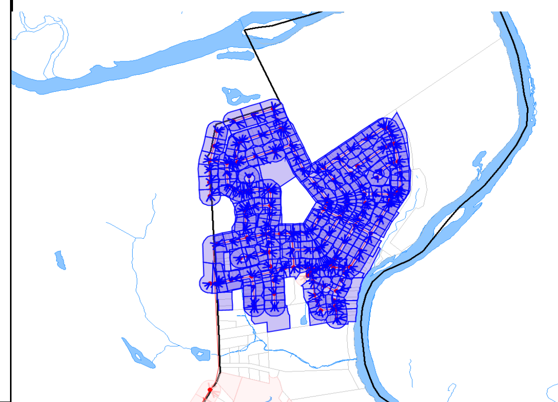
Node	311920	311719	1859
System type	sanitary	sanitary	sanitary
ground (m AD)	308.550	308.900	308.700

FLOW MONITOR DATA OVERVIEW



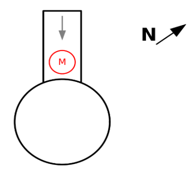
Notes: Data is noted as variable due to two distinct trends in the velocity vs. depth scatterplot observed in early October. FM19 is located upstream of Falconridge SPS.

METERSHED CONTEXT



MONITOR INFO			
Monitor ID	**FM20**	**Start**	Aug 01, 2021
Sewer Type	Sanitary	**End**	Nov 30, 2021
Installed in	Incoming Pipe	**Duration**	122
Drawing Ref.	0		
Location	King St at Hwy 401		
	GIS	**Model**	
MH ID	303424	303424	
Pipe ID	303425.1	303425.1	
Shape	ROUND	CIRC	
Height/Dia. (mm)	375	375	
Width (mm)	375	375	
Location Notes & Confirmation	The GIS and model meter location and diameter match.		

MONITOR INSTALLATION PLAN

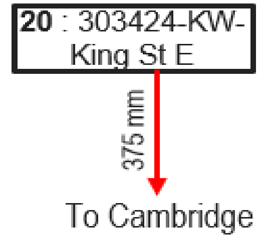


TRIBUTARY AREA CHARACTERISTICS

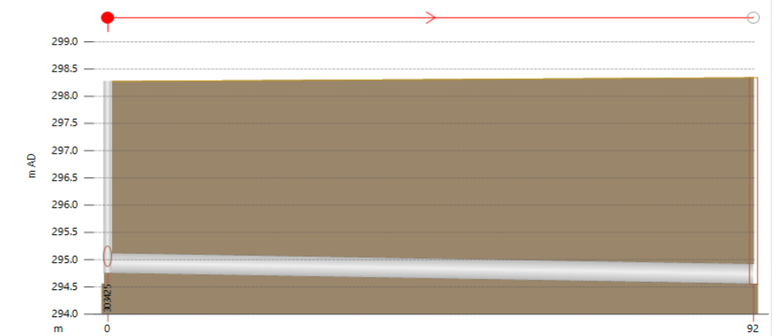
Monitors in Series?	No	
Bifurcations?	No	
	Total Trib.	**Sub-Basin Only**
Drainage Area (ha)	39.6	39.6
RES Area (ha)	0.8 (2%)	0.8 (2%)
ICI Area (ha)	33.1 (84%)	33.1 (84%)
Vacant Area (ha)	5.7 (14%)	5.7 (14%)
Total Population	1,159	1,159
RES Pop.	12 (1%)	12 (1%)
ICI Pop.	1,147 (99%)	1,147 (99%)
HD Pop.	N/A	N/A

Notes: The land use is ICI. The metershed flows to Cambridge.

MONITOR SCHEMATIC

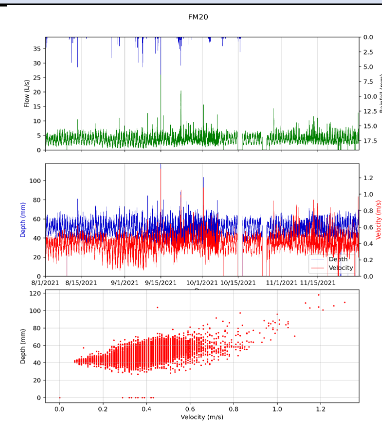


MODEL PROFILE



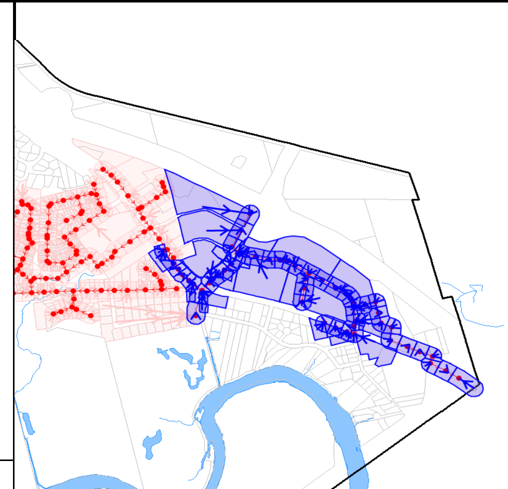
Link	303425.1	
System type	sanitary	
length (m)	91.9	
Shape ID	CIRC	
width (mm)	375	
us inv (m AD)	294.751	
ds inv (m AD)	294.554	
grad (m/m)	0.00214	
pfc (m3/s)	0.081	
Node	303425	303424
System type	sanitary	sanitary
ground (m AD)	298.271	298.339

FLOW MONITOR DATA OVERVIEW

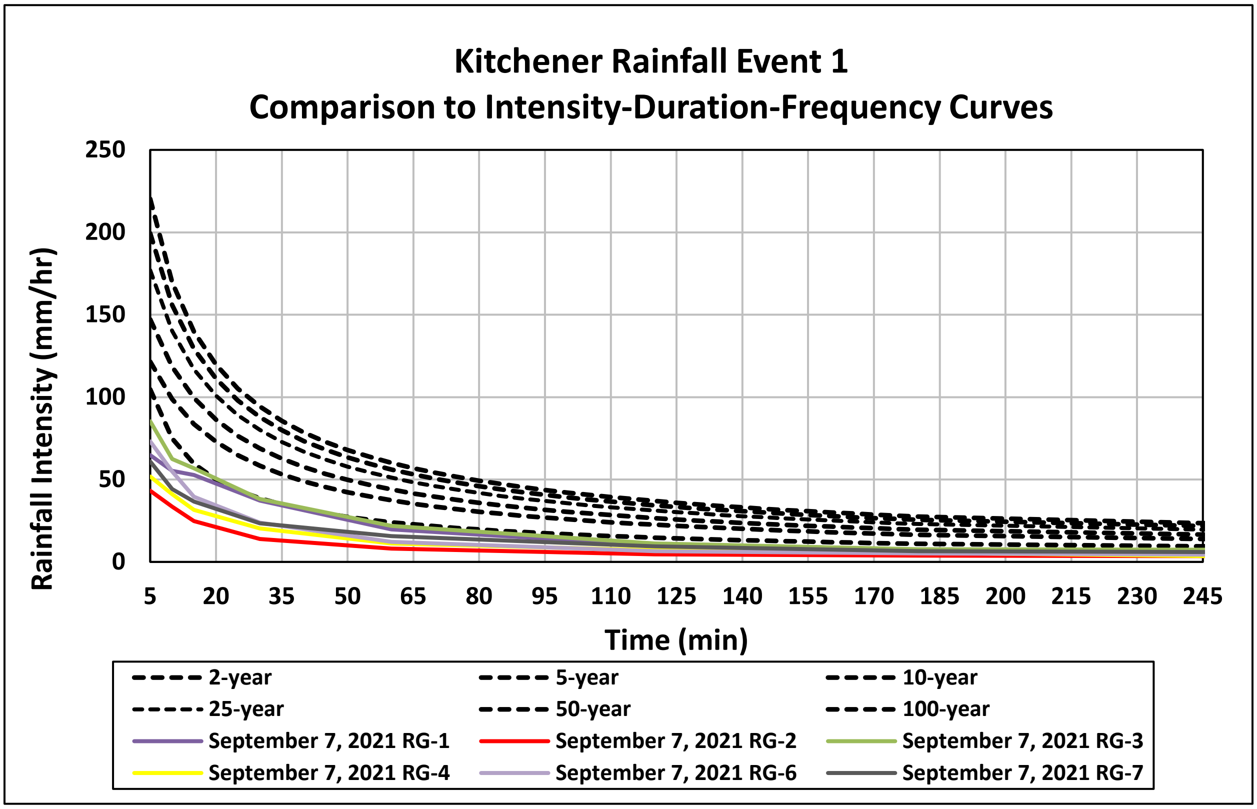


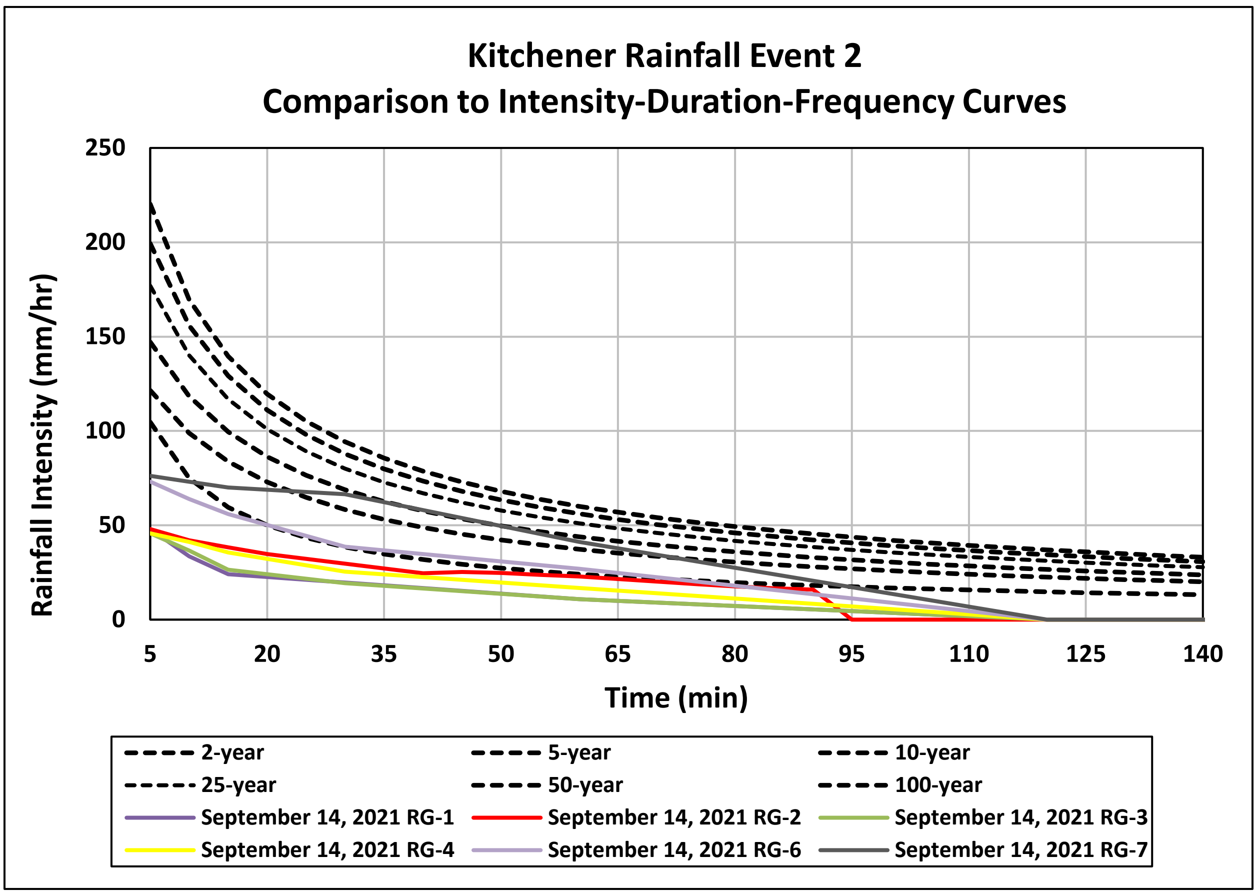
Notes: Some velocity dropouts observed, though not during the DWF periods and WWF periods selected. Generally good quality data observed.

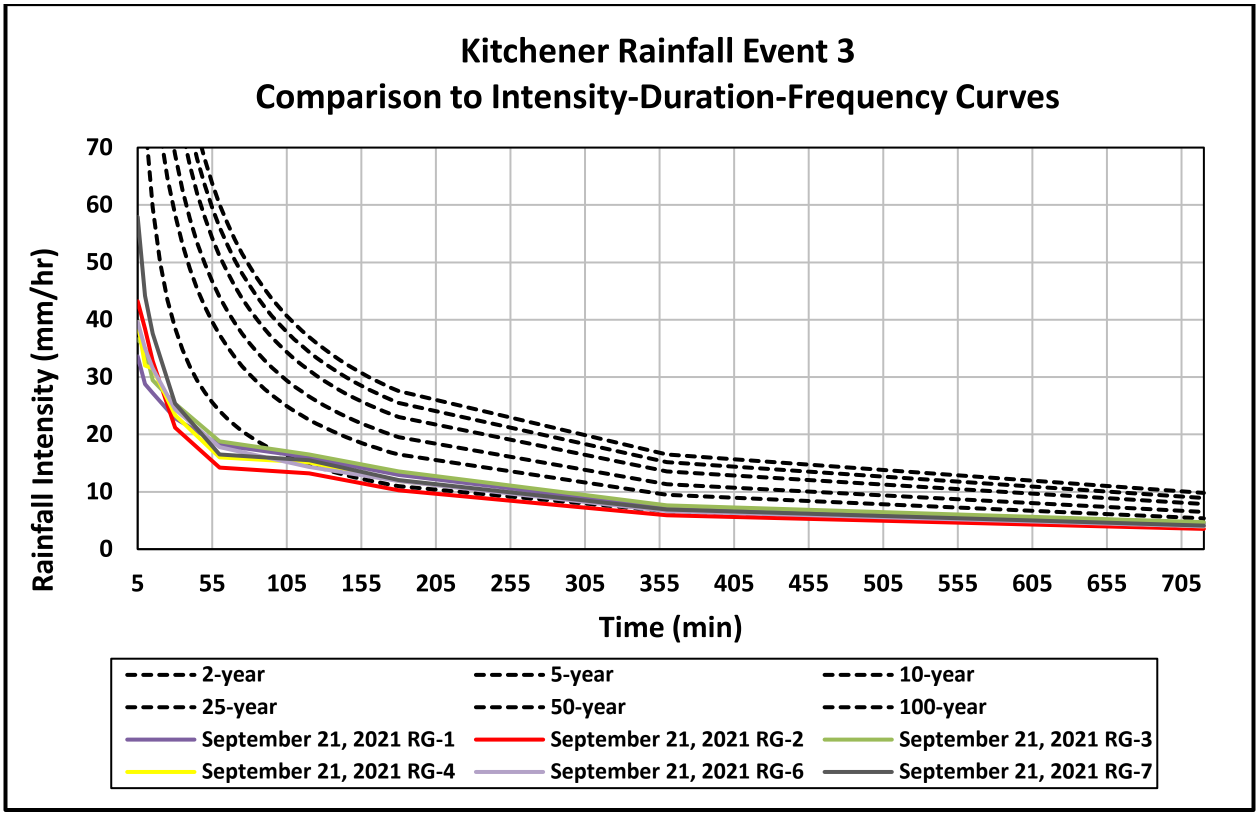
METERSHED CONTEXT

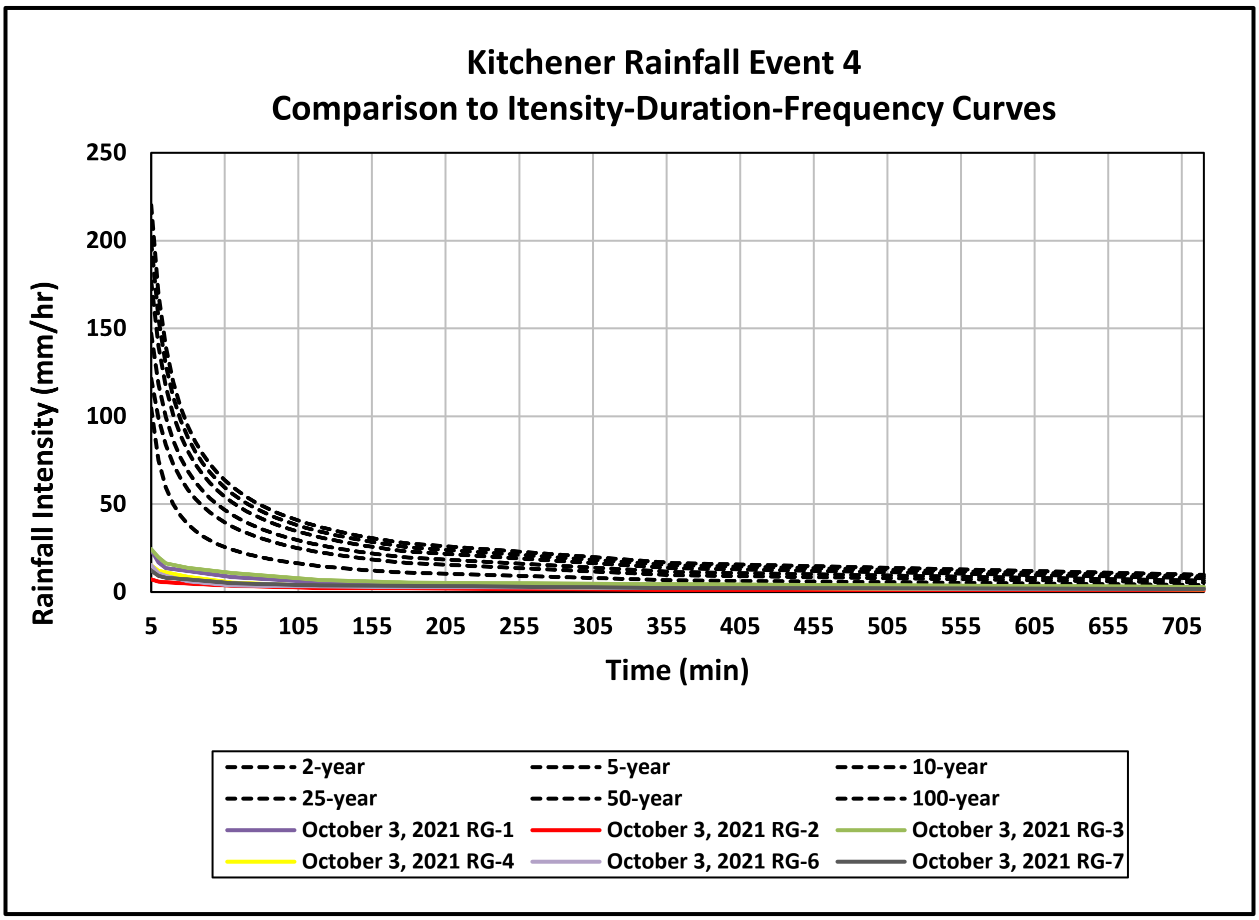


APPENDIX D - RAINFALL DATA REVIEW


Kitchener Rainfall Event 1
Comparison to Intensity-Duration-Frequency Curves
Rainfall Intensity (mm/hr)
250
200
150
100
50
0
5
20
35
50
65
80
95
110
125
140
155
170
185
200
215
230
245
Time (min)
2-year
5-year
10-year
25-year
50-year
100-year
September 7, 2021 RG-1
September 7, 2021 RG-2
September 7, 2021 RG-3
September 7, 2021 RG-4
September 7, 2021 RG-6
September 7, 2021 RG-7


Kitchener Rainfall Event 2
Comparison to Intensity-Duration-Frequency Curves
Rainfall Intensity (mm/hr)
250
200
150
100
50
0
5
20
35
50
65
80
95
110
125
140
Time (min)
2-year
5-year
10-year
25-year
50-year
100-year
September 14, 2021 RG-1
September 14, 2021 RG-2
September 14, 2021 RG-3
September 14, 2021 RG-4
September 14, 2021 RG-6
September 14, 2021 RG-7


Kitchener Rainfall Event 3
Comparison to Intensity-Duration-Frequency Curves
Rainfall Intensity (mm/hr)
70
60
50
40
30
20
10
0
5
55
105
155
205
255
305
355
405
455
505
555
605
655
705
Time (min)
2-year
5-year
10-year
25-year
50-year
100-year
September 21, 2021 RG-1
September 21, 2021 RG-2
September 21, 2021 RG-3
September 21, 2021 RG-4
September 21, 2021 RG-6
September 21, 2021 RG-7


Kitchener Rainfall Event 4
Comparison to Itensity-Duration-Frequency Curves
Rainfall Intensity (mm/hr)
250
200
150
100
50
0
5
55
105
155
205
255
305
355
405
455
505
555
605
655
705
Time (min)
2-year
5-year
10-year
25-year
50-year
100-year
October 3, 2021 RG-1
October 3, 2021 RG-2
October 3, 2021 RG-3
October 3, 2021 RG-4
October 3, 2021 RG-6
October 3, 2021 RG-7

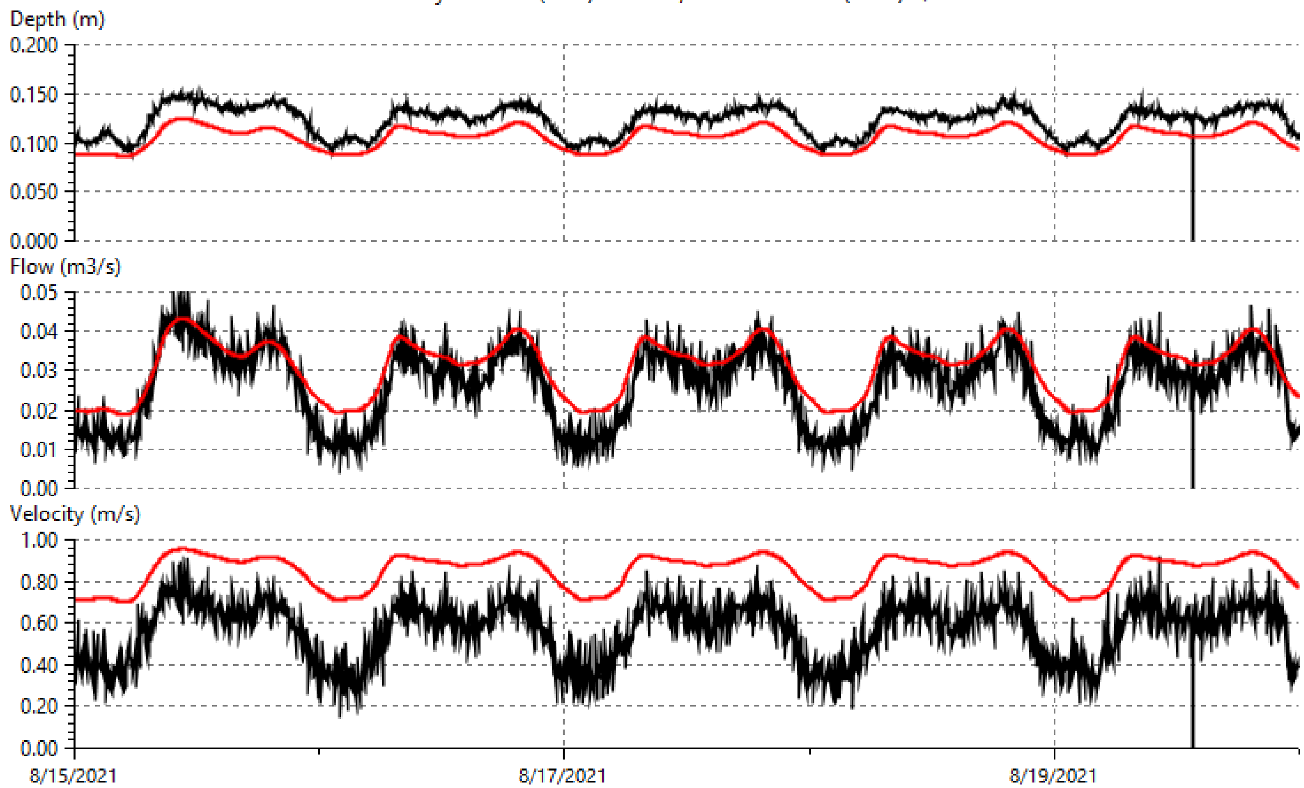
APPENDIX E - CALIBRATION GRAPHS

FM1

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 16 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 308299.1, Model Location (Pred.) D/S 308299.1



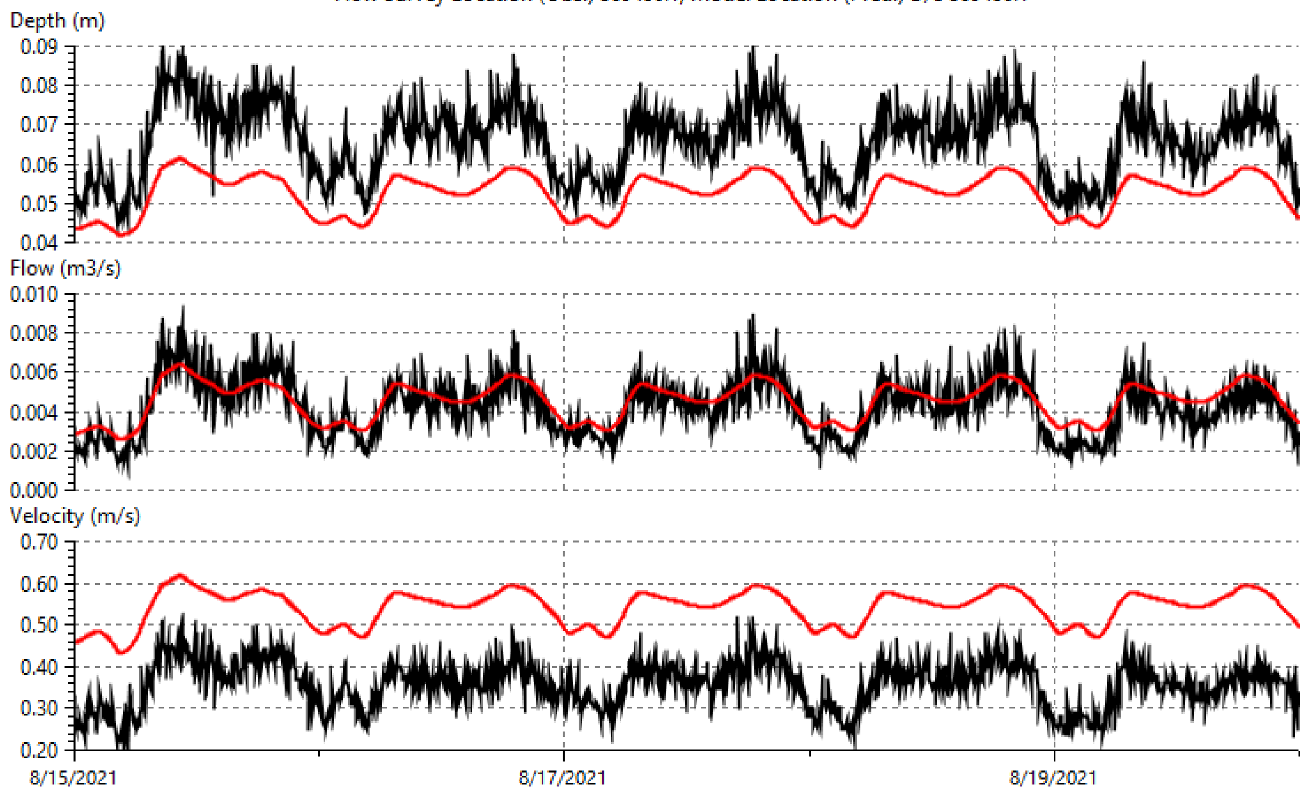
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.000	0.152	0.000	0.049	11321.661	0.000	0.840
Modelled	0.087	0.125	0.019	0.043	13331.752	0.699	0.955

FM1b

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 17 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 309486.1, Model Location (Pred.) D/S 309486.1



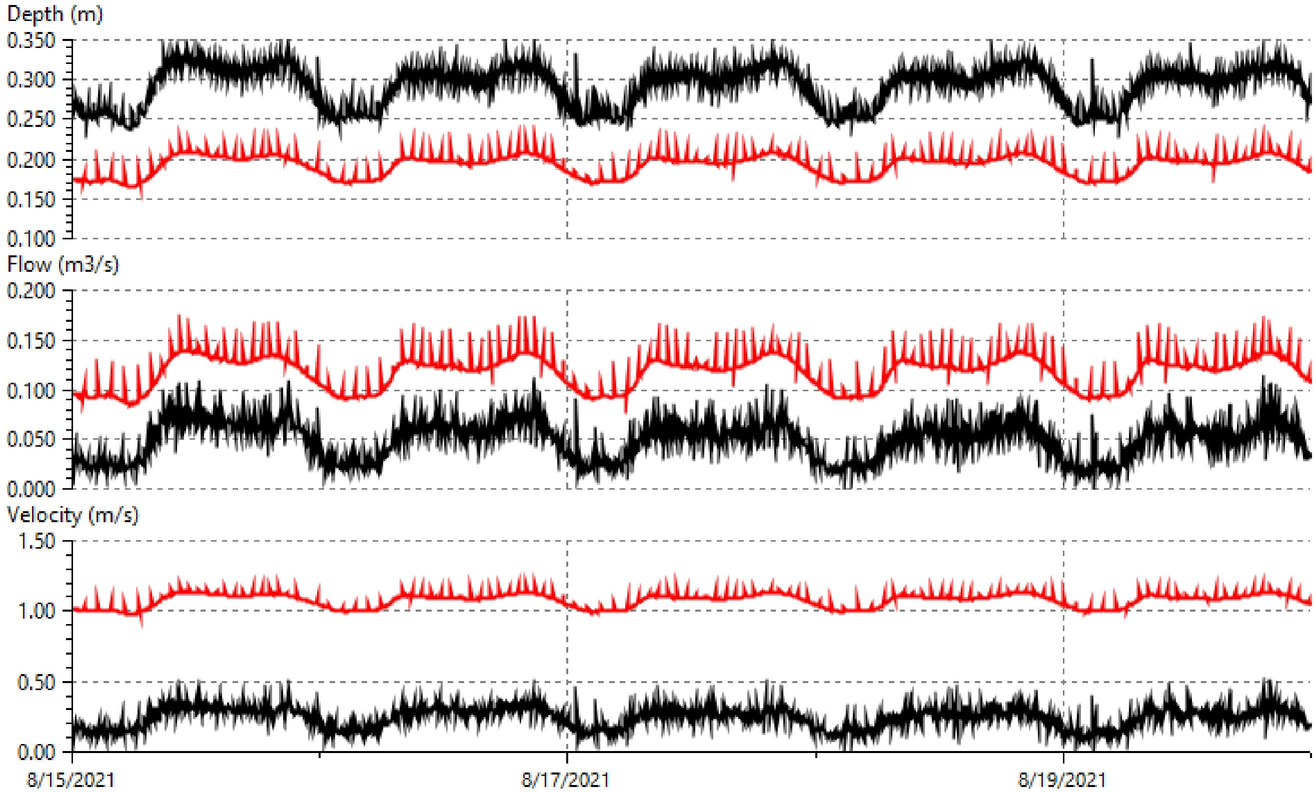
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.045	0.088	0.001	0.009	1835.653	0.210	0.490
Modelled	0.042	0.061	0.003	0.006	1967.441	0.433	0.618

FM2

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 11 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 304472.1, Model Location (Pred.) D/S 304472.1



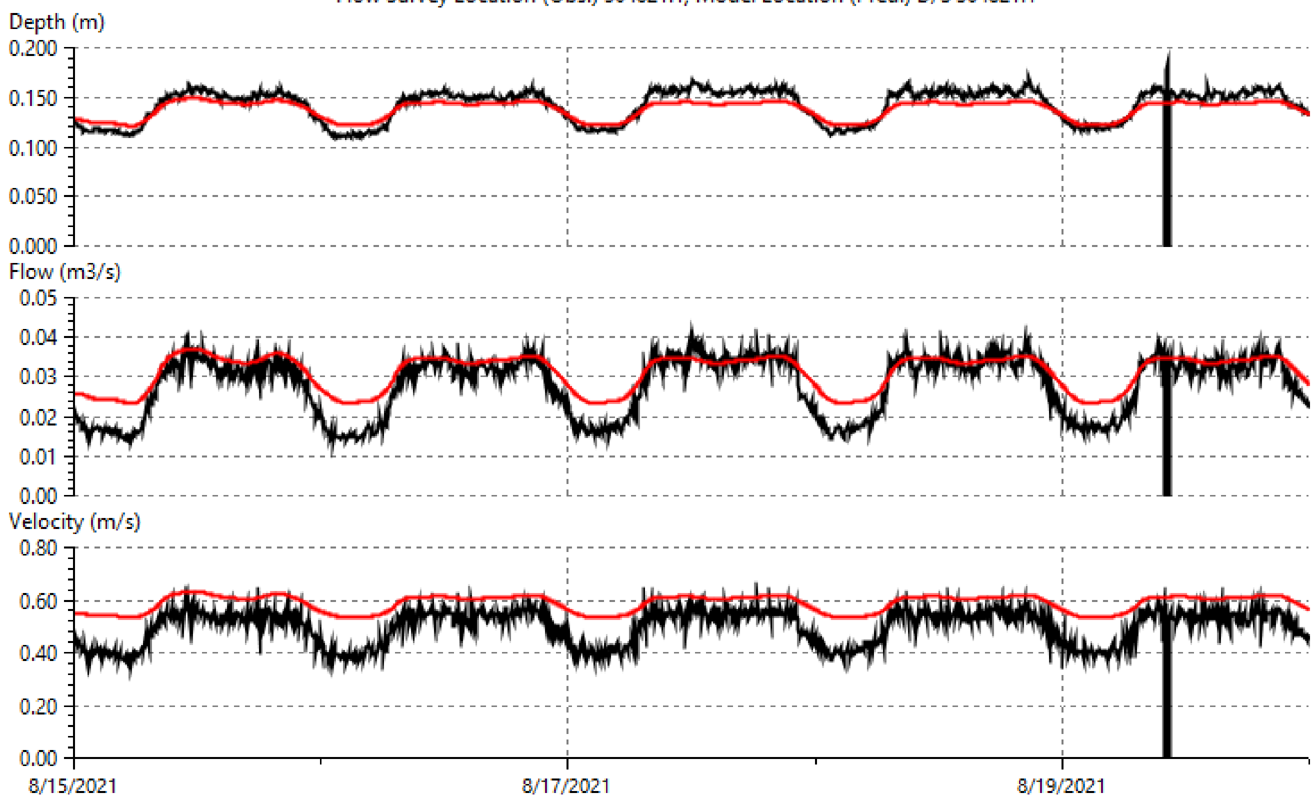
		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	(black line)	0.238	0.340	0.011	0.097	21562.174	0.070	0.410
Modelled	(red line)	0.165	0.222	0.085	0.158	51063.141	0.976	1.184

FM2b

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 12 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 304821.1, Model Location (Pred.) D/S 304821.1



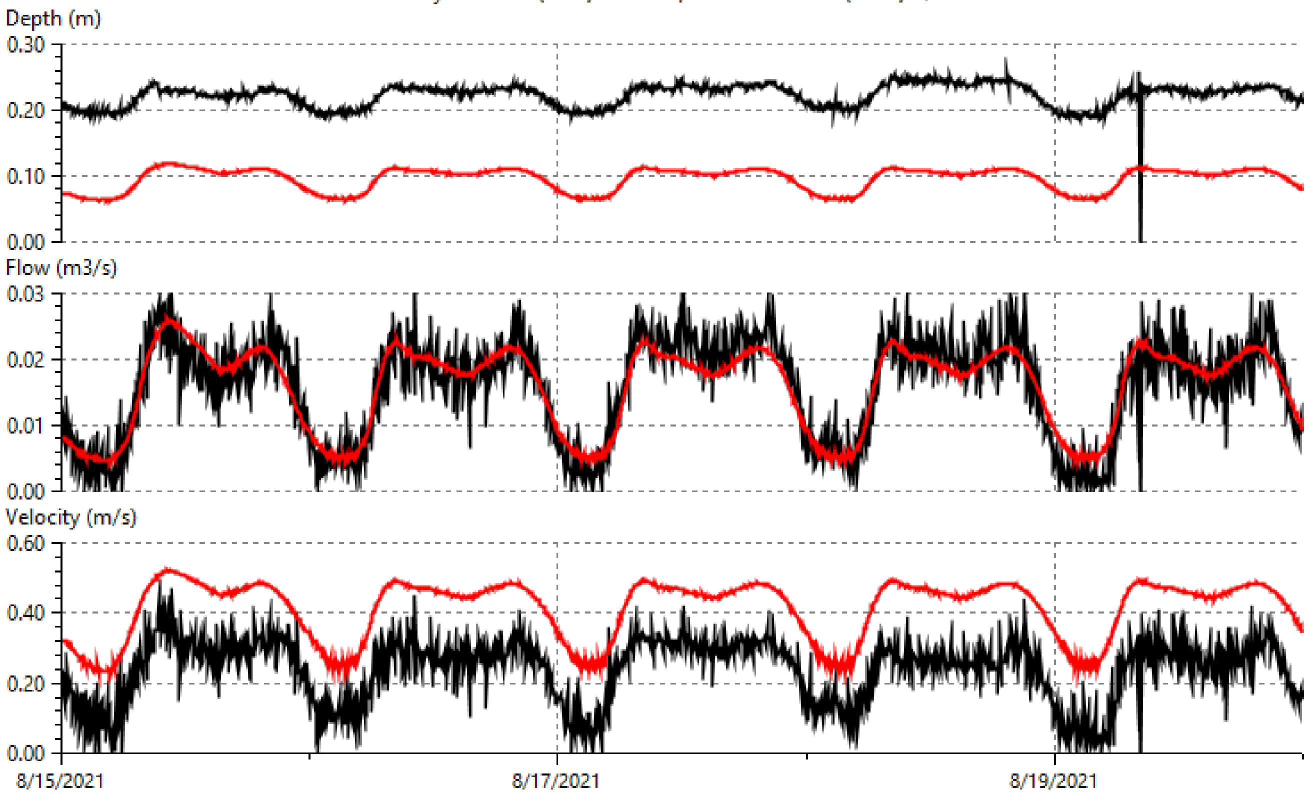
		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	▬ (black)	0.000	0.185	0.000	0.040	12097.218	0.000	0.600
Modelled	▬ (red)	0.121	0.149	0.023	0.037	13448.630	0.534	0.631

FM3

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 18 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 311167.1, Model Location (Pred.) D/S 311167.1



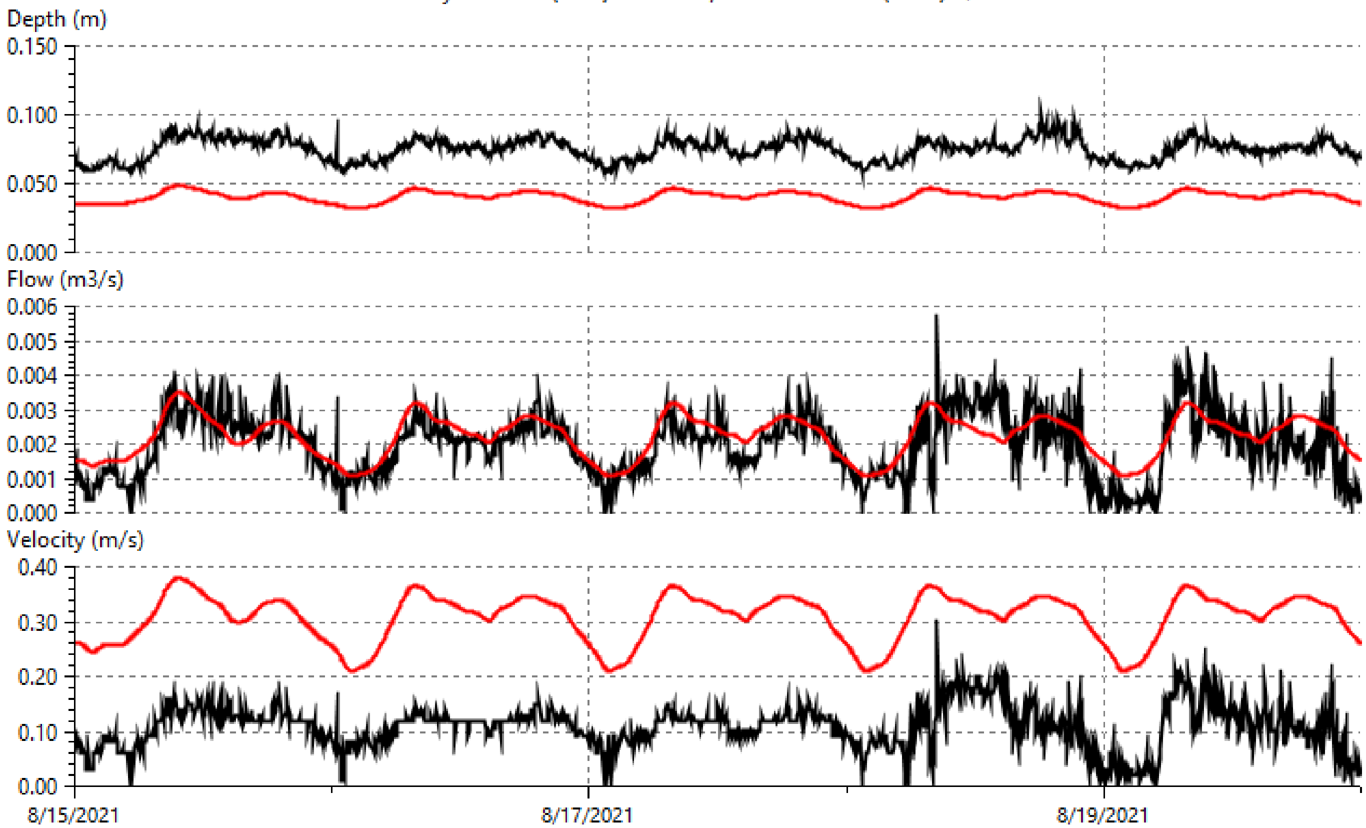
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.000	0.253	0.000	0.029	6838.321	0.000	0.450
Modelled	0.063	0.119	0.004	0.026	6848.467	0.222	0.524

FM3b

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 2 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 2091735.1, Model Location (Pred.) D/S 2091735.1



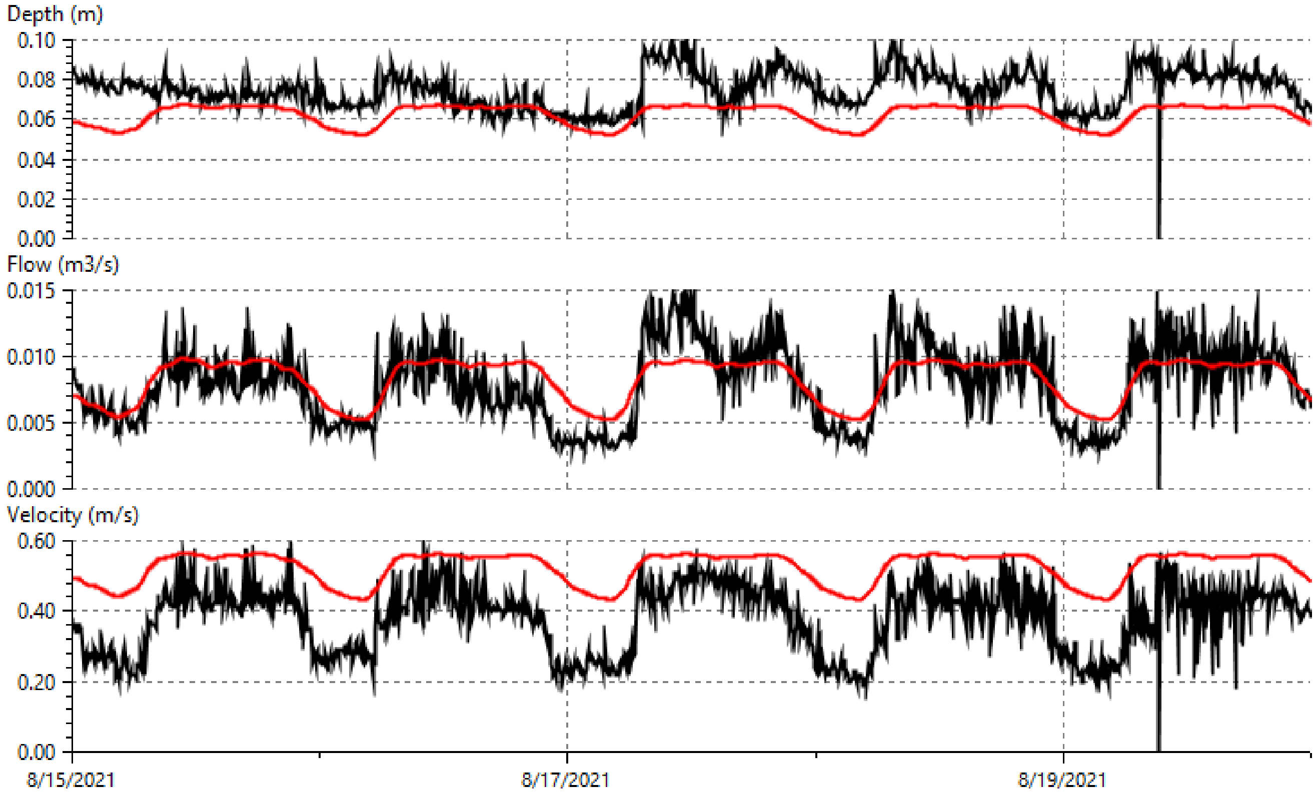
		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	(black line)	0.058	0.101	0.000	0.005	863.812	0.010	0.270
Modelled	(red line)	0.032	0.048	0.001	0.004	956.868	0.210	0.380

FM4

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 10 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 303748.1, Model Location (Pred.) D/S 303748.1

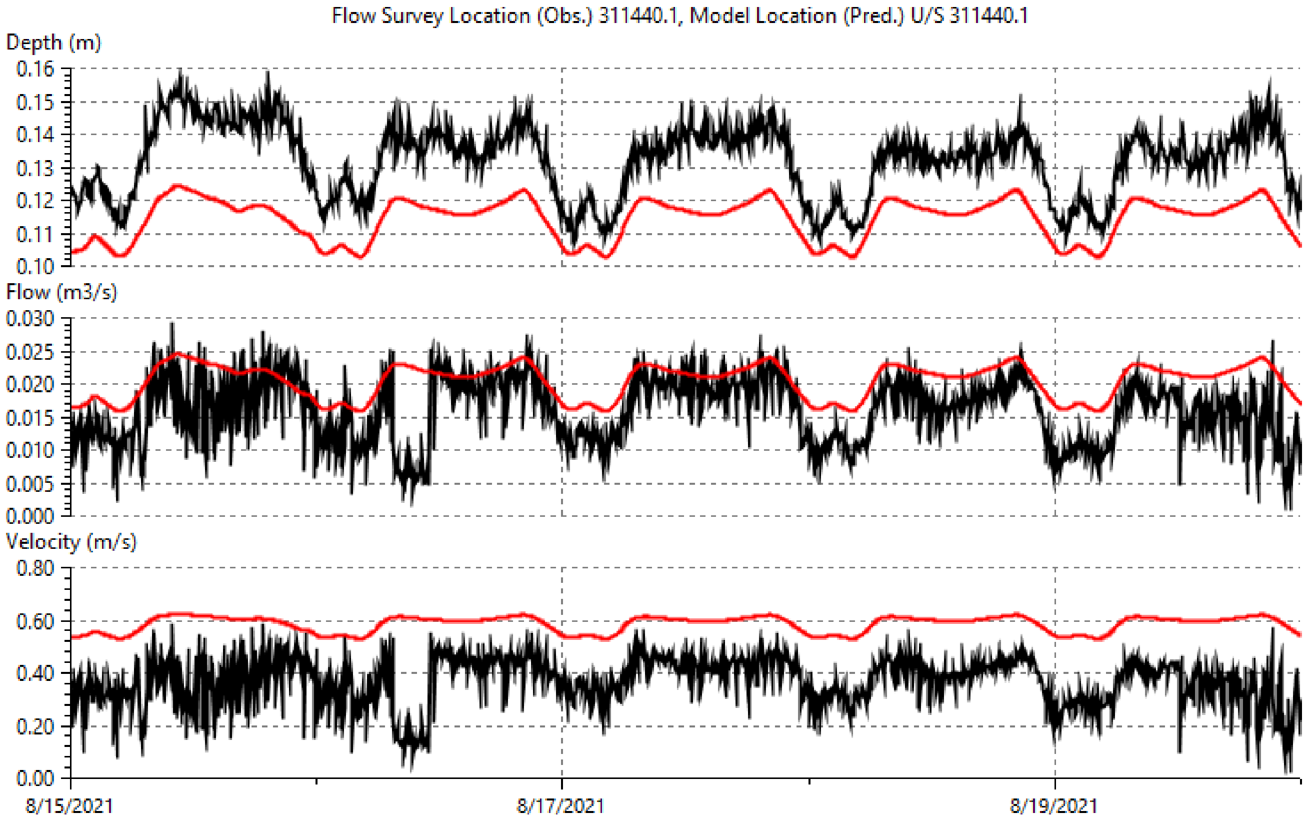


		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	(black line)	0.000	0.099	0.000	0.015	3439.971	0.000	0.570
Modelled	(red line)	0.053	0.067	0.005	0.010	3579.021	0.434	0.565

FM5b

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/26/2022 11:46:41 AM) Page 19 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM5blink (3/1/2022 9:01:2...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

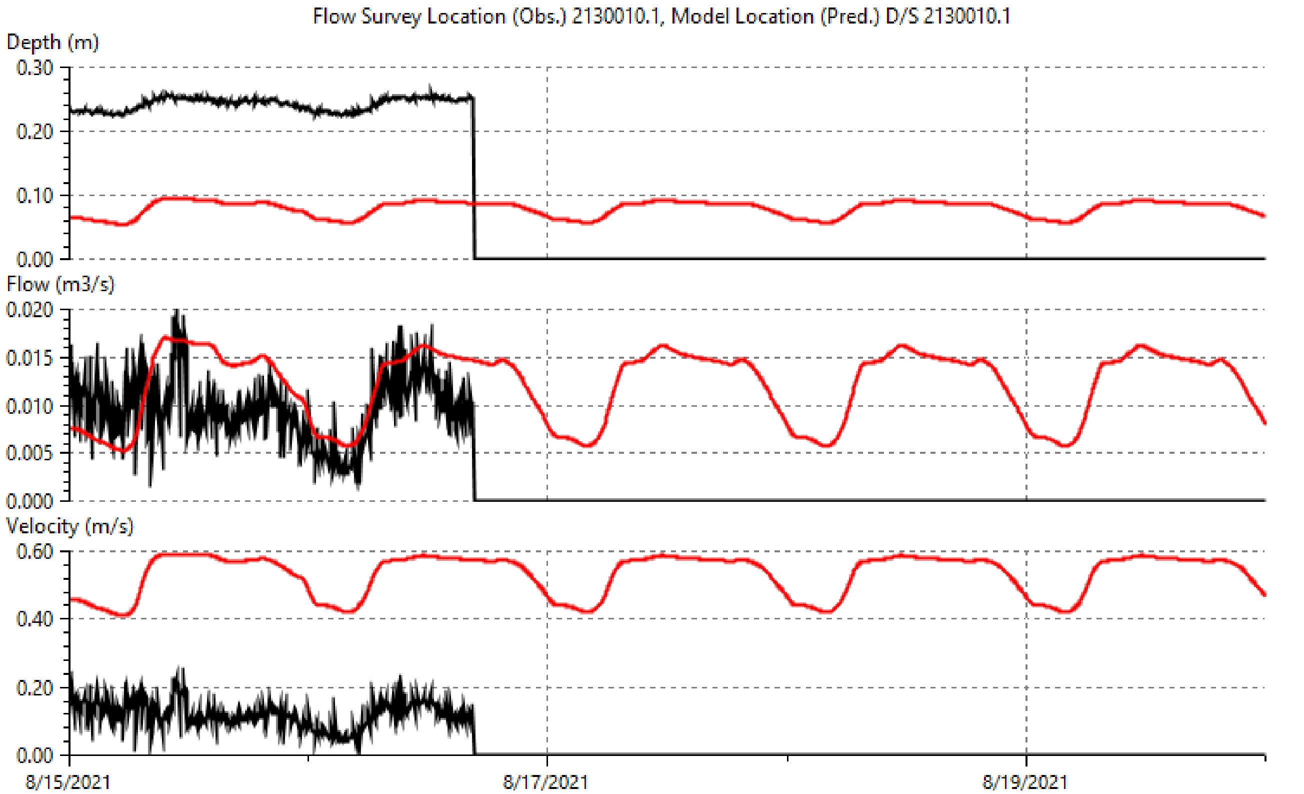


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.107	0.156	0.003	0.027	6892.613	0.080	0.520
Modelled	0.103	0.125	0.016	0.025	8848.598	0.530	0.624

FM6

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 3 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...



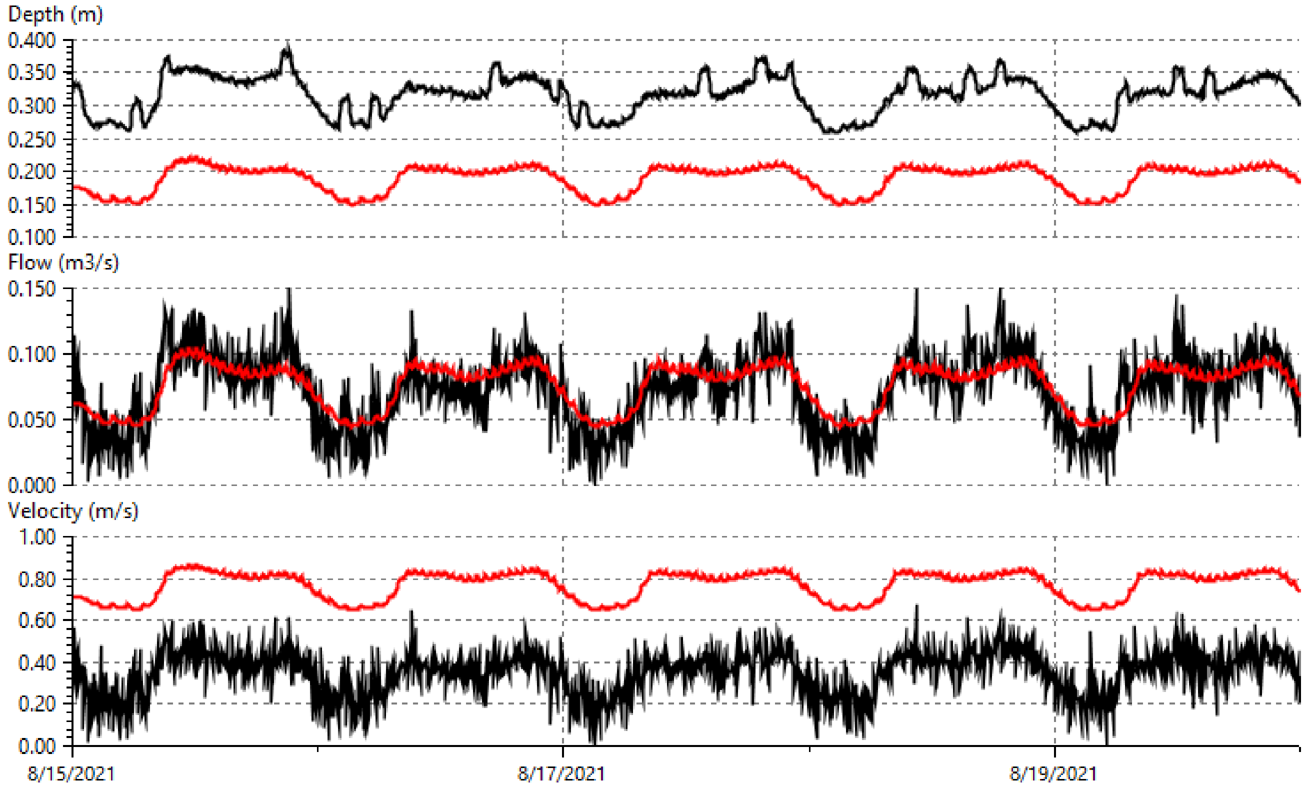
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.000	0.259	0.000	0.020	1395.558	0.000	0.230
Modelled	0.055	0.095	0.005	0.017	5240.006	0.411	0.591

FM7

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 13 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 306527.1, Model Location (Pred.) D/S 306527.1

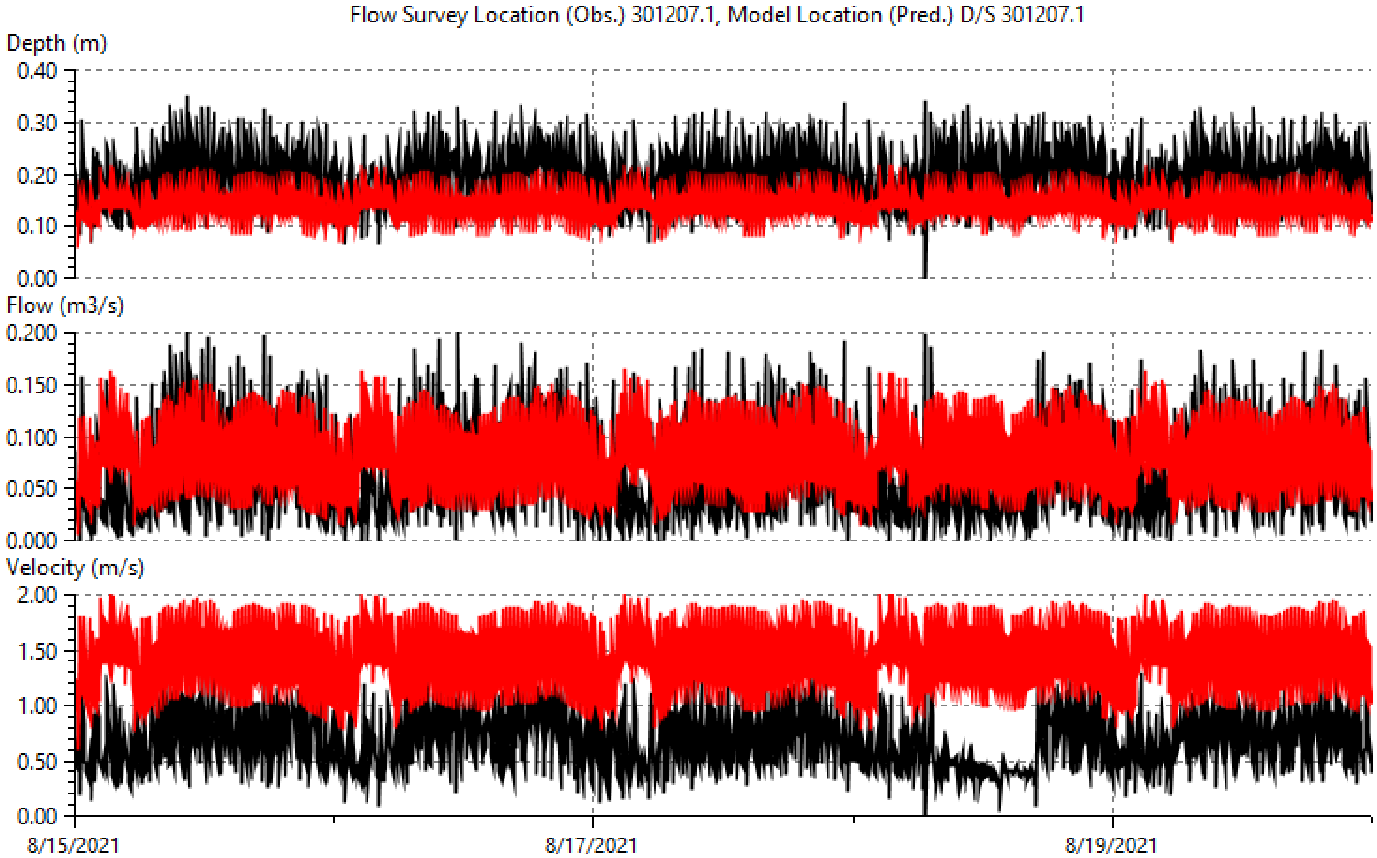


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.258	0.384	0.008	0.143	31294.273	0.050	0.590
Modelled	0.150	0.221	0.045	0.104	32785.780	0.651	0.861

FM9

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 5 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...



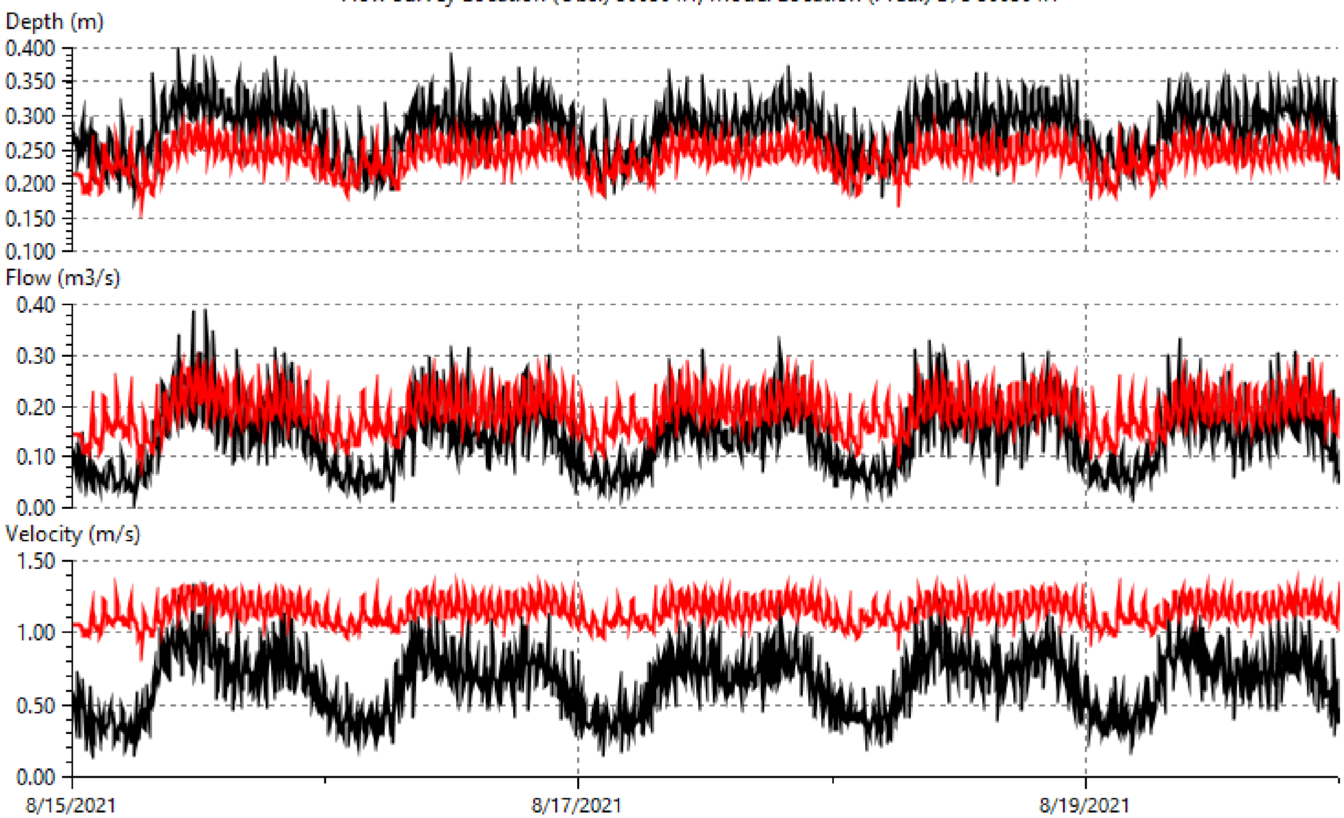
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.000	0.316	0.000	0.184	28479.369	0.000	1.230
Modelled	0.095	0.184	0.024	0.147	33241.271	0.761	1.861

FM10

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 4 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 300304.1, Model Location (Pred.) D/S 300304.1

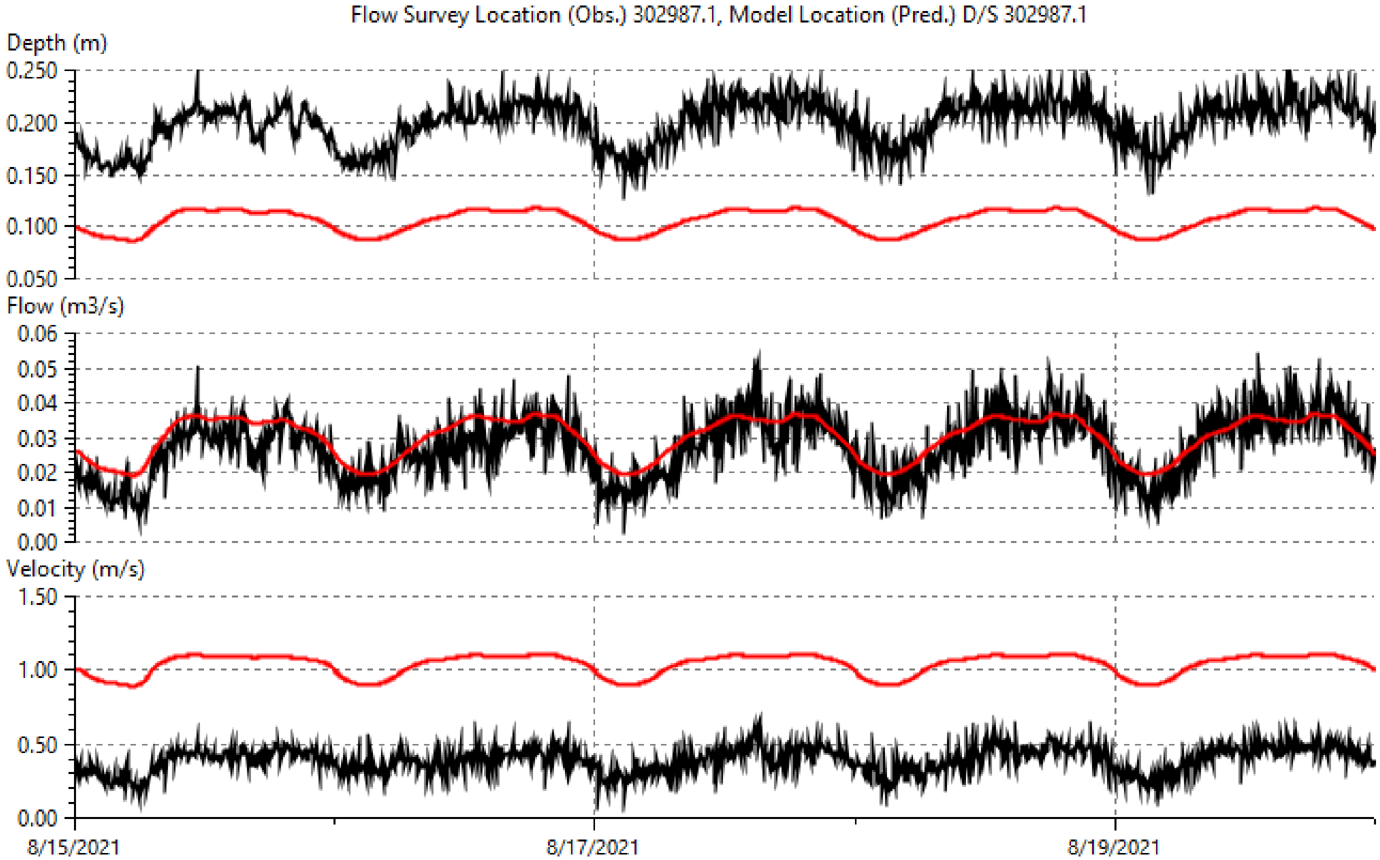


		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	black line	0.186	0.376	0.029	0.356	60002.344	0.240	1.230
Modelled	red line	0.176	0.291	0.096	0.281	81028.720	0.934	1.330

FM11

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 6 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...



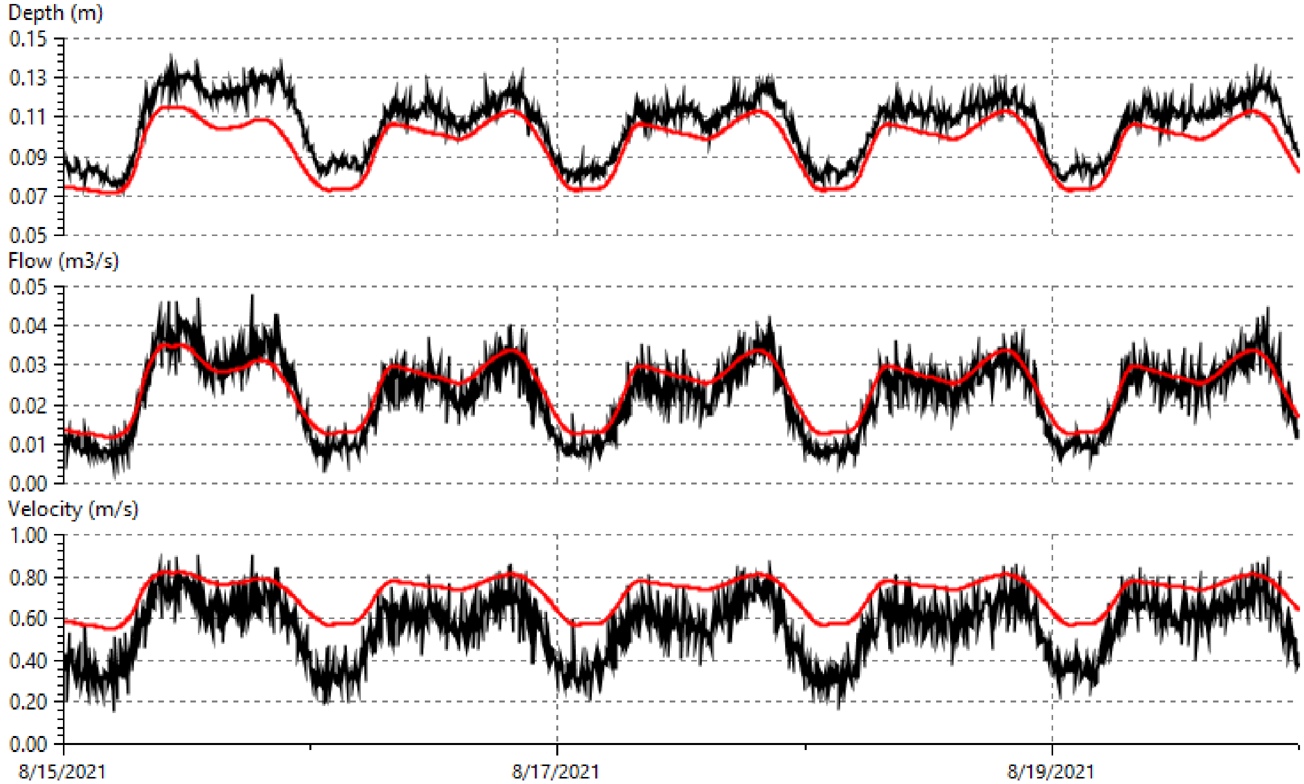
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.143	0.245	0.007	0.051	11903.105	0.150	0.620
Modelled	0.087	0.118	0.019	0.037	12961.460	0.893	1.106

FM12

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 15 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 307136.1, Model Location (Pred.) D/S 307136.1

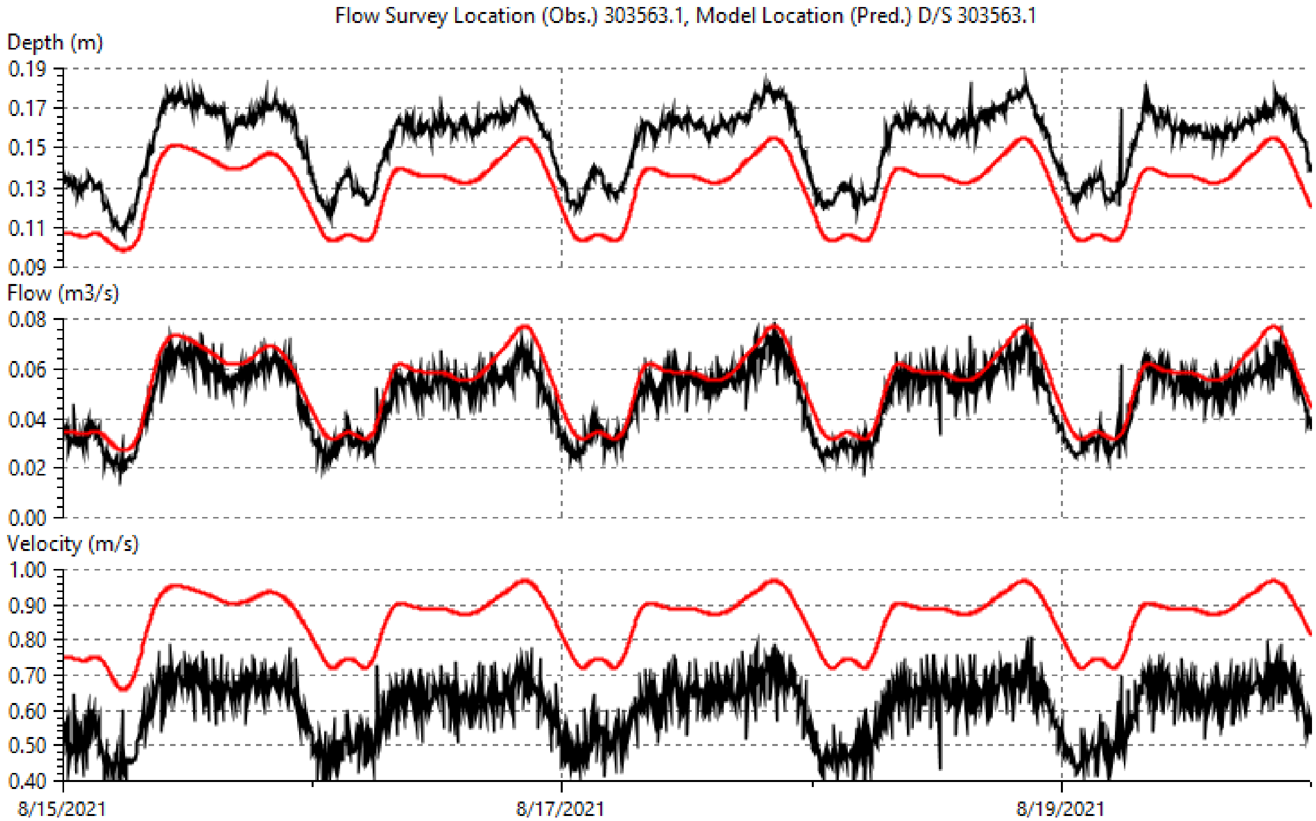


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.074	0.134	0.006	0.044	9690.978	0.240	0.830
Modelled	0.071	0.115	0.012	0.035	10546.054	0.551	0.820

FM13

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 9 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

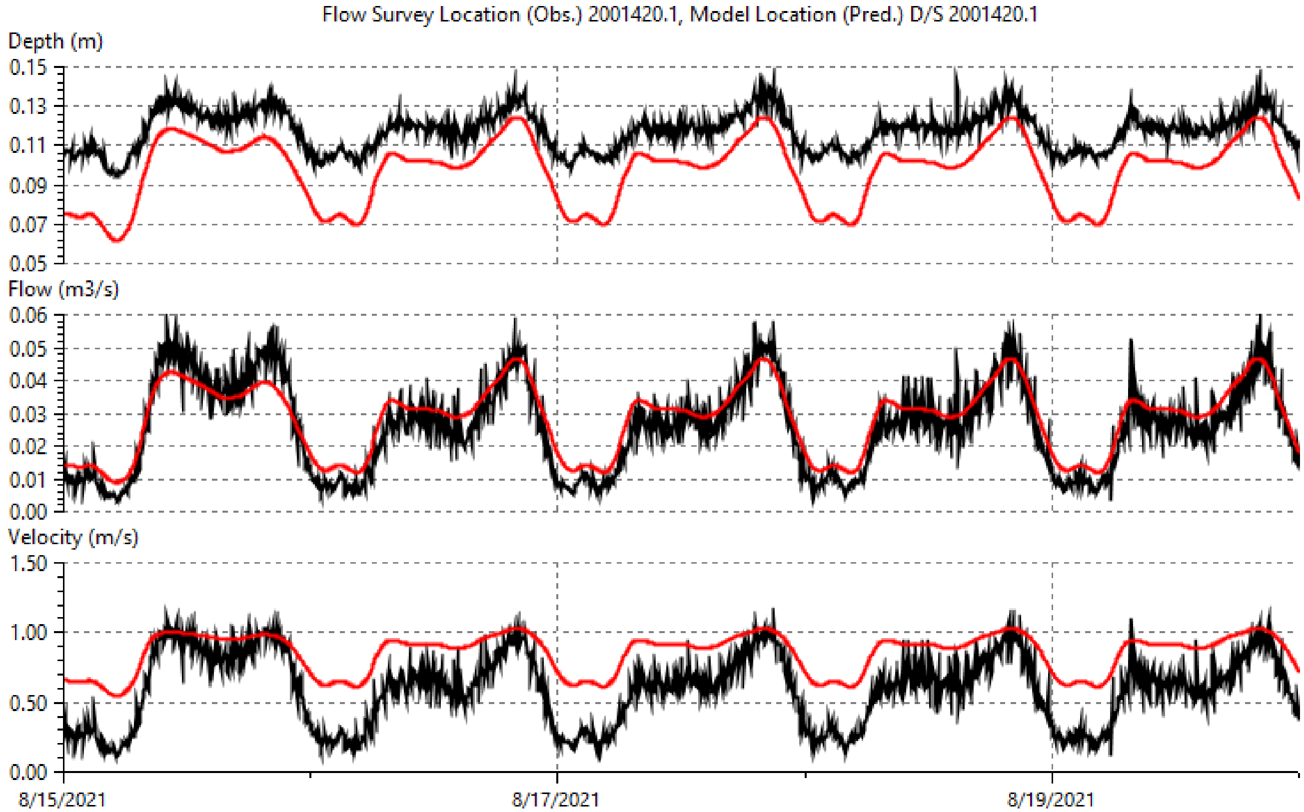


		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	(black line)	0.106	0.182	0.020	0.075	20994.411	0.400	0.780
Modelled	(red line)	0.099	0.155	0.027	0.077	23304.828	0.660	0.968

FM13b

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 1 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...



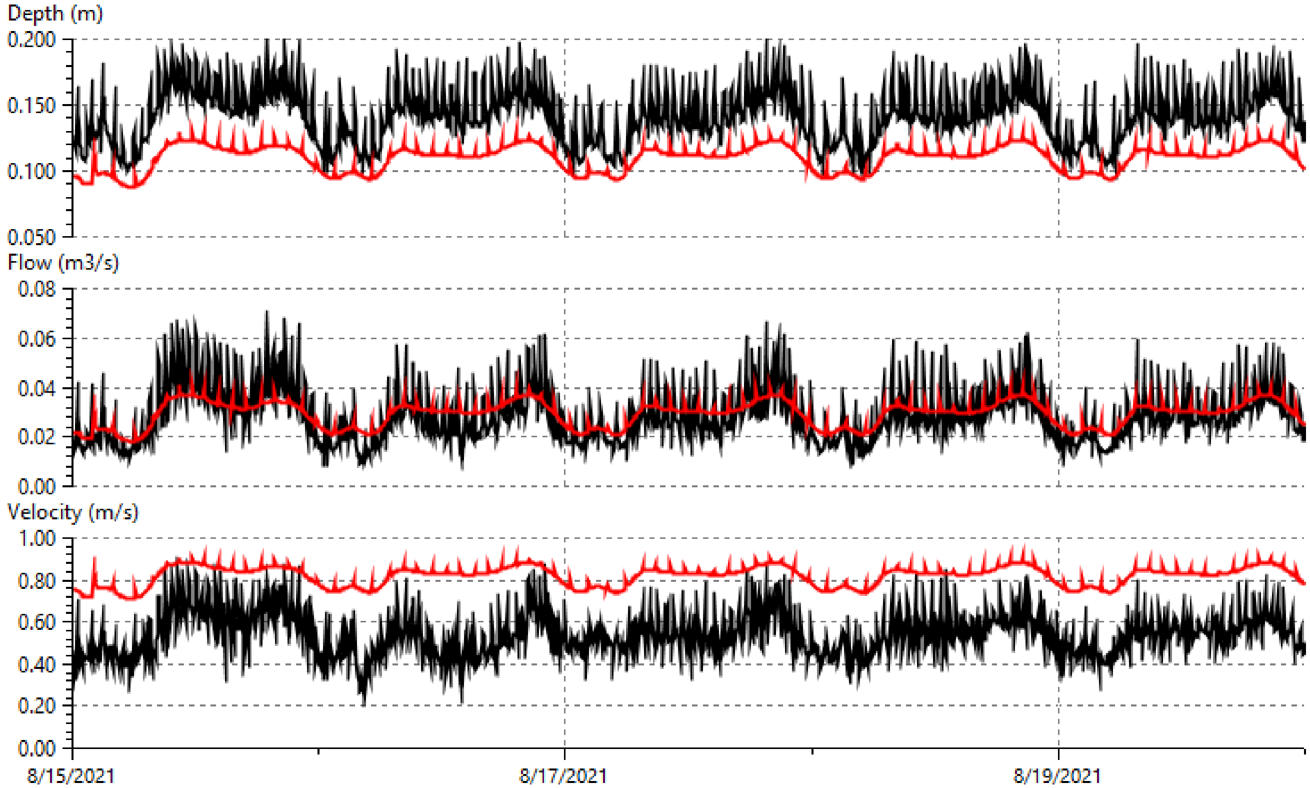
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.094	0.142	0.003	0.057	11278.306	0.110	1.100
Modelled	0.062	0.124	0.009	0.047	12328.421	0.544	1.029

FM15

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 7 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 303239.1, Model Location (Pred.) D/S 303239.1

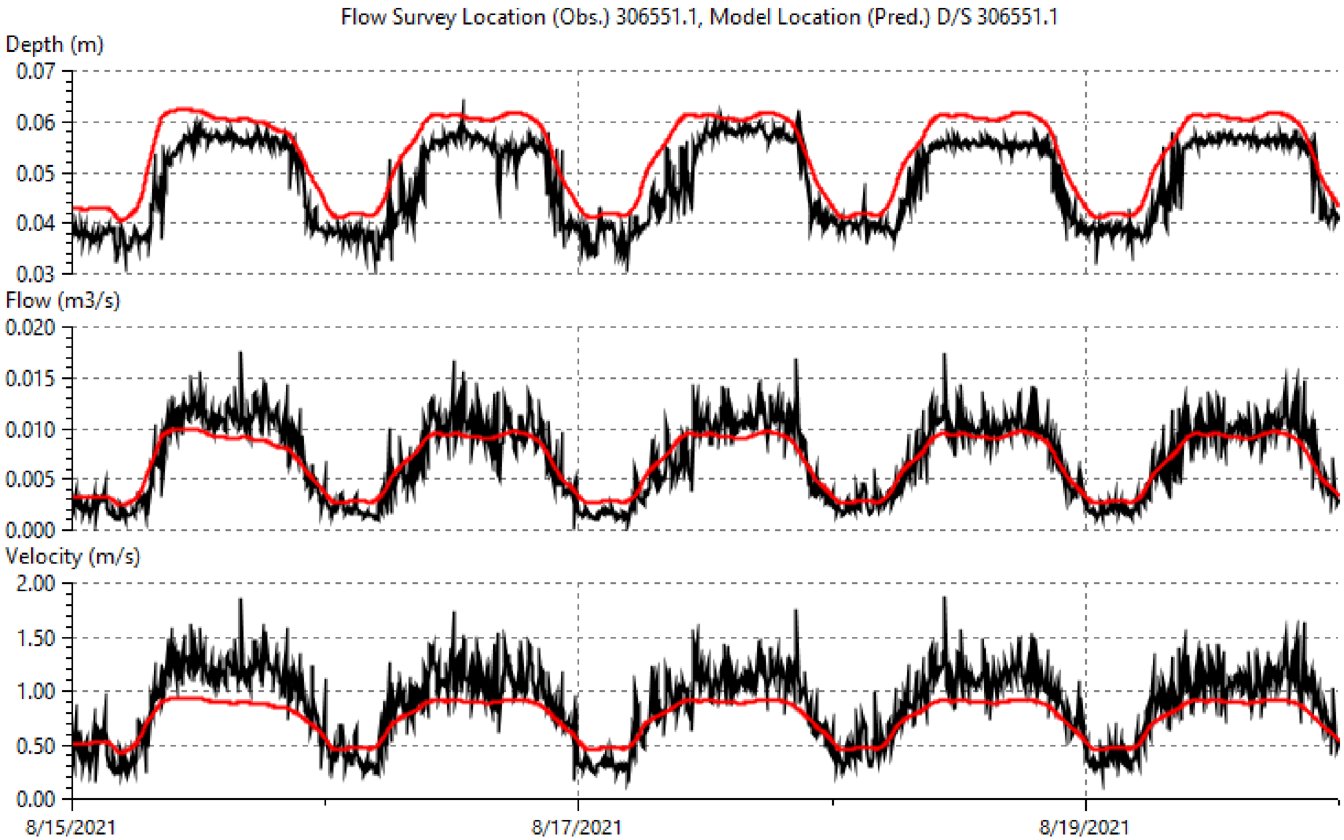


		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	black line	0.101	0.195	0.009	0.064	12360.195	0.270	0.840
Modelled	red line	0.088	0.130	0.018	0.041	12725.165	0.709	0.912

FM18

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 14 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

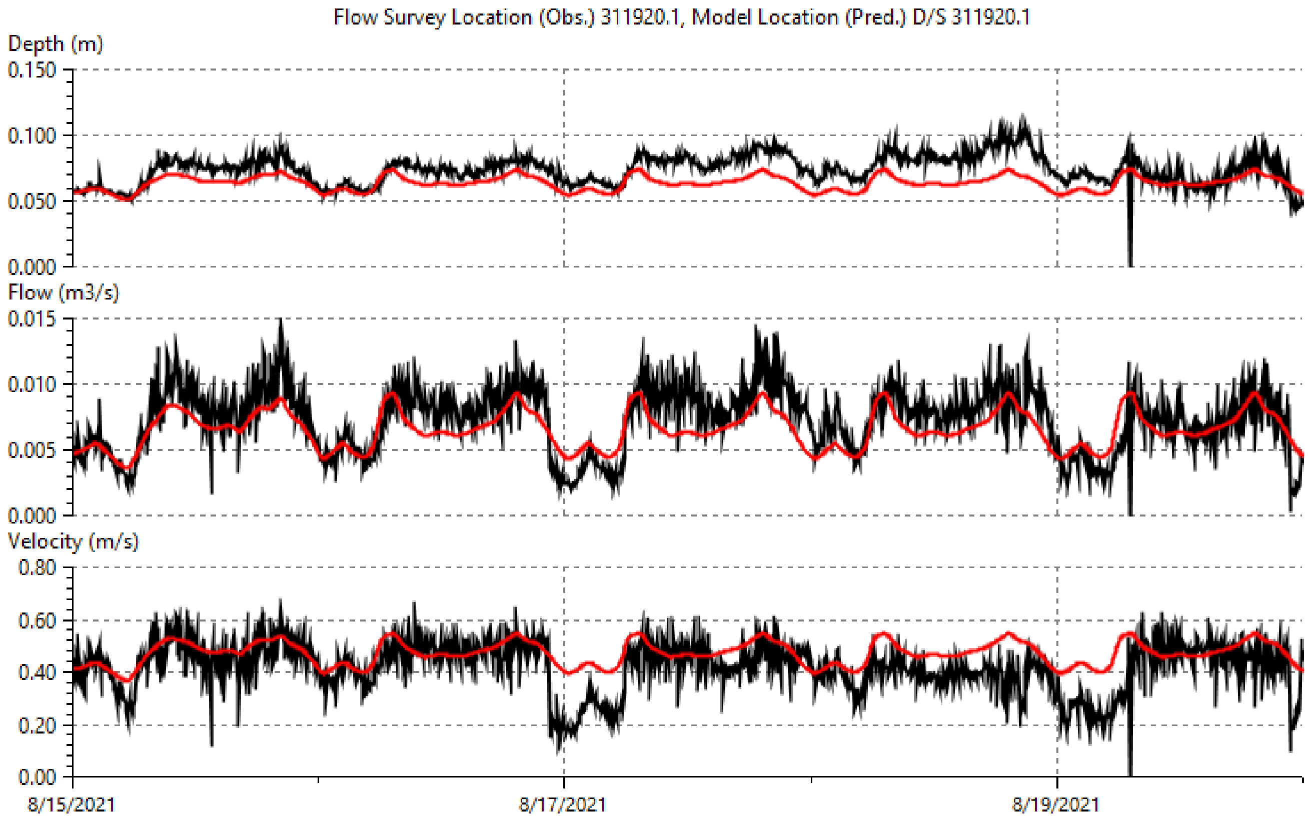


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.032	0.061	0.001	0.016	3075.451	0.230	1.720
Modelled	0.041	0.062	0.002	0.010	2948.568	0.426	0.935

FM19

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 20 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...



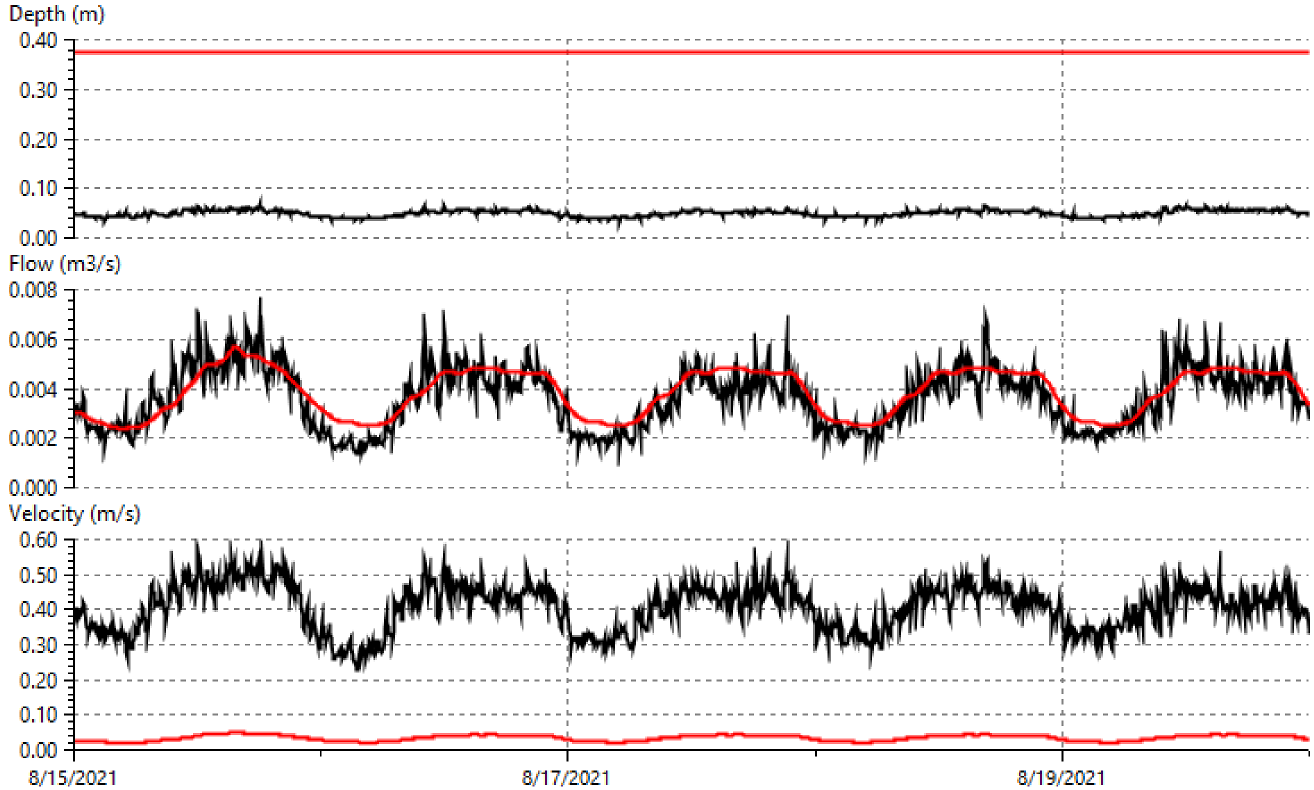
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.000	0.106	0.000	0.014	3173.013	0.000	0.620
Modelled	0.051	0.074	0.004	0.009	2840.896	0.367	0.547

FM20

DWF Period 1

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 10:12:19 AM) Page 8 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#1_20210815_Link_FM2FM9link (3/1/2022 9:0...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E1_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 303425.1, Model Location (Pred.) D/S 303425.1

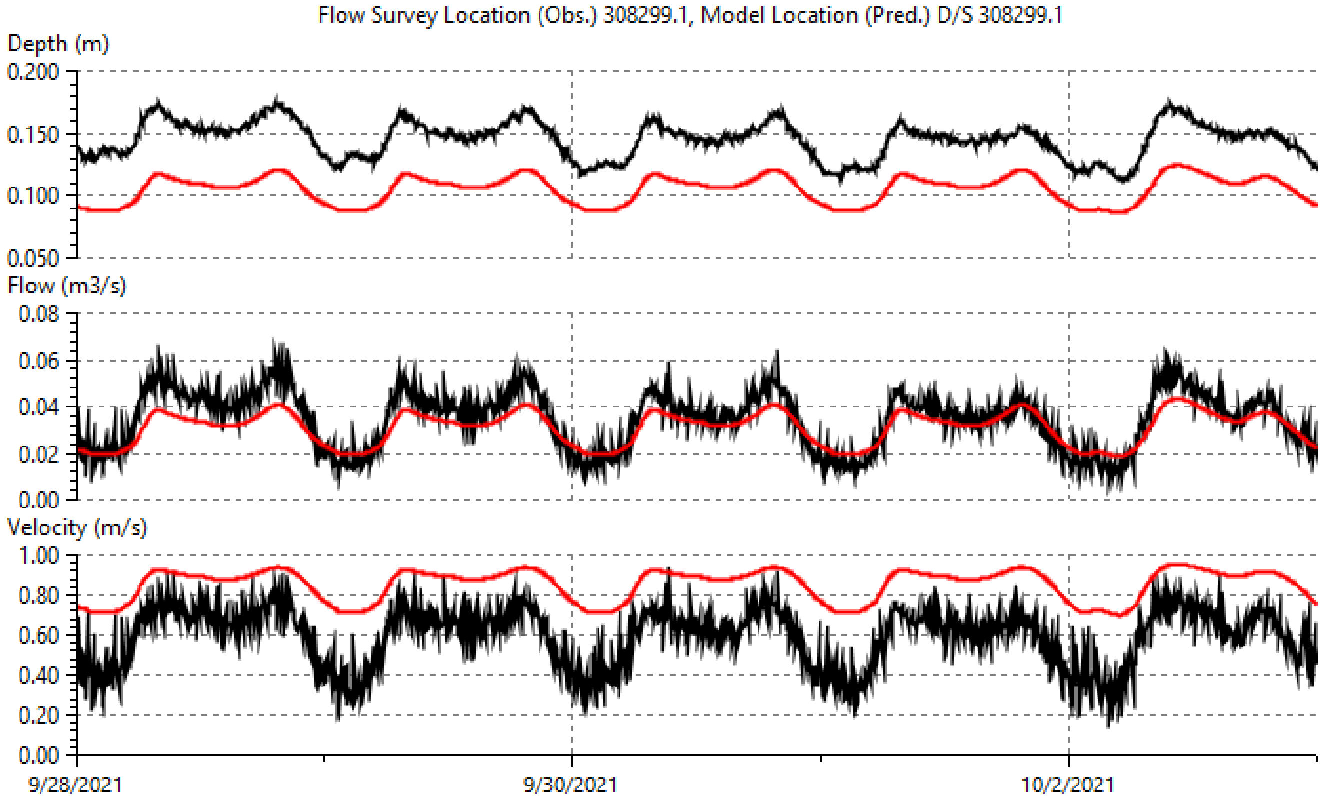


		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	black line	0.033	0.067	0.001	0.007	1569.756	0.230	0.560
Modelled	red line	0.375	0.375	0.002	0.006	1669.375	0.022	0.051

FM1

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 16 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

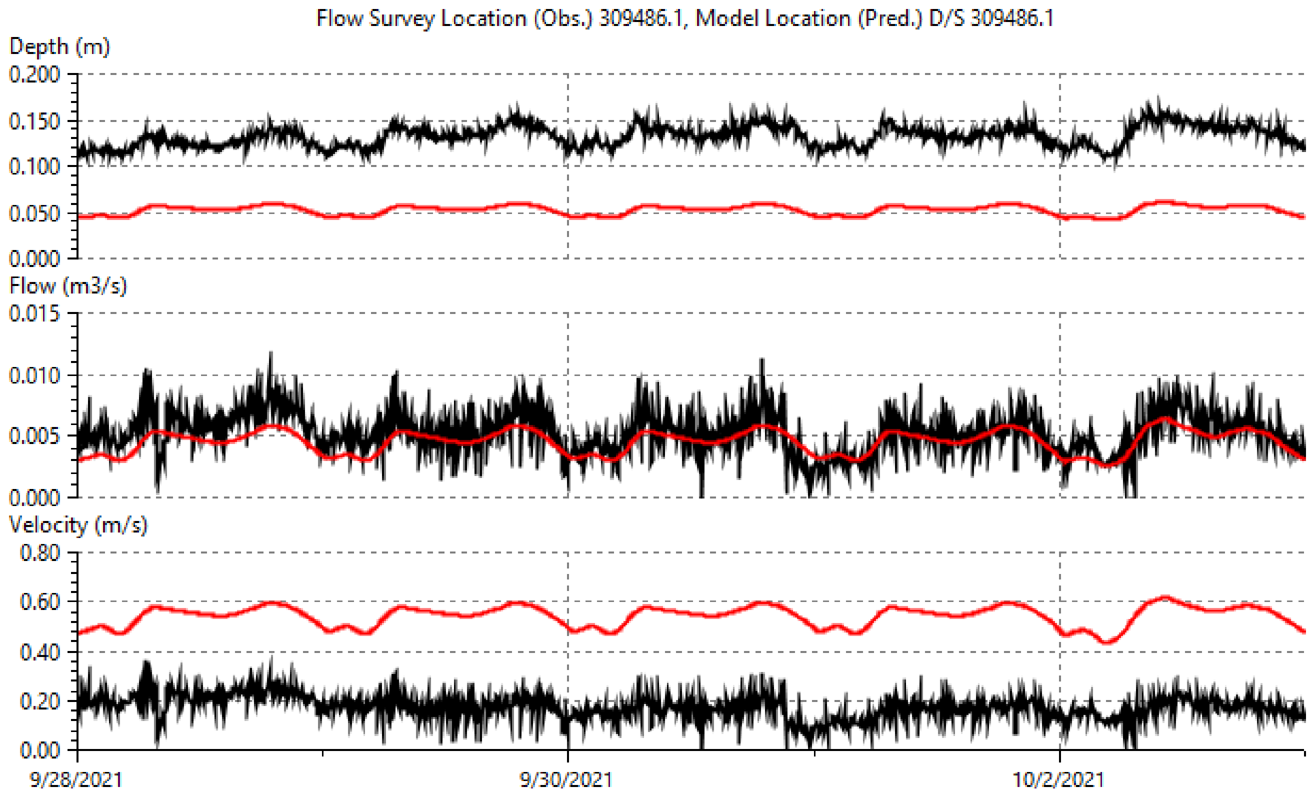


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.113	0.174	0.010	0.062	14979.650	0.230	0.850
Modelled	0.087	0.125	0.019	0.043	13334.571	0.699	0.955

FM1b

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 17 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

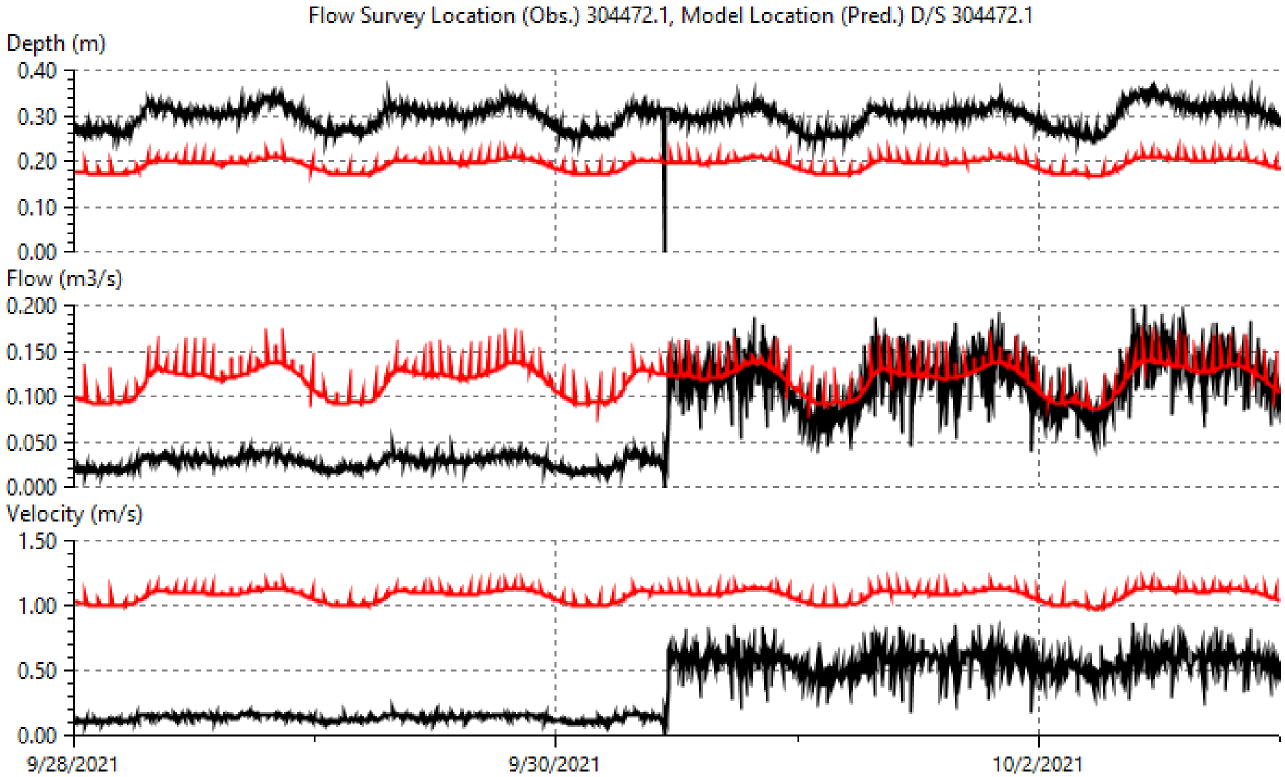


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.108	0.160	0.000	0.011	2286.490	0.000	0.310
Modelled	0.042	0.061	0.003	0.006	1967.405	0.433	0.618

FM2

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 11 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

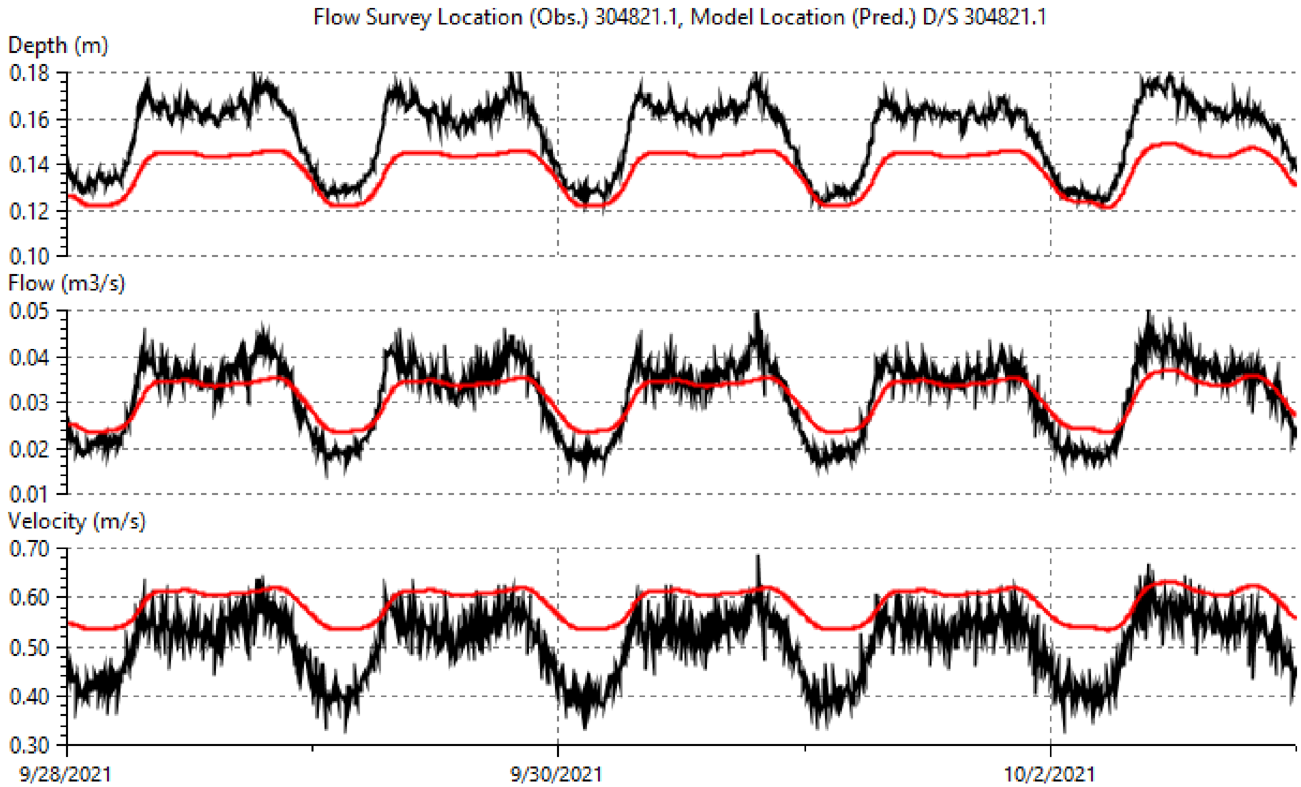


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.000	0.358	0.000	0.186	31597.287	0.000	0.760
Modelled	0.166	0.222	0.086	0.158	51071.645	0.977	1.183

FM2b

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 12 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...



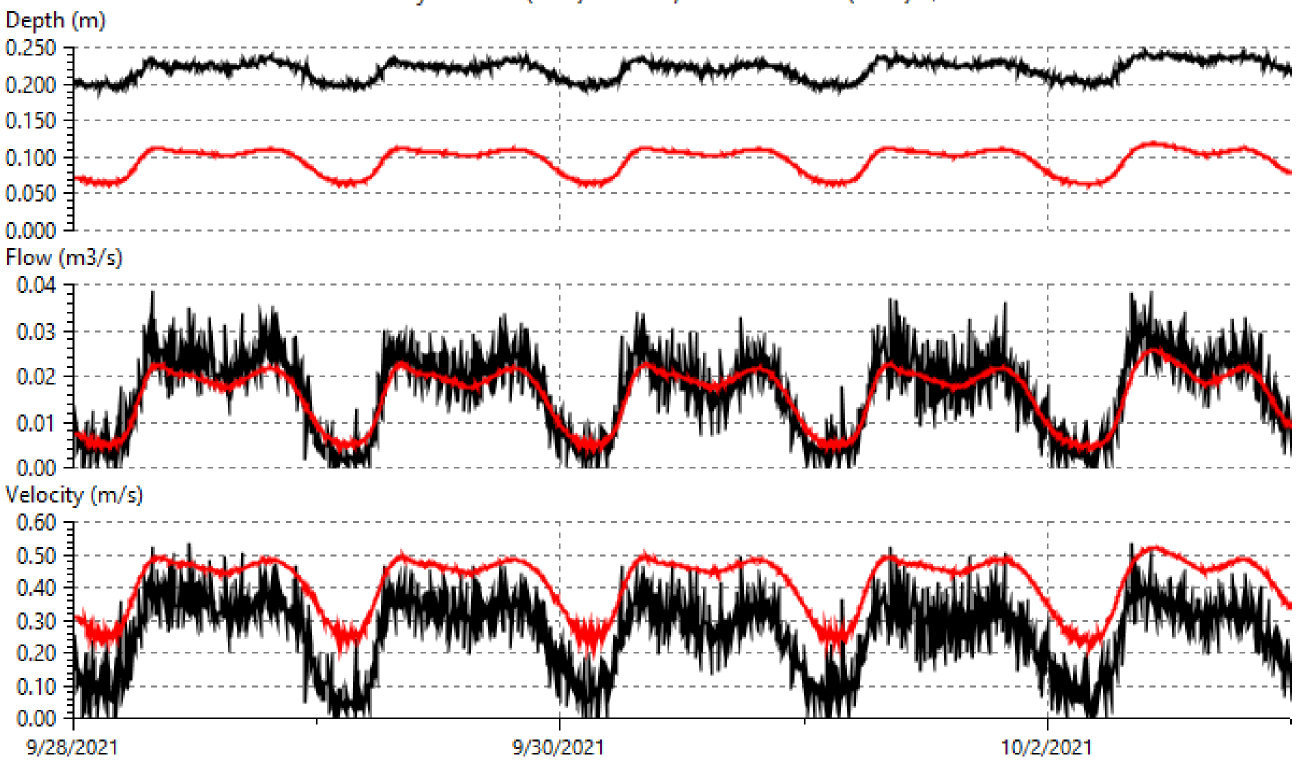
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.123	0.179	0.016	0.047	13665.572	0.360	0.650
Modelled	0.121	0.149	0.023	0.037	13450.174	0.534	0.631

FM3

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 18 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

Flow Survey Location (Obs.) 311167.1, Model Location (Pred.) D/S 311167.1



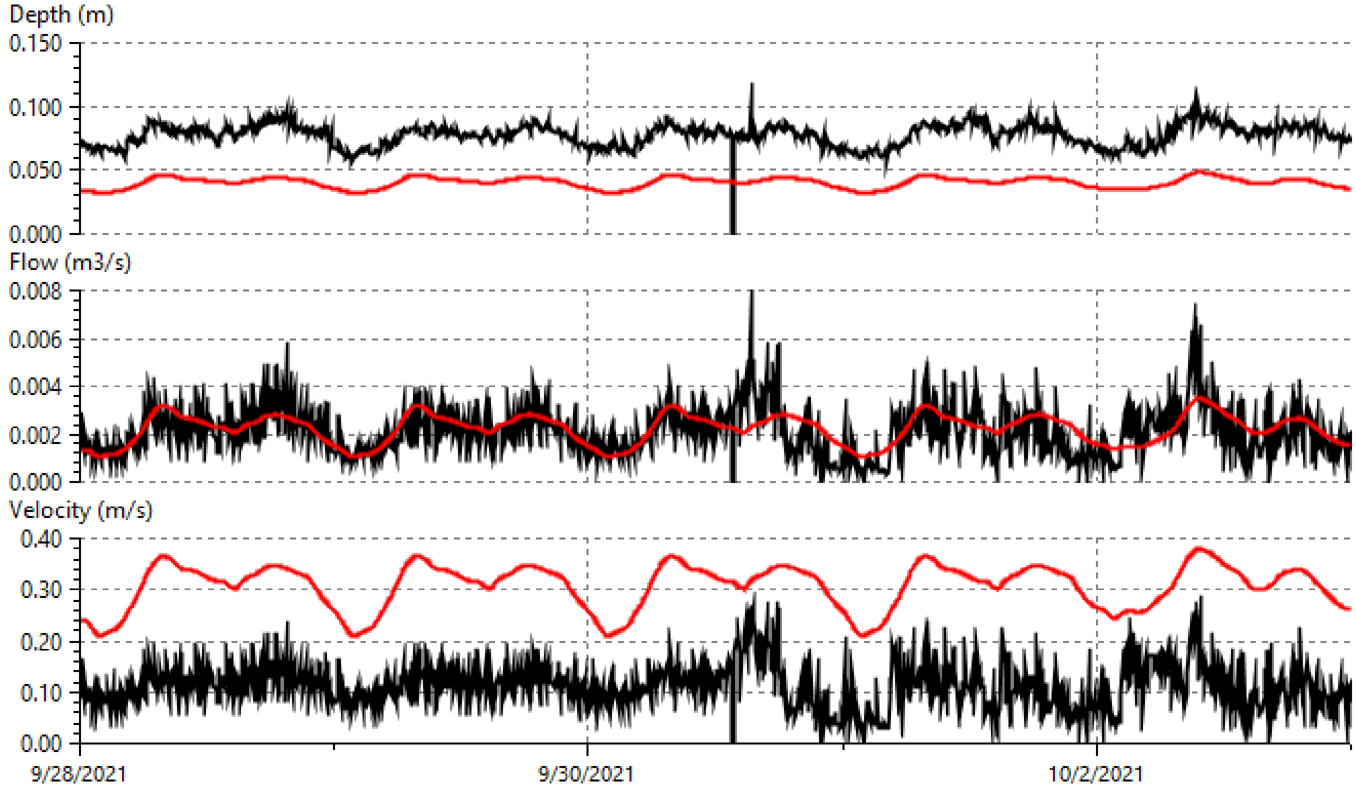
		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	black line	0.193	0.245	0.001	0.035	7267.746	0.020	0.480
Modelled	red line	0.062	0.119	0.004	0.026	6848.554	0.219	0.522

FM3b

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 2 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

Flow Survey Location (Obs.) 2091735.1, Model Location (Pred.) D/S 2091735.1

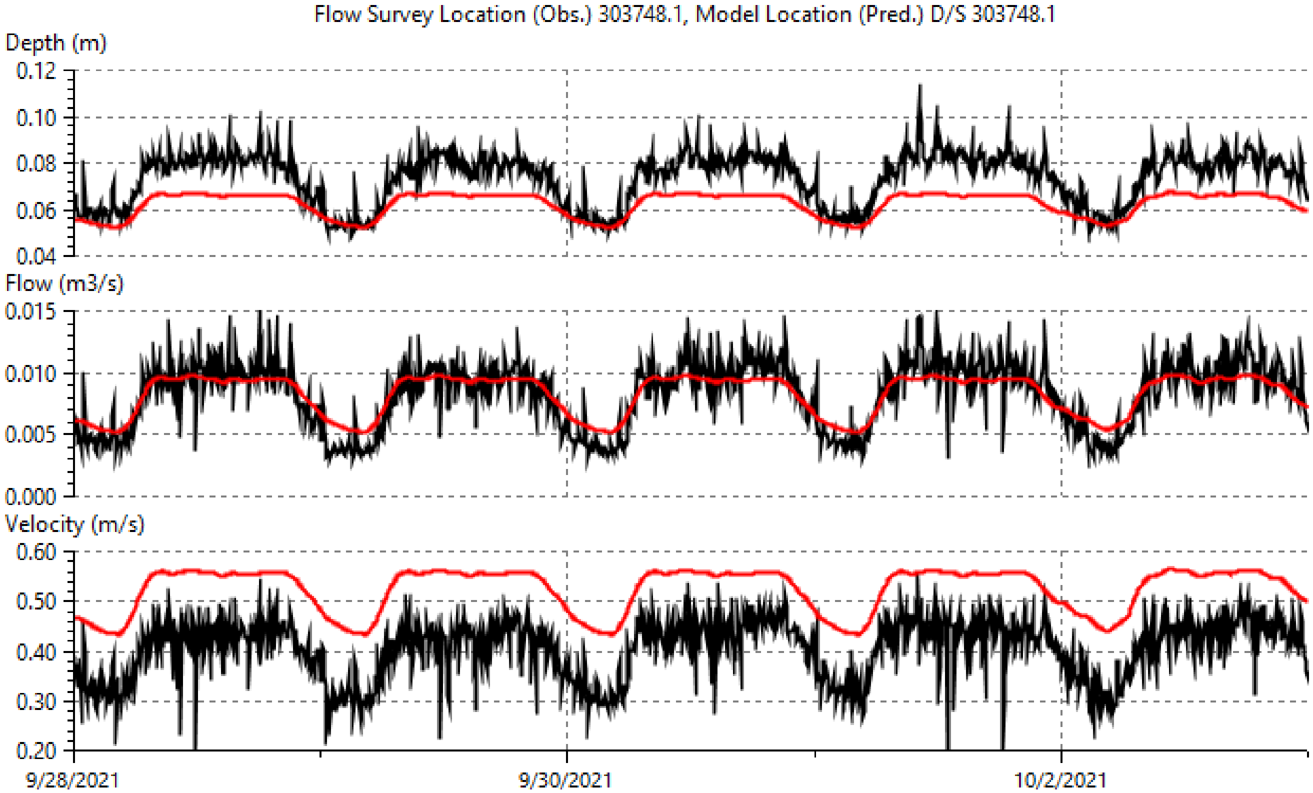


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.000	0.104	0.000	0.007	919.237	0.000	0.270
Modelled	0.032	0.048	0.001	0.004	956.915	0.210	0.380

FM4

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 10 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...



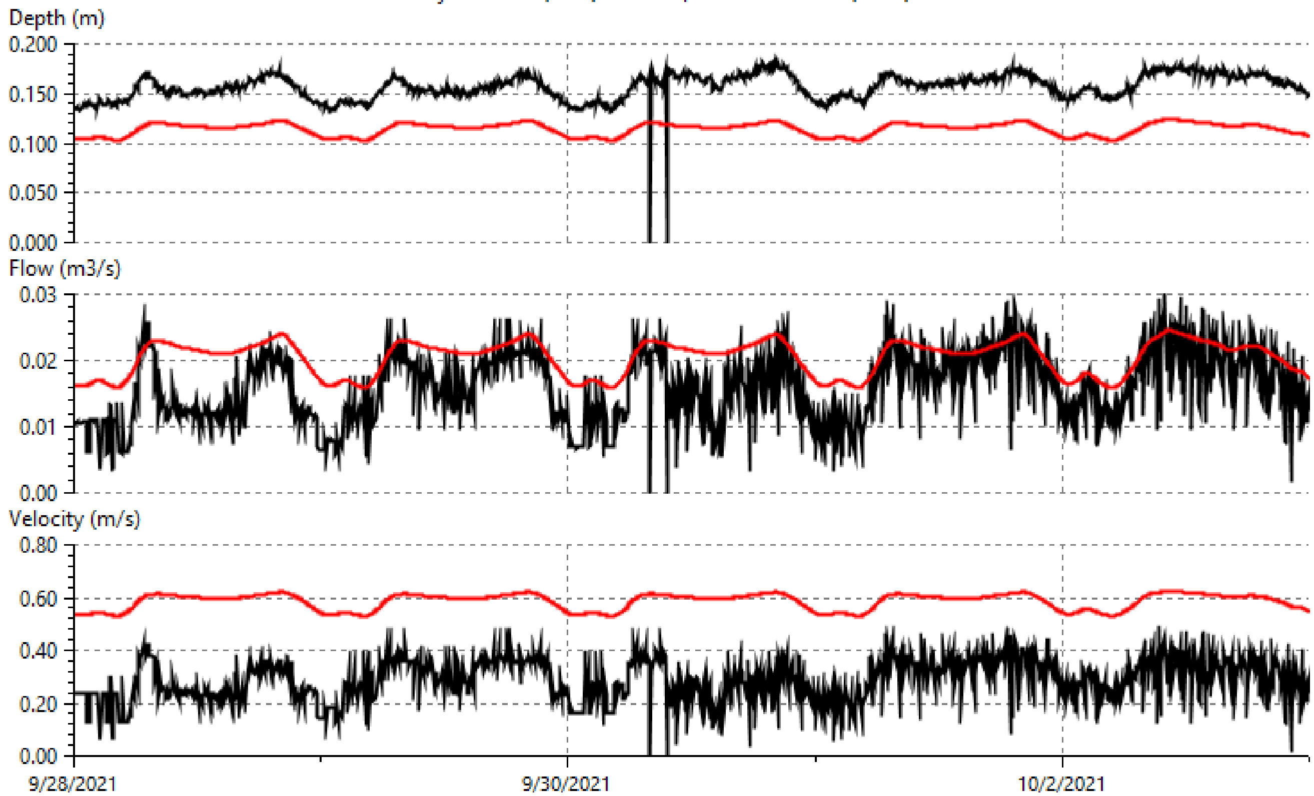
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.050	0.106	0.003	0.015	3593.593	0.200	0.520
Modelled	0.053	0.067	0.005	0.010	3579.459	0.434	0.565

FM5b

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/26/2022 12:09:49 PM) Page 19 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM5blink (3/3/2022 2:45:3...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF (4/7/20...

Flow Survey Location (Obs.) 311440.1, Model Location (Pred.) U/S 311440.1

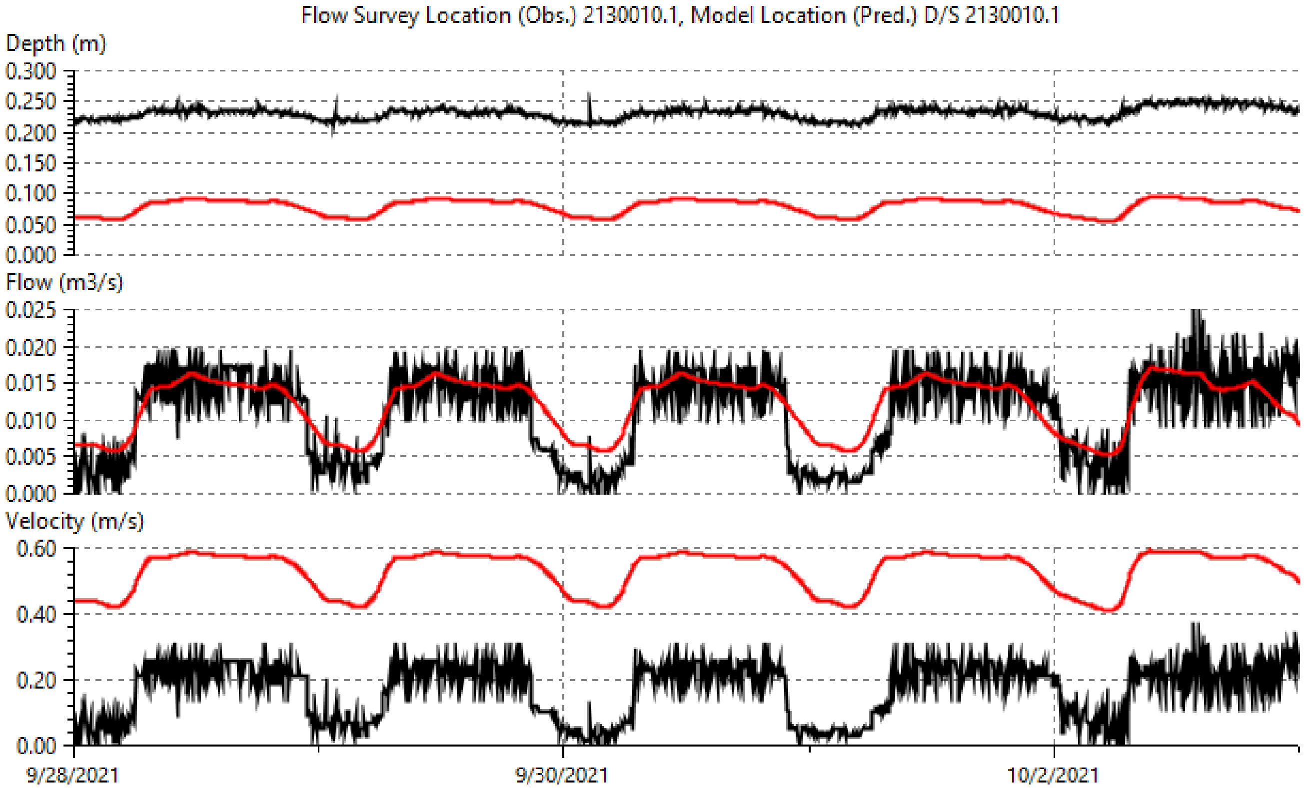


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.000	0.183	0.000	0.029	6903.430	0.000	0.450
Modelled	0.103	0.125	0.016	0.025	8848.798	0.530	0.624

FM6

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 3 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...



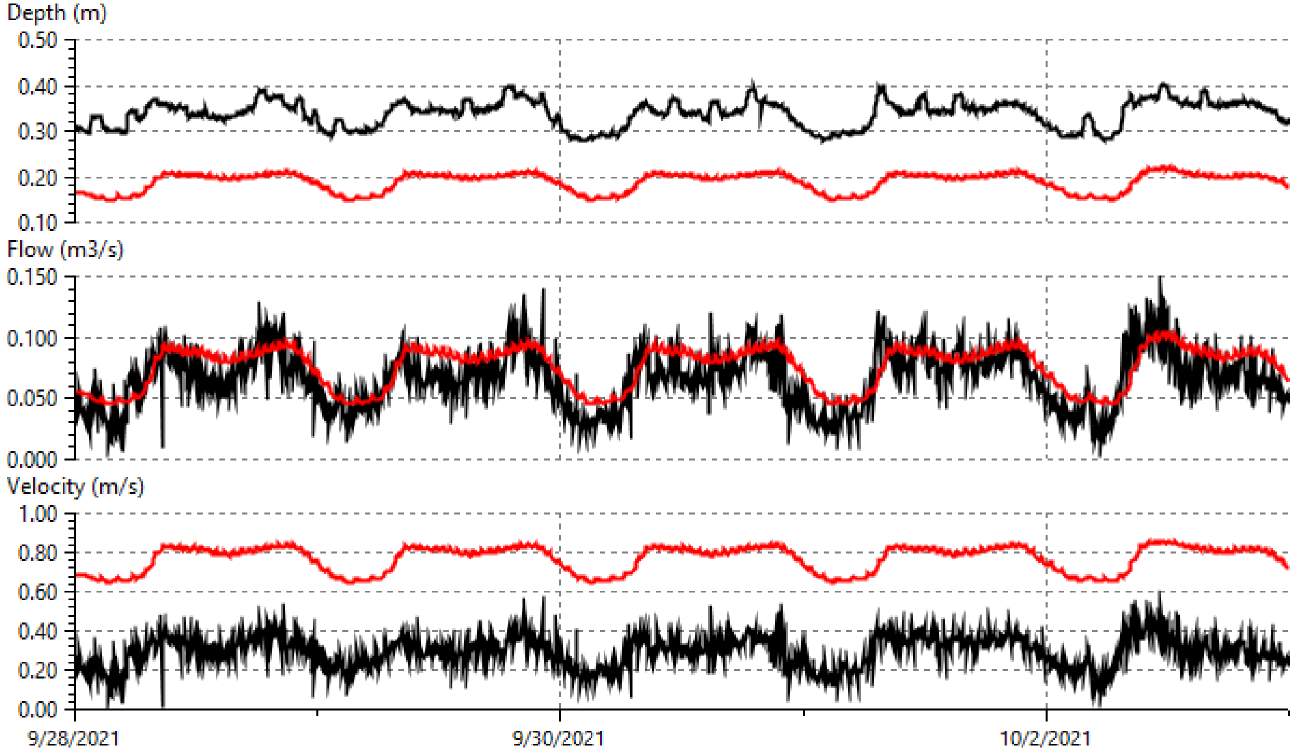
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.212	0.255	0.000	0.024	4803.511	0.000	0.320
Modelled	0.055	0.095	0.005	0.017	5239.002	0.411	0.591

FM7

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 13 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

Flow Survey Location (Obs.) 306527.1, Model Location (Pred.) D/S 306527.1



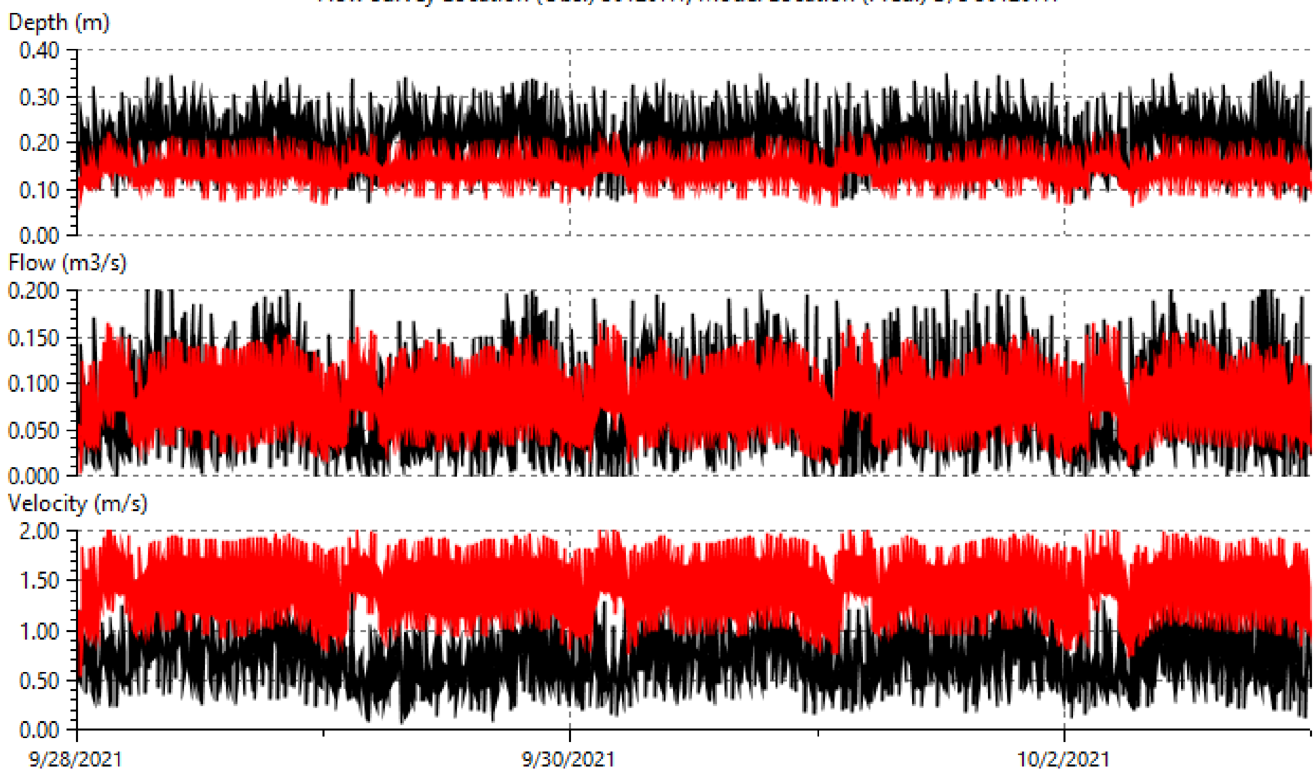
		Depth		Flow			Velocity	
		Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed		0.280	0.404	0.012	0.139	28468.743	0.070	0.510
Modelled		0.150	0.221	0.045	0.105	32780.270	0.651	0.862

FM9

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 5 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

Flow Survey Location (Obs.) 301207.1, Model Location (Pred.) D/S 301207.1

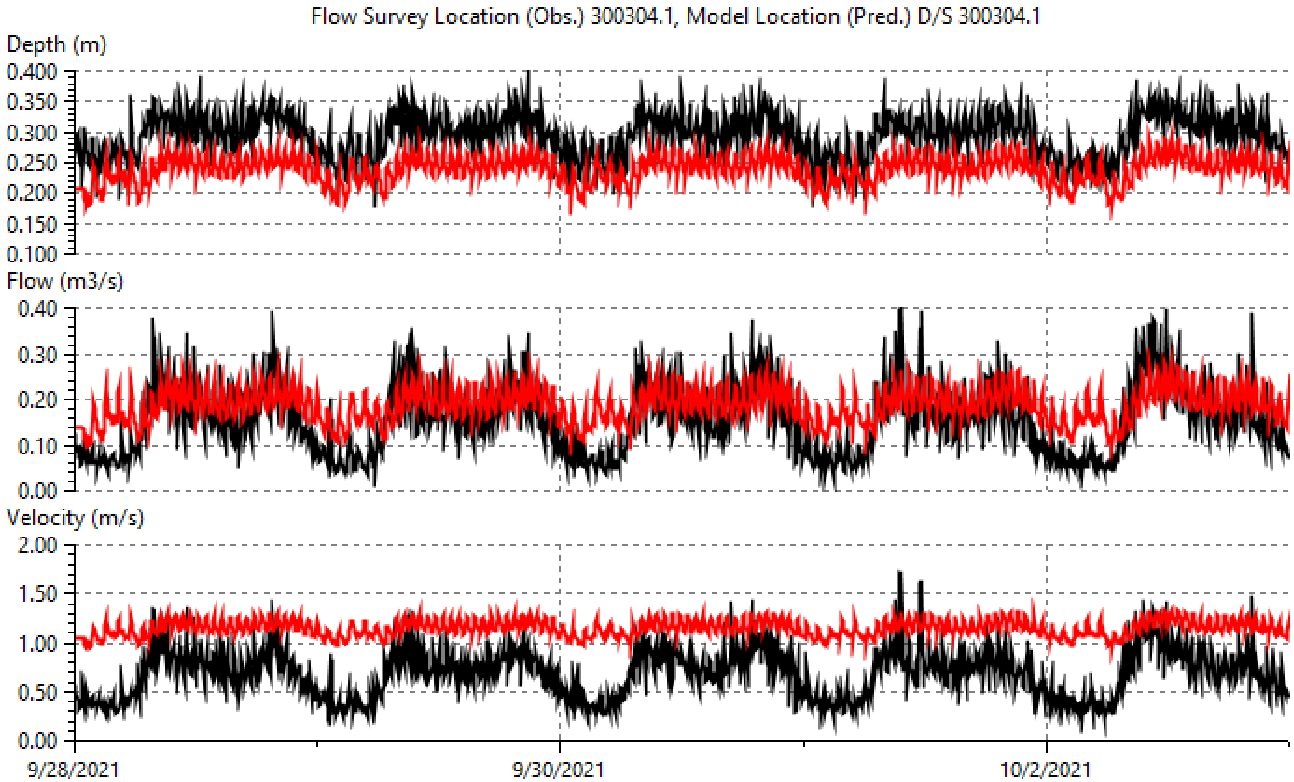


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.105	0.314	0.009	0.198	32323.995	0.170	1.250
Modelled	0.094	0.183	0.022	0.145	33197.016	0.731	1.850

FM10

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 4 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

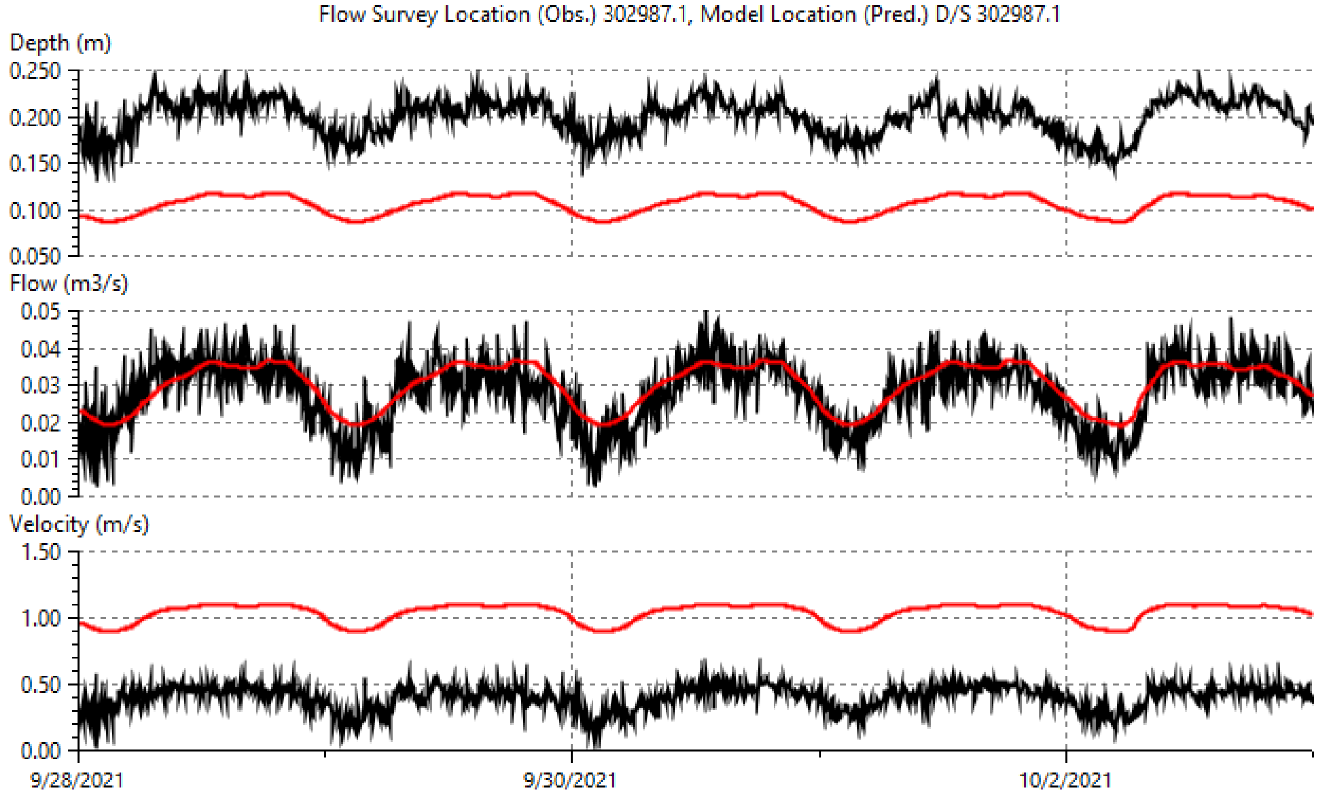


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.207	0.378	0.030	0.380	67057.420	0.220	1.570
Modelled	0.180	0.291	0.102	0.283	81032.922	0.957	1.334

FM11

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 6 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

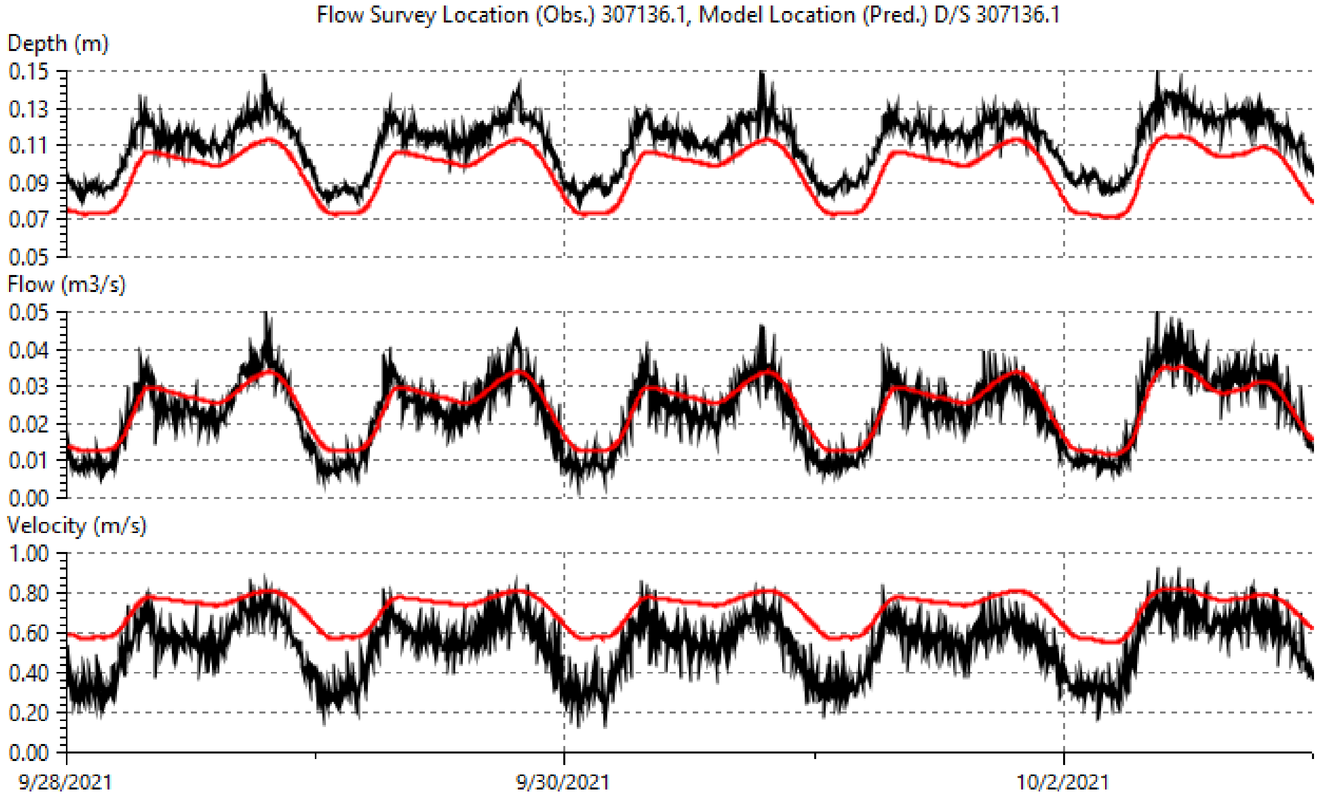


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.147	0.241	0.007	0.048	12176.059	0.140	0.570
Modelled	0.087	0.118	0.019	0.037	12964.103	0.893	1.106

FM12

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 15 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...



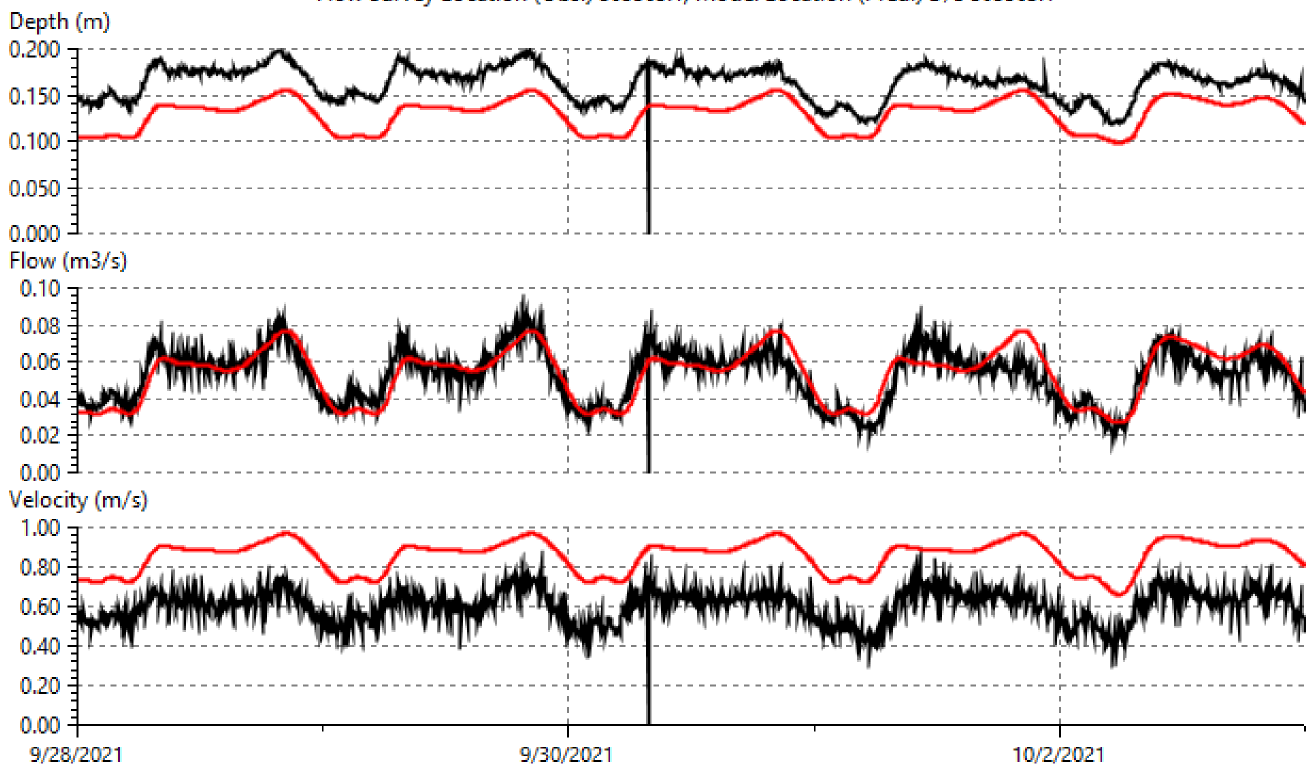
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.081	0.143	0.006	0.049	9976.614	0.220	0.840
Modelled	0.071	0.115	0.012	0.035	10547.915	0.551	0.820

FM13

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 9 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

Flow Survey Location (Obs.) 303563.1, Model Location (Pred.) D/S 303563.1

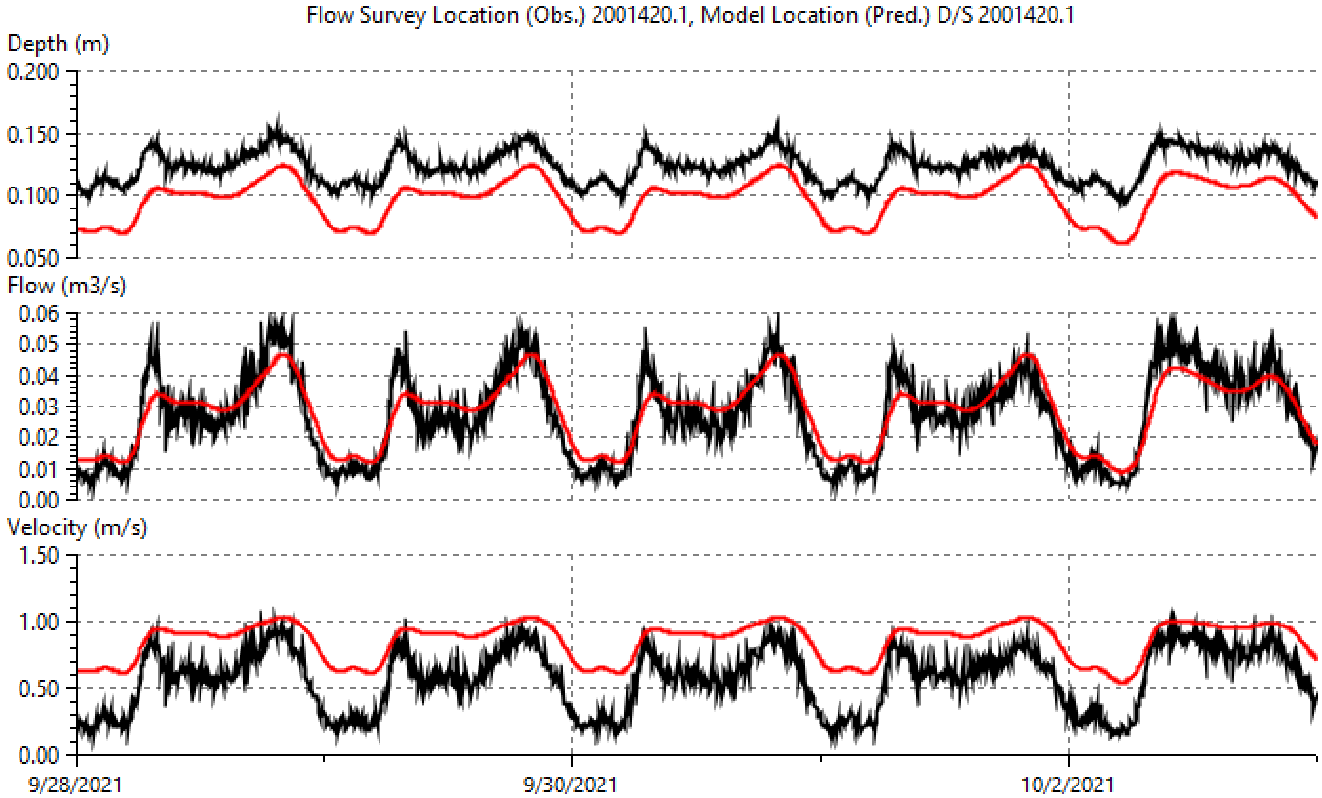


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.000	0.199	0.000	0.086	22934.014	0.000	0.810
Modelled	0.099	0.155	0.027	0.077	23304.763	0.660	0.968

FM13b

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 1 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...



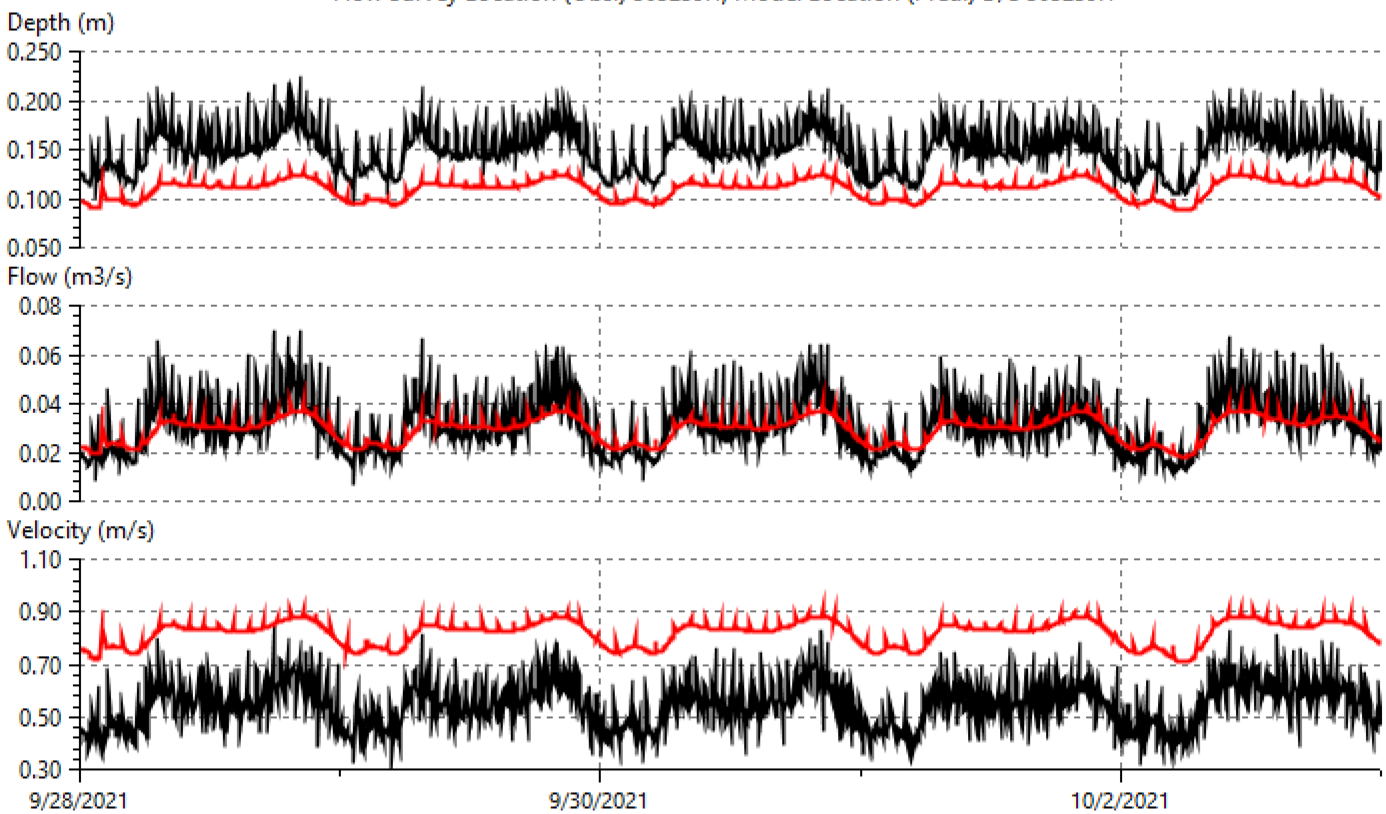
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.095	0.154	0.005	0.058	11816.190	0.140	1.000
Modelled	0.062	0.124	0.009	0.047	12329.280	0.544	1.029

FM15

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 7 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

Flow Survey Location (Obs.) 303239.1, Model Location (Pred.) D/S 303239.1



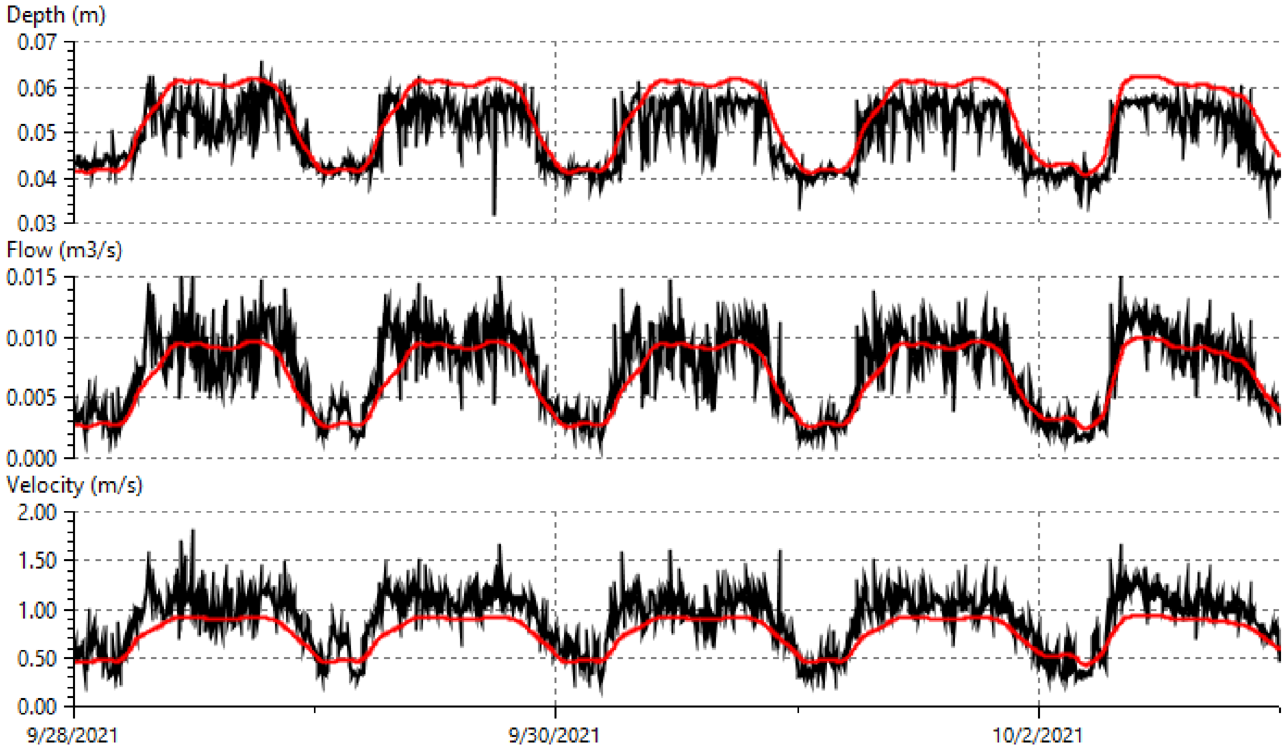
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.104	0.206	0.013	0.062	13436.501	0.370	0.770
Modelled	0.088	0.131	0.018	0.041	12724.330	0.709	0.913

FM18

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 14 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

Flow Survey Location (Obs.) 306551.1, Model Location (Pred.) D/S 306551.1

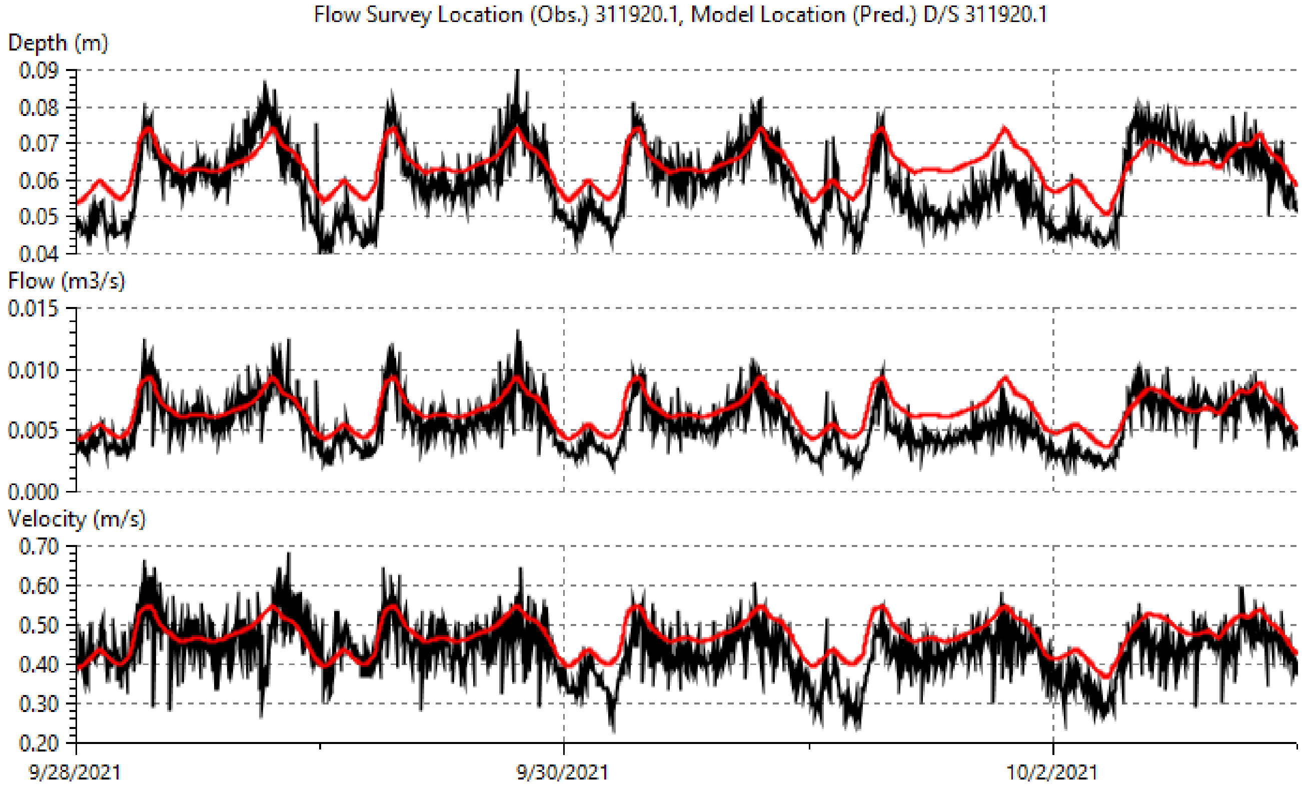


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.035	0.062	0.001	0.015	3159.502	0.270	1.640
Modelled	0.041	0.062	0.002	0.010	2948.620	0.426	0.935

FM19

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 20 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...

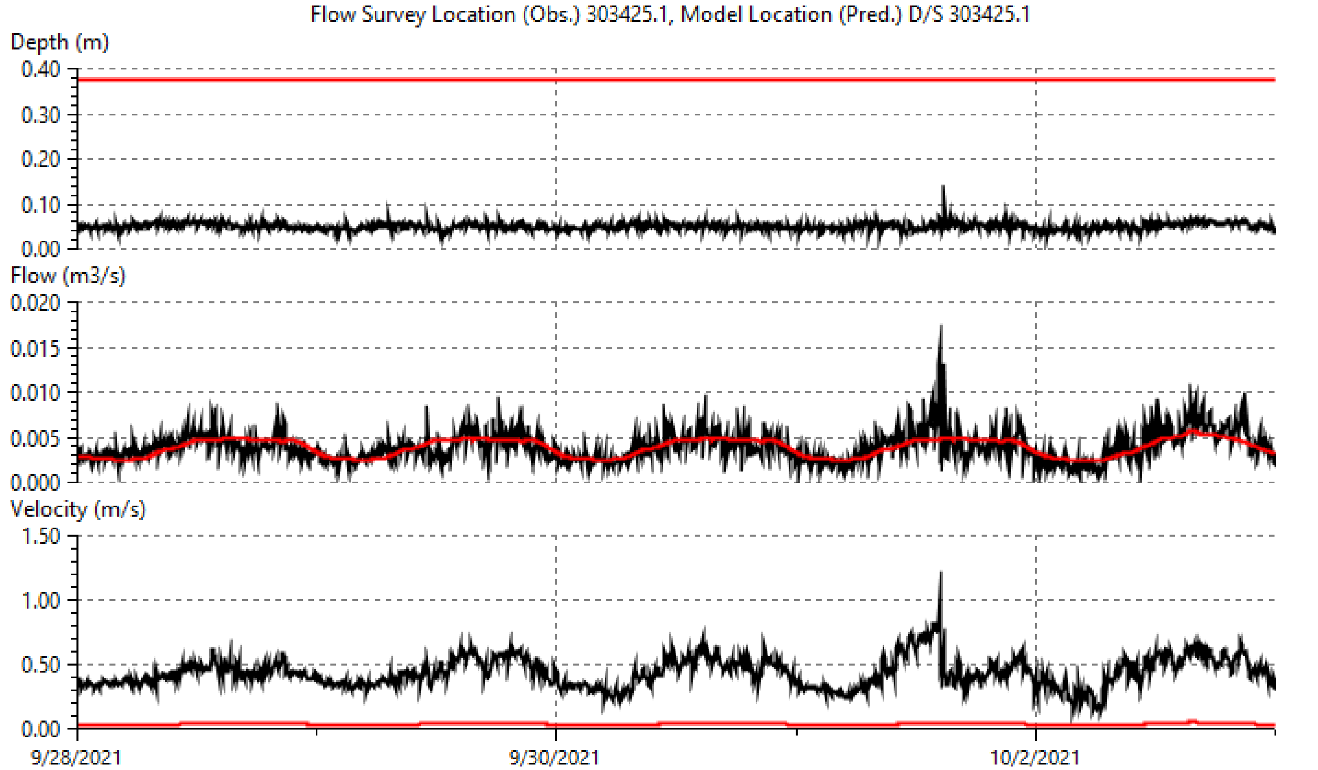


	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.041	0.088	0.002	0.012	2407.468	0.260	0.640
Modelled	0.051	0.074	0.004	0.009	2841.418	0.367	0.547

FM20

DWF Period 2

Kitchener Sanitary Master Plan - Dry Weather Calibration
Observed / Predicted Report Produced by vbassan (4/20/2022 11:33:36 AM) Page 8 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>DWF#2_20210928_Link_FM2FM9link (3/3/...
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>DWF-Calibration>DWF_E2_rev3_v10_it14_TM2c>WWF_it10 DWF ...



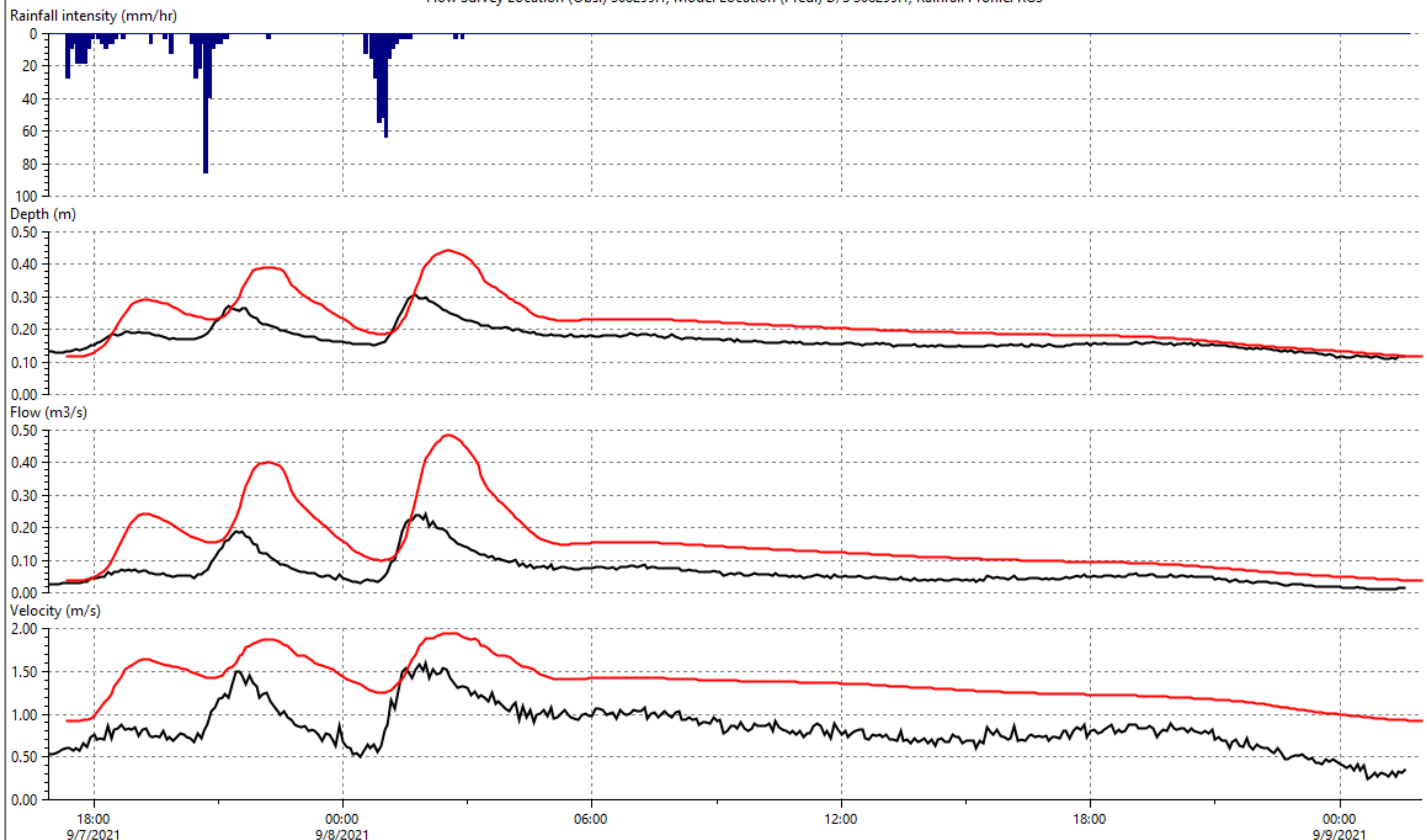
	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.029	0.104	0.001	0.016	1719.169	0.140	1.080
Modelled	0.375	0.375	0.002	0.006	1669.510	0.022	0.051

FM1

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 16 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 308299.1, Model Location (Pred.) D/S 308299.1, Rainfall Profile: RG3



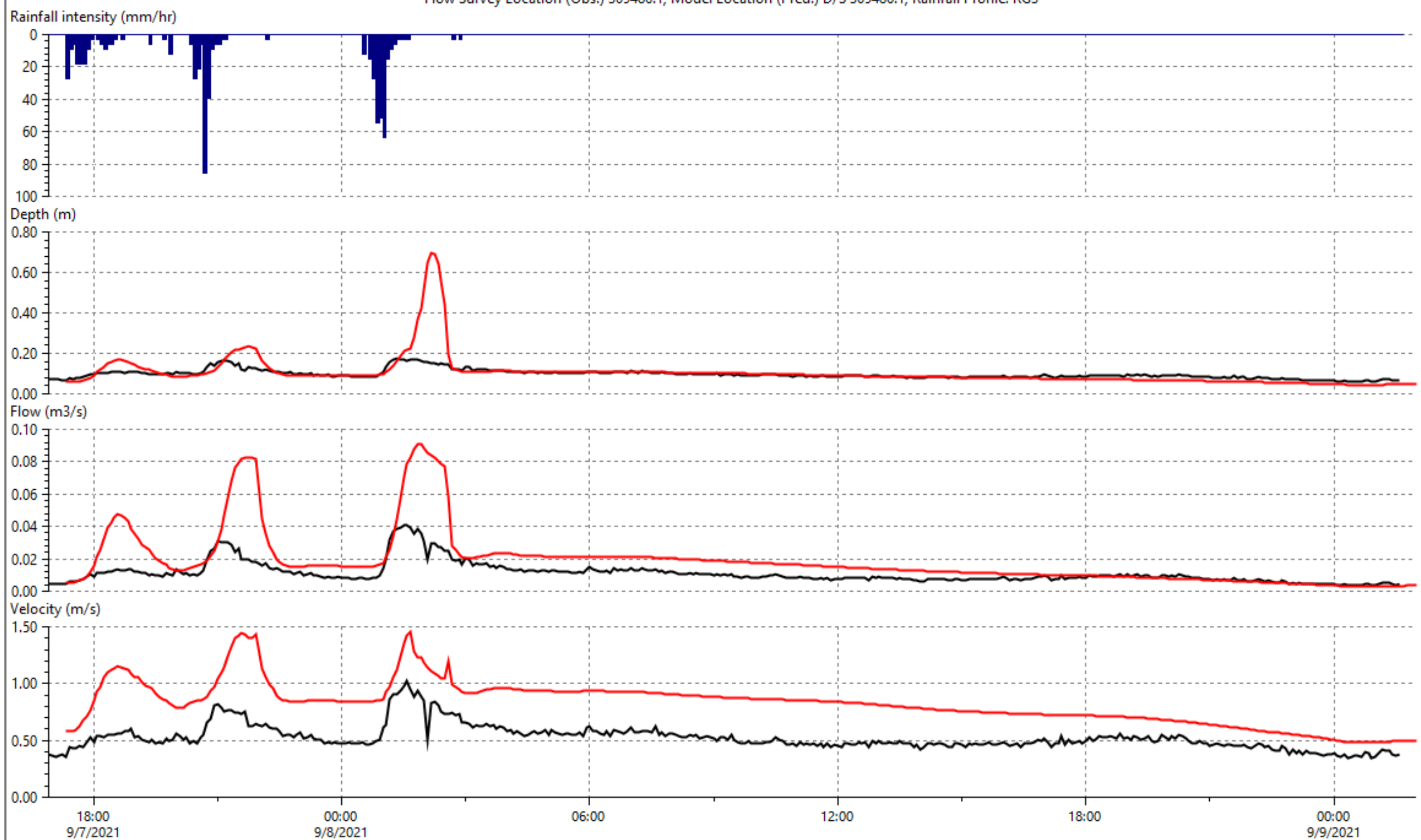
		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	blue line	54.867	85.340	1.671							
Observed	black line				0.110	0.307	0.010	0.244	7650.399	0.250	1.590
Modelled	red line				0.116	0.444	0.037	0.485	17659.840	0.919	1.944

FM1b

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 17 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 309486.1, Model Location (Pred.) D/S 309486.1, Rainfall Profile: RG3



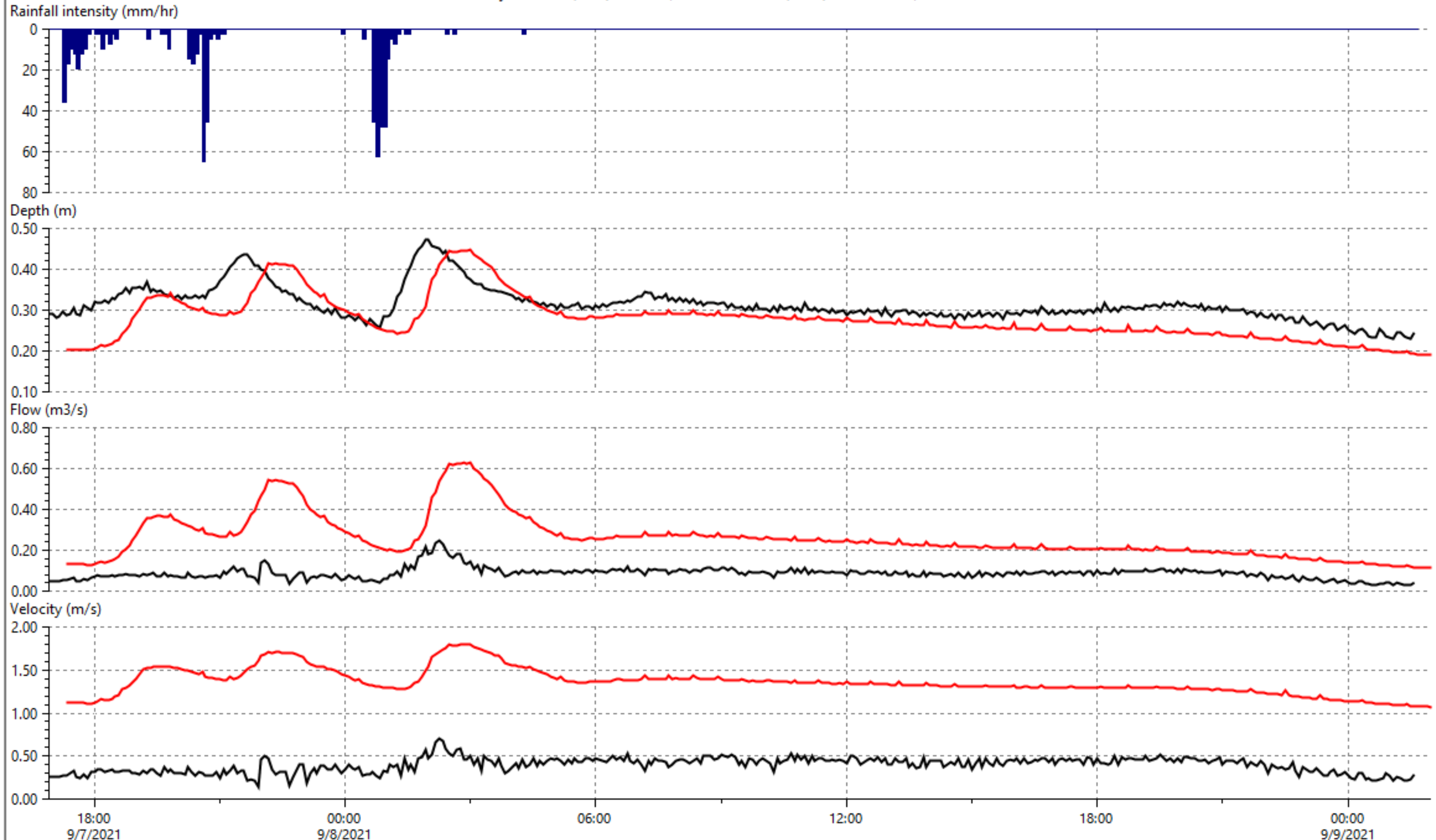
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	54.867	85.340	1.671							
Observed				0.061	0.174	0.004	0.041	1309.351	0.350	1.020
Modelled				0.045	0.699	0.003	0.091	2247.838	0.481	1.455

FM2

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 11 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 304472.1, Model Location (Pred.) D/S 304472.1, Rainfall Profile: RG1



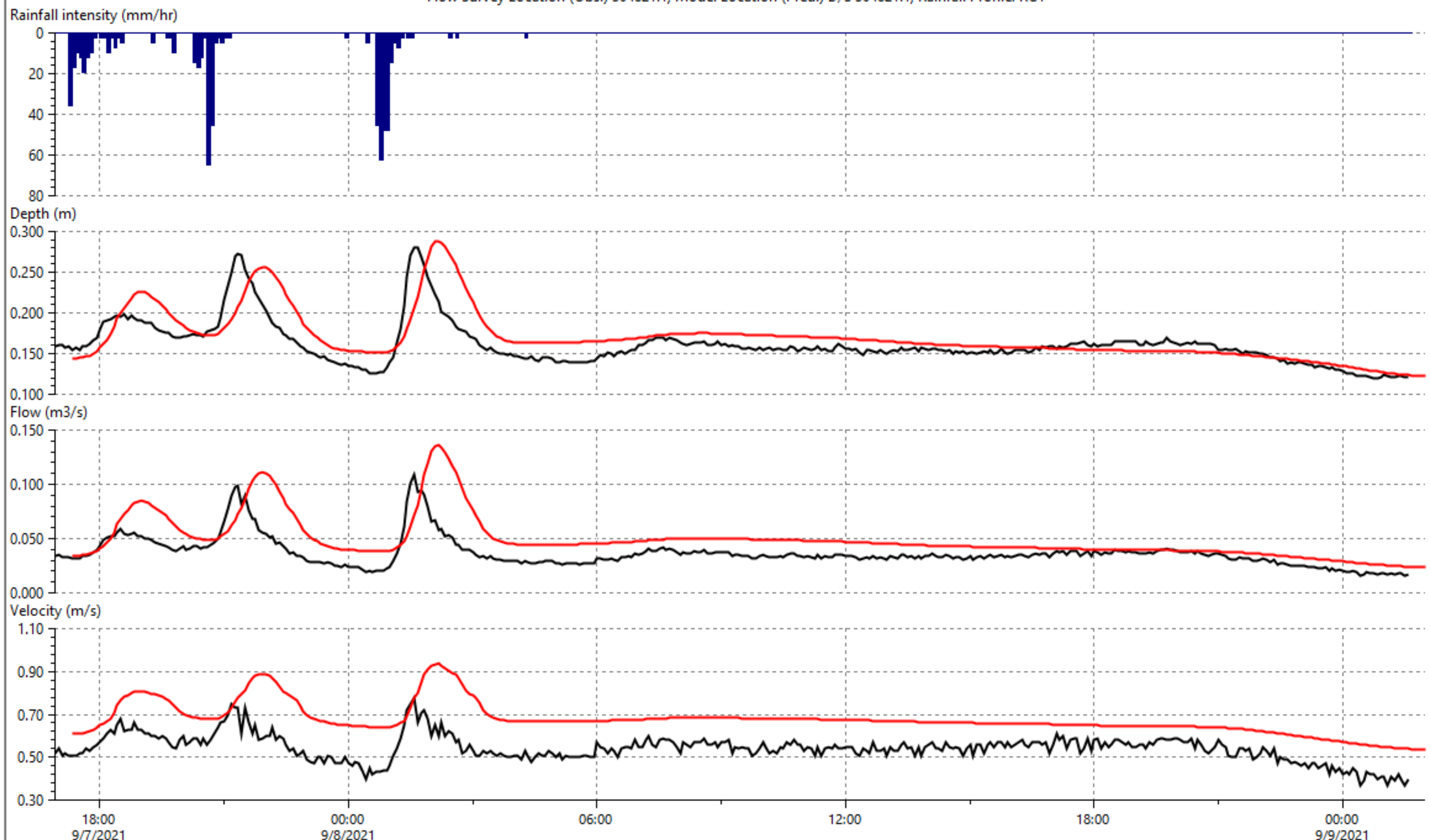
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	49.400	64.800	1.505							
Observed				0.230	0.474	0.030	0.249	10345.747	0.140	0.700
Modelled				0.190	0.447	0.115	0.633	30806.883	1.072	1.798

FM2b

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 12 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 304821.1, Model Location (Pred.) D/S 304821.1, Rainfall Profile: RG1



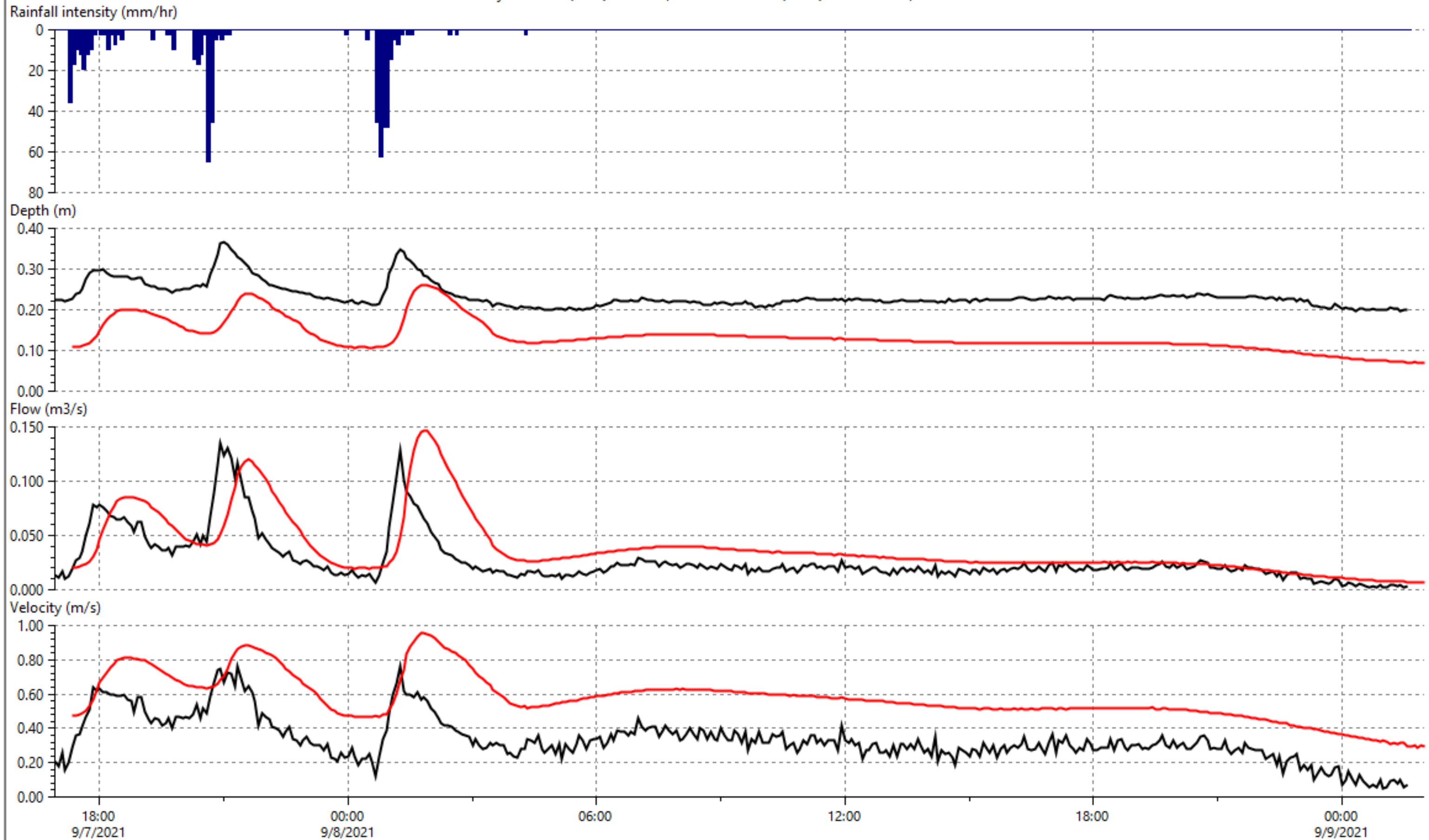
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	49.400	64.800	1.505							
Observed				0.120	0.281	0.016	0.109	4315.209	0.370	0.780
Modelled				0.122	0.288	0.024	0.136	5813.697	0.537	0.936

FM3

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 18 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 311167.1, Model Location (Pred.) D/S 311167.1, Rainfall Profile: RG1



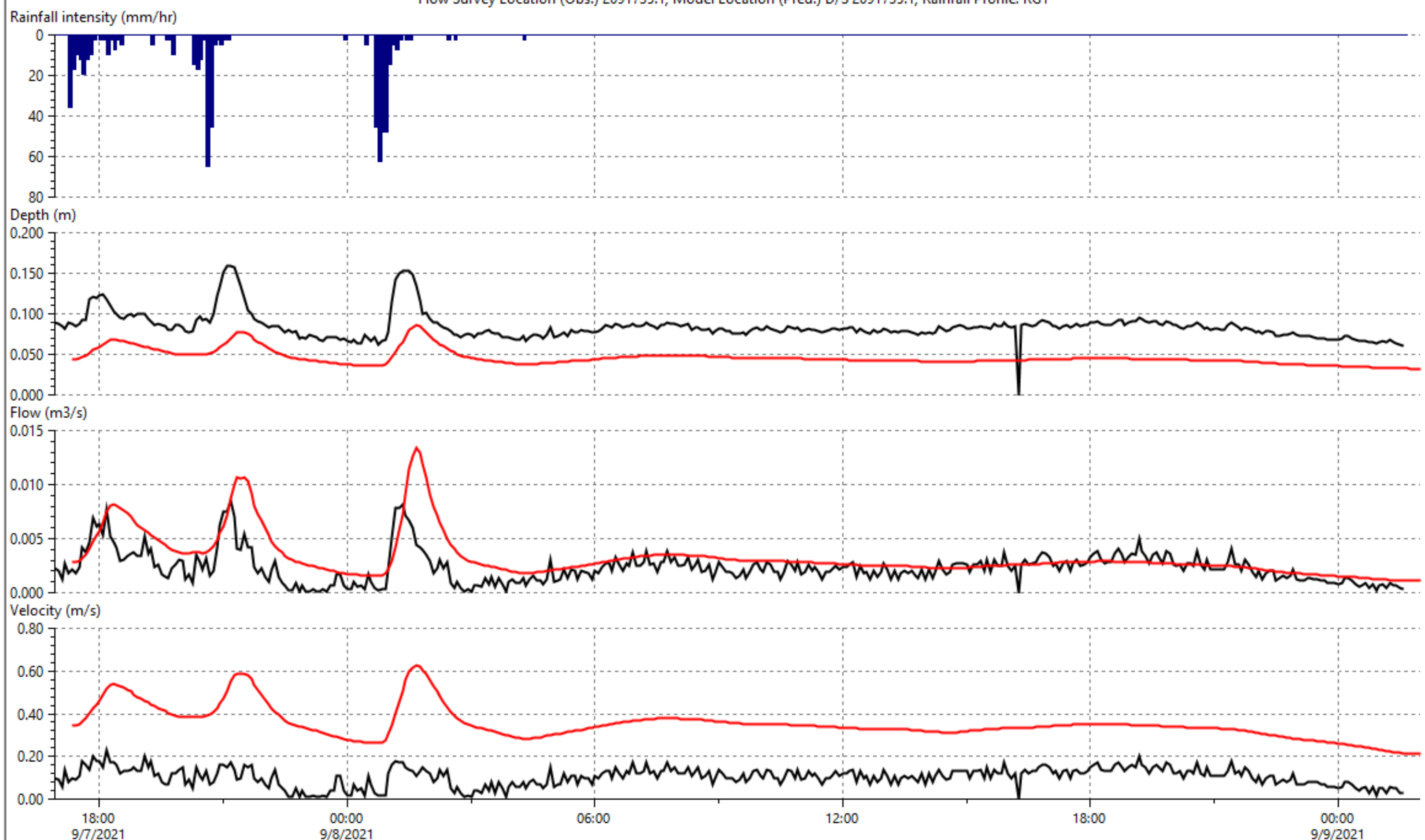
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	49.400	64.800	1.505							
Observed				0.198	0.368	0.002	0.135	3196.485	0.050	0.760
Modelled				0.070	0.262	0.007	0.147	4536.343	0.290	0.956

FM3b

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 2 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 2091735.1, Model Location (Pred.) D/S 2091735.1, Rainfall Profile: RG1

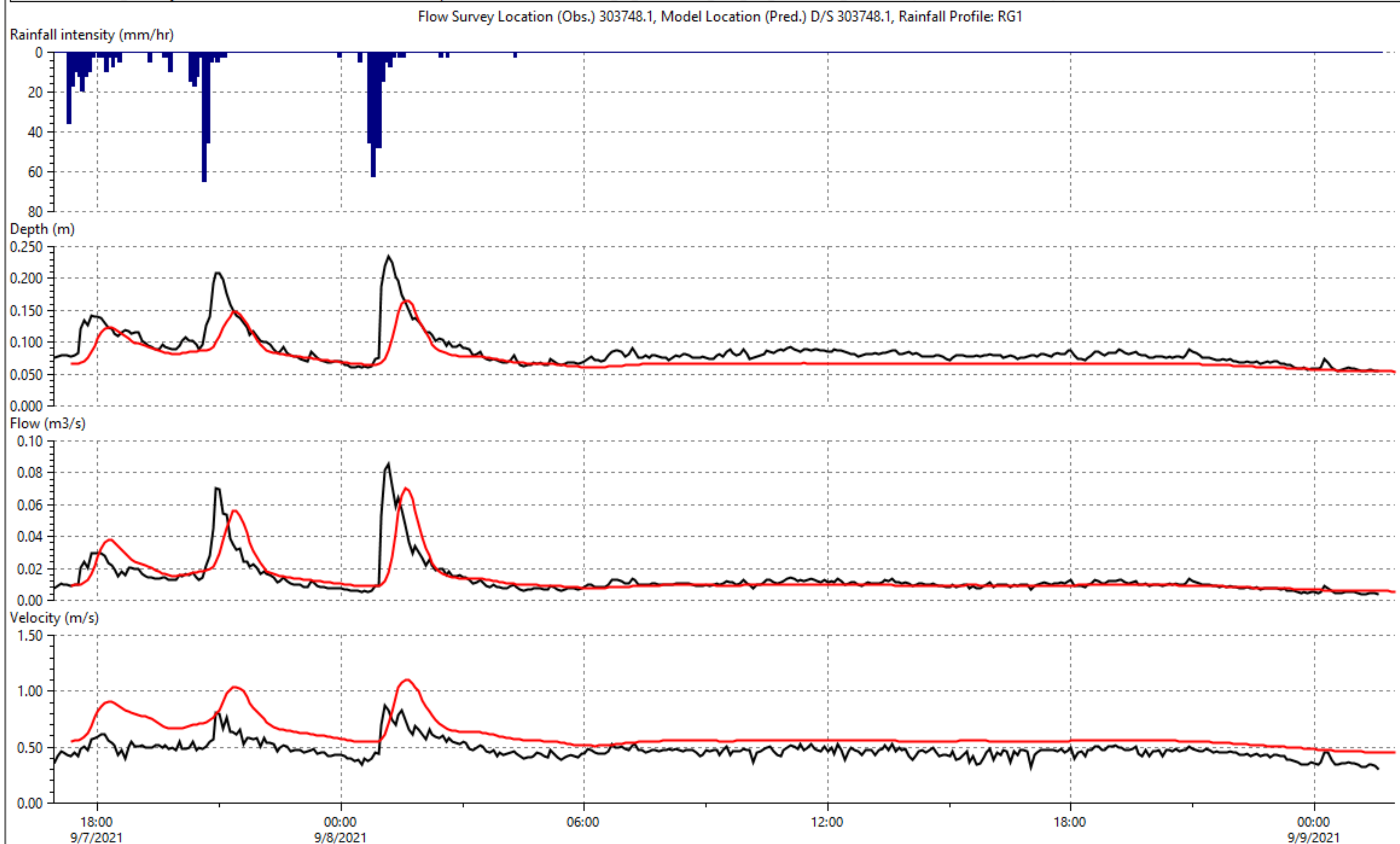


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	49.400	64.800	1.505							
Observed				0.000	0.159	0.000	0.009	271.973	0.000	0.230
Modelled				0.033	0.086	0.001	0.013	382.783	0.213	0.629

FM4

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 10 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)



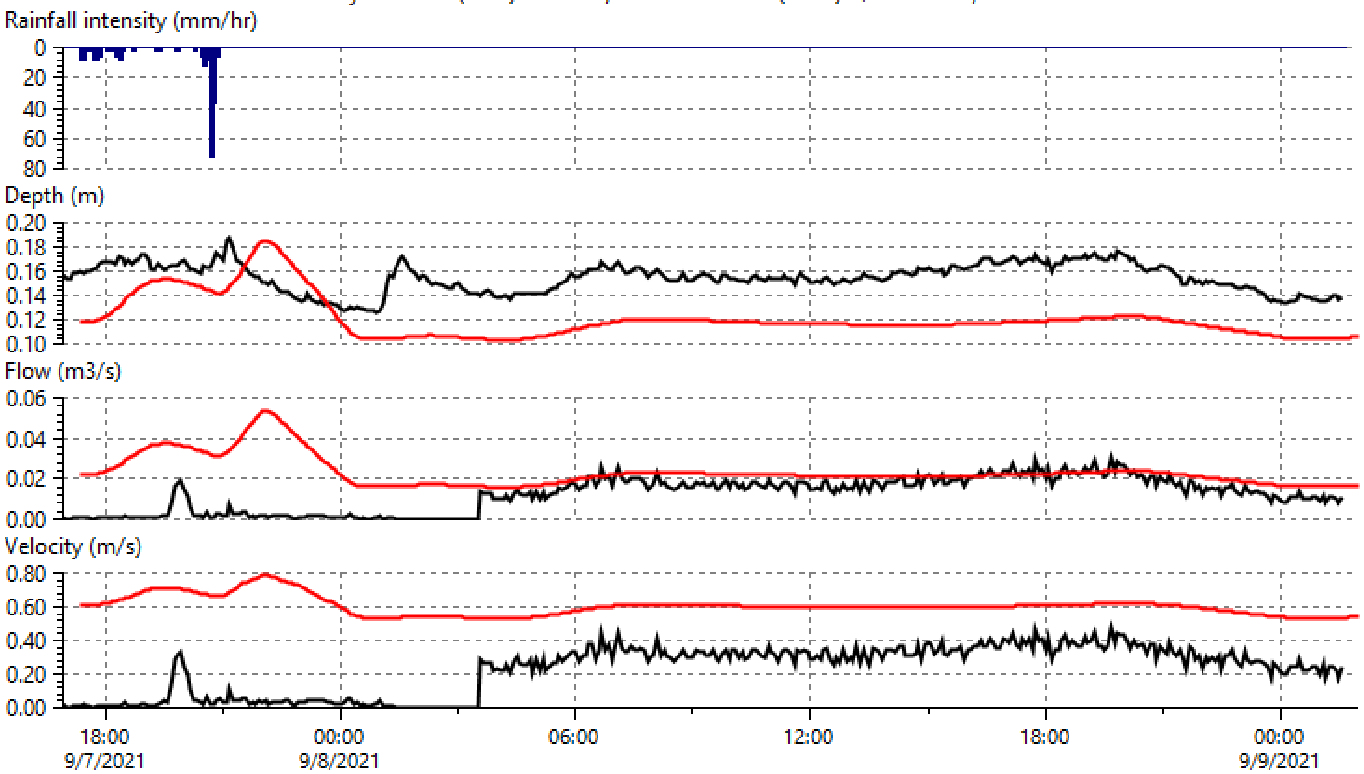
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	49.400	64.800	1.505							
Observed				0.054	0.236	0.004	0.086	1553.307	0.300	0.870
Modelled				0.054	0.166	0.006	0.070	1557.021	0.448	1.104

FM5b

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/26/2022 11:45:30 AM) Page 19 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1_FM5blink (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10_TM2c>WWF_it10 ...

Flow Survey Location (Obs.) 311440.1, Model Location (Pred.) U/S 311440.1, Rainfall Profile: RG6



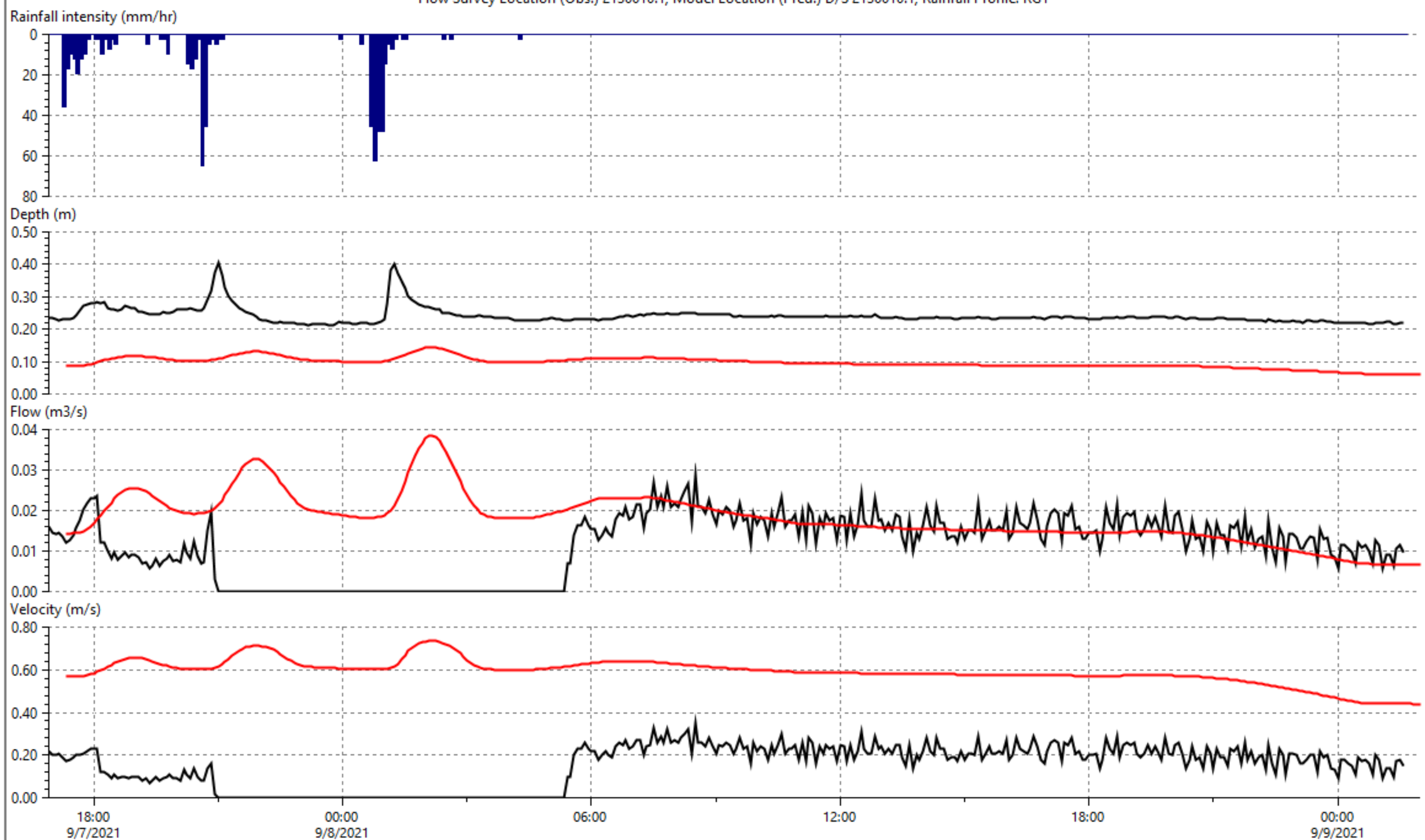
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	19.559	73.150	0.596							
Observed				0.126	0.187	0.000	0.030	1456.065	0.000	0.480
Modelled				0.103	0.185	0.016	0.054	2741.767	0.530	0.787

FM6

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 3 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

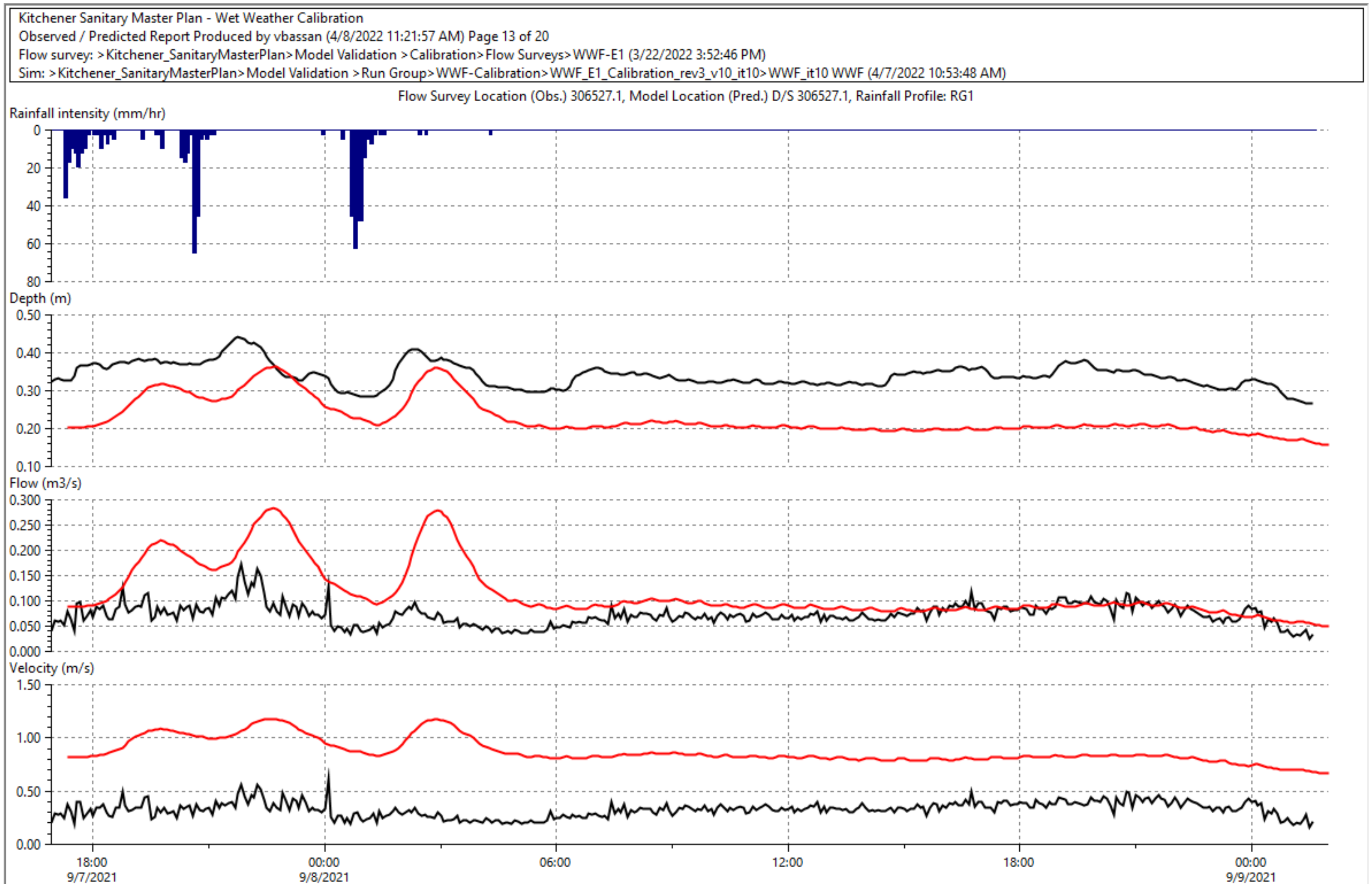
Flow Survey Location (Obs.) 2130010.1, Model Location (Pred.) D/S 2130010.1, Rainfall Profile: RG1



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	49.400	64.800	1.505							
Observed				0.213	0.407	0.000	0.029	1322.522	0.000	0.350
Modelled				0.061	0.145	0.007	0.039	2123.895	0.439	0.736

FM7

WWF Event 1

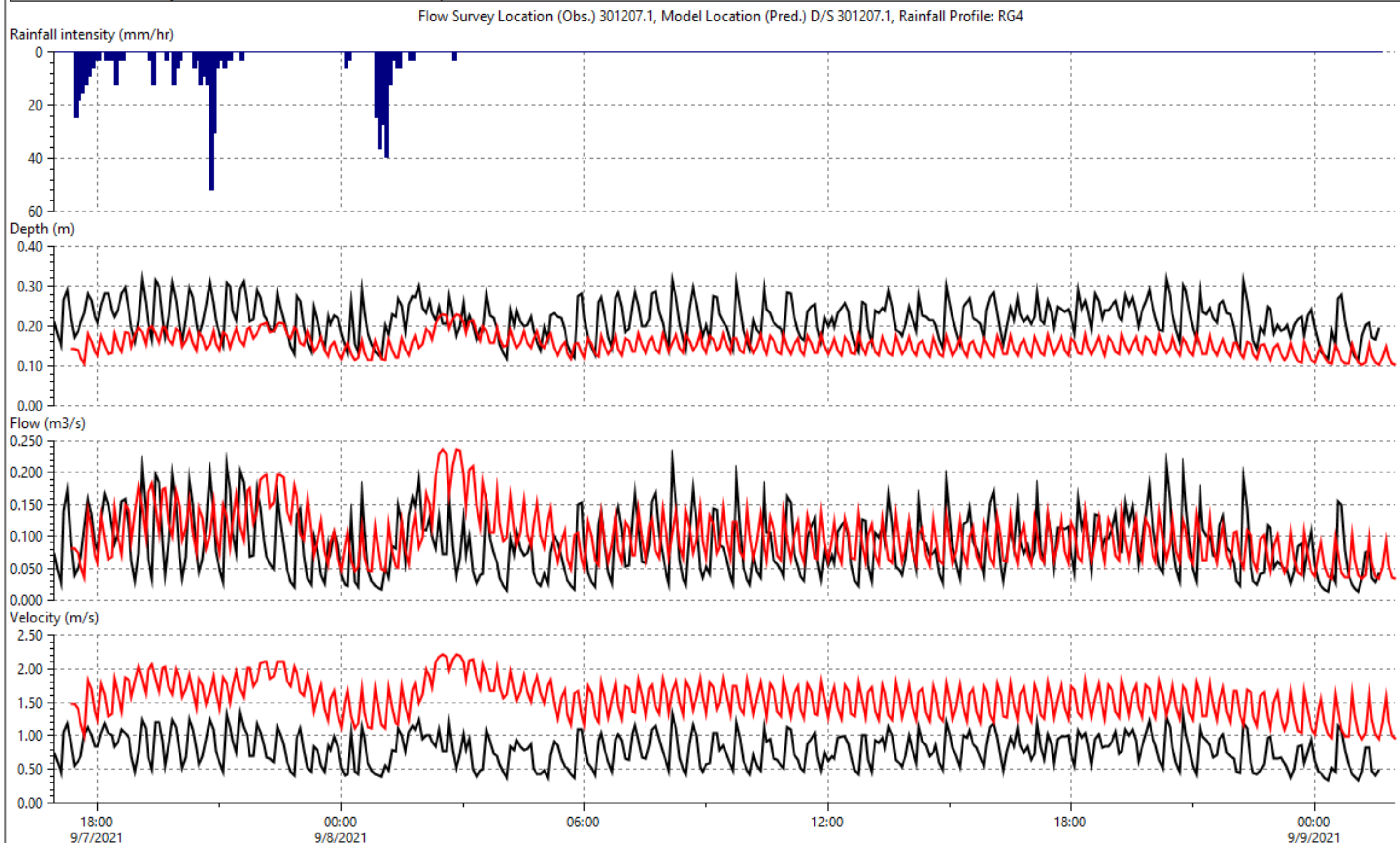


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	49.400	64.800	1.505							
Observed				0.266	0.443	0.025	0.173	8669.804	0.160	0.610
Modelled				0.156	0.363	0.049	0.284	13692.474	0.665	1.179

FM9

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 5 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)



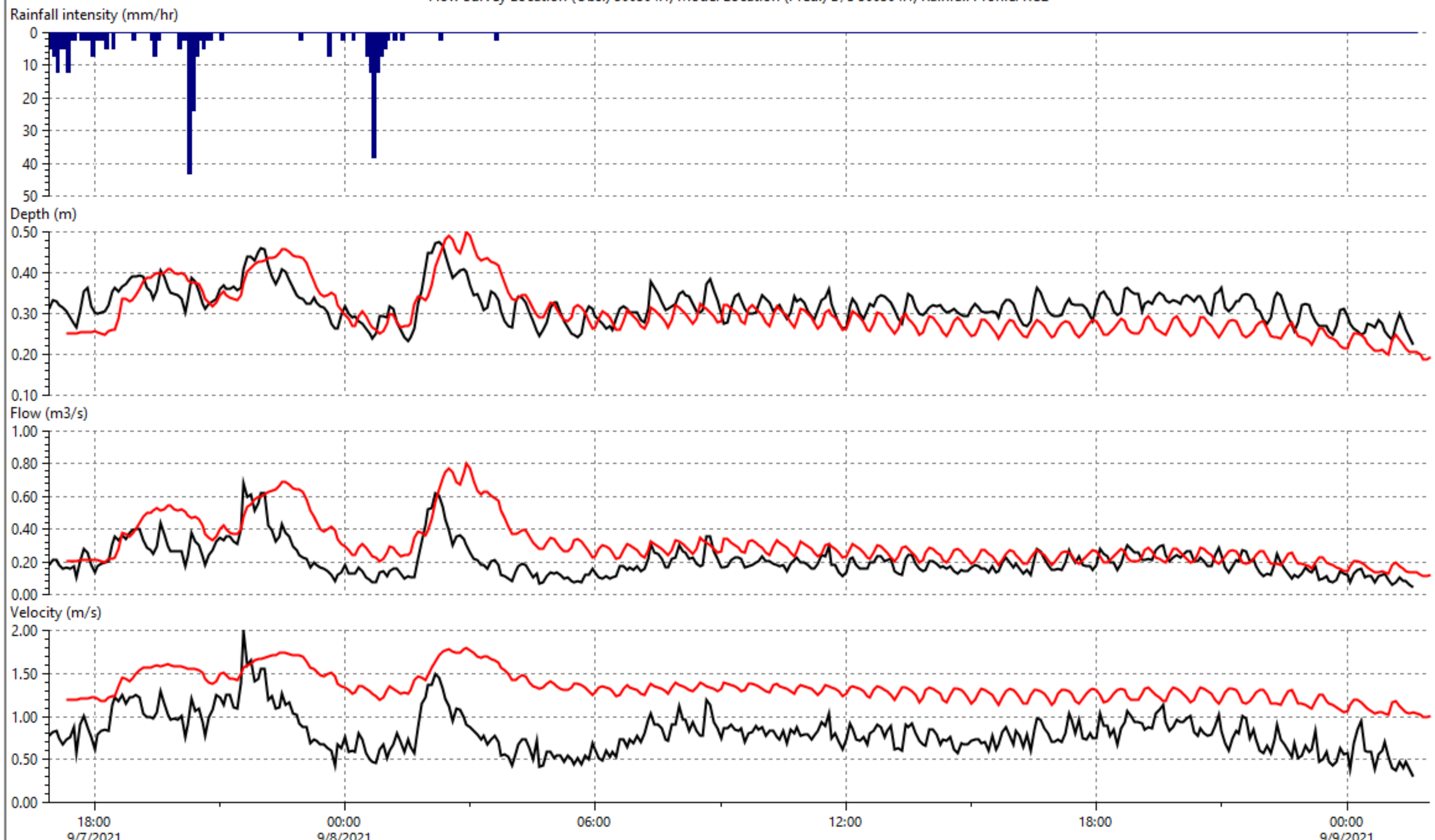
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	40.136	51.820	1.222							
Observed				0.117	0.319	0.014	0.217	10266.139	0.340	1.340
Modelled				0.104	0.229	0.034	0.236	11743.802	0.956	2.205

FM10

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 4 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 300304.1, Model Location (Pred.) D/S 300304.1, Rainfall Profile: RG2



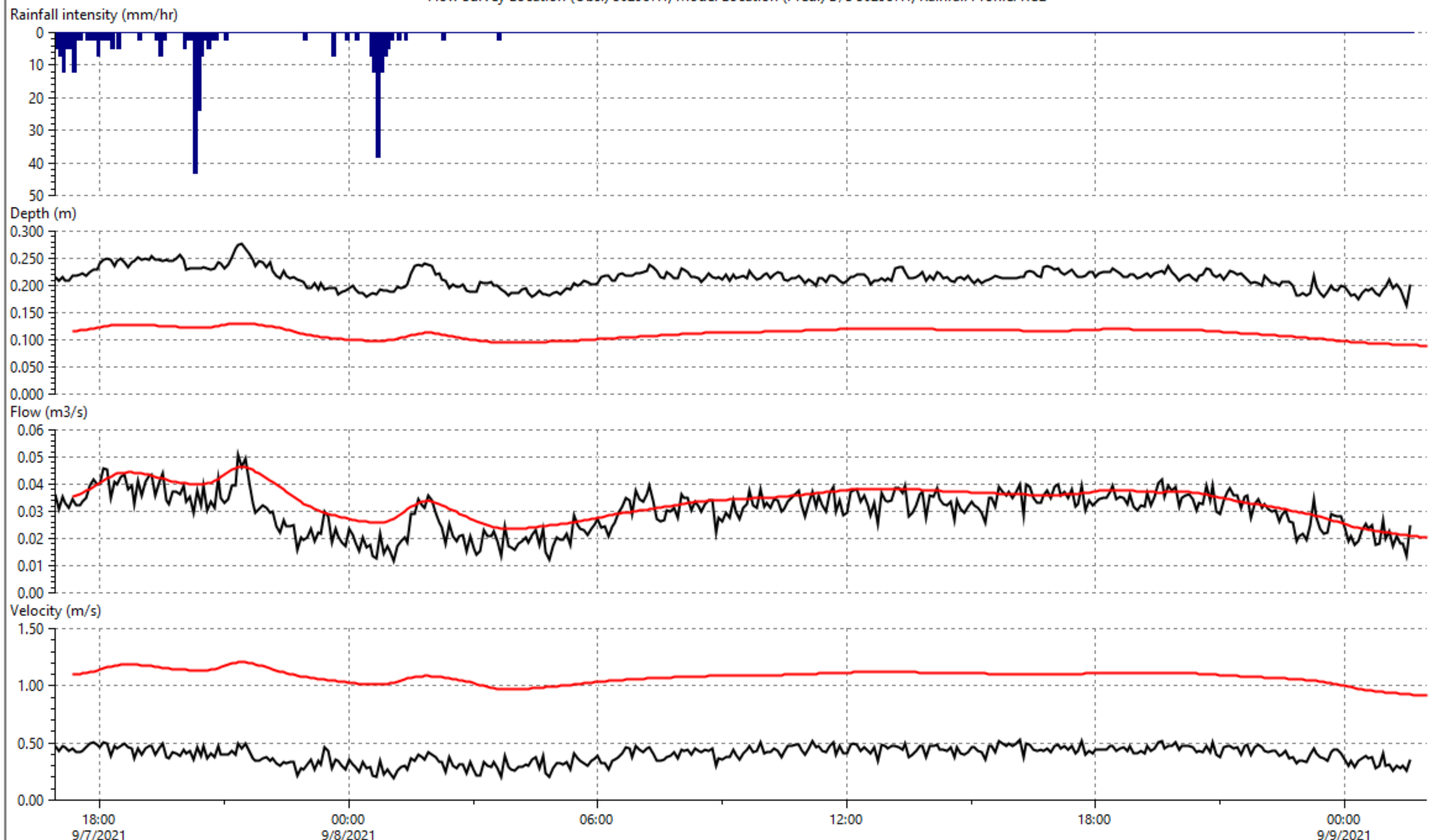
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	25.200	43.200	0.768							
Observed				0.225	0.475	0.044	0.683	24611.073	0.300	2.000
Modelled				0.187	0.499	0.111	0.801	36592.972	0.986	1.798

FM11

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 6 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 302987.1, Model Location (Pred.) D/S 302987.1, Rainfall Profile: RG2



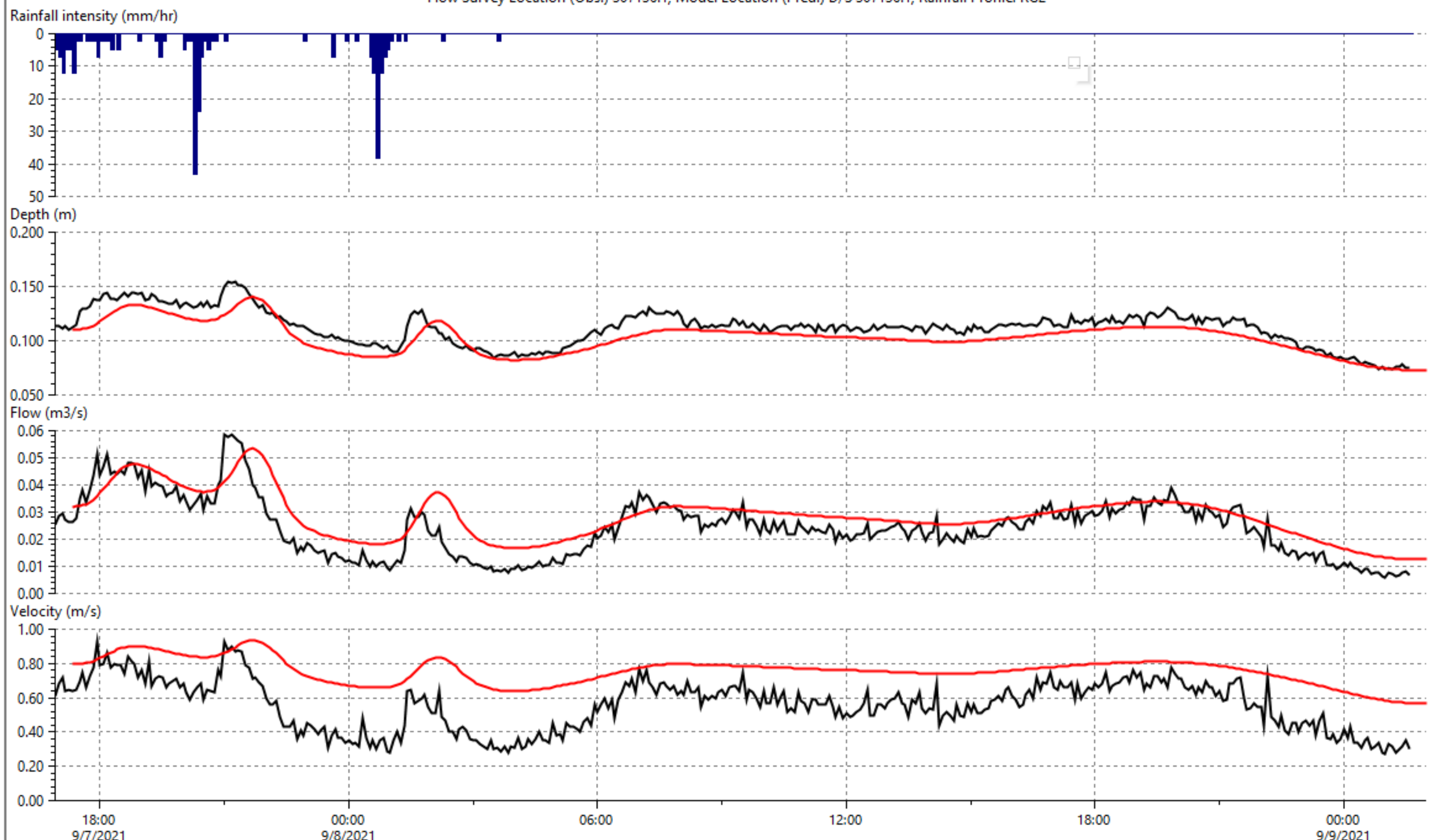
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	25.200	43.200	0.768							
Observed				0.164	0.277	0.012	0.051	3541.855	0.190	0.530
Modelled				0.089	0.131	0.020	0.046	3956.574	0.913	1.207

FM12

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 15 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 307136.1, Model Location (Pred.) D/S 307136.1, Rainfall Profile: RG2



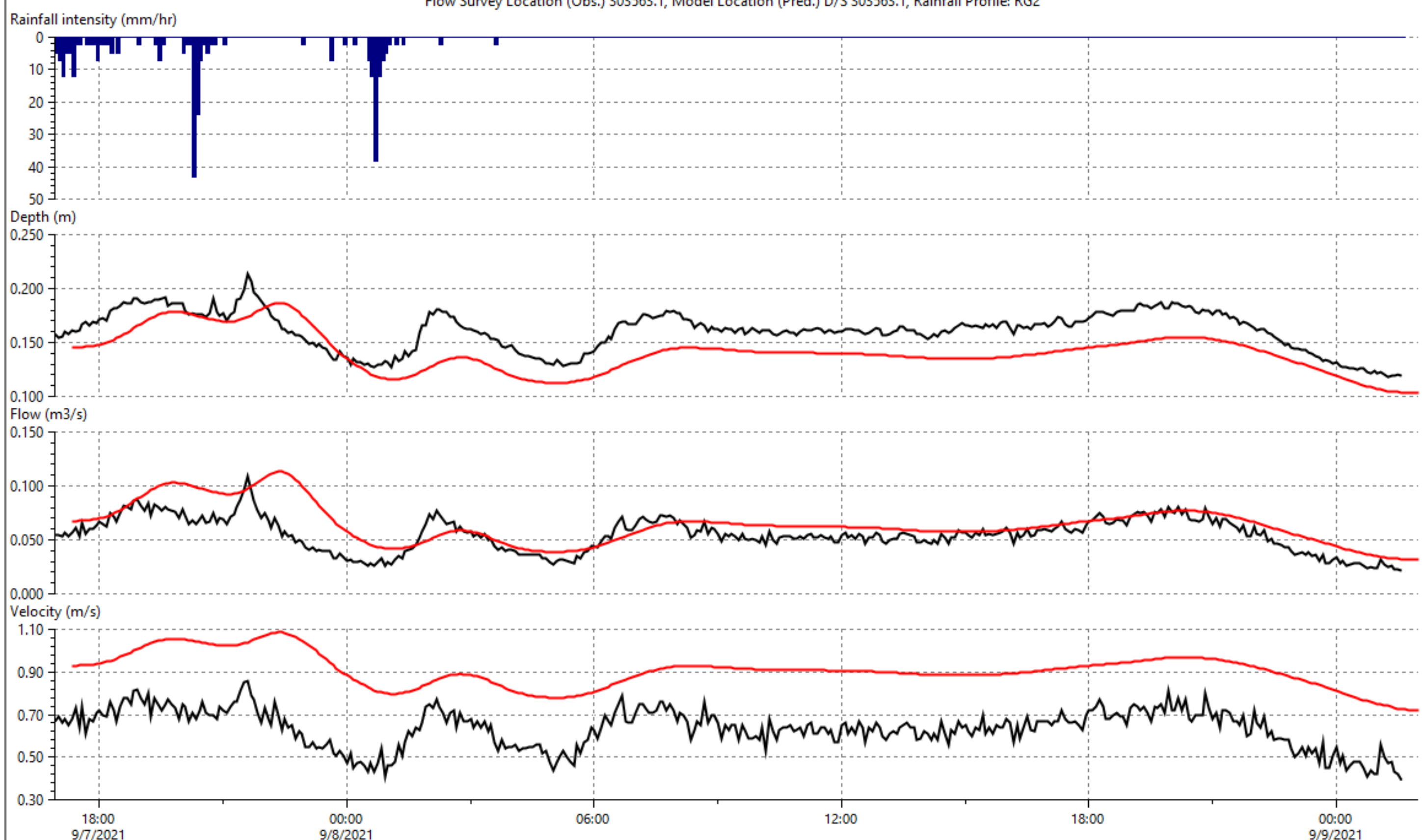
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	25.200	43.200	0.768							
Observed				0.074	0.155	0.006	0.059	2875.149	0.270	0.930
Modelled				0.073	0.141	0.013	0.054	3342.486	0.569	0.934

FM13

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 9 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 303563.1, Model Location (Pred.) D/S 303563.1, Rainfall Profile: RG2



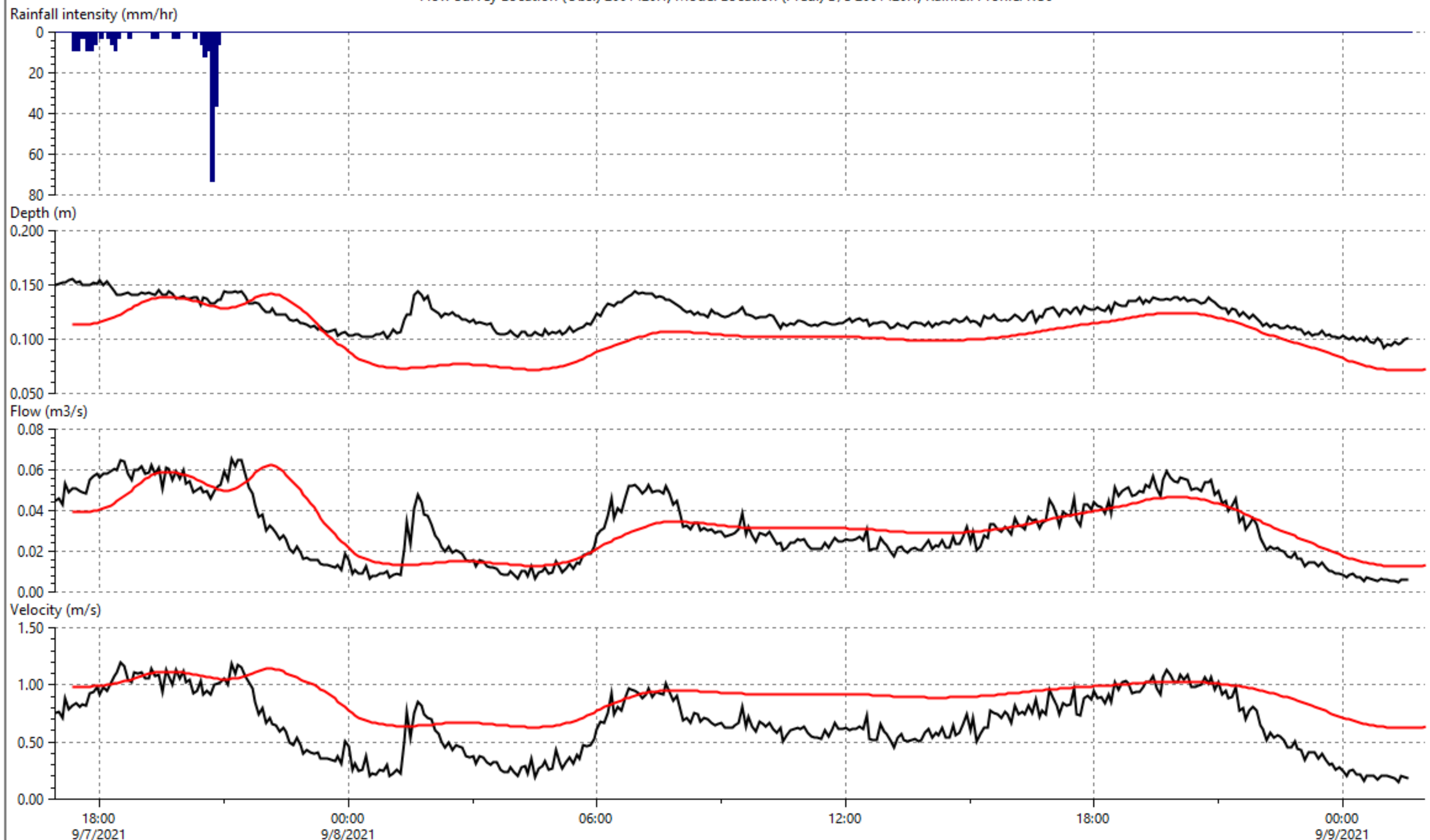
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	25.200	43.200	0.768							
Observed				0.118	0.214	0.021	0.109	6463.693	0.390	0.860
Modelled				0.103	0.187	0.032	0.113	7527.470	0.721	1.086

FM13b

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 1 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 2001420.1, Model Location (Pred.) D/S 2001420.1, Rainfall Profile: RG6

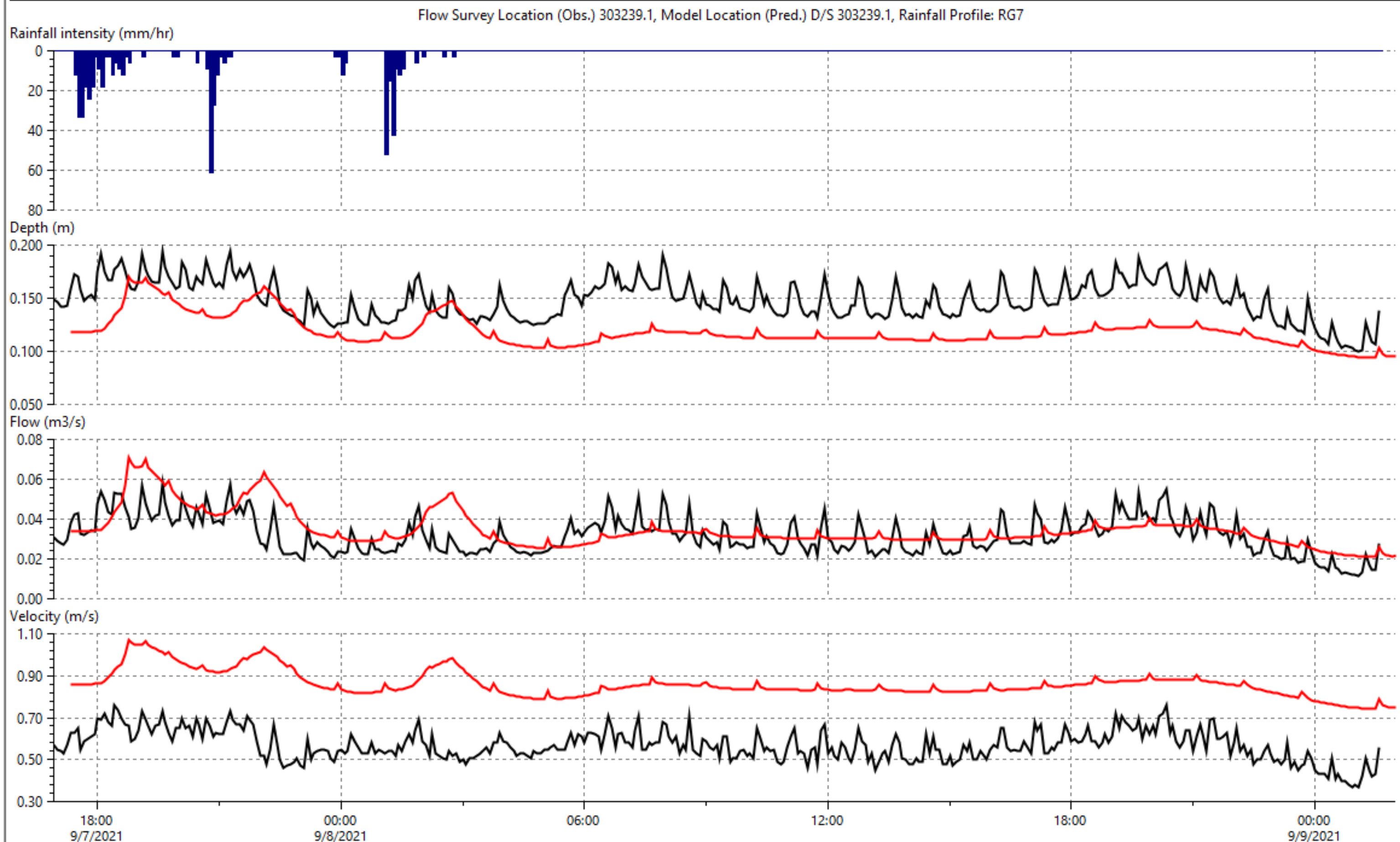


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	19.559	73.150	0.596							
Observed				0.092	0.155	0.005	0.066	3668.097	0.150	1.200
Modelled				0.071	0.142	0.013	0.062	3783.305	0.624	1.143

FM15

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 7 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)



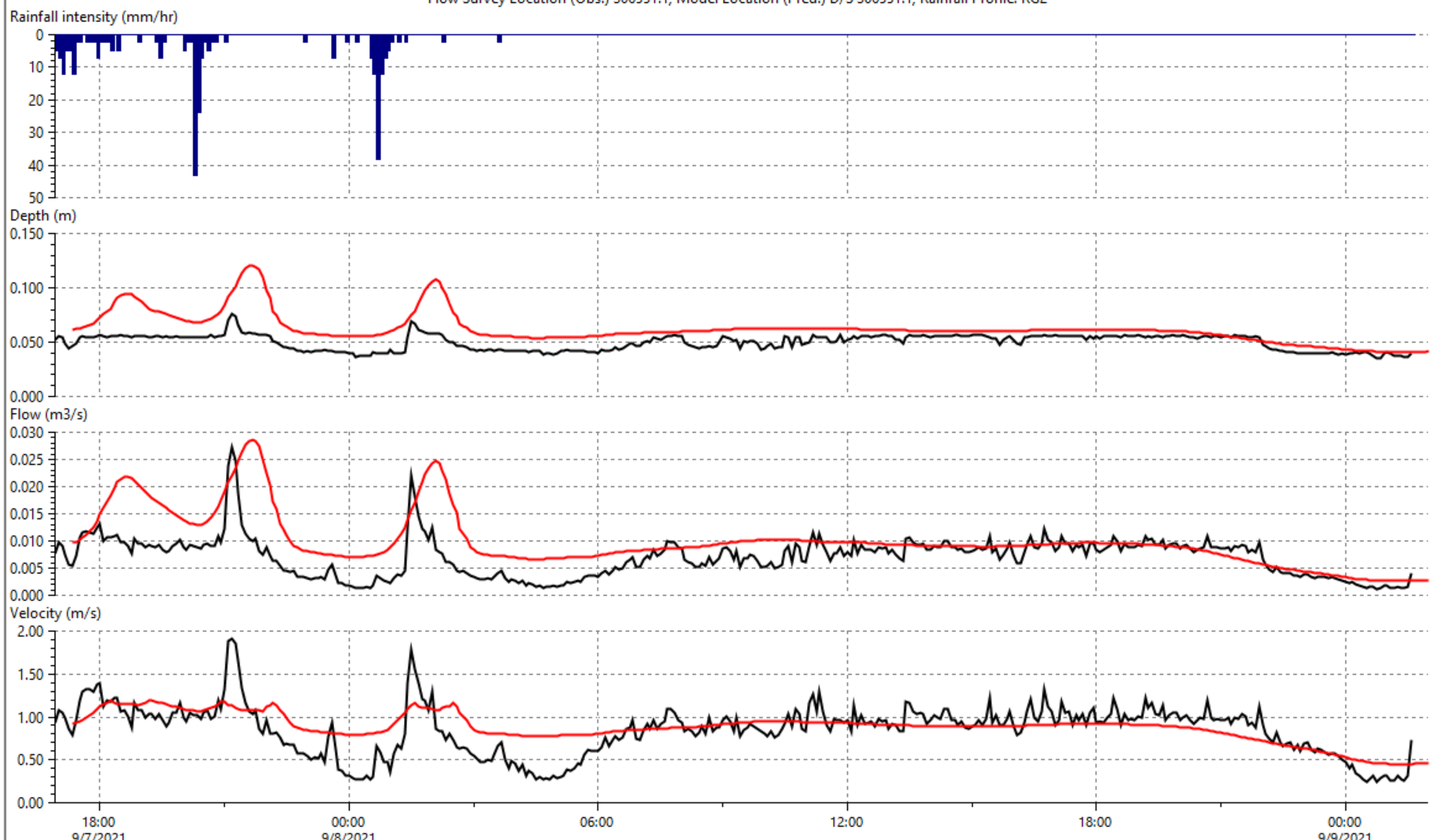
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	45.468	60.960	1.385							
Observed				0.100	0.194	0.012	0.058	3742.249	0.370	0.760
Modelled				0.094	0.171	0.021	0.071	4088.249	0.744	1.073

FM18

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 14 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

Flow Survey Location (Obs.) 306551.1, Model Location (Pred.) D/S 306551.1, Rainfall Profile: RG2

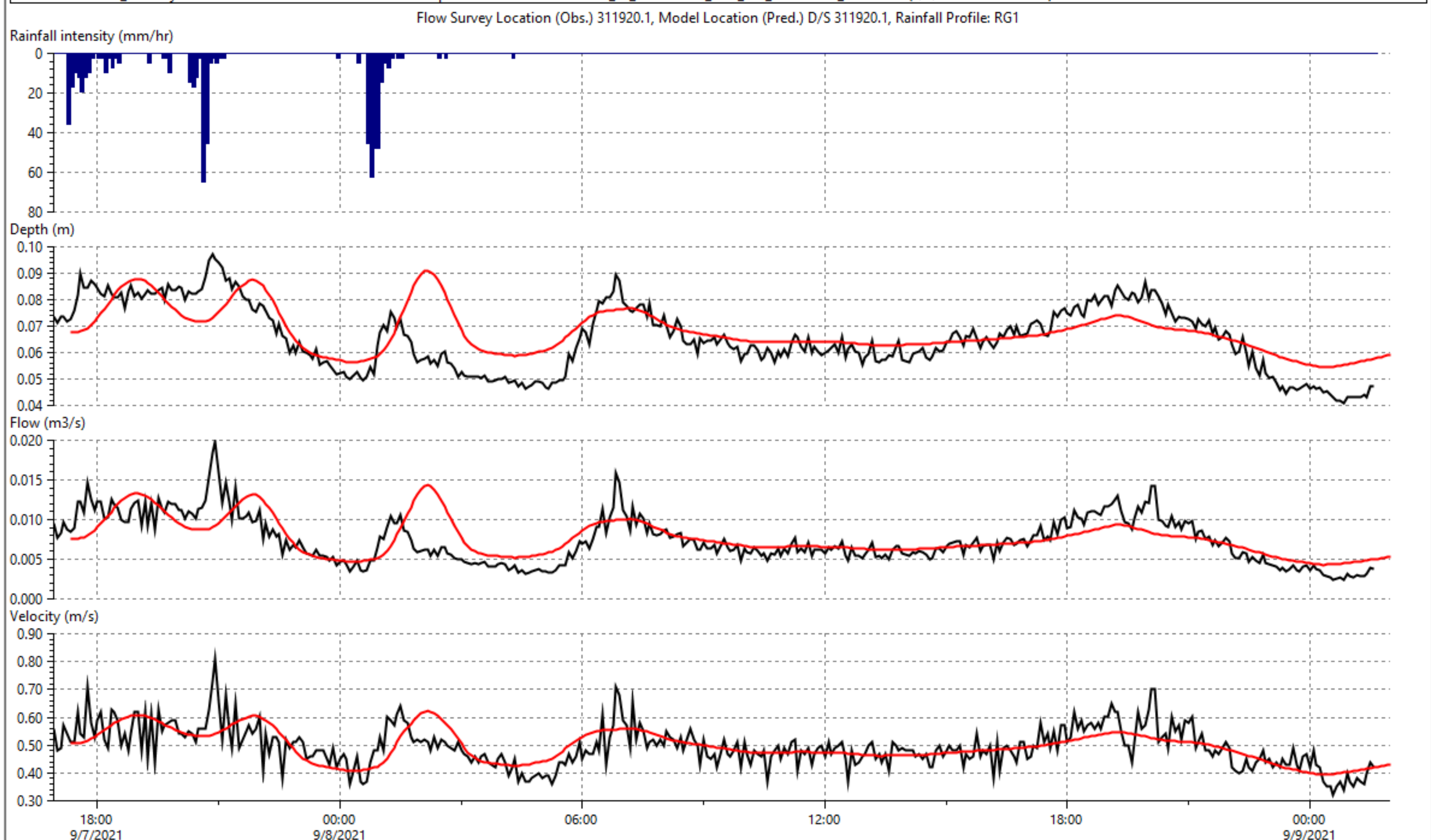


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	25.200	43.200	0.768							
Observed				0.036	0.076	0.001	0.027	824.443	0.250	1.920
Modelled				0.041	0.121	0.003	0.029	1170.445	0.451	1.201

FM19

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 20 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

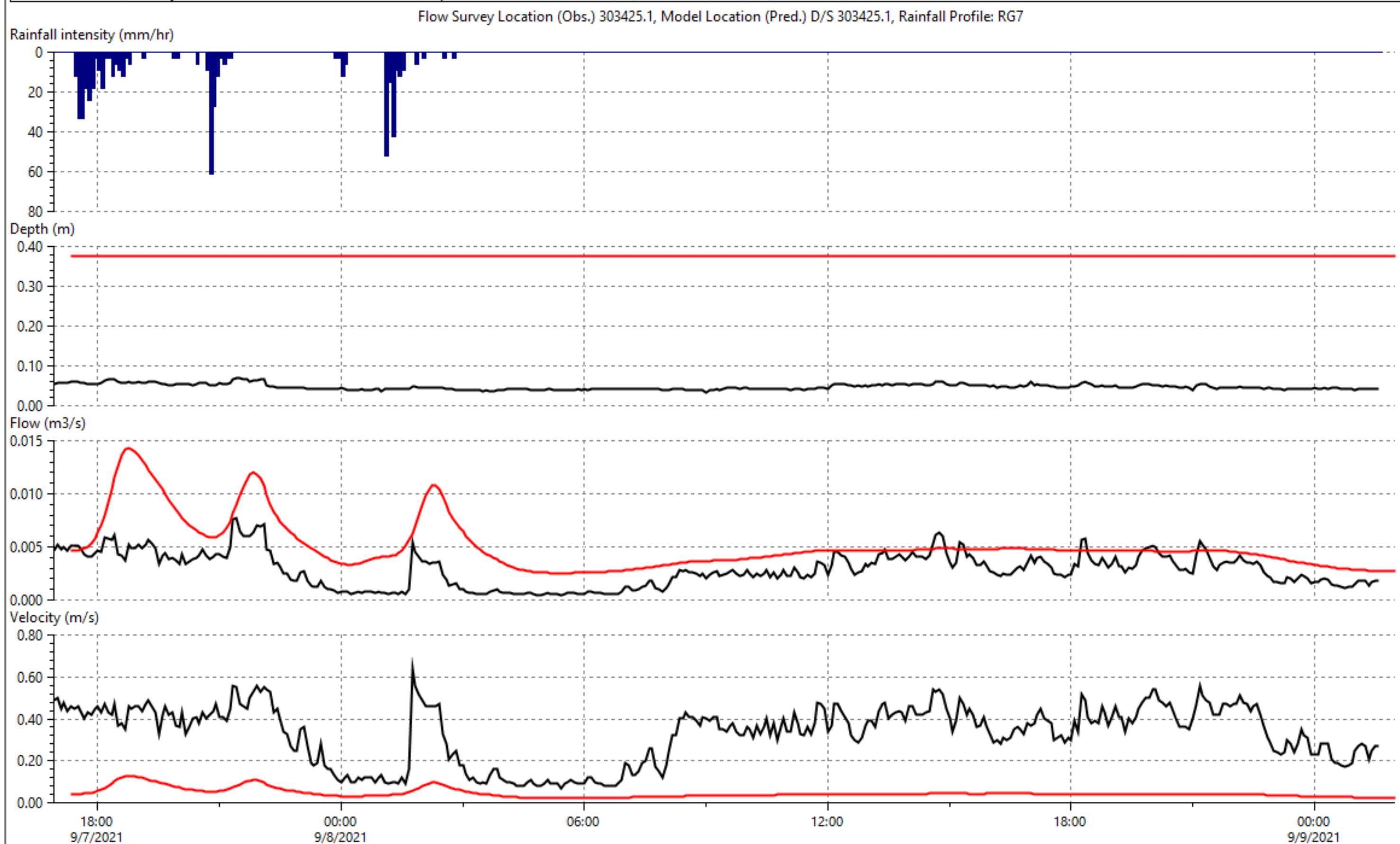


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	49.400	64.800	1.505							
Observed				0.041	0.097	0.002	0.020	872.988	0.320	0.810
Modelled				0.054	0.091	0.004	0.014	898.241	0.395	0.623

FM20

WWF Event 1

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:21:57 AM) Page 8 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E1 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E1_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:53:48 AM)

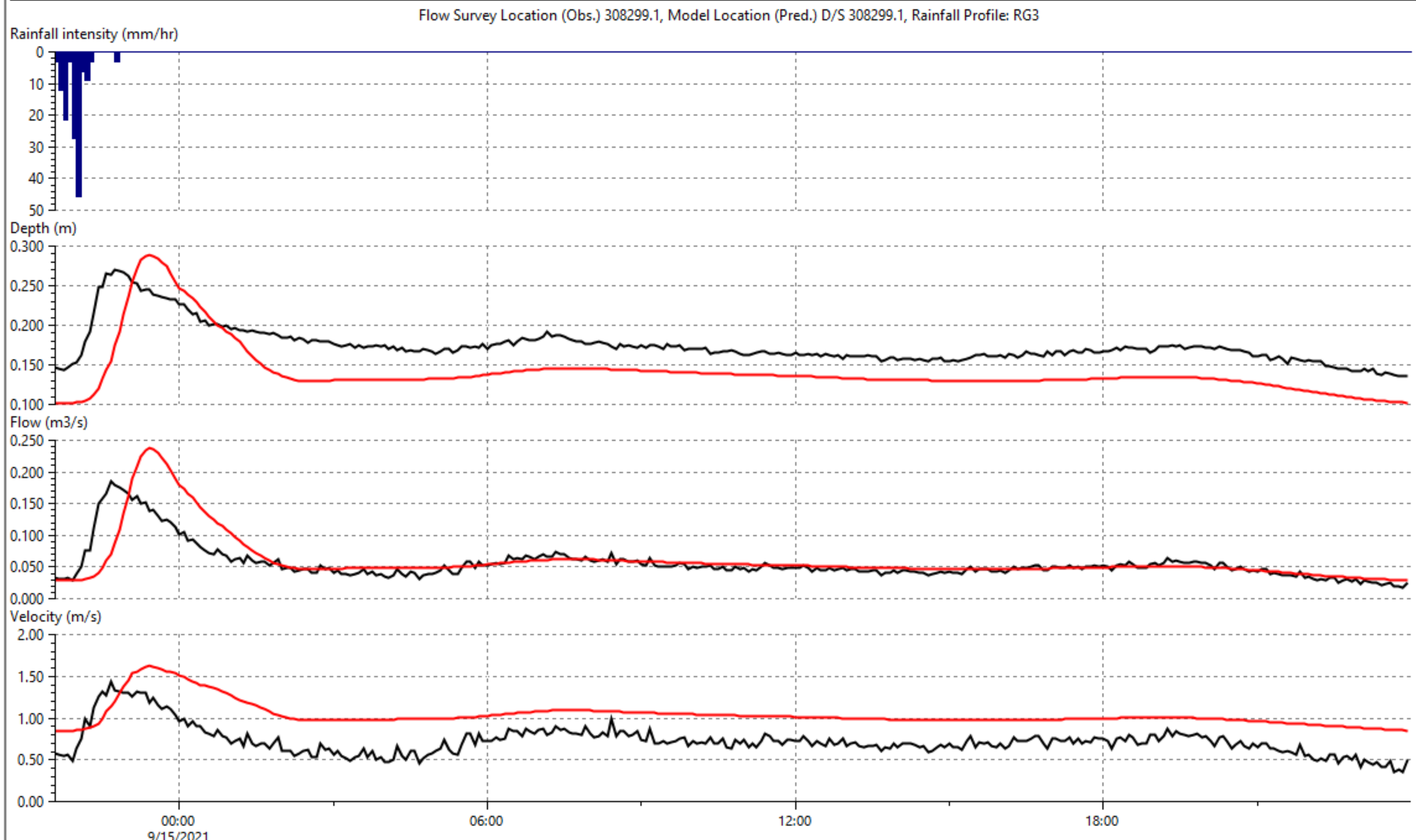


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	45.468	60.960	1.385							
Observed				0.034	0.069	0.000	0.008	335.483	0.070	0.640
Modelled				0.375	0.375	0.003	0.014	593.093	0.023	0.129

FM1

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 16 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)



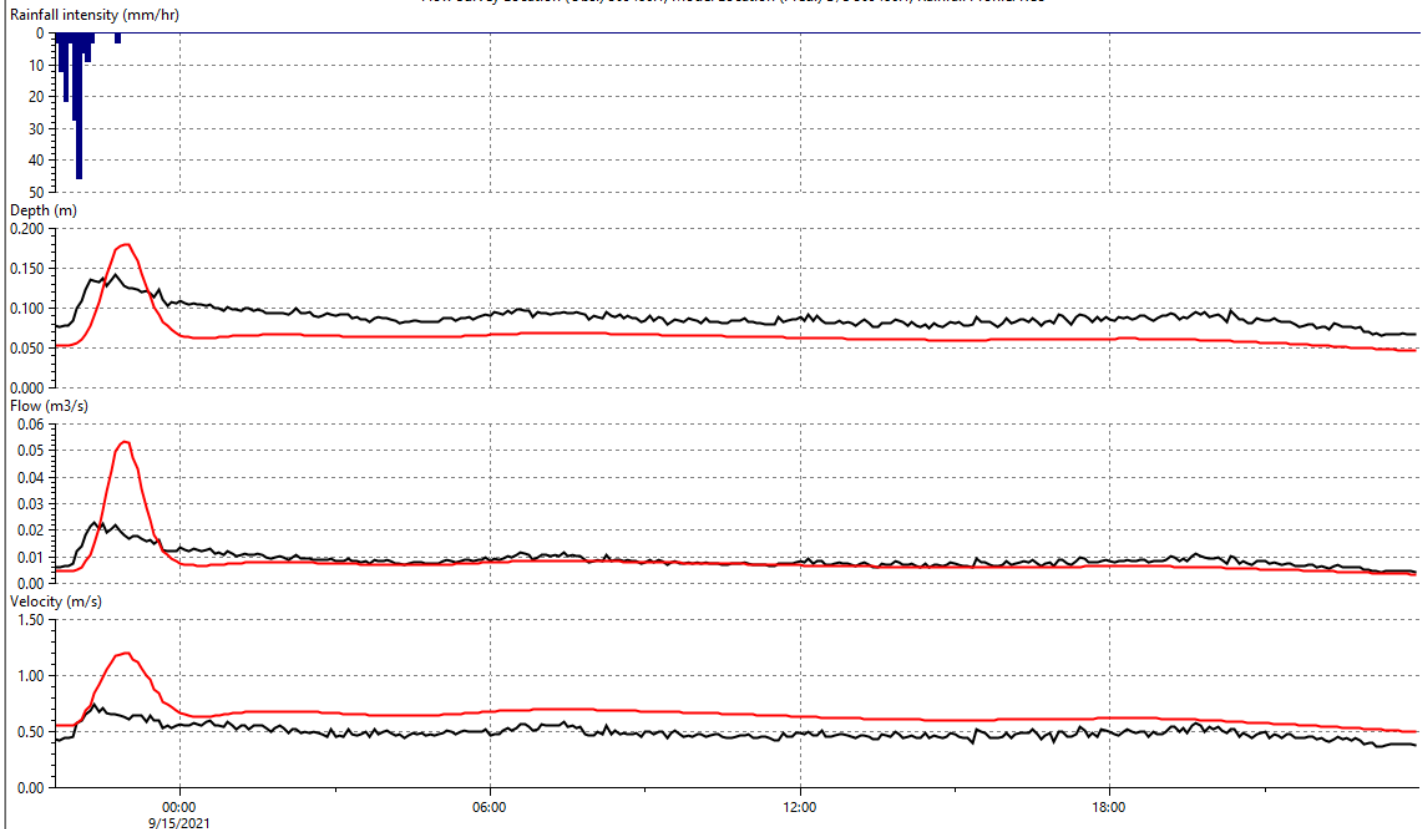
		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	blue line	11.177	45.720	0.422							
Observed	black line				0.135	0.271	0.018	0.186	5271.106	0.350	1.440
Modelled	red line				0.102	0.289	0.029	0.238	5720.099	0.850	1.624

FM1b

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 17 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

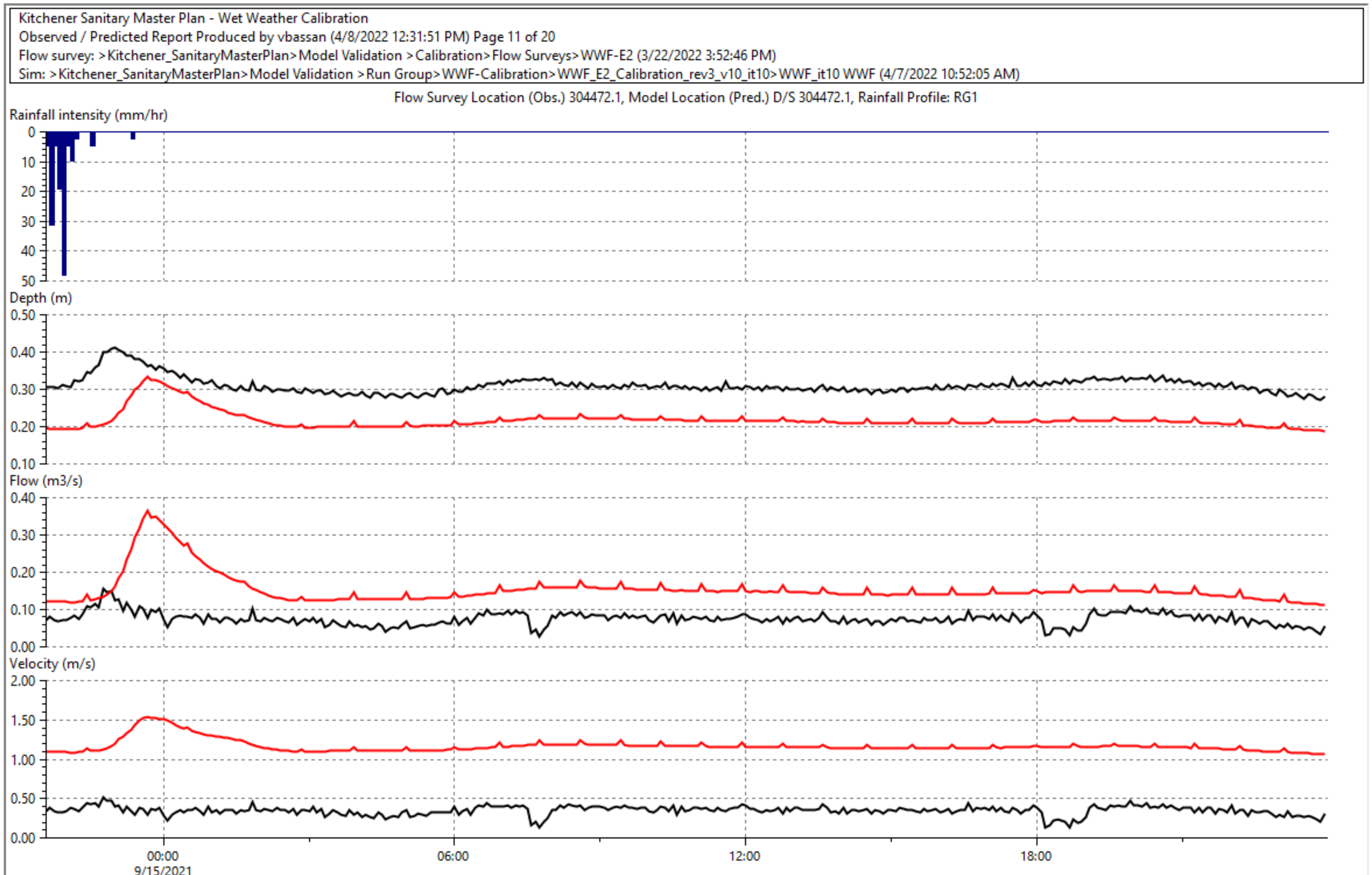
Flow Survey Location (Obs.) 309486.1, Model Location (Pred.) D/S 309486.1, Rainfall Profile: RG3



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.177	45.720	0.422							
Observed				0.066	0.143	0.004	0.023	846.979	0.370	0.740
Modelled				0.046	0.180	0.003	0.053	775.677	0.496	1.202

FM2

WWF Event 2



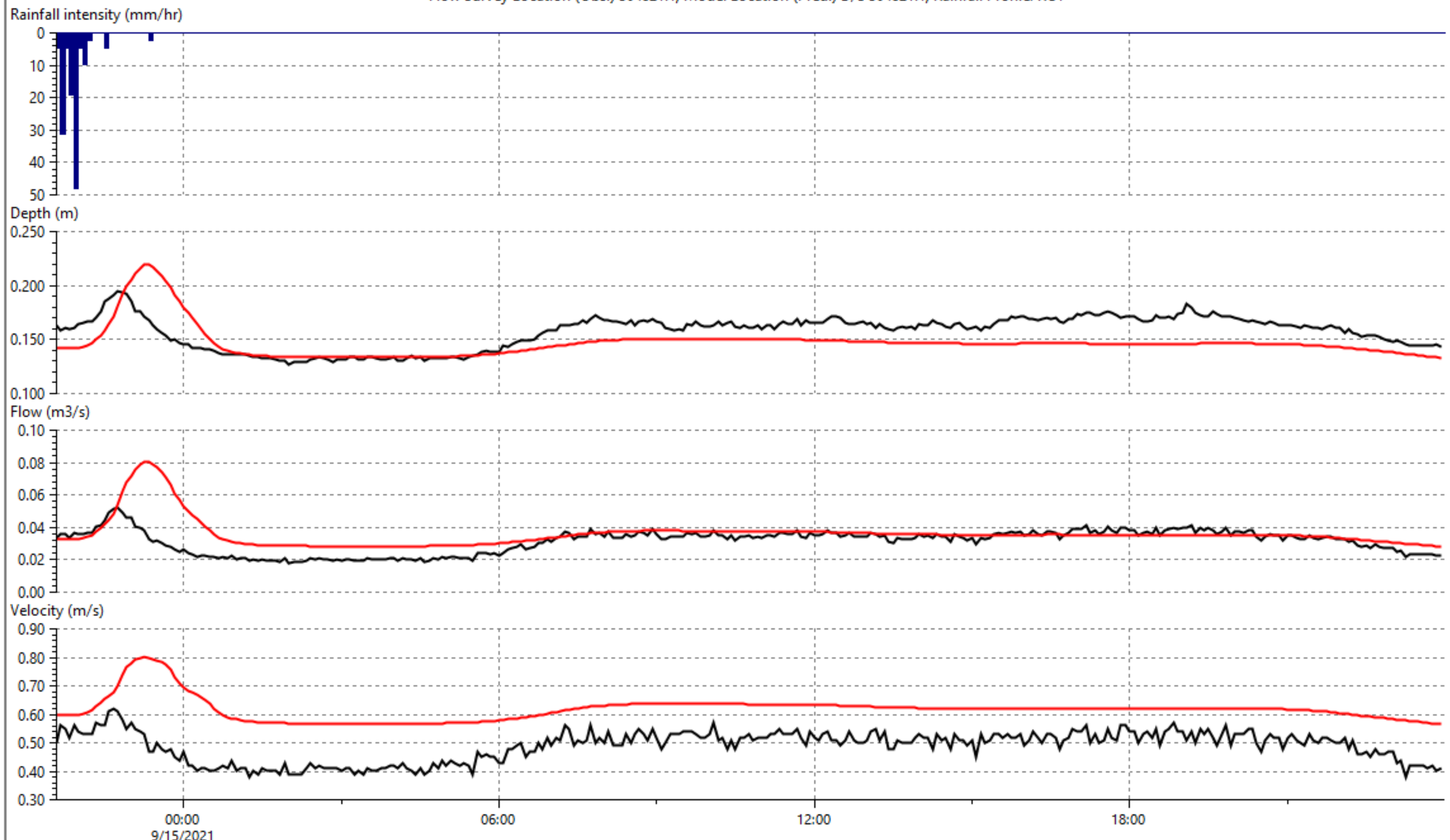
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.000	48.000	0.415							
Observed				0.270	0.412	0.030	0.157	7146.576	0.130	0.520
Modelled				0.189	0.335	0.113	0.366	14604.819	1.066	1.536

FM2b

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 12 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 304821.1, Model Location (Pred.) D/S 304821.1, Rainfall Profile: RG1



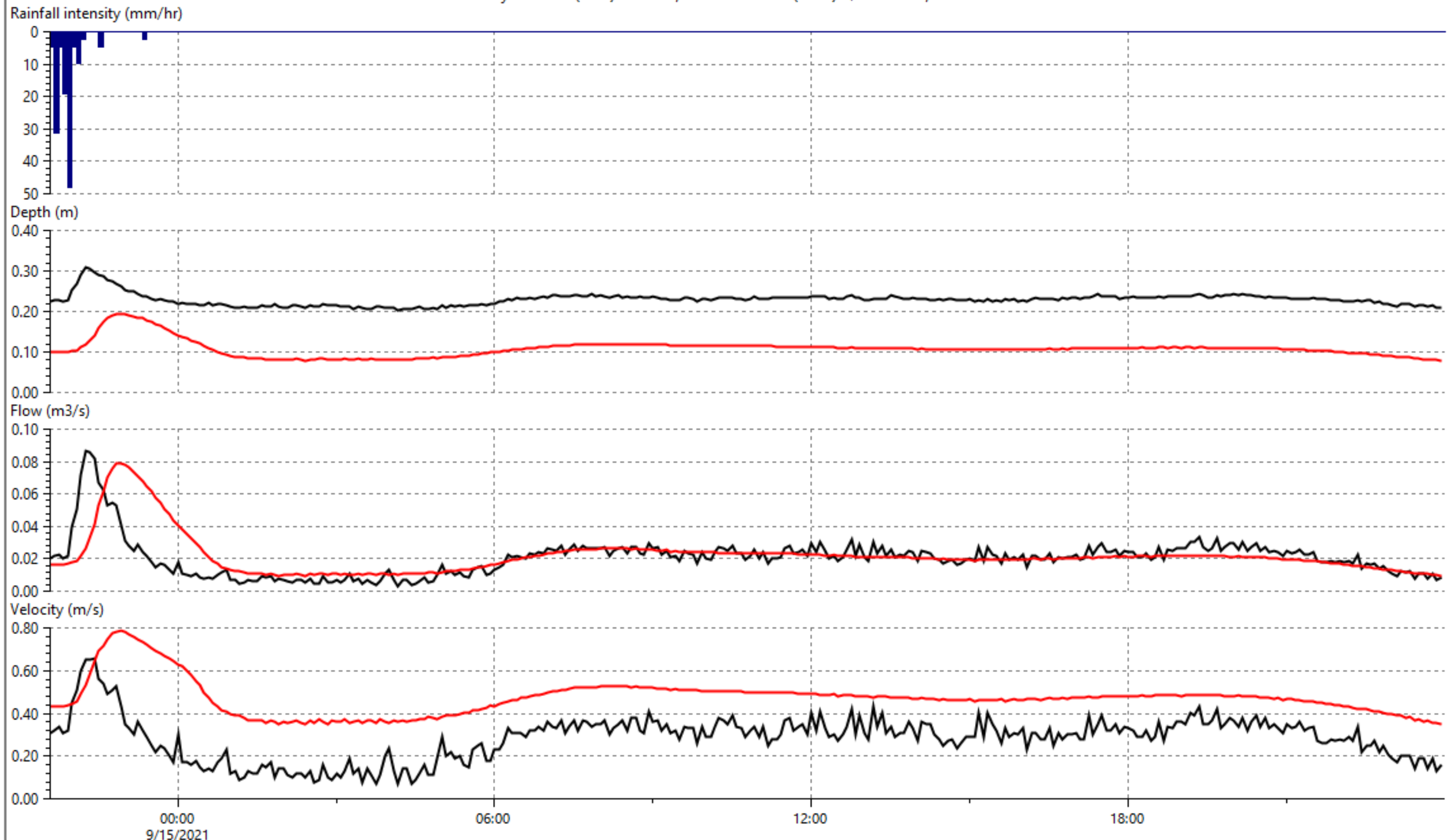
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.000	48.000	0.415							
Observed				0.127	0.194	0.018	0.052	2988.903	0.380	0.620
Modelled				0.133	0.220	0.028	0.081	3410.308	0.565	0.800

FM3

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 18 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 311167.1, Model Location (Pred.) D/S 311167.1, Rainfall Profile: RG1



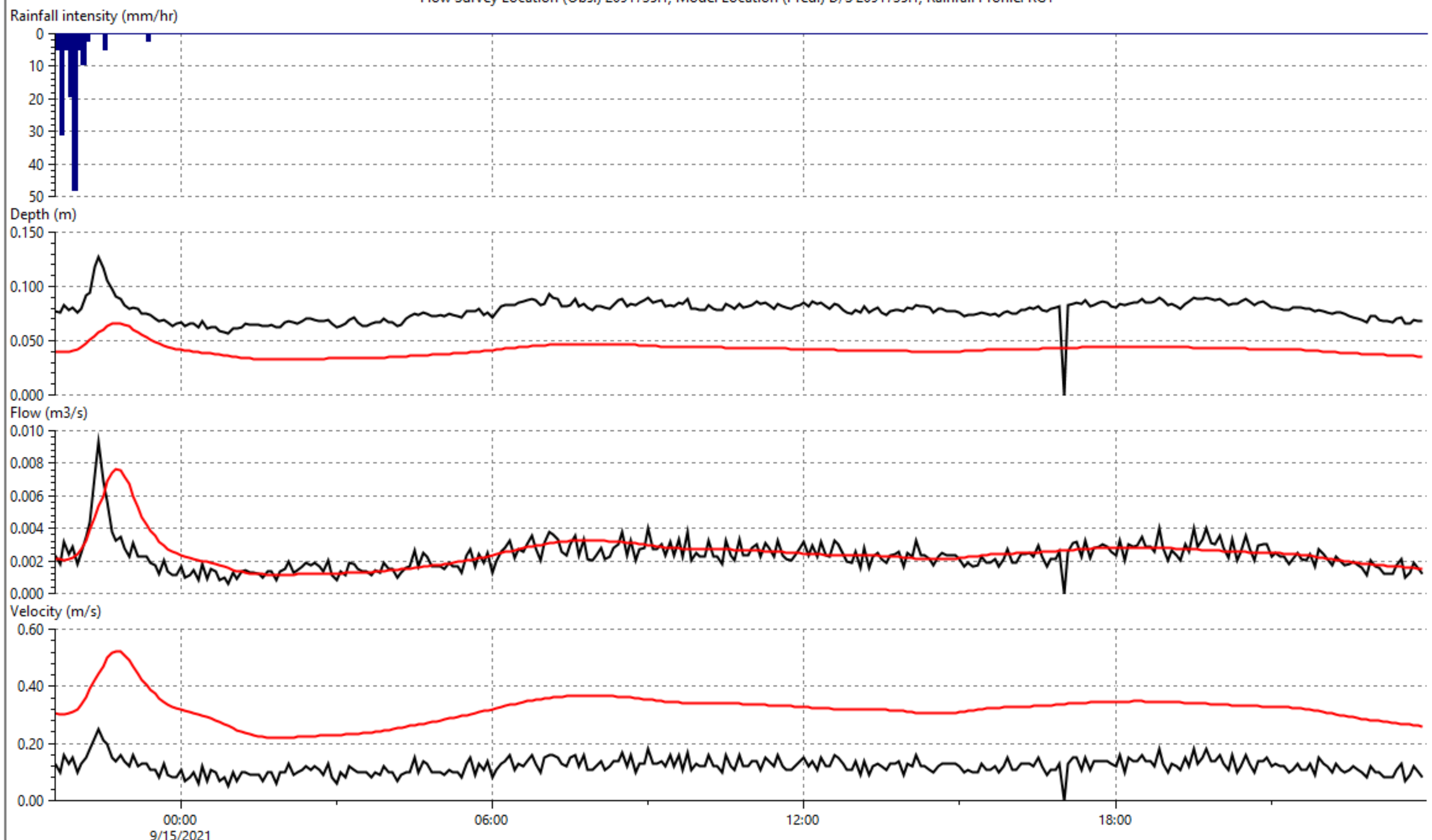
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.000	48.000	0.415							
Observed				0.204	0.308	0.003	0.087	1959.768	0.070	0.660
Modelled				0.079	0.194	0.009	0.079	2069.506	0.347	0.786

FM3b

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:31:05 AM) Page 2 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 2091735.1, Model Location (Pred.) D/S 2091735.1, Rainfall Profile: RG1



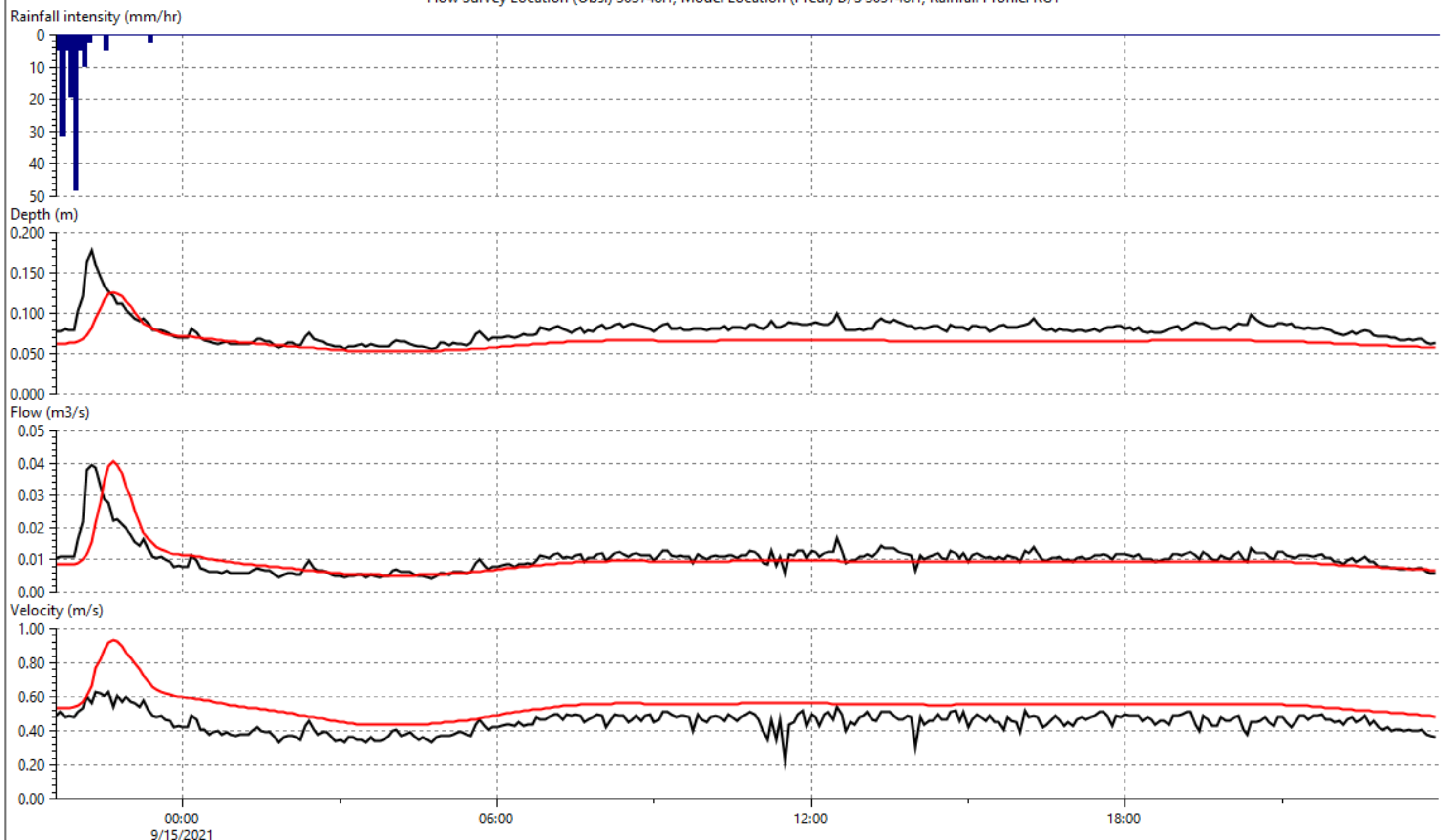
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.000	48.000	0.415							
Observed				0.000	0.128	0.000	0.009	219.286	0.000	0.250
Modelled				0.033	0.066	0.001	0.008	234.291	0.219	0.523

FM4

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 10 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 303748.1, Model Location (Pred.) D/S 303748.1, Rainfall Profile: RG1



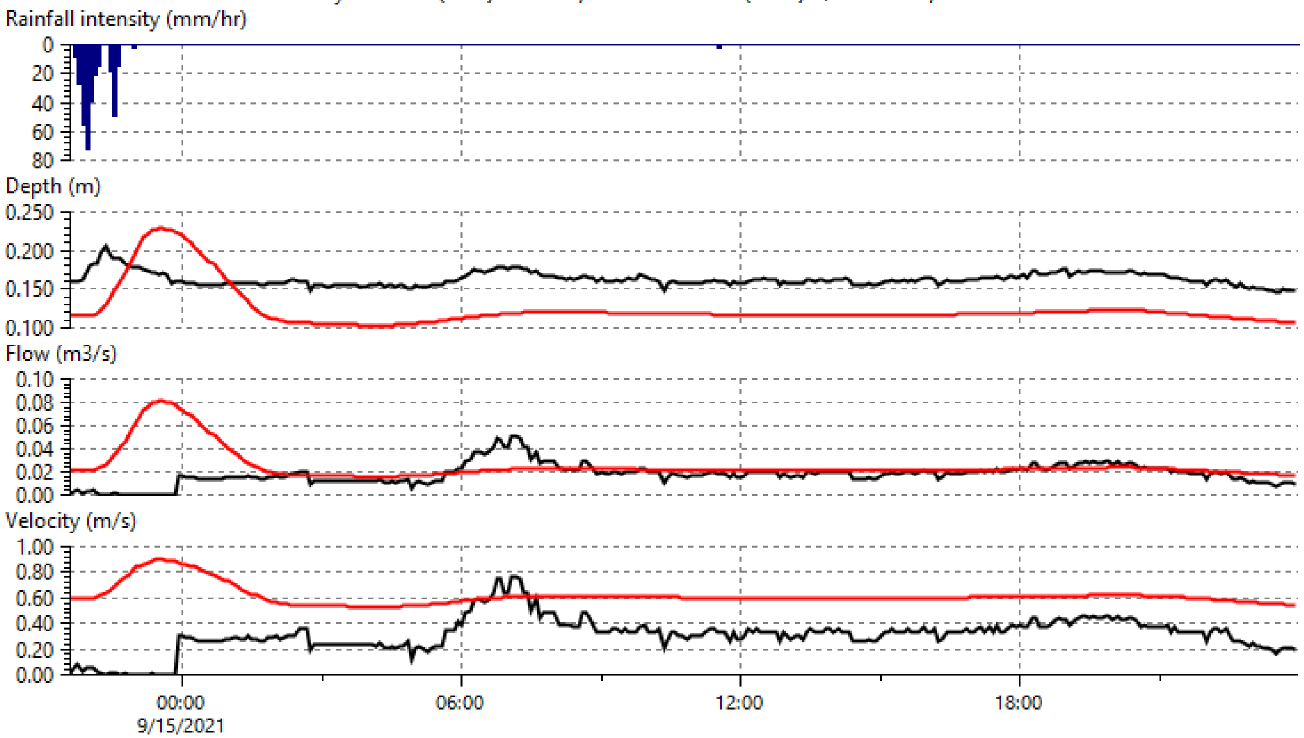
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.000	48.000	0.415							
Observed				0.057	0.178	0.004	0.039	987.912	0.230	0.630
Modelled				0.053	0.127	0.005	0.041	910.831	0.434	0.935

FM5b

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/26/2022 11:46:07 AM) Page 19 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2_FM5blink (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10_TM2c>WWF_it10 ...

Flow Survey Location (Obs.) 311440.1, Model Location (Pred.) U/S 311440.1, Rainfall Profile: RG6

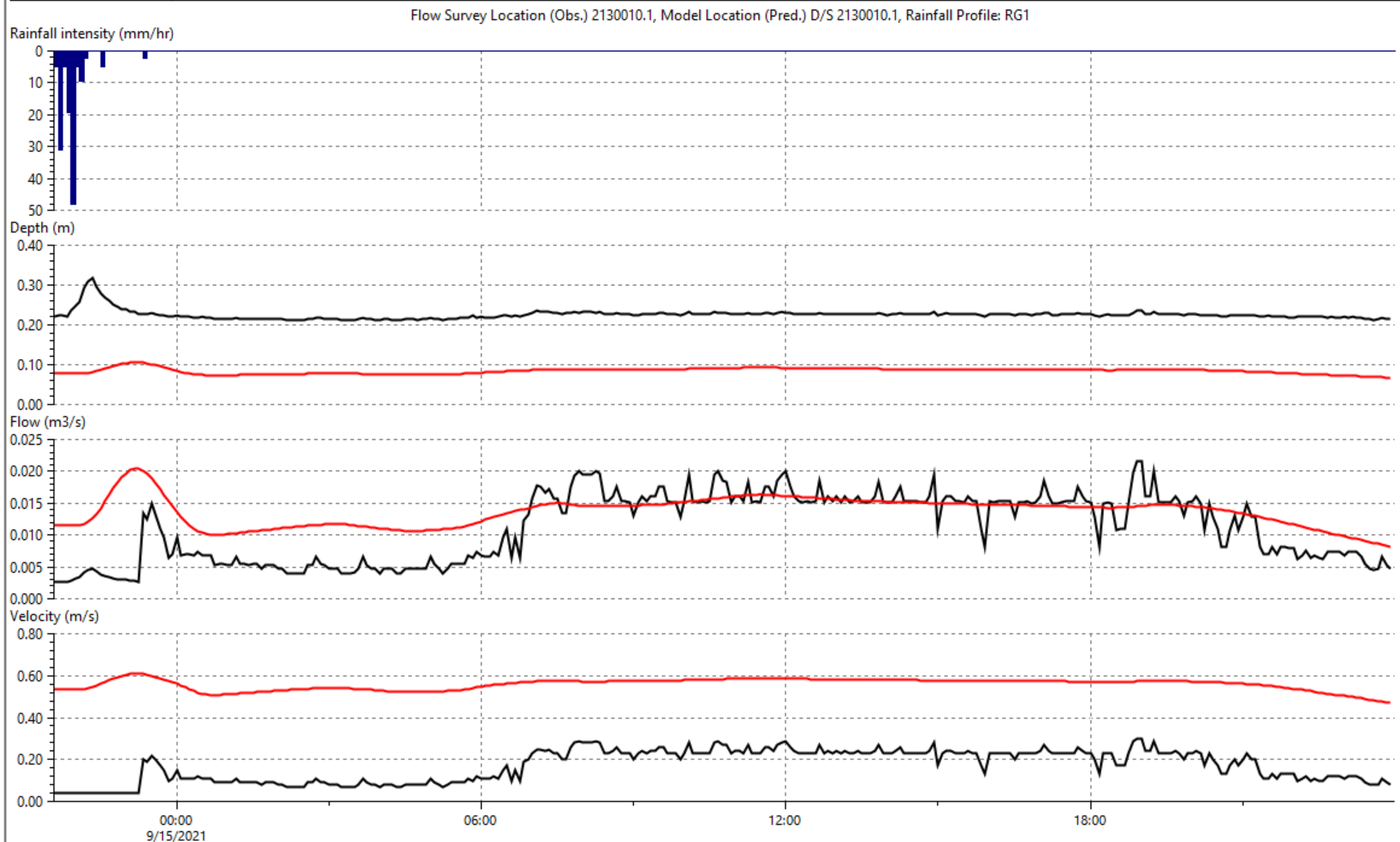


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	27.432	73.150	1.035							
Observed				0.146	0.207	0.000	0.050	1728.034	0.000	0.770
Modelled				0.103	0.228	0.016	0.081	2391.748	0.530	0.898

FM6

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:31:05 AM) Page 3 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

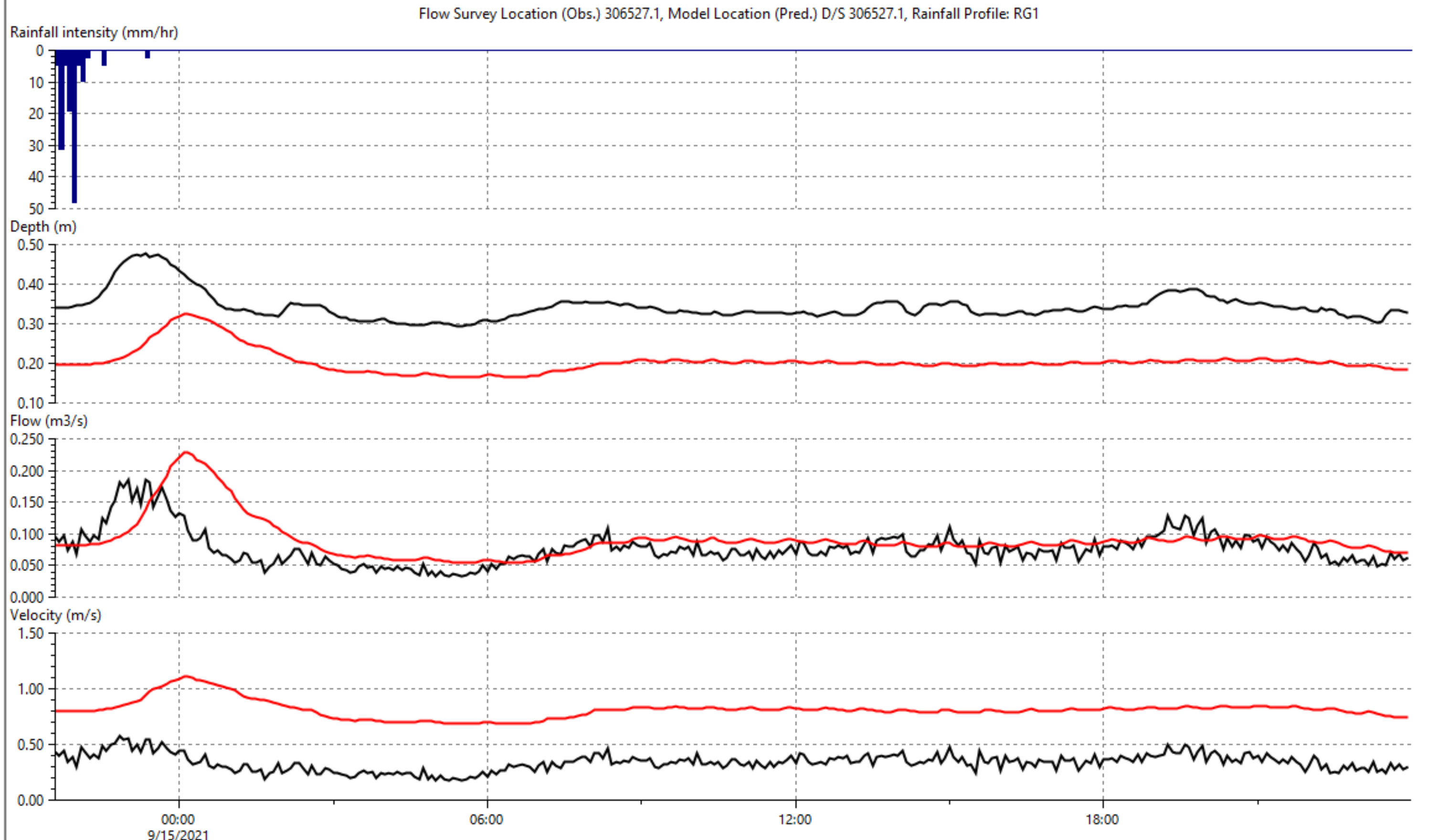


		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain		11.000	48.000	0.415							
Observed					0.211	0.318	0.003	0.022	1061.752	0.040	0.300
Modelled					0.067	0.105	0.008	0.020	1291.991	0.470	0.612

FM7

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 13 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	11.000	48.000	0.415							
Observed				0.295	0.477	0.033	0.186	7330.956	0.180	0.580
Modelled				0.165	0.325	0.055	0.229	8611.629	0.685	1.107

FM9

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
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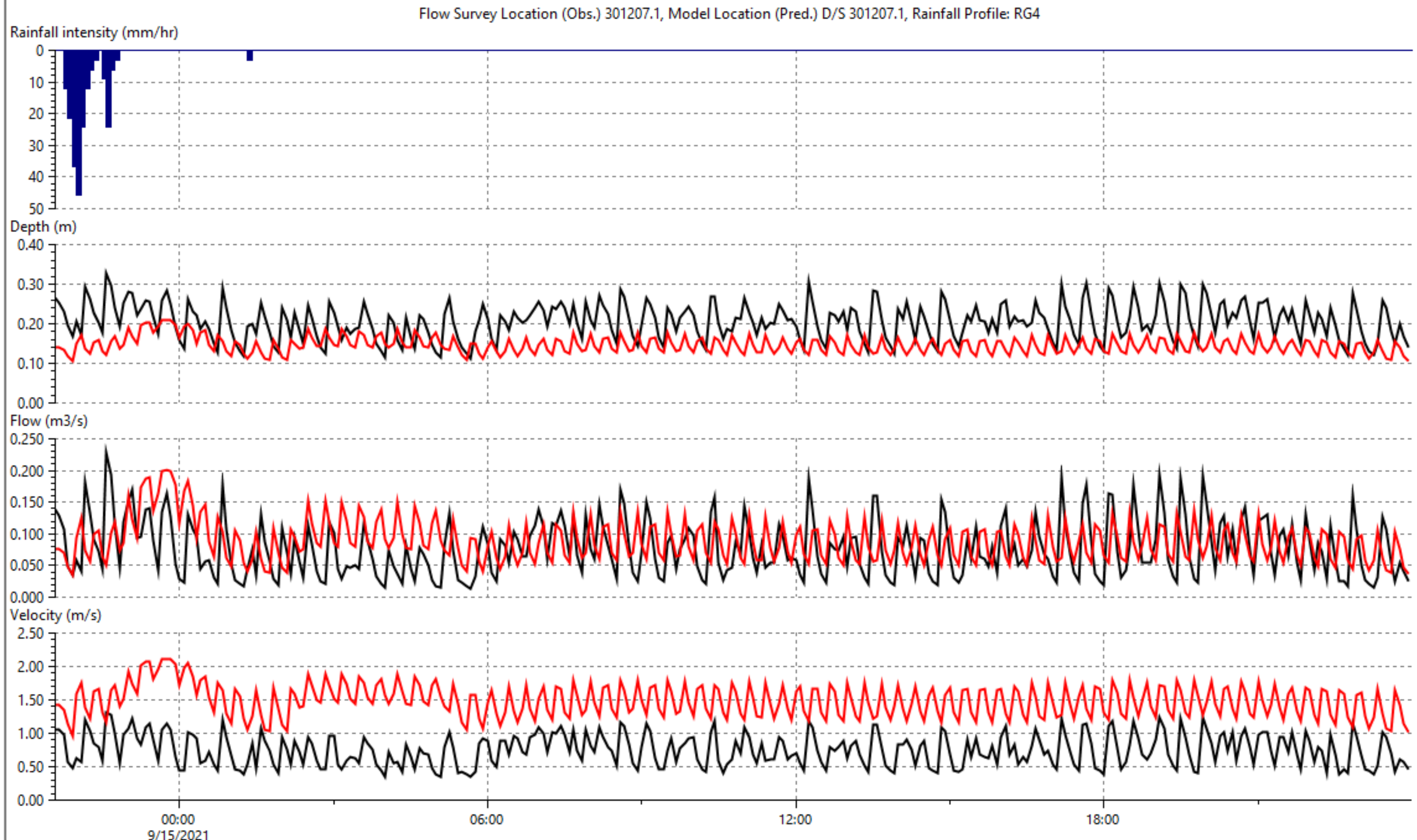
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)



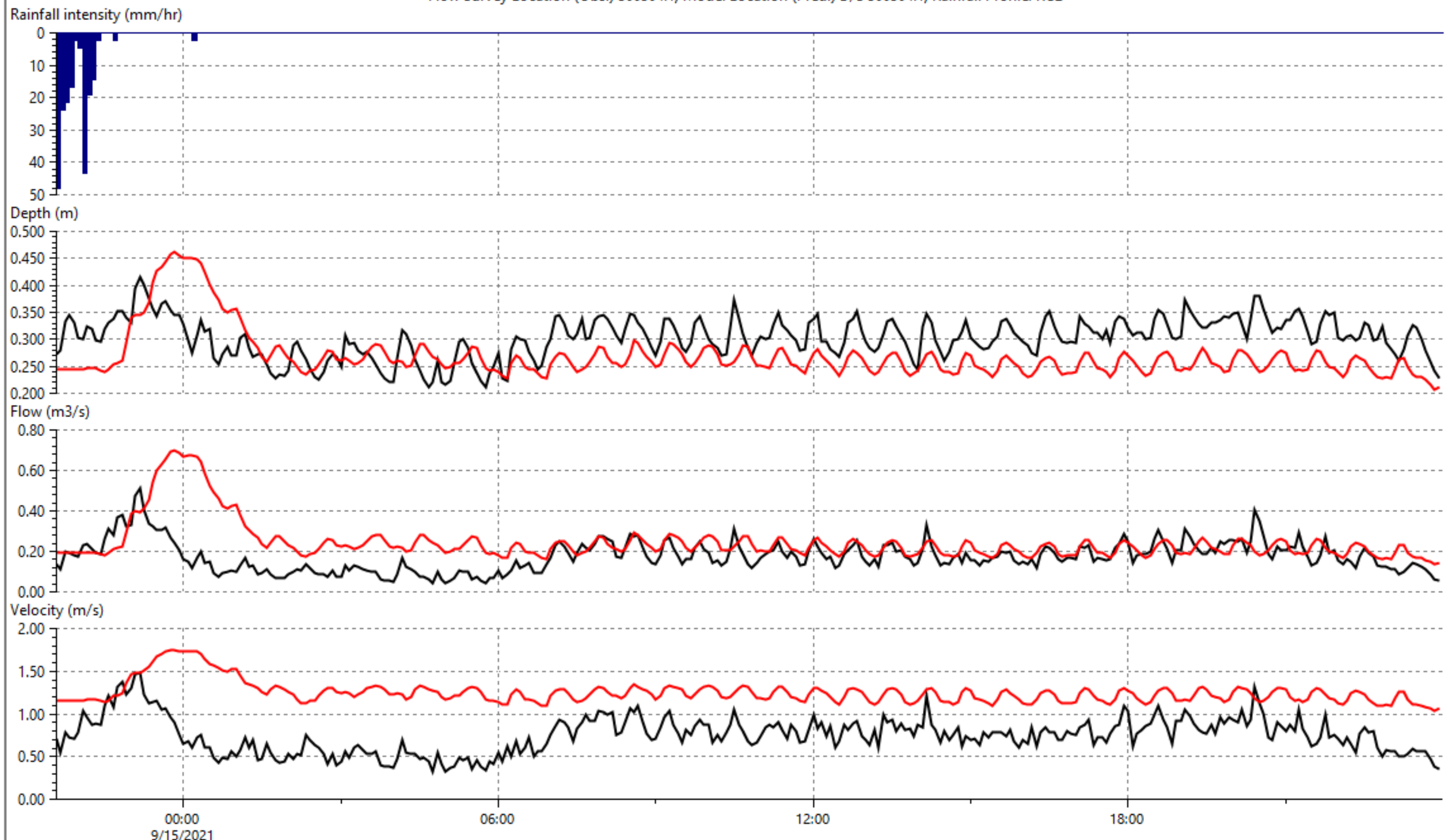
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	17.273	45.720	0.652							
Observed				0.114	0.329	0.014	0.229	7292.007	0.360	1.320
Modelled				0.105	0.210	0.034	0.201	8423.058	0.971	2.116

FM10

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 4 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 300304.1, Model Location (Pred.) D/S 300304.1, Rainfall Profile: RG2



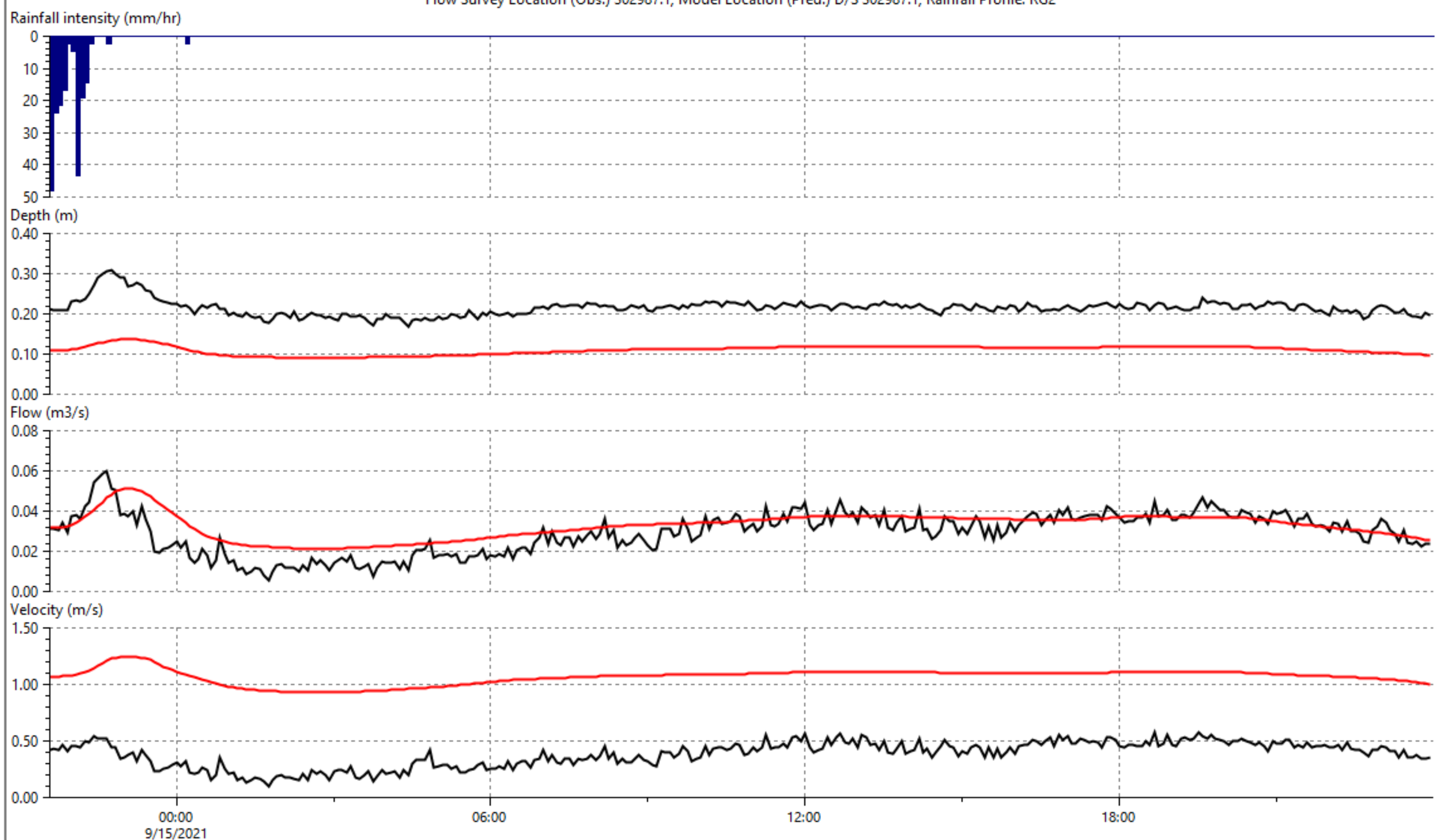
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	16.800	48.000	0.634							
Observed				0.211	0.415	0.046	0.514	16614.591	0.320	1.480
Modelled				0.208	0.461	0.137	0.701	23229.731	1.041	1.749

FM11

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 6 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 302987.1, Model Location (Pred.) D/S 302987.1, Rainfall Profile: RG2



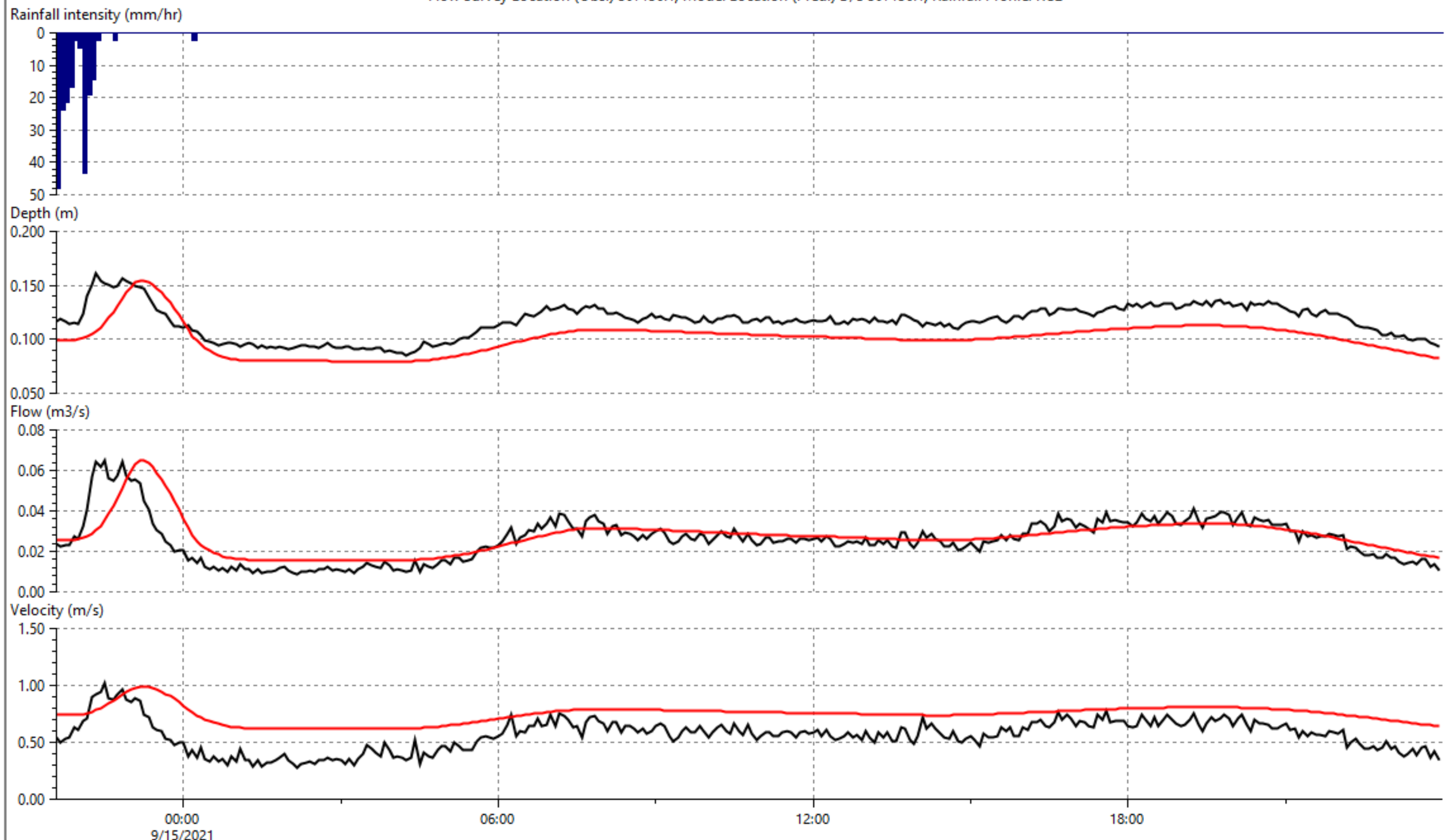
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	16.800	48.000	0.634							
Observed				0.168	0.309	0.006	0.060	2781.895	0.100	0.580
Modelled				0.091	0.138	0.021	0.051	3105.784	0.929	1.248

FM12

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 15 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 307136.1, Model Location (Pred.) D/S 307136.1, Rainfall Profile: RG2

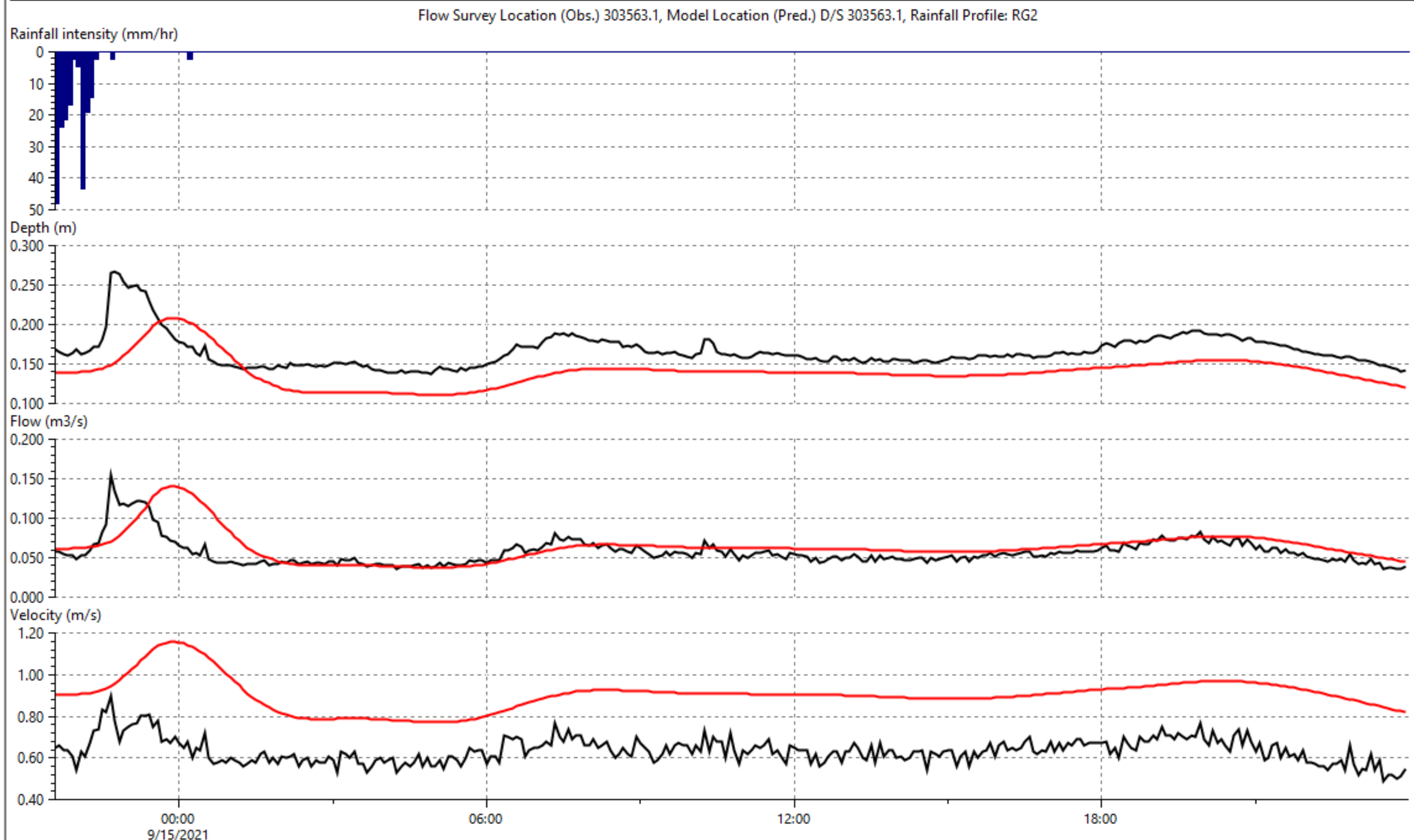


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	16.800	48.000	0.634							
Observed				0.085	0.161	0.009	0.065	2470.071	0.280	1.020
Modelled				0.079	0.154	0.015	0.065	2587.985	0.621	0.989

FM13

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 9 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)



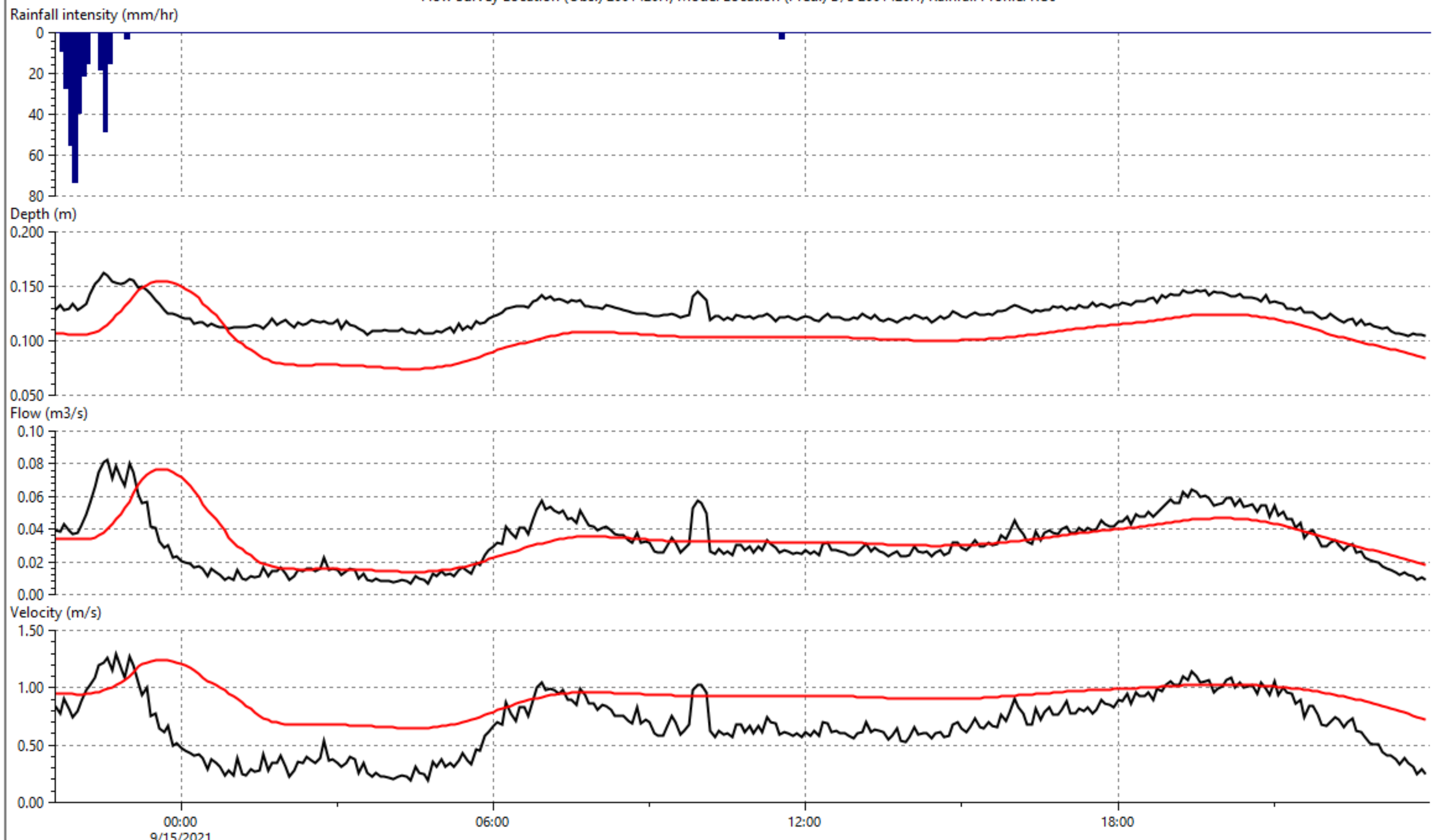
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	16.800	48.000	0.634							
Observed				0.138	0.266	0.035	0.155	5394.759	0.490	0.900
Modelled				0.111	0.208	0.038	0.141	6041.702	0.771	1.158

FM13b

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 11:31:05 AM) Page 1 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 2001420.1, Model Location (Pred.) D/S 2001420.1, Rainfall Profile: RG6



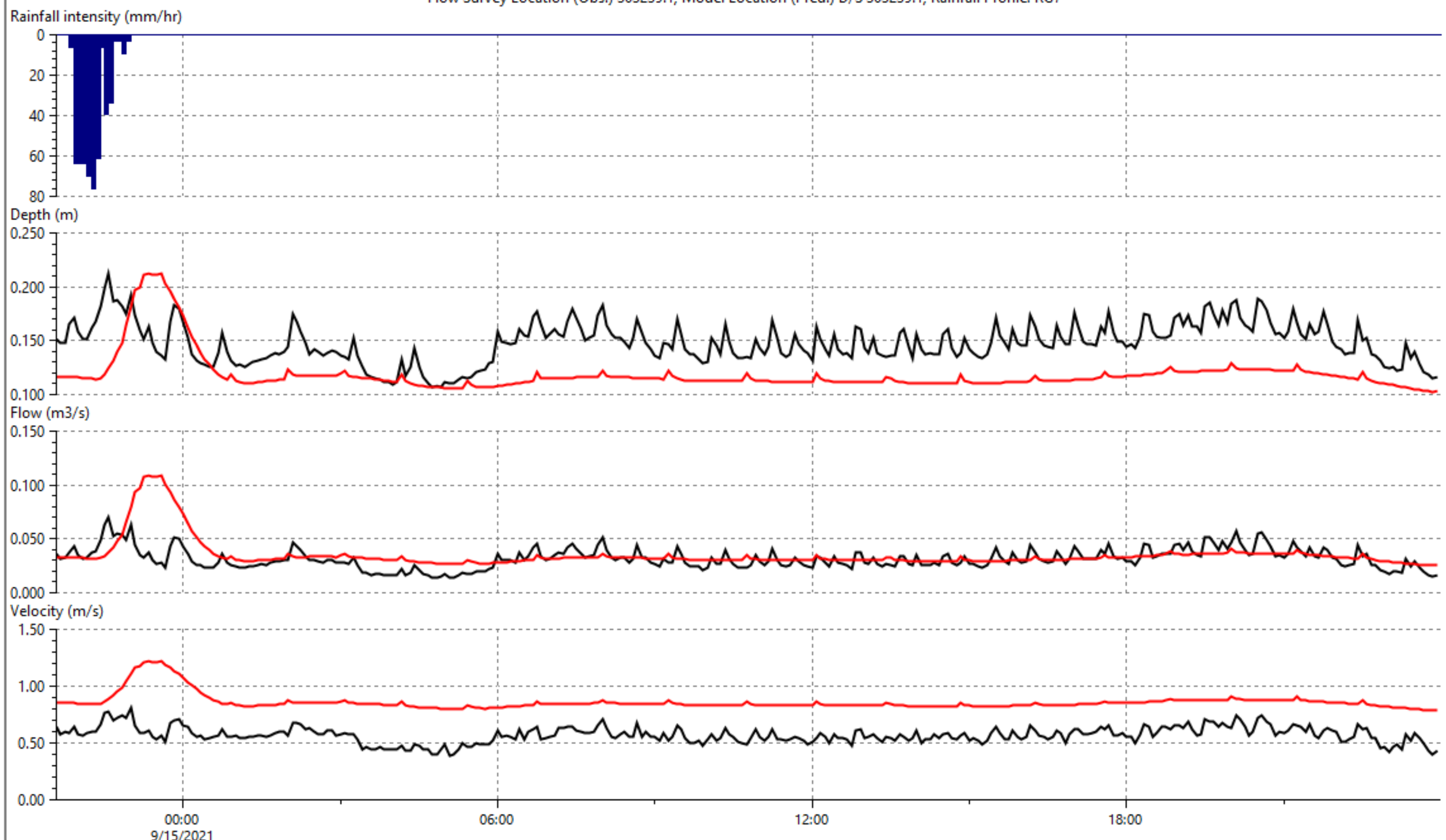
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	27.432	73.150	1.035							
Observed				0.105	0.163	0.007	0.082	3091.753	0.190	1.290
Modelled				0.074	0.155	0.014	0.077	3163.789	0.648	1.238

FM15

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 7 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 303239.1, Model Location (Pred.) D/S 303239.1, Rainfall Profile: RG7



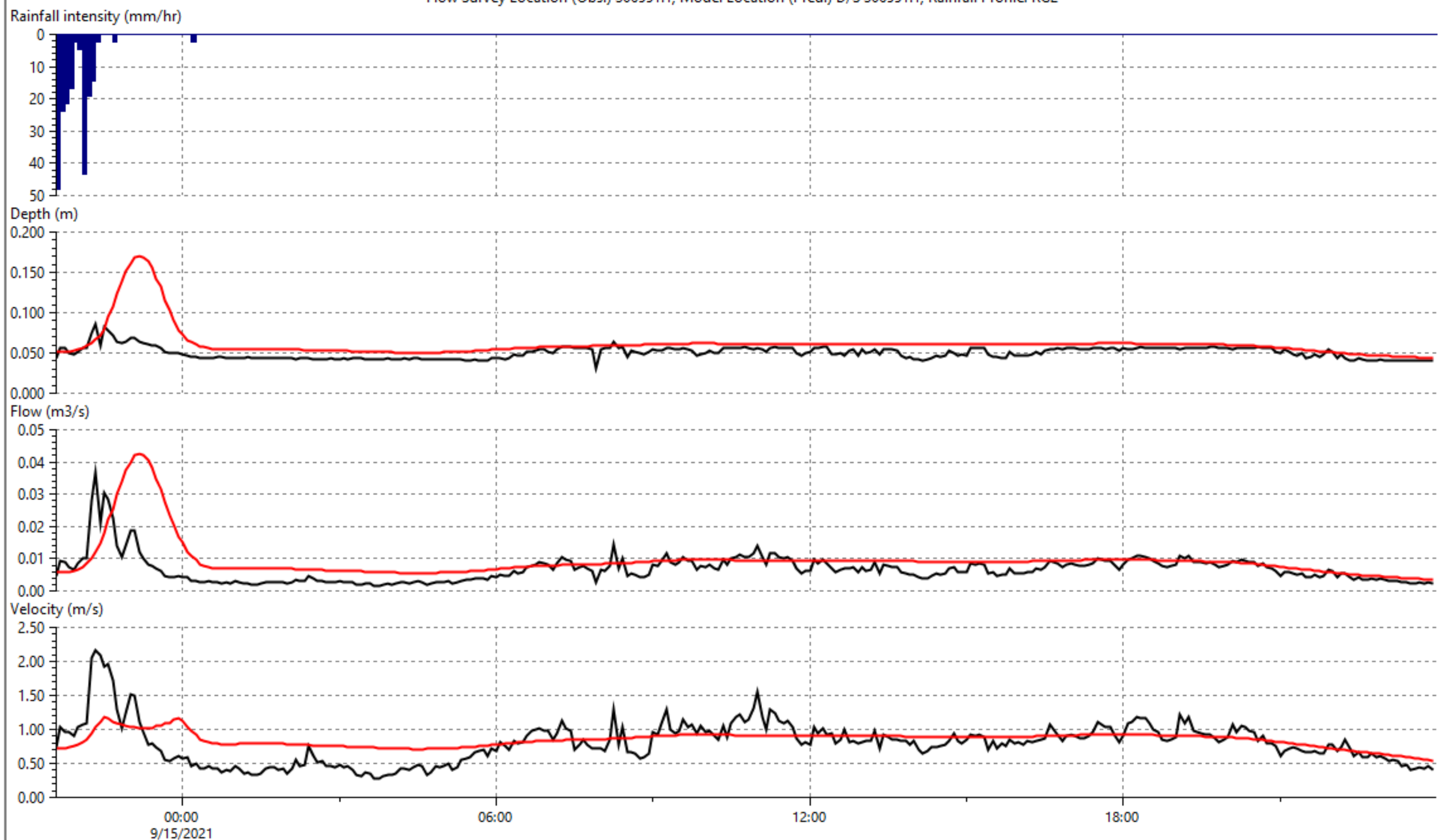
		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain		41.911	76.200	1.582							
Observed					0.107	0.213	0.014	0.070	3006.827	0.390	0.810
Modelled					0.102	0.212	0.025	0.109	3328.471	0.786	1.219

FM18

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 14 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

Flow Survey Location (Obs.) 306551.1, Model Location (Pred.) D/S 306551.1, Rainfall Profile: RG2

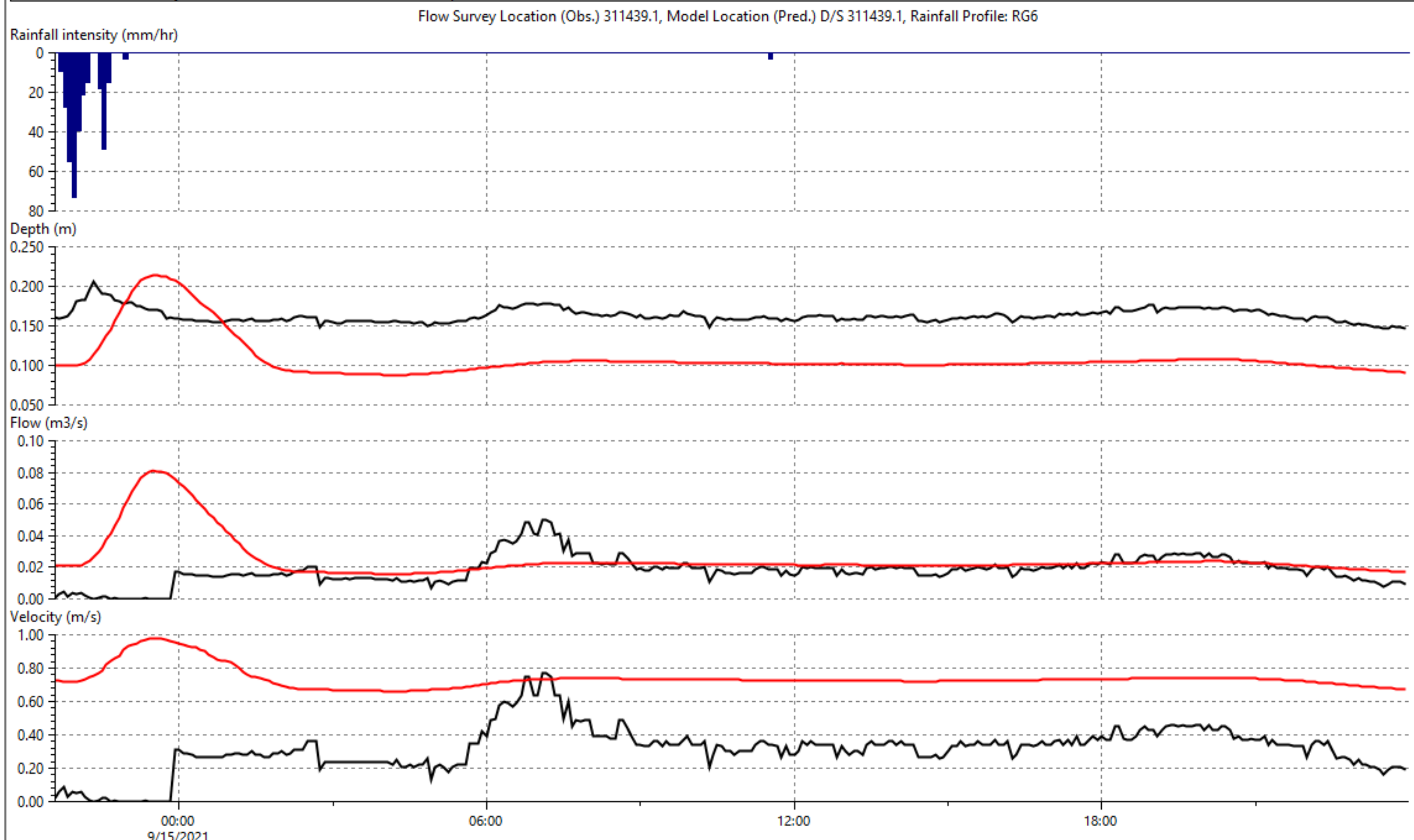


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	16.800	48.000	0.634							
Observed				0.031	0.086	0.002	0.037	639.967	0.270	2.170
Modelled				0.044	0.171	0.003	0.042	885.117	0.541	1.191

FM19

WWF Event 2

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 19 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)

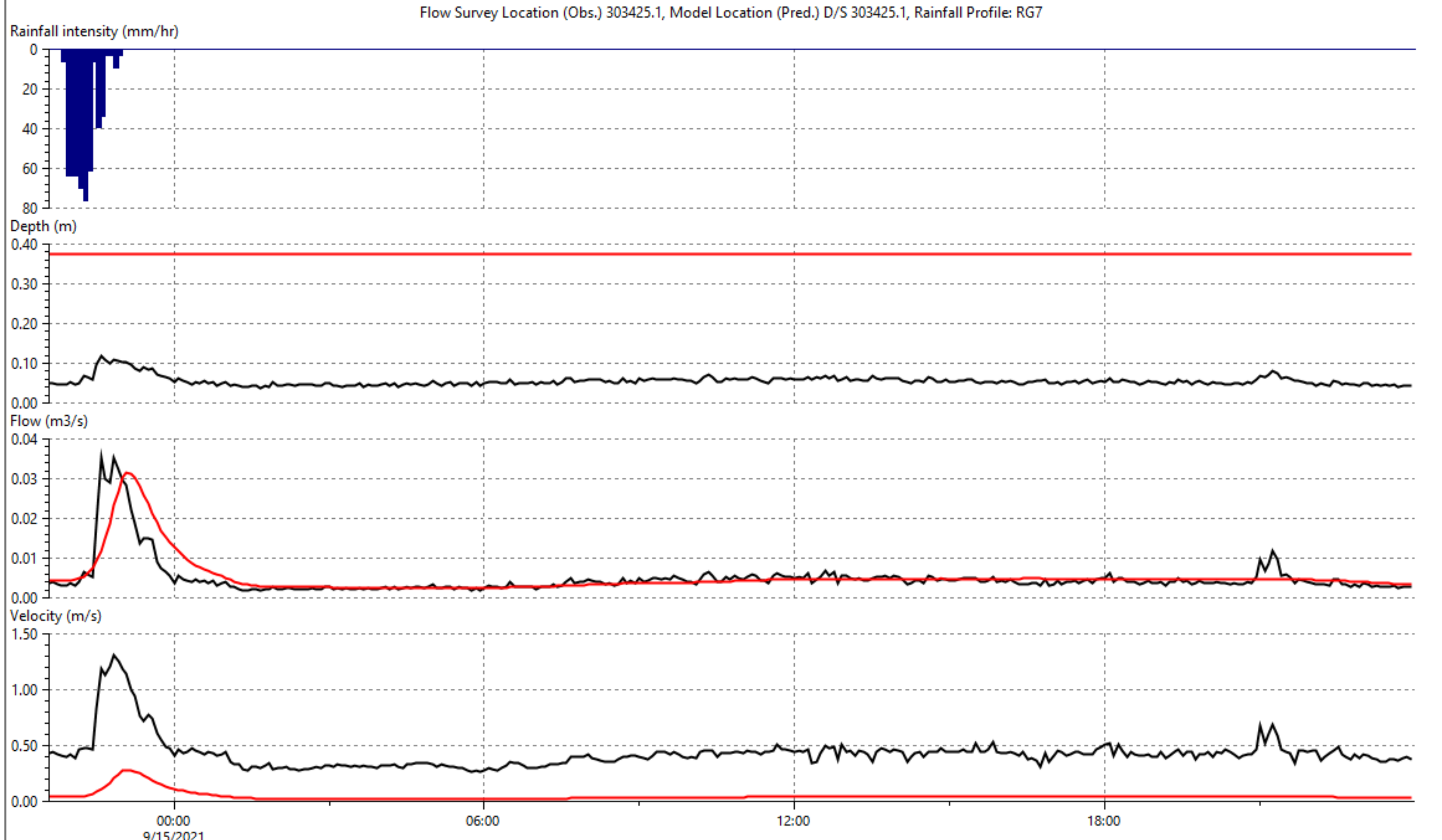


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	27.432	73.150	1.035							
Observed				0.146	0.207	0.000	0.050	1728.034	0.000	0.770
Modelled				0.088	0.214	0.016	0.081	2384.904	0.662	0.979

FM20

WWF Event 2

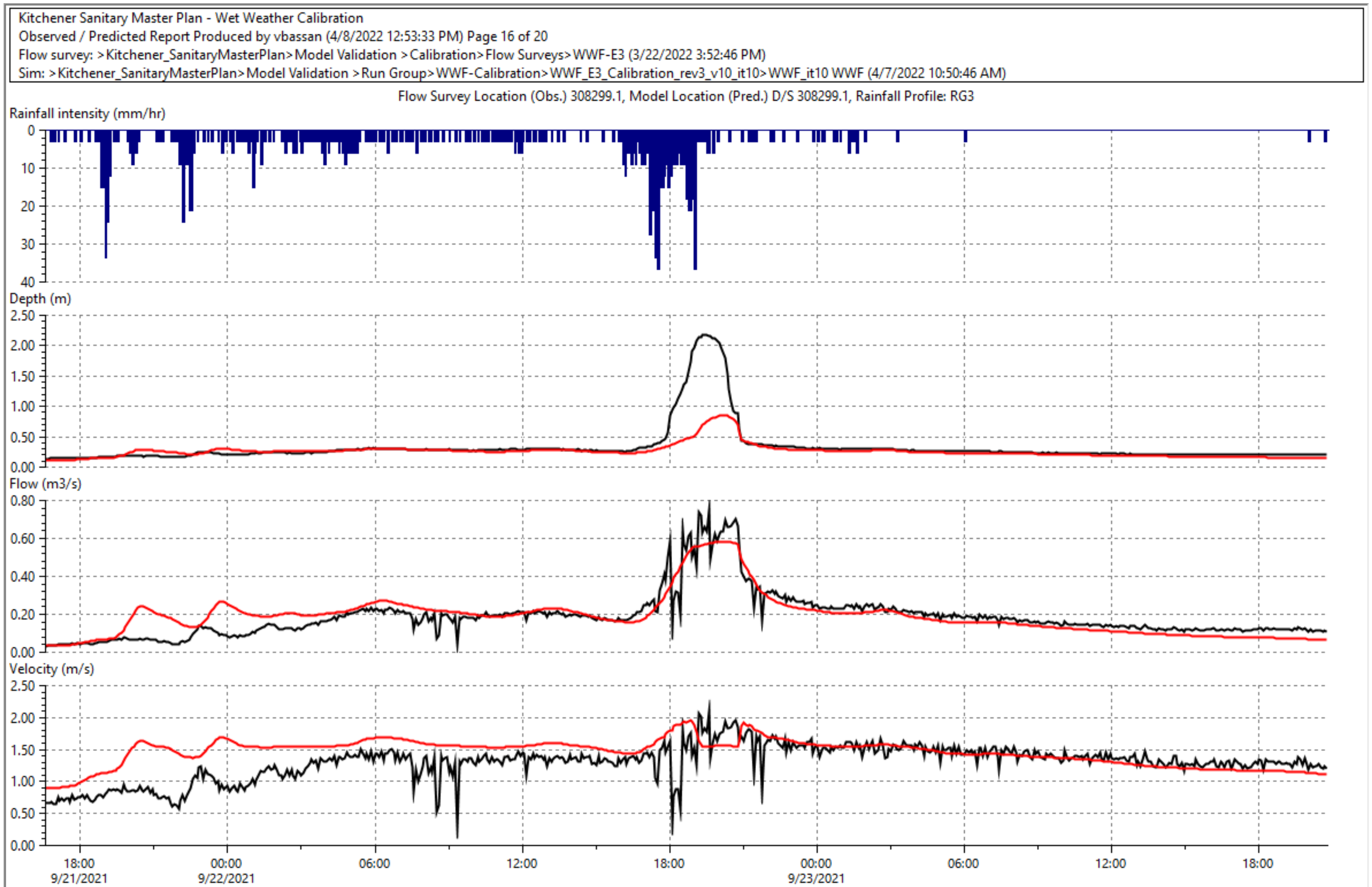
Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:31:51 PM) Page 8 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E2 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E2_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:52:05 AM)



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	41.911	76.200	1.582							
Observed				0.038	0.118	0.002	0.035	463.515	0.270	1.310
Modelled				0.375	0.375	0.003	0.032	489.534	0.023	0.283

FM1

WWF Event 3



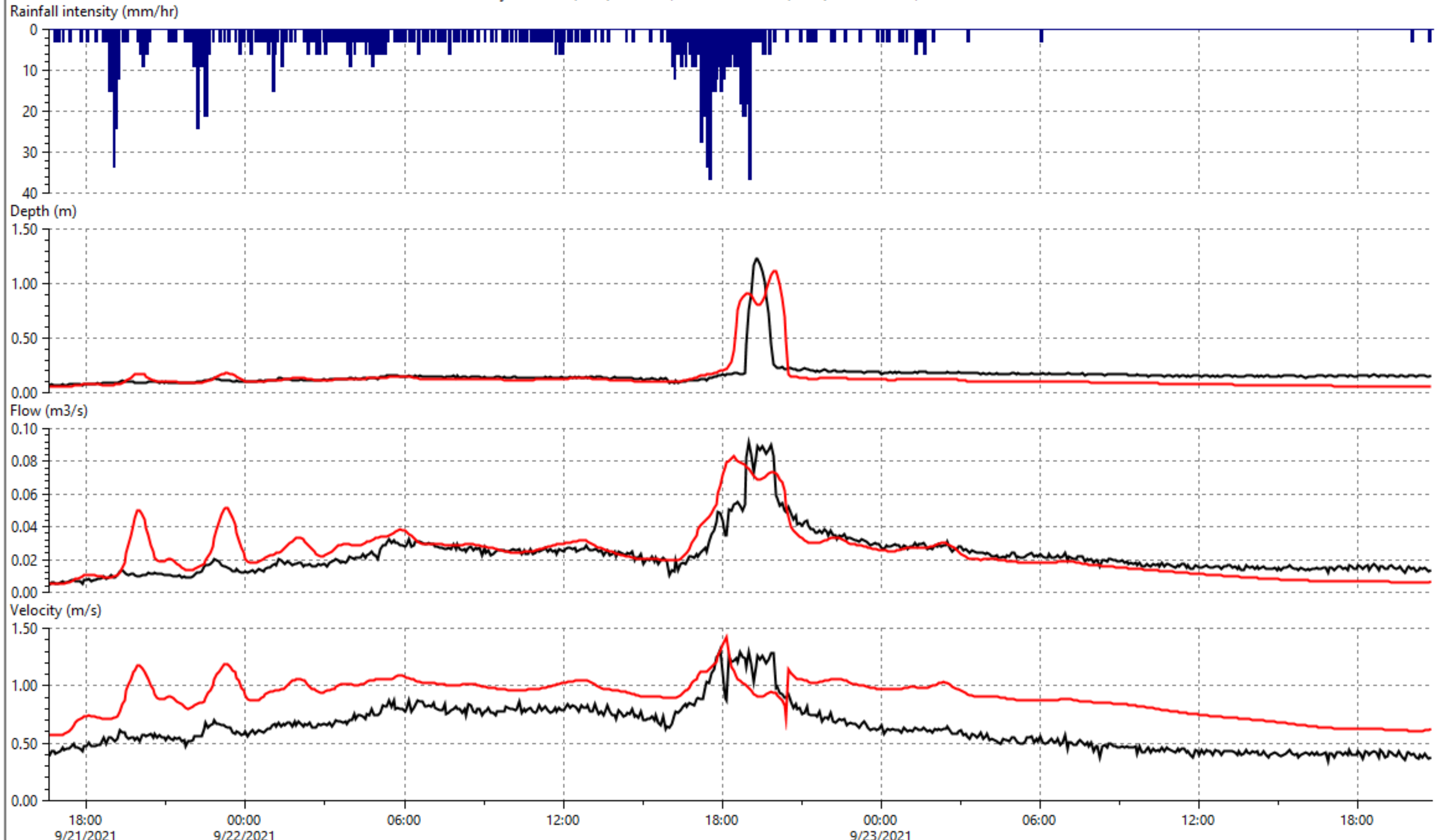
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	118.145	36.580	2.258							
Observed				0.134	2.186	0.033	0.751	35217.672	0.290	2.100
Modelled				0.112	0.857	0.035	0.584	36058.074	0.905	1.958

FM1b

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 17 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)

Flow Survey Location (Obs.) 309486.1, Model Location (Pred.) D/S 309486.1, Rainfall Profile: RG3



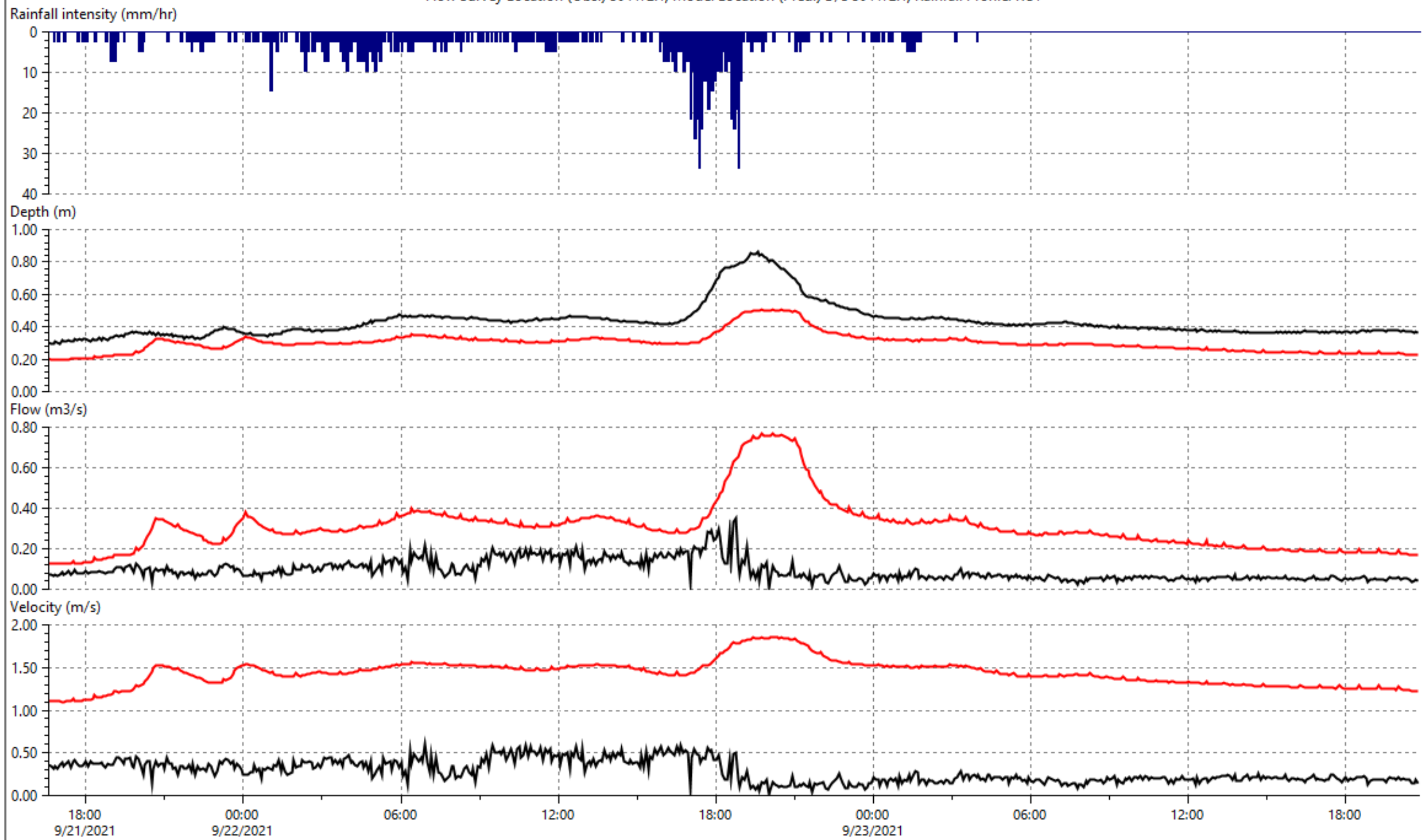
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	118.145	36.580	2.258							
Observed				0.067	1.230	0.005	0.092	4292.907	0.340	1.320
Modelled				0.056	1.113	0.005	0.083	4530.784	0.571	1.425

FM2

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 11 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)

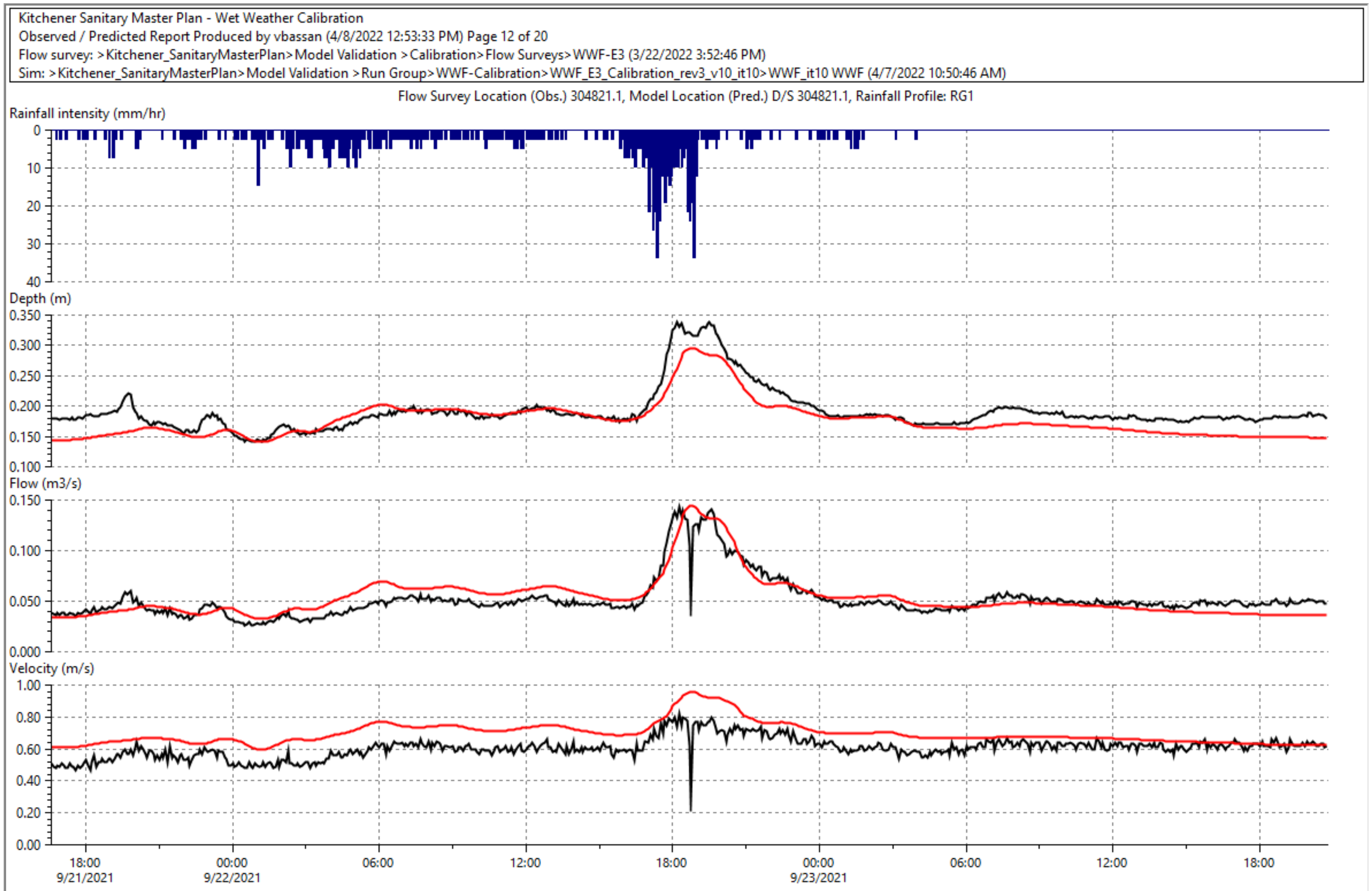
Flow Survey Location (Obs.) 304472.1, Model Location (Pred.) D/S 304472.1, Rainfall Profile: RG1



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	96.400	33.600	1.842							
Observed				0.297	0.860	0.007	0.351	17576.776	0.010	0.600
Modelled				0.198	0.508	0.125	0.771	58001.401	1.100	1.860

FM2b

WWF Event 3

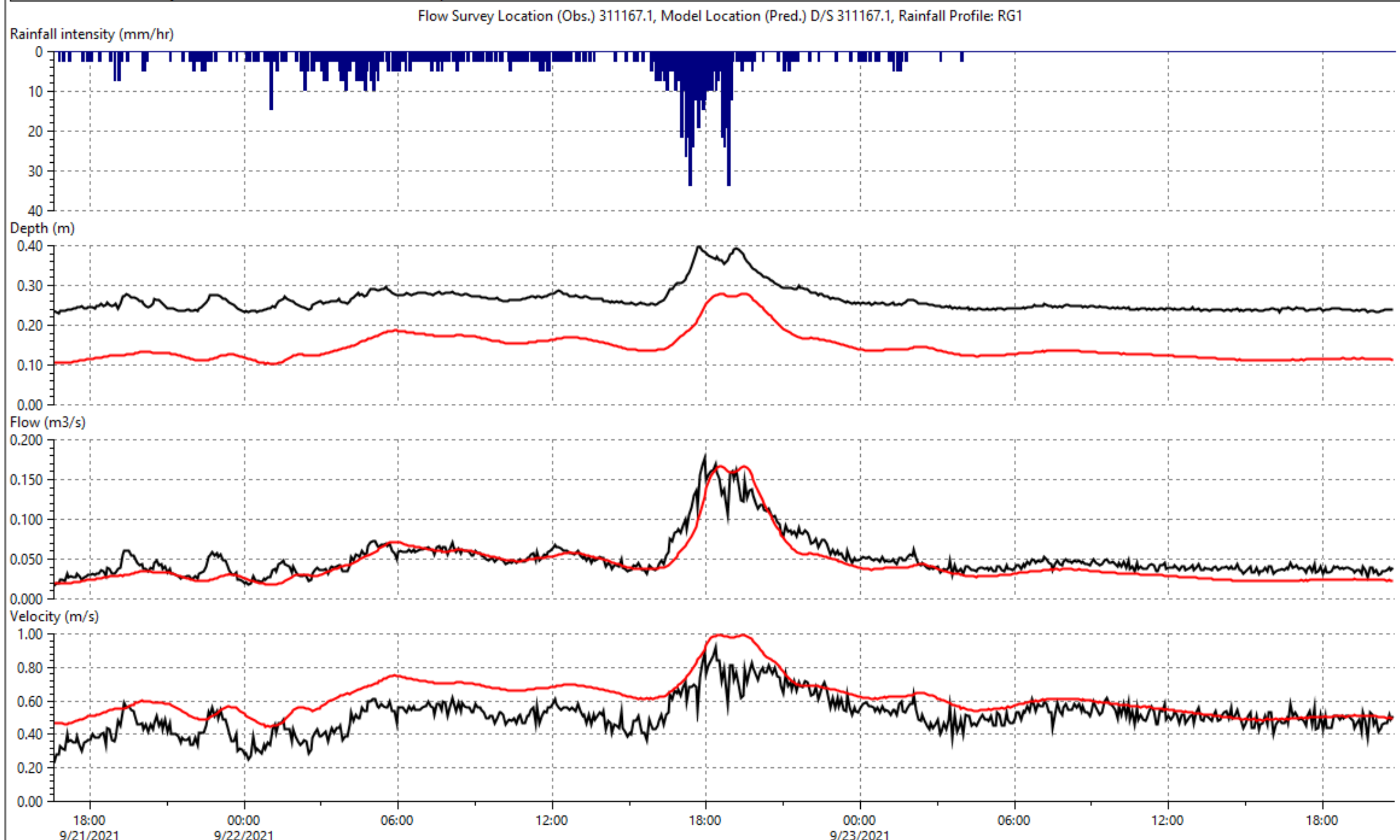


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	96.400	33.600	1.842							
Observed				0.141	0.339	0.026	0.143	9735.264	0.280	0.820
Modelled				0.141	0.296	0.032	0.144	10085.954	0.597	0.958

FM3

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 18 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)



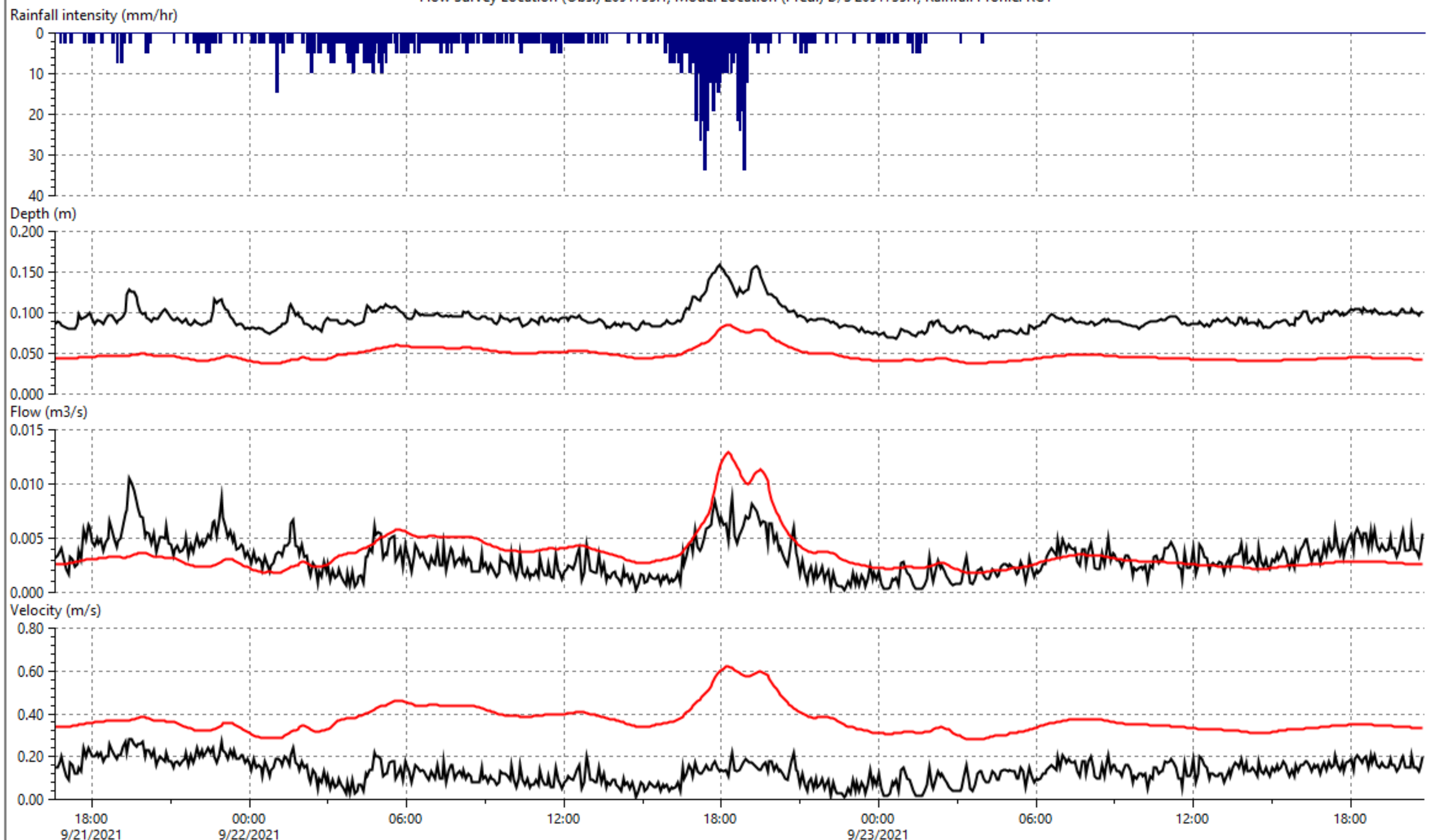
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	96.400	33.600	1.842							
Observed				0.232	0.397	0.017	0.178	9673.948	0.230	0.920
Modelled				0.102	0.280	0.018	0.167	8322.475	0.445	0.992

FM3b

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 2 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)

Flow Survey Location (Obs.) 2091735.1, Model Location (Pred.) D/S 2091735.1, Rainfall Profile: RG1

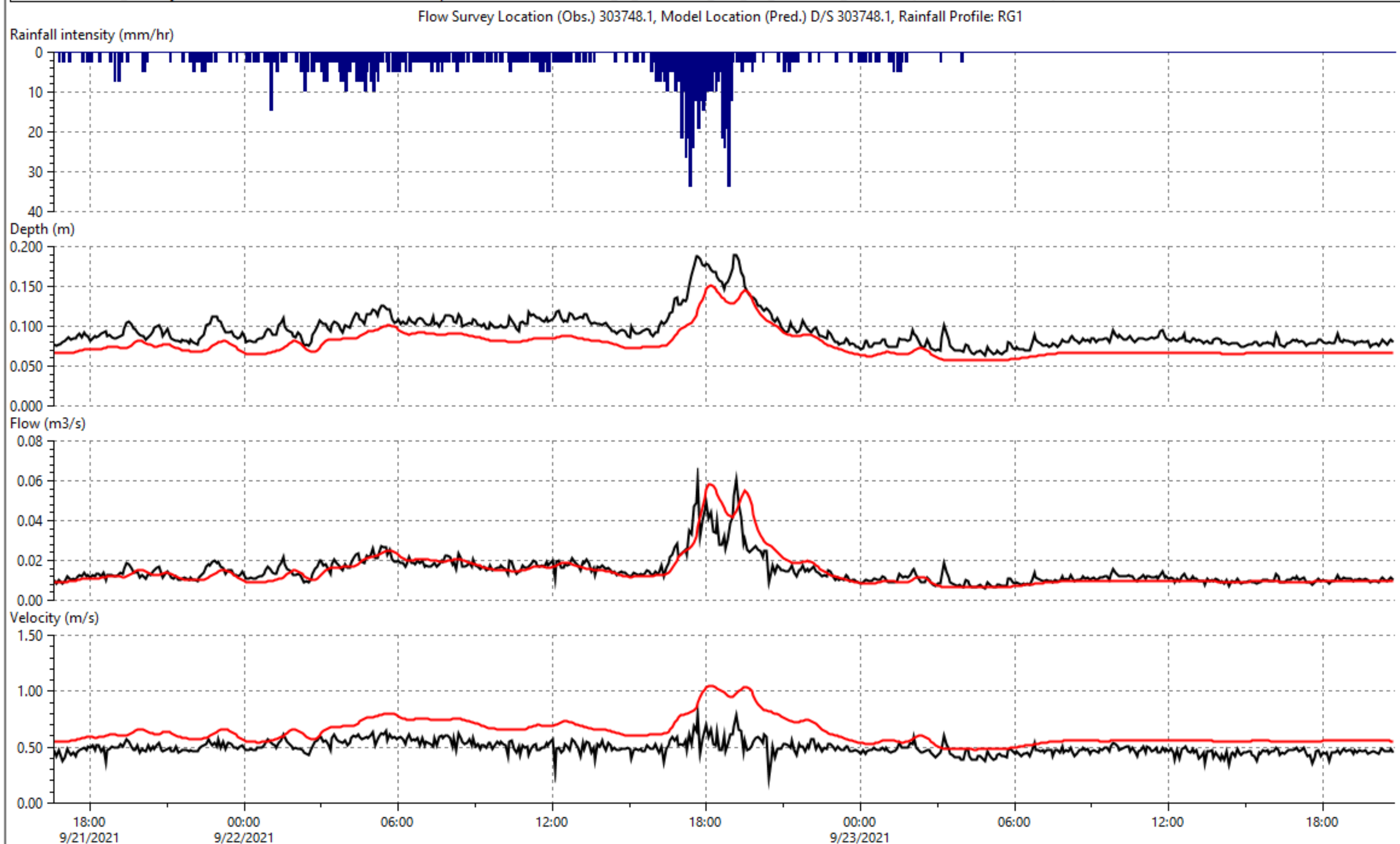


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	96.400	33.600	1.842							
Observed				0.068	0.159	0.000	0.011	607.519	0.010	0.280
Modelled				0.038	0.085	0.002	0.013	670.971	0.282	0.621

FM4

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 10 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)



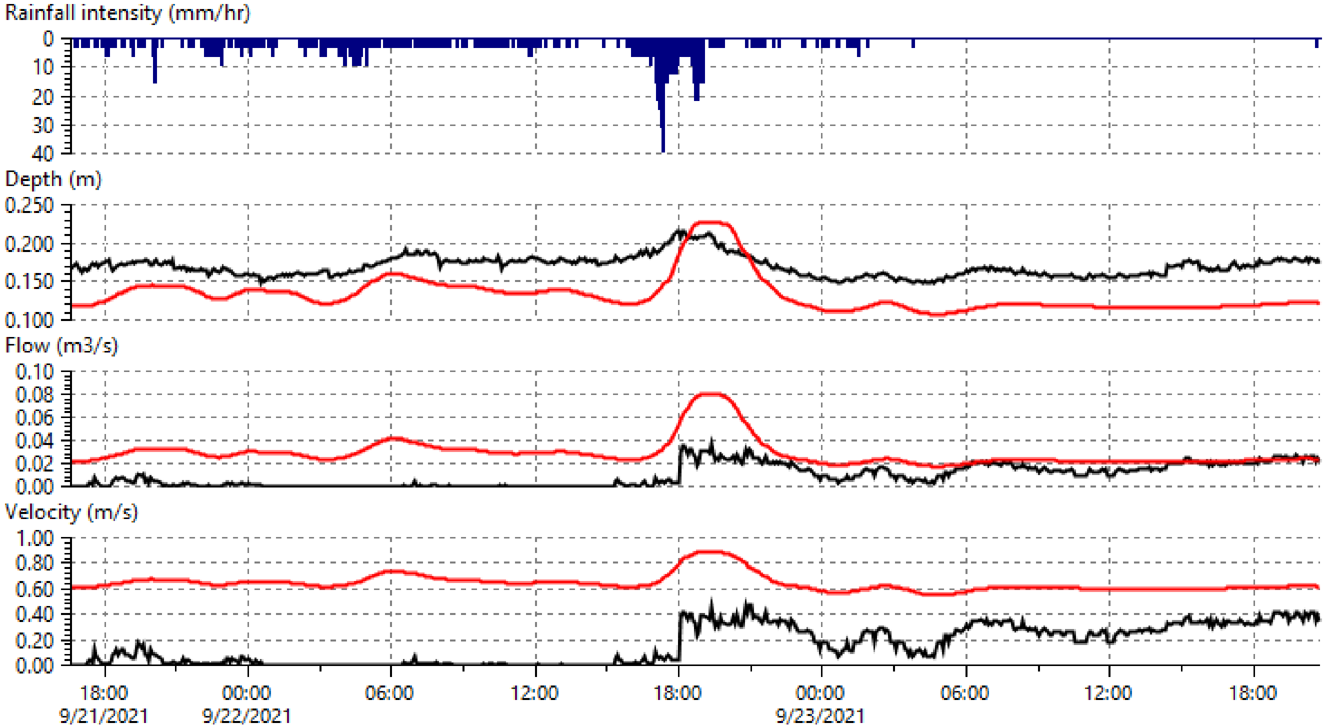
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	96.400	33.600	1.842							
Observed				0.064	0.190	0.006	0.061	2768.725	0.230	0.800
Modelled				0.057	0.151	0.007	0.058	2717.293	0.479	1.047

FM5b

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/26/2022 11:45:02 AM) Page 19 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3_FM5blink (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10_TM2c>WWF_it10 ...

Flow Survey Location (Obs.) 311440.1, Model Location (Pred.) U/S 311440.1, Rainfall Profile: RG6

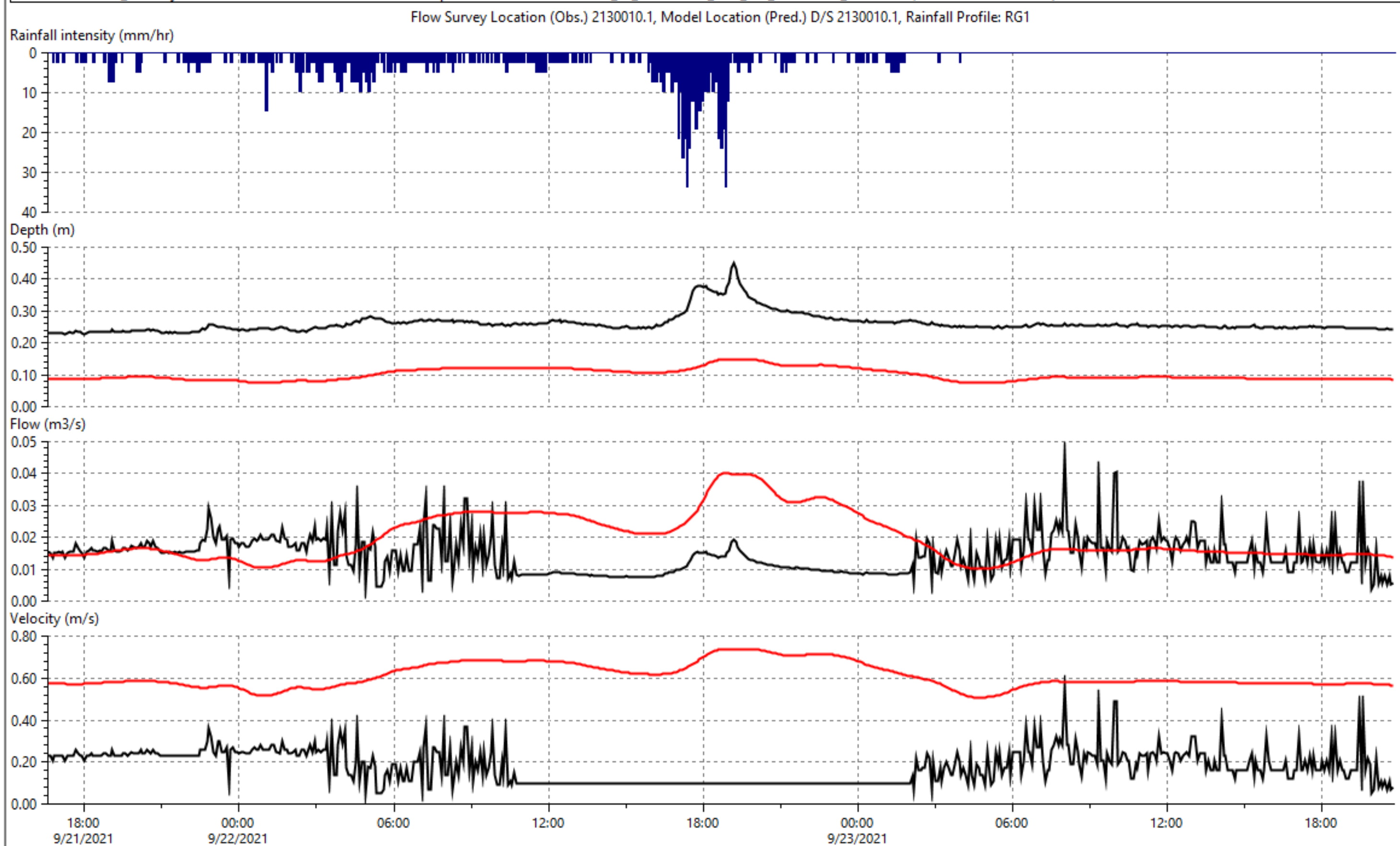


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	90.204	39.620	1.724							
Observed				0.148	0.216	0.000	0.037	1785.384	0.000	0.470
Modelled				0.108	0.227	0.018	0.080	5404.531	0.551	0.893

FM6

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 3 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)



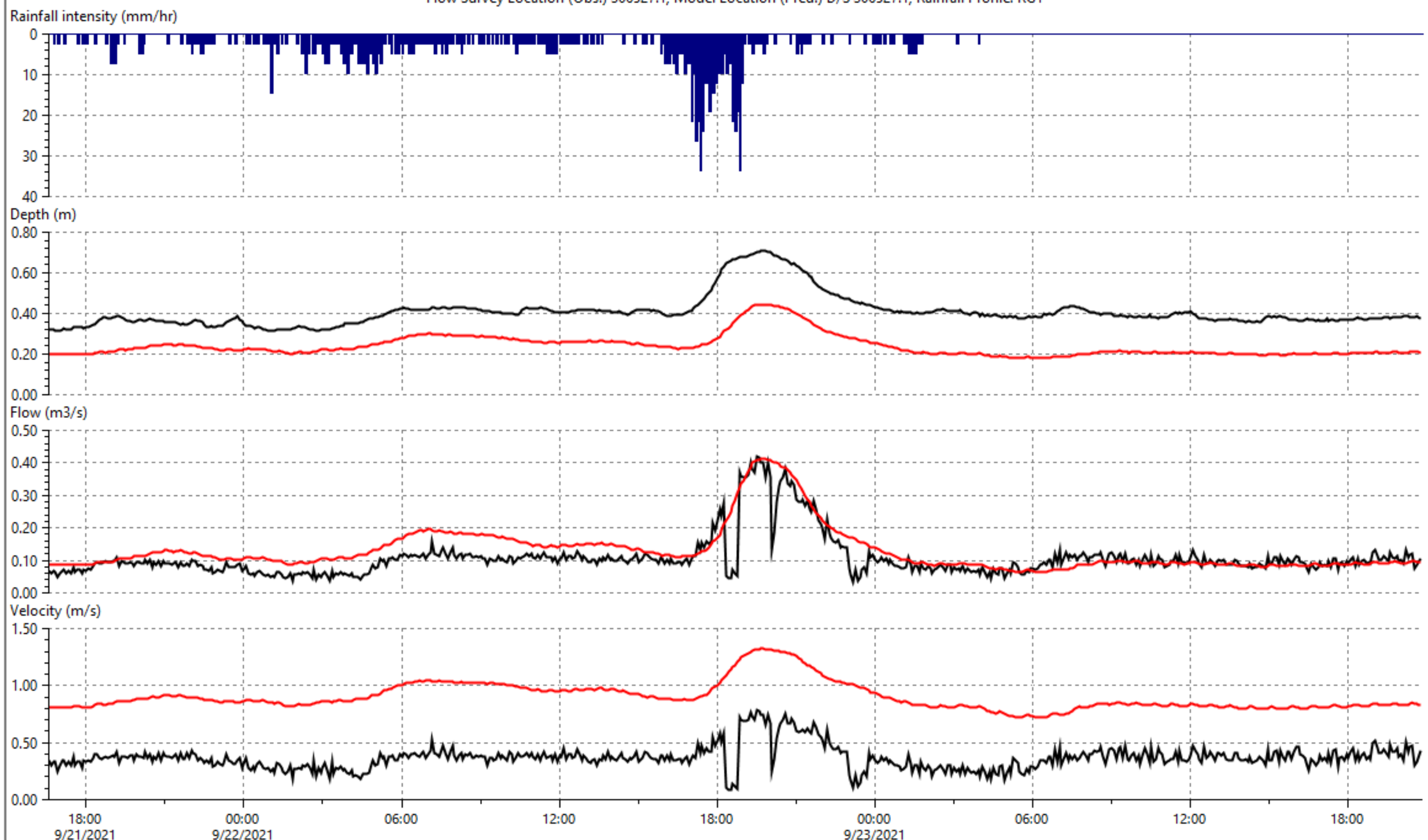
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	96.400	33.600	1.842							
Observed				0.229	0.450	0.004	0.046	2706.208	0.050	0.560
Modelled				0.074	0.149	0.010	0.040	3717.215	0.507	0.738

FM7

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 13 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)

Flow Survey Location (Obs.) 306527.1, Model Location (Pred.) D/S 306527.1, Rainfall Profile: RG1



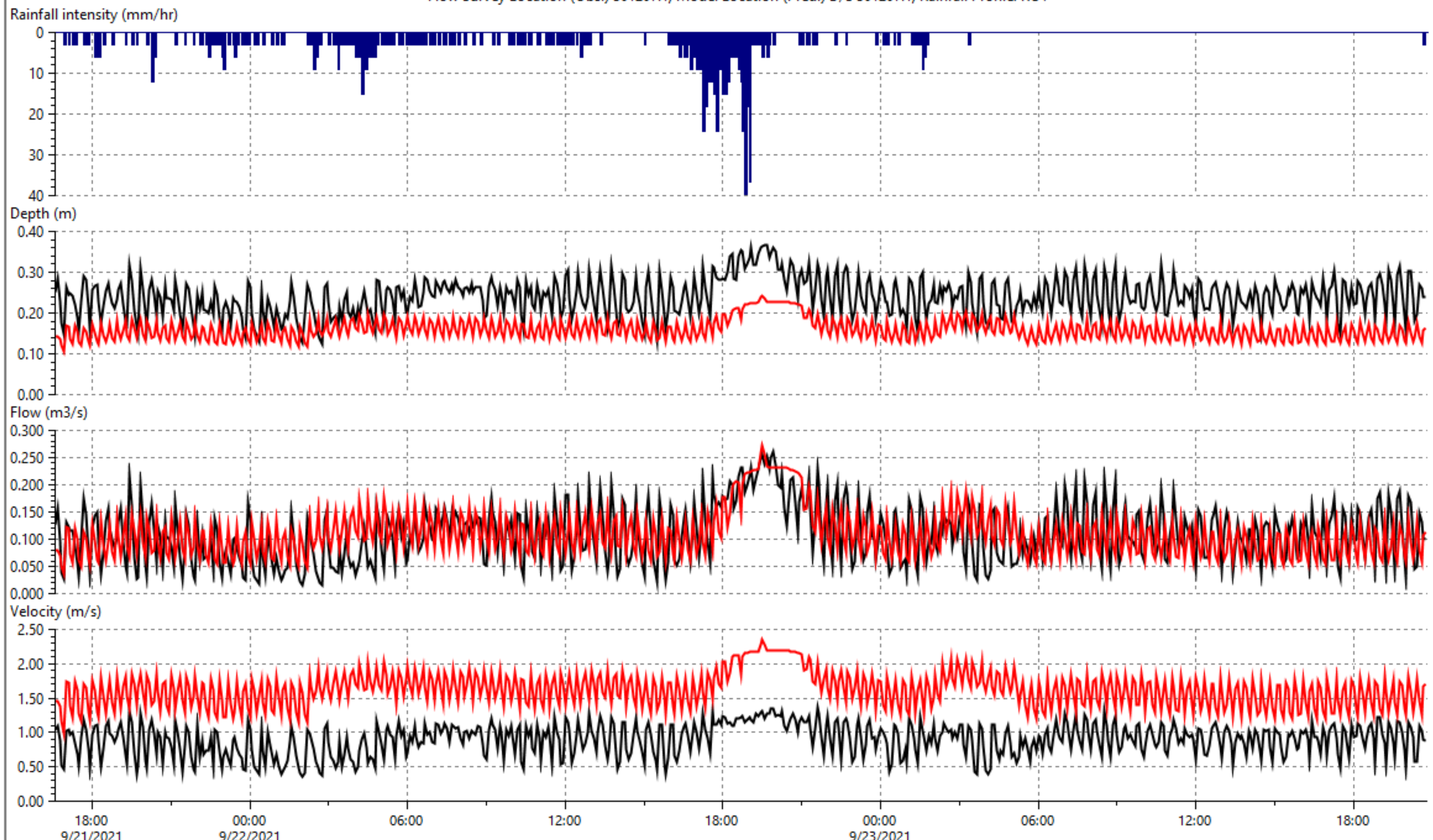
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	96.400	33.600	1.842							
Observed				0.315	0.709	0.036	0.421	20297.742	0.090	0.790
Modelled				0.179	0.445	0.065	0.415	24503.822	0.724	1.322

FM9

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 5 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)

Flow Survey Location (Obs.) 301207.1, Model Location (Pred.) D/S 301207.1, Rainfall Profile: RG4

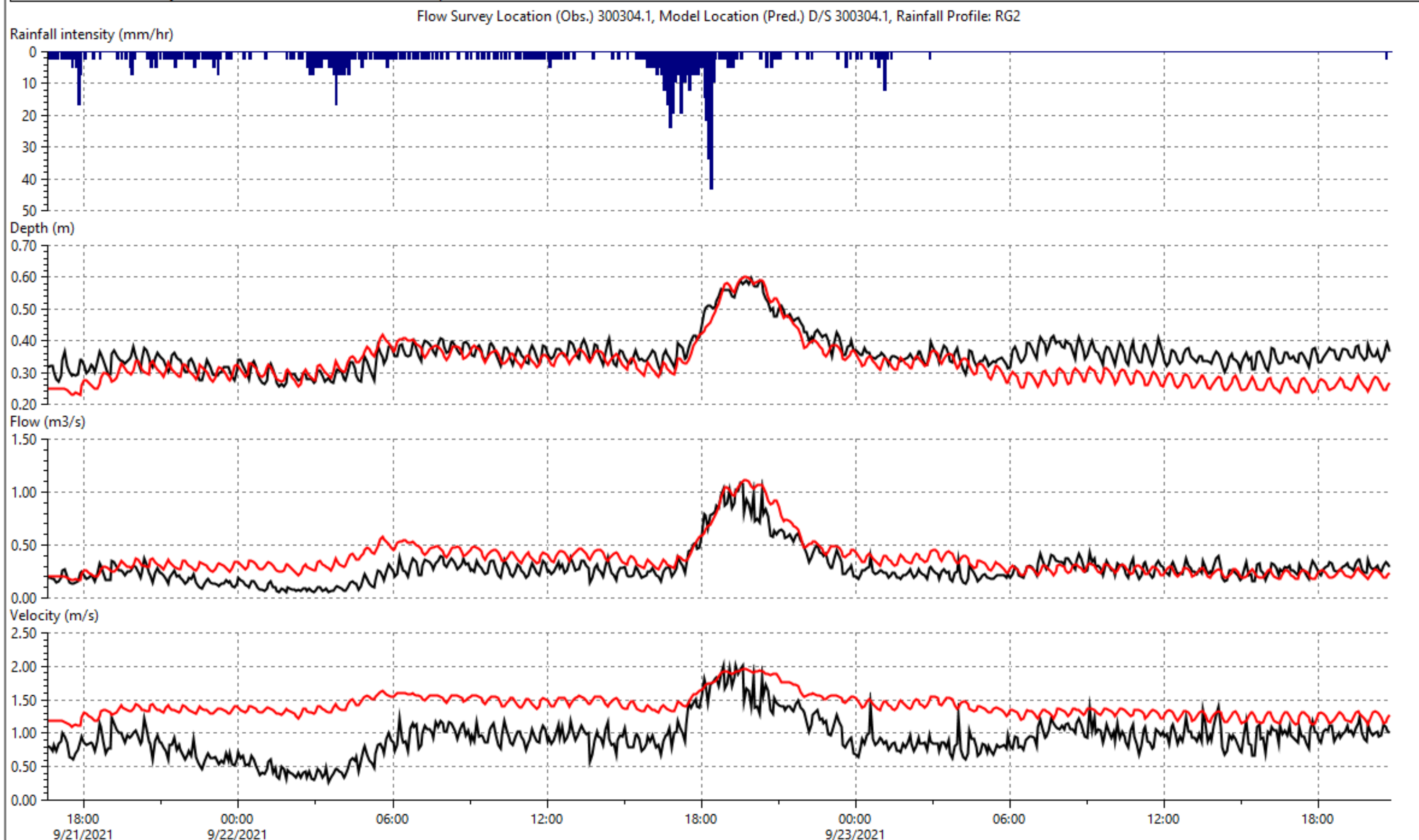


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	86.895	39.620	1.660							
Observed				0.124	0.366	0.017	0.262	20627.409	0.360	1.360
Modelled				0.106	0.244	0.036	0.274	20598.721	0.988	2.354

FM10

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 4 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)



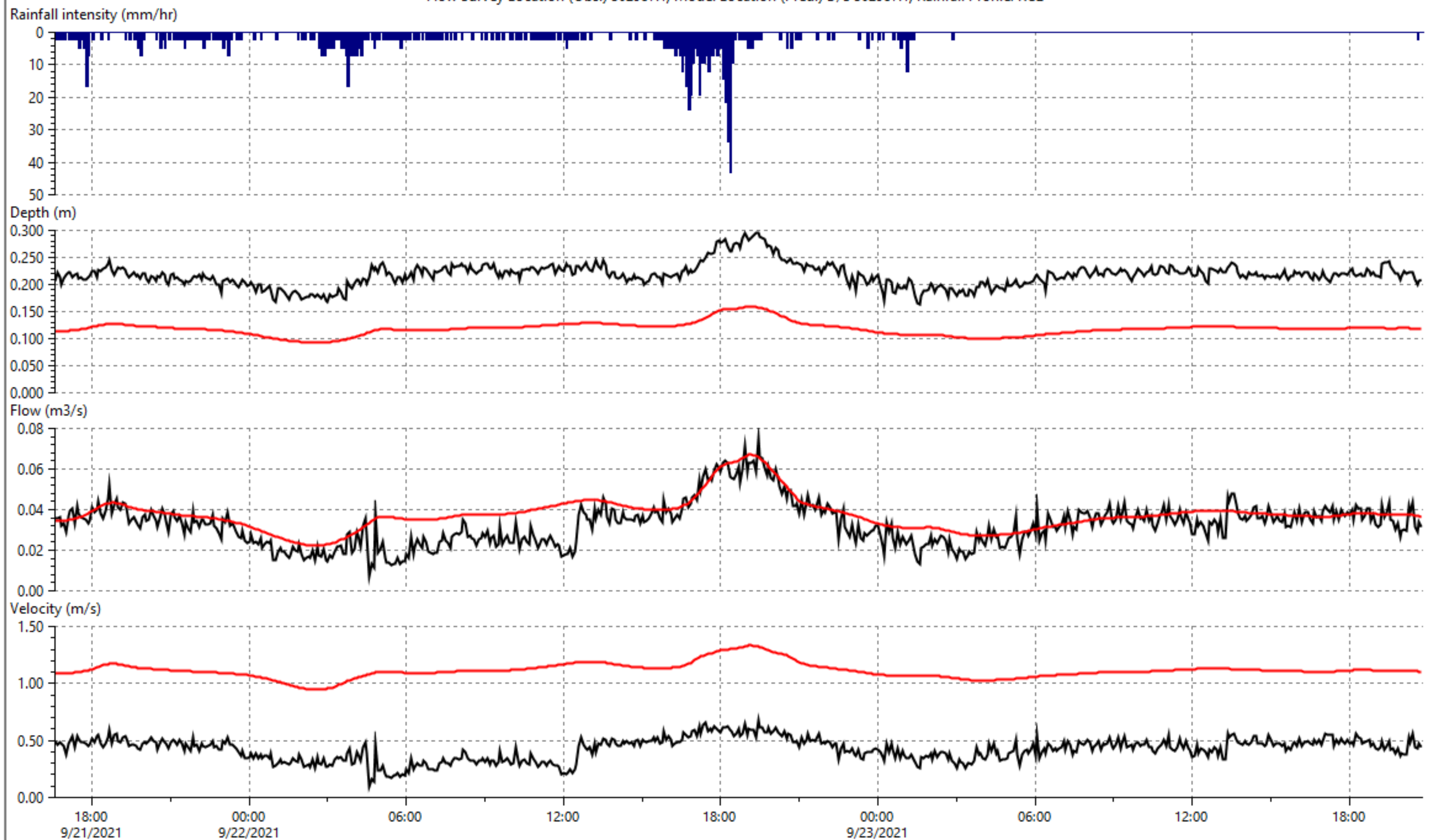
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	81.800	43.200	1.563							
Observed				0.255	0.597	0.055	1.086	54085.971	0.270	2.010
Modelled				0.230	0.603	0.169	1.117	69597.589	1.105	1.963

FM11

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 6 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)

Flow Survey Location (Obs.) 302987.1, Model Location (Pred.) D/S 302987.1, Rainfall Profile: RG2

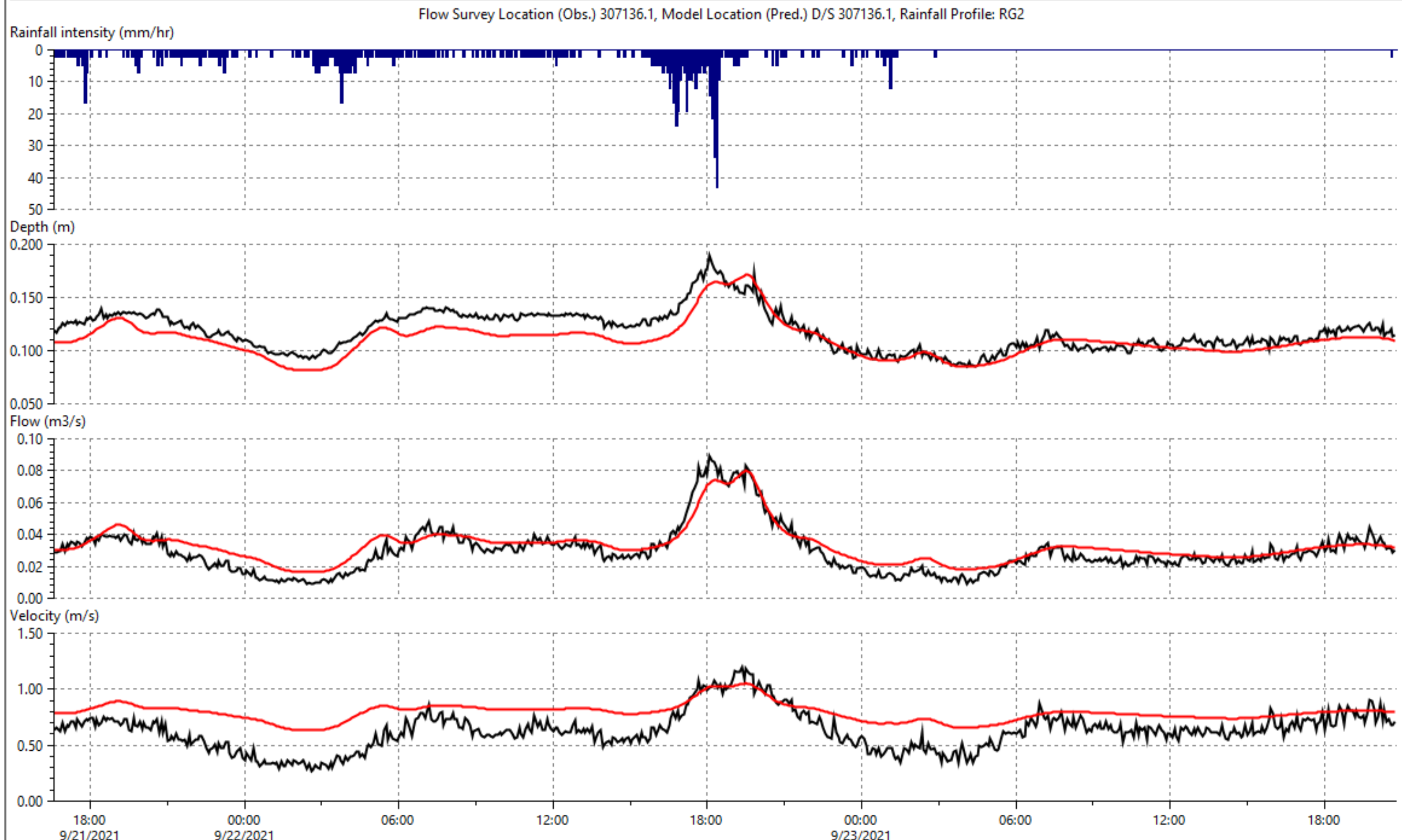


		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain		81.800	43.200	1.563							
Observed					0.164	0.296	0.007	0.075	6180.386	0.100	0.680
Modelled					0.093	0.159	0.022	0.067	7058.617	0.946	1.334

FM12

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 15 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)



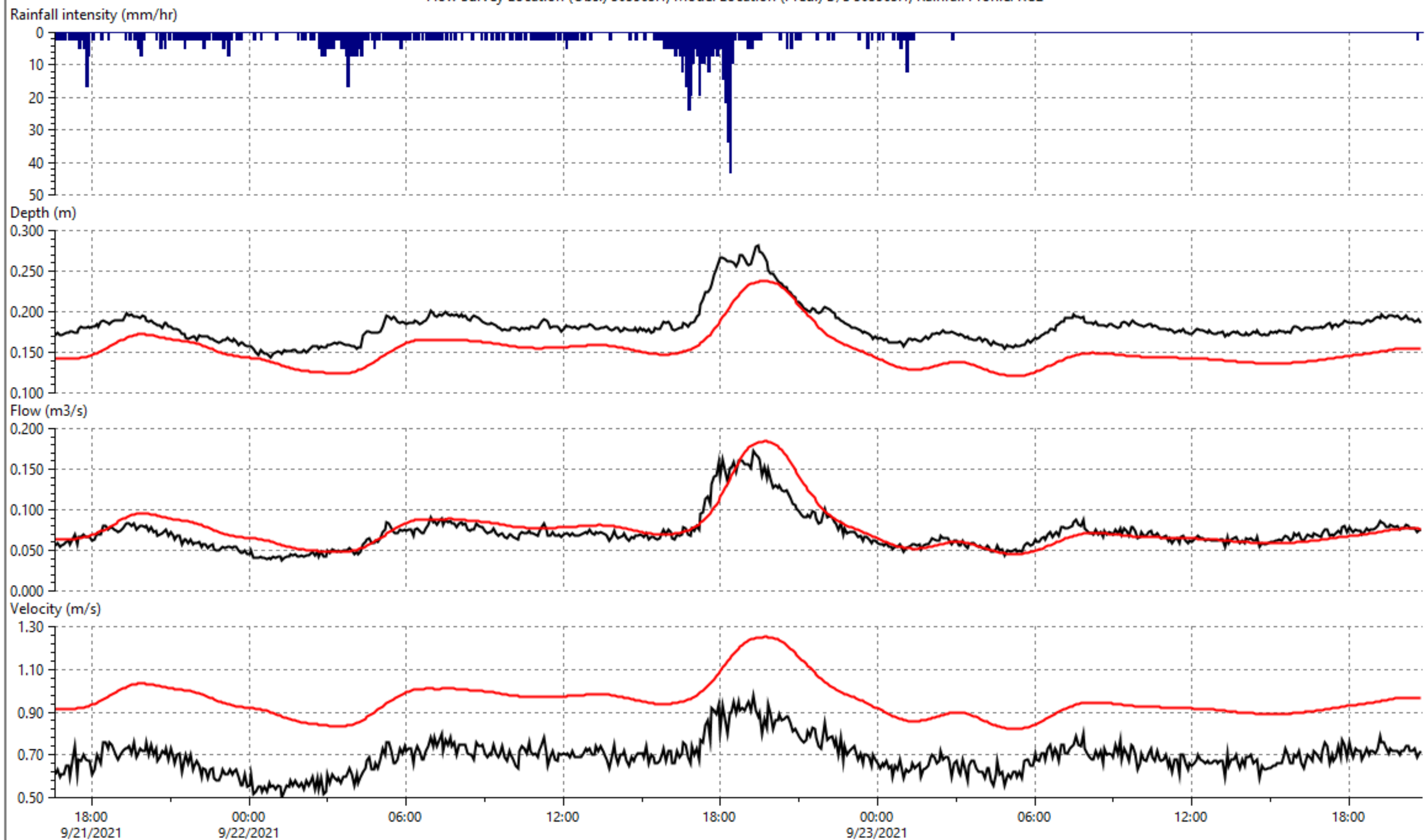
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	81.800	43.200	1.563							
Observed				0.085	0.190	0.009	0.089	5579.640	0.270	1.200
Modelled				0.081	0.171	0.016	0.080	6183.497	0.634	1.053

FM13

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 9 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)

Flow Survey Location (Obs.) 303563.1, Model Location (Pred.) D/S 303563.1, Rainfall Profile: RG2

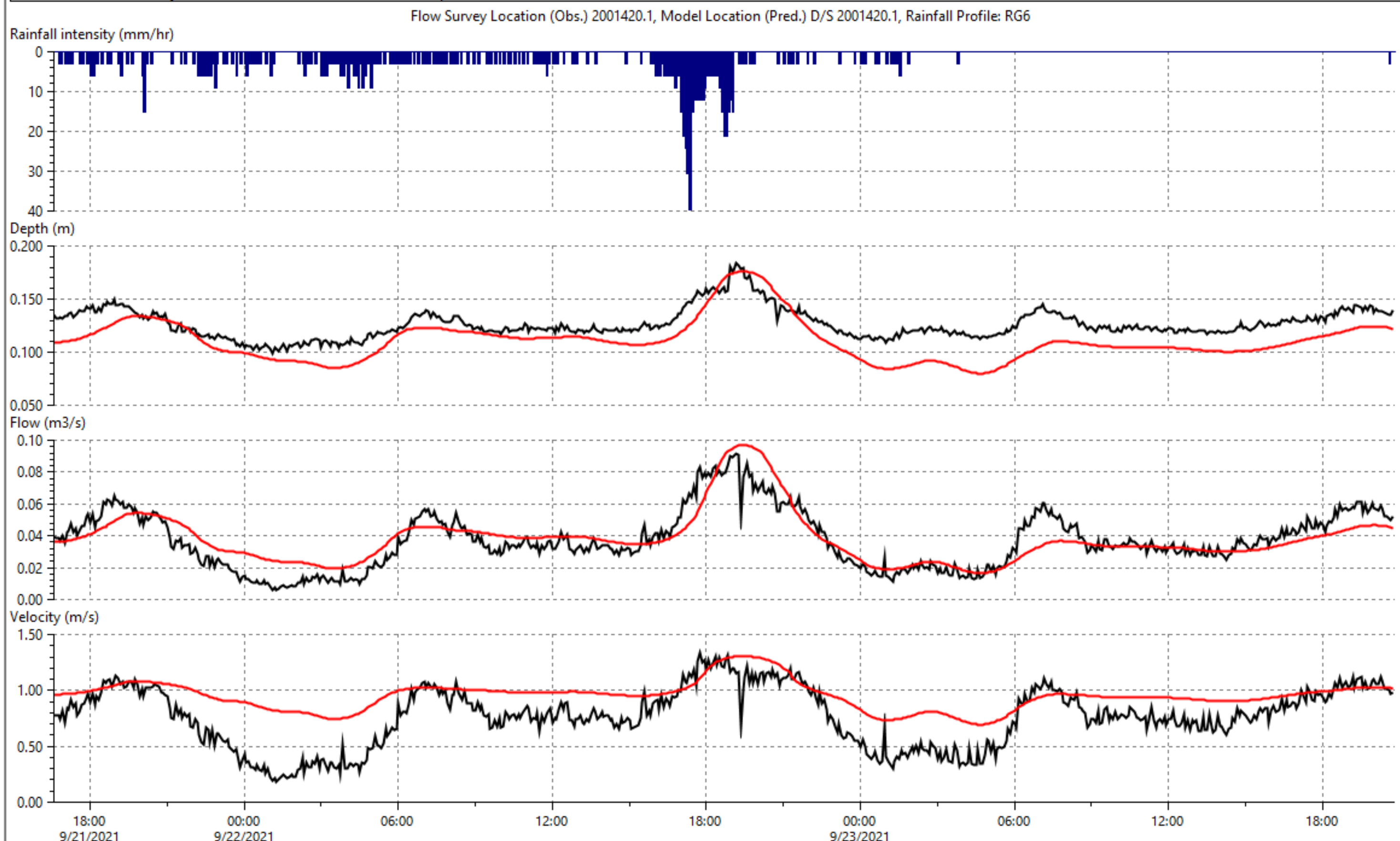


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	81.800	43.200	1.563							
Observed				0.144	0.282	0.037	0.173	13473.015	0.500	0.980
Modelled				0.121	0.238	0.046	0.184	14276.740	0.821	1.252

FM13b

WWF Event 3

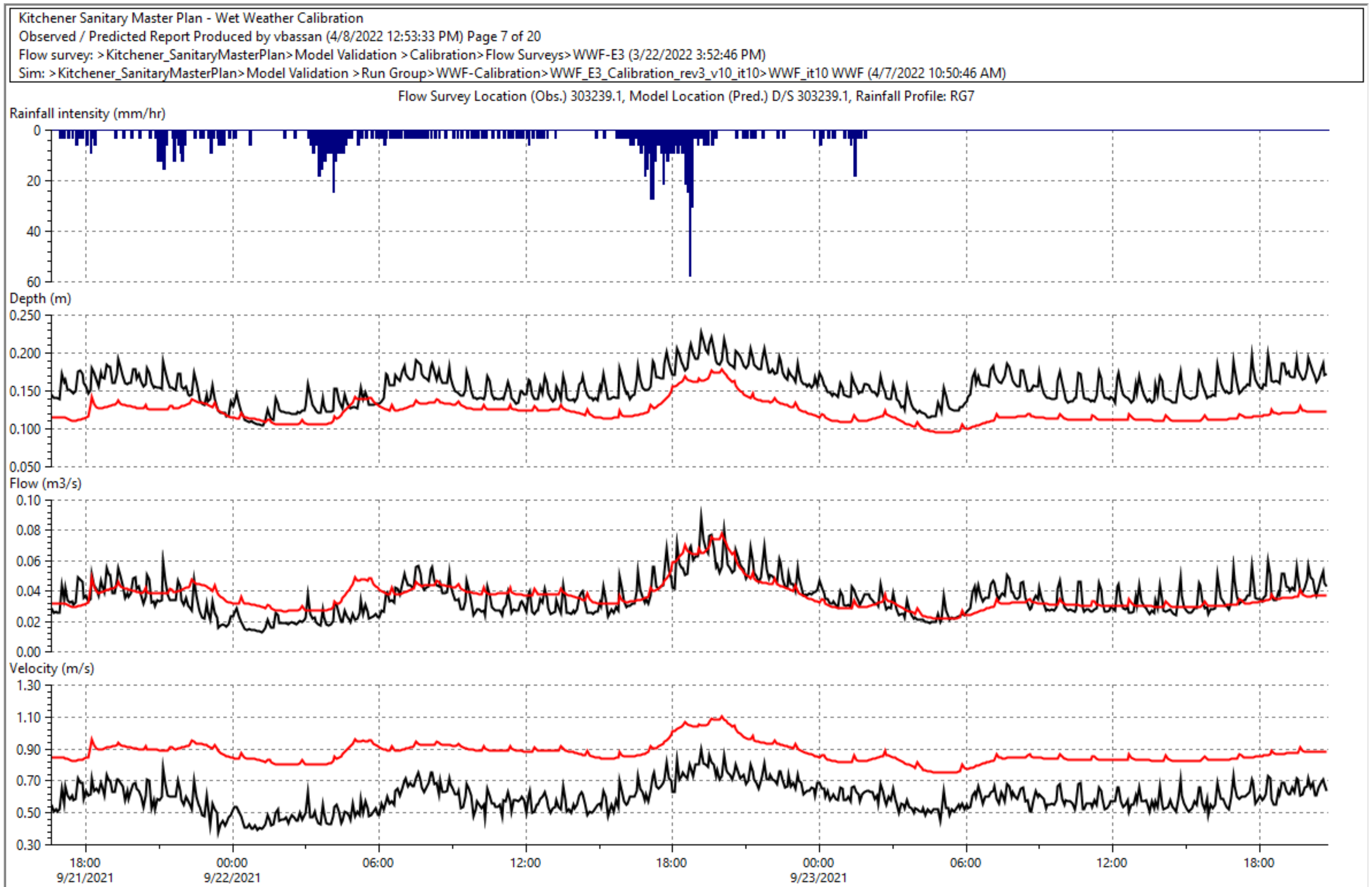
Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 1 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)



		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain		90.204	39.620	1.724							
Observed					0.099	0.184	0.006	0.092	7017.131	0.180	1.340
Modelled					0.080	0.176	0.017	0.097	7173.795	0.695	1.304

FM15

WWF Event 3



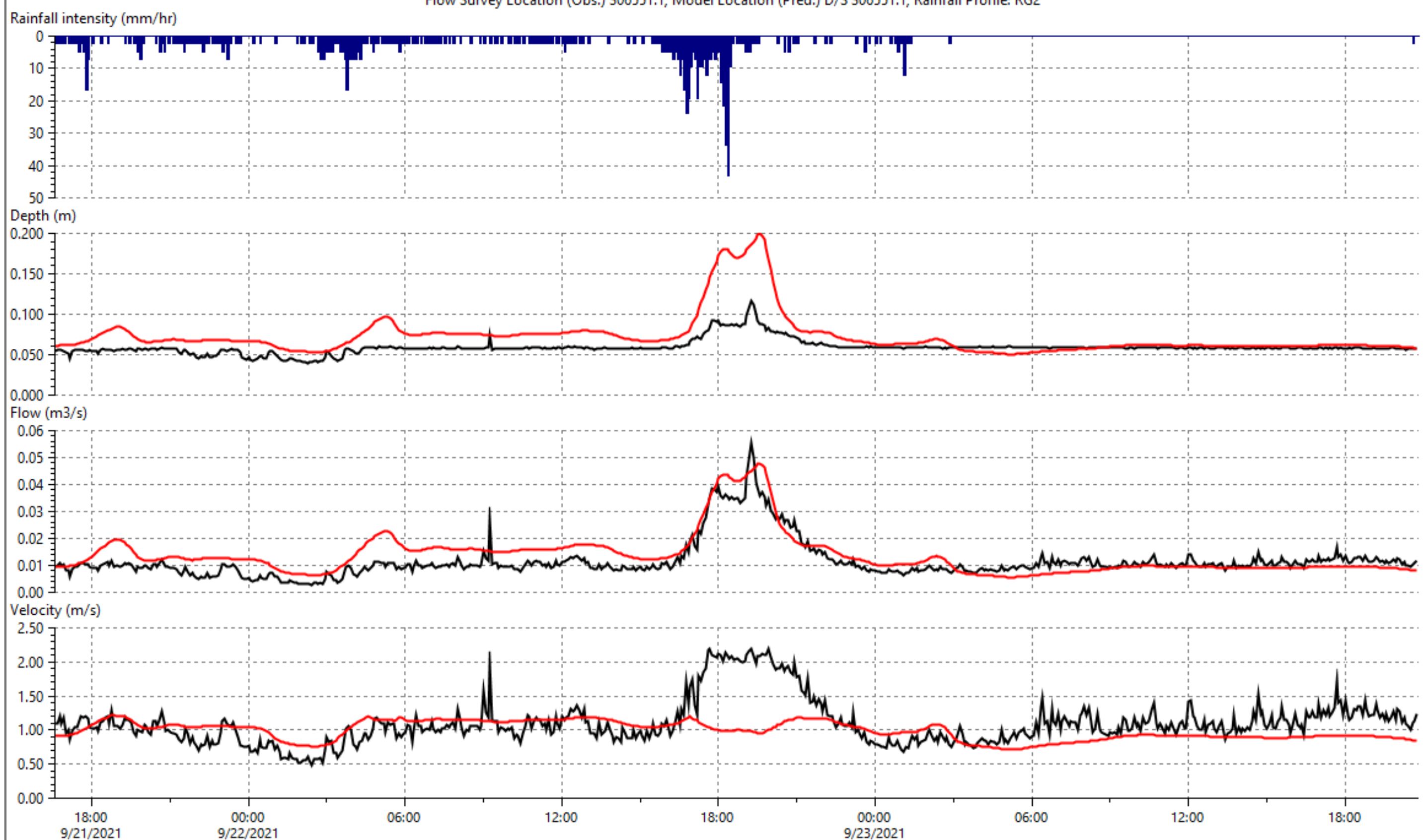
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	101.116	57.910	1.932							
Observed				0.104	0.227	0.013	0.088	6682.153	0.380	0.900
Modelled				0.095	0.179	0.022	0.078	6884.924	0.750	1.103

FM18

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 14 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)

Flow Survey Location (Obs.) 306551.1, Model Location (Pred.) D/S 306551.1, Rainfall Profile: RG2

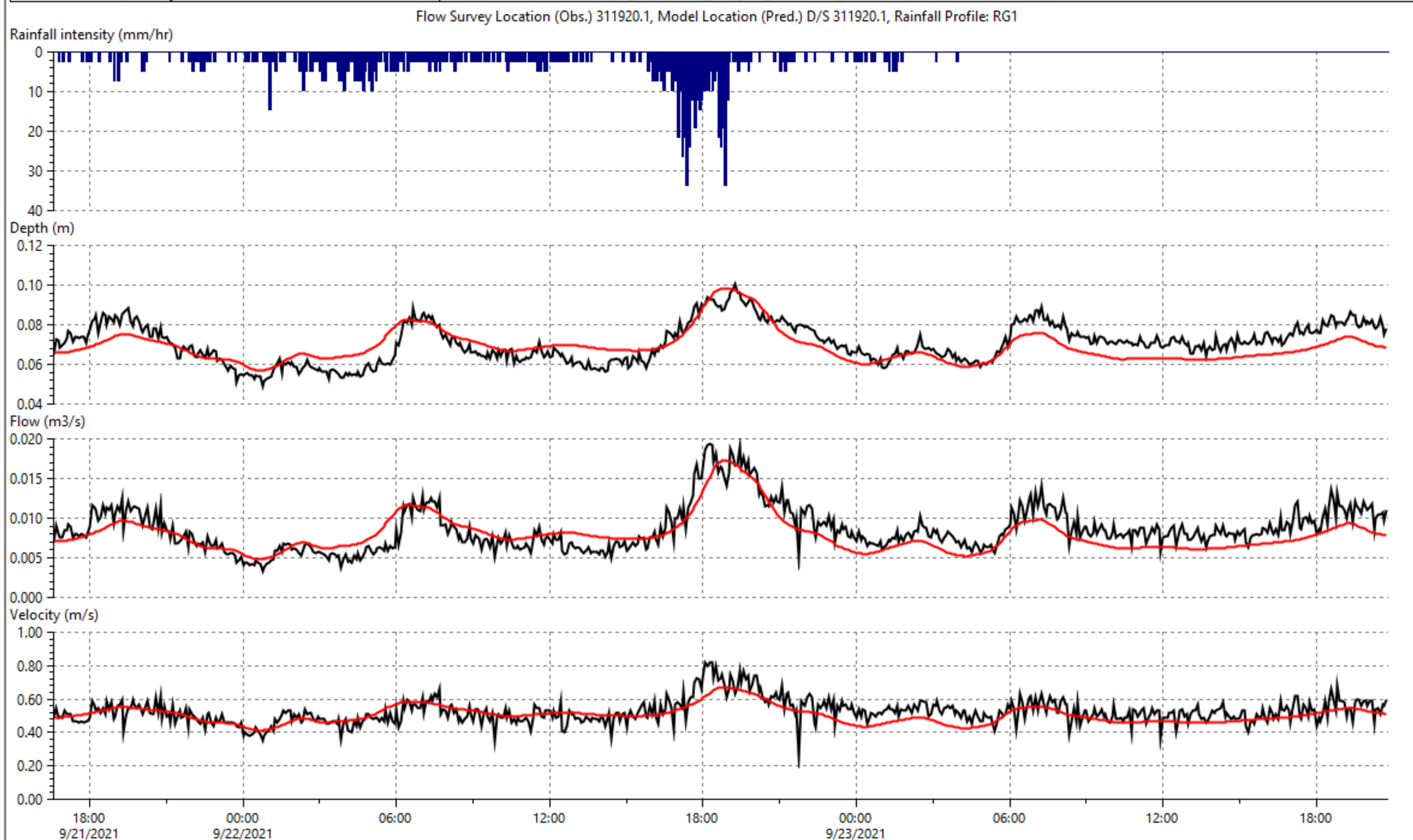


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	81.800	43.200	1.563							
Observed				0.040	0.116	0.003	0.055	2172.369	0.490	2.190
Modelled				0.051	0.200	0.006	0.048	2571.704	0.717	1.217

FM19

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 20 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)



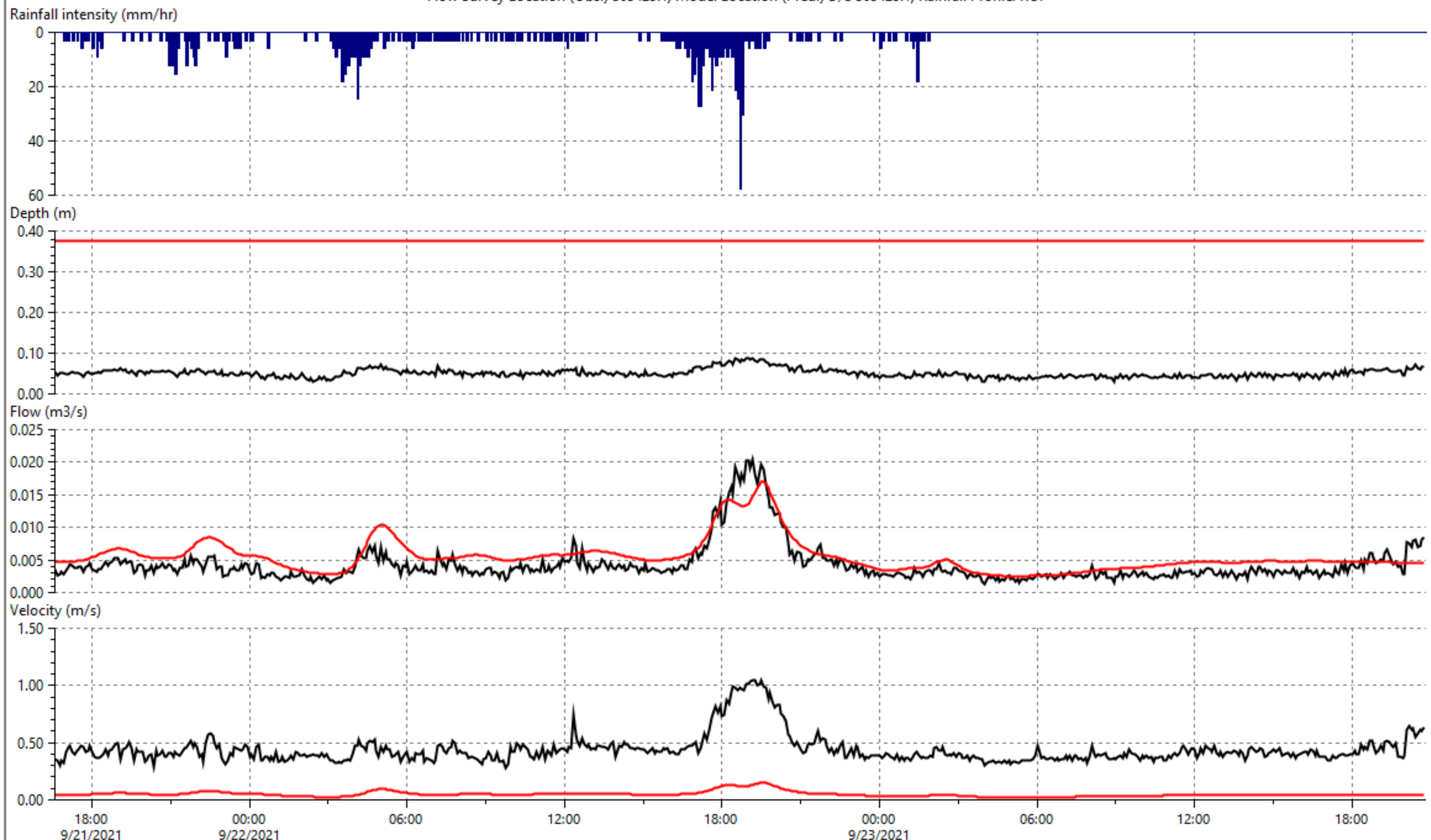
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	96.400	33.600	1.842							
Observed				0.049	0.100	0.003	0.019	1621.909	0.260	0.820
Modelled				0.057	0.098	0.005	0.017	1496.727	0.413	0.670

FM20

WWF Event 3

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 12:53:33 PM) Page 8 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E3 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E3_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:50:46 AM)

Flow Survey Location (Obs.) 303425.1, Model Location (Pred.) D/S 303425.1, Rainfall Profile: RG7

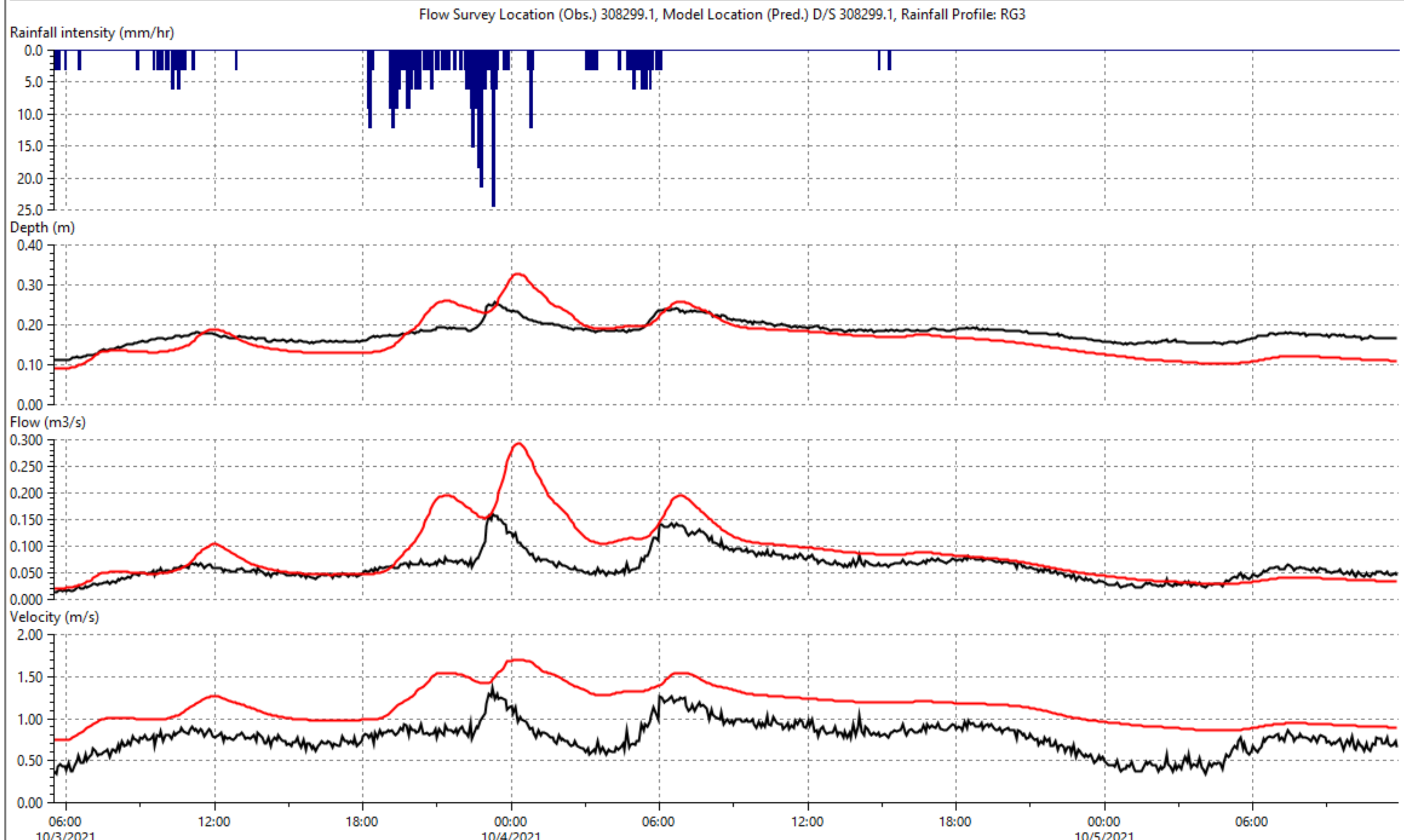


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	101.116	57.910	1.932							
Observed				0.029	0.089	0.001	0.020	806.872	0.280	1.050
Modelled				0.375	0.375	0.003	0.017	1030.823	0.023	0.153

FM1

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 16 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

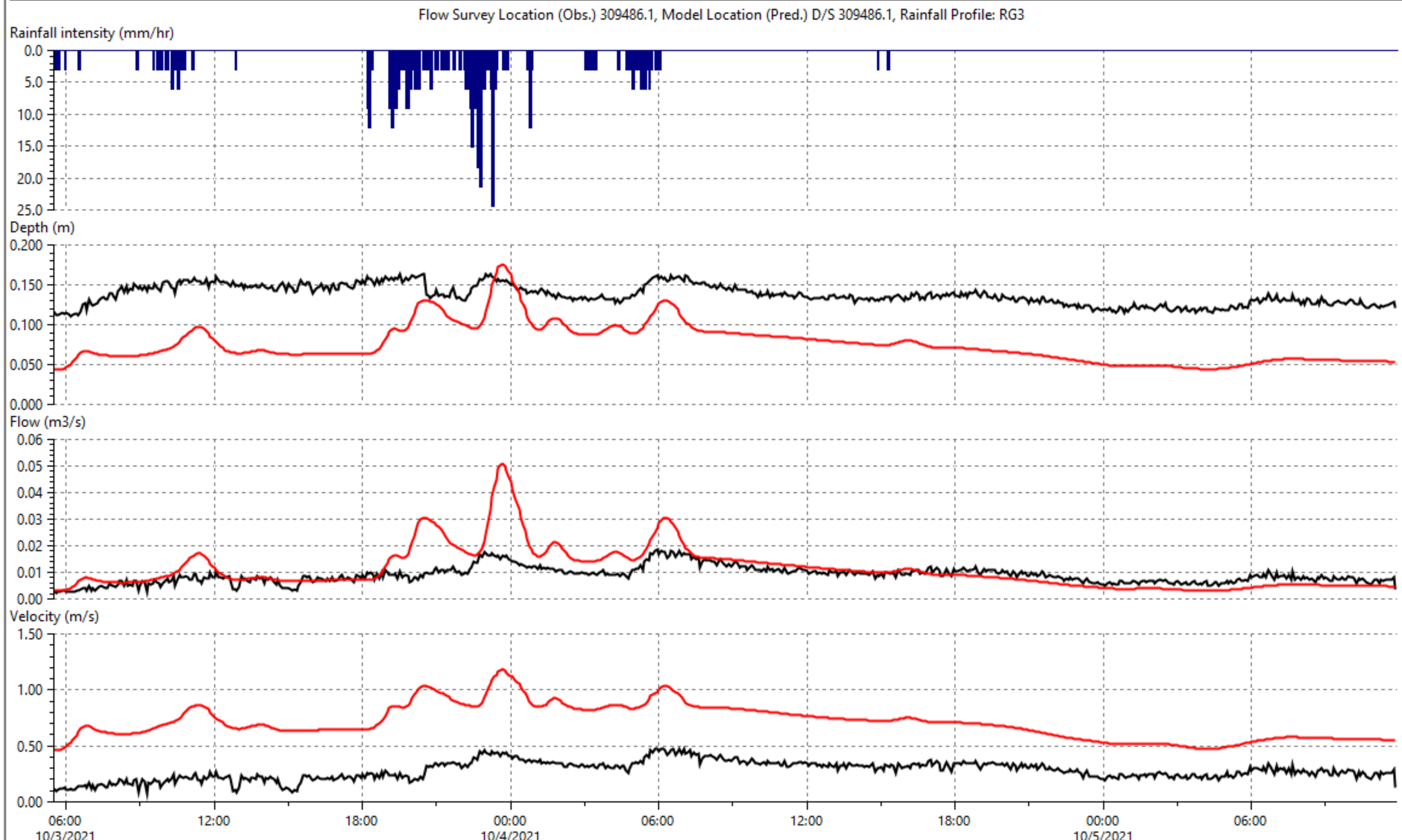


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	40.907	24.380	0.751							
Observed				0.112	0.258	0.014	0.162	12119.432	0.350	1.360
Modelled				0.091	0.327	0.021	0.293	16717.307	0.741	1.701

FM1b

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 17 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)



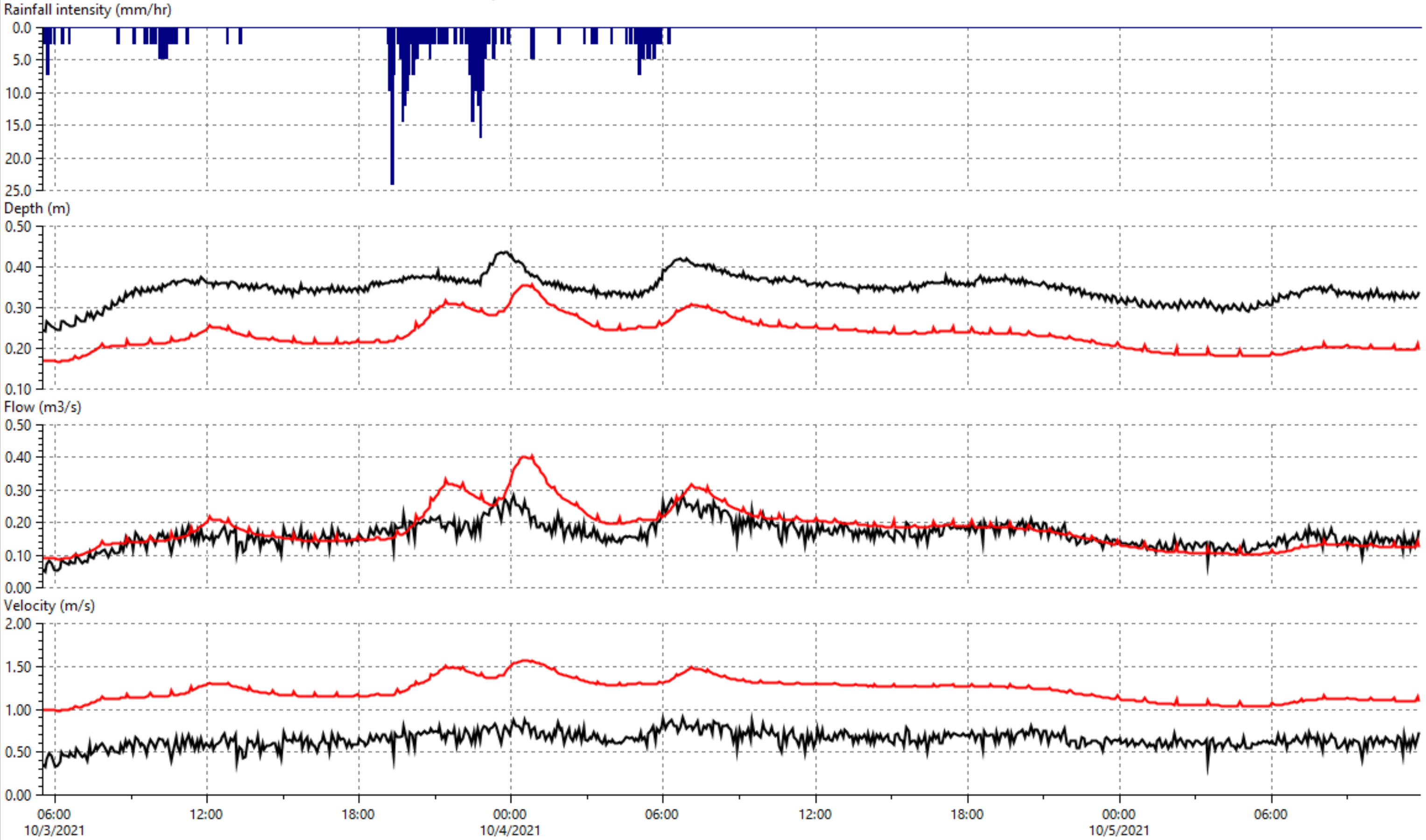
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	40.907	24.380	0.751							
Observed				0.111	0.164	0.002	0.018	1760.056	0.080	0.470
Modelled				0.044	0.176	0.003	0.051	2177.356	0.464	1.184

FM2

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 11 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 304472.1, Model Location (Pred.) D/S 304472.1, Rainfall Profile: RG1



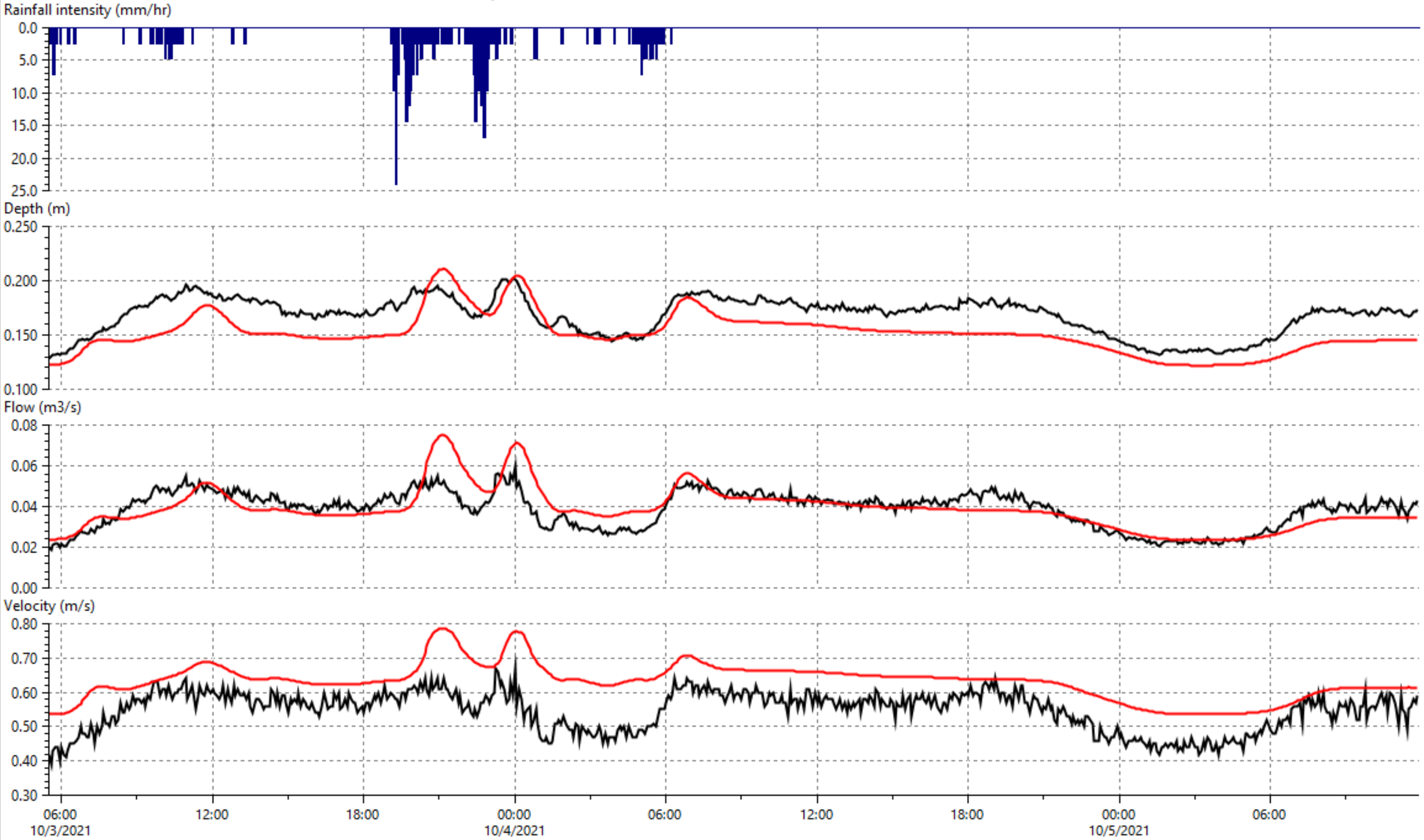
		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	blue line	34.000	24.000	0.624							
Observed	black line				0.244	0.438	0.050	0.287	32173.858	0.330	0.900
Modelled	red line				0.167	0.356	0.087	0.407	35686.153	0.981	1.571

FM2b

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 12 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 304821.1, Model Location (Pred.) D/S 304821.1, Rainfall Profile: RG1



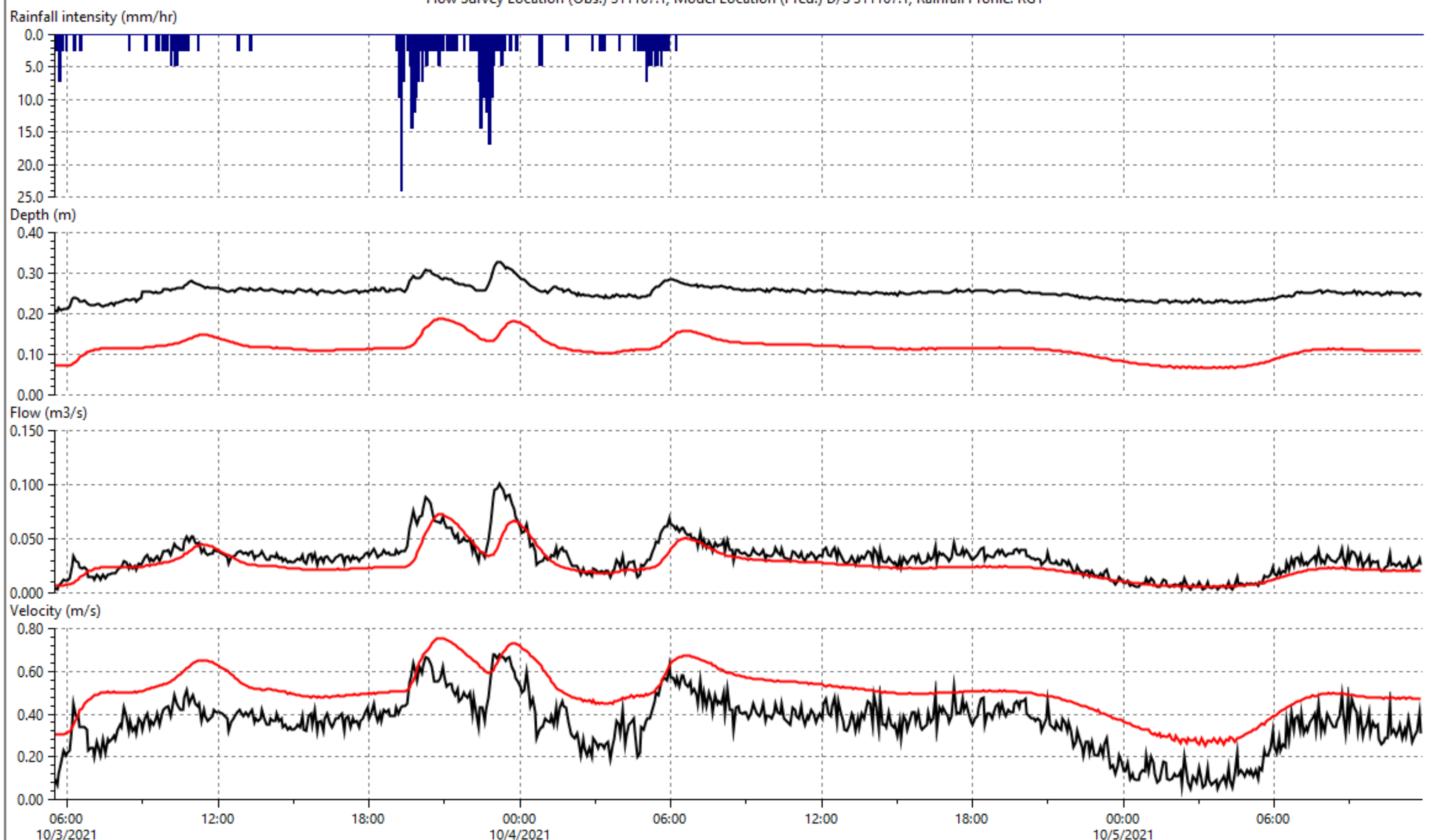
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	34.000	24.000	0.624							
Observed				0.129	0.202	0.019	0.060	7577.511	0.390	0.670
Modelled				0.122	0.211	0.024	0.075	7565.594	0.536	0.787

FM3

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 18 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 311167.1, Model Location (Pred.) D/S 311167.1, Rainfall Profile: RG1



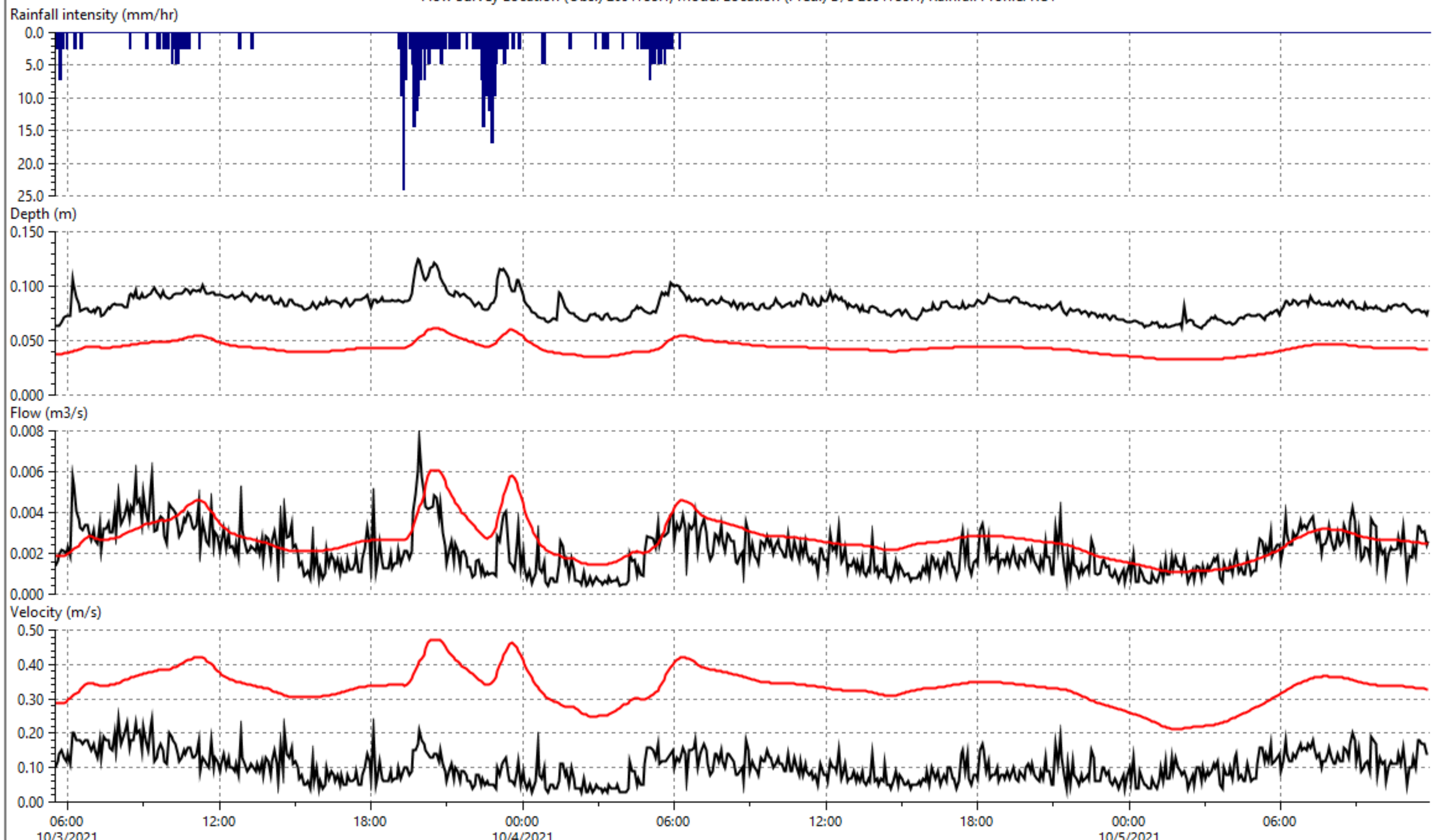
		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	blue line	34.000	24.000	0.624							
Observed	black line				0.207	0.328	0.003	0.101	6336.945	0.050	0.680
Modelled	red line				0.066	0.188	0.005	0.073	5054.609	0.255	0.757

FM3b

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 2 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 2091735.1, Model Location (Pred.) D/S 2091735.1, Rainfall Profile: RG1



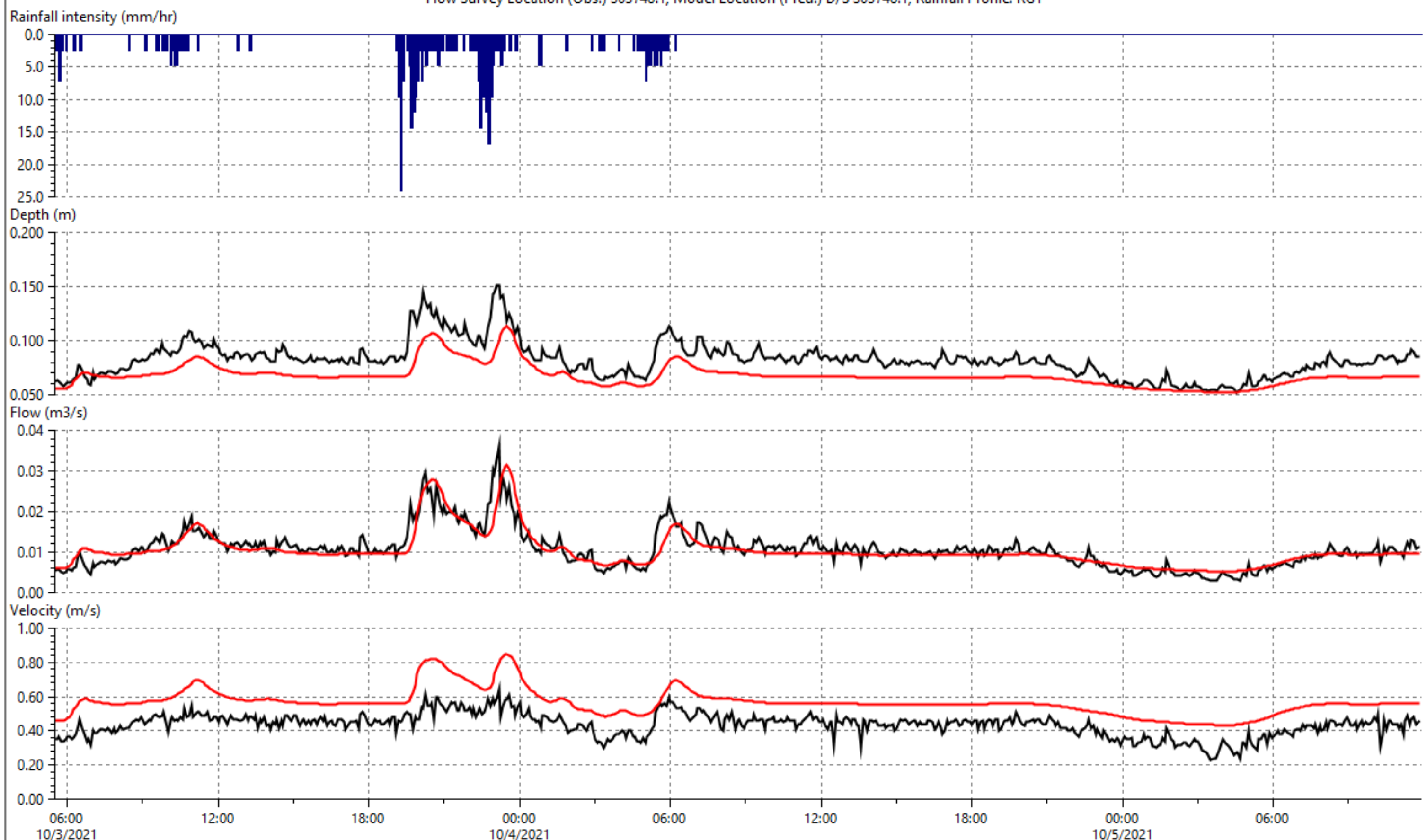
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	34.000	24.000	0.624							
Observed				0.062	0.125	0.000	0.007	412.994	0.030	0.240
Modelled				0.032	0.061	0.001	0.006	527.023	0.212	0.473

FM4

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 10 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 303748.1, Model Location (Pred.) D/S 303748.1, Rainfall Profile: RG1

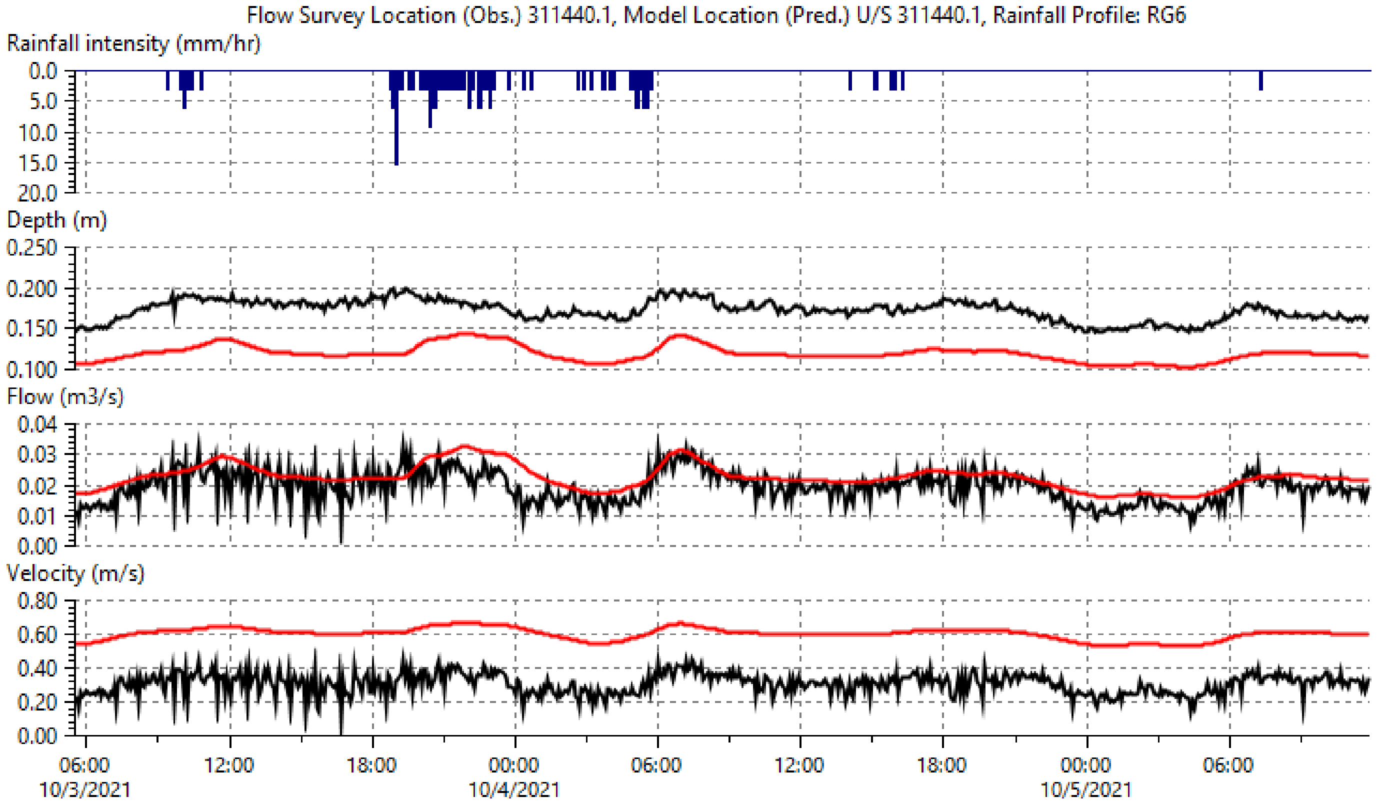


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	34.000	24.000	0.624							
Observed				0.053	0.151	0.003	0.036	2089.752	0.230	0.650
Modelled				0.053	0.113	0.005	0.032	2028.153	0.434	0.851

FM5b

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/26/2022 11:43:07 AM) Page 19 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4_FM5blink (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10_TM2c>WWF_it10 ...



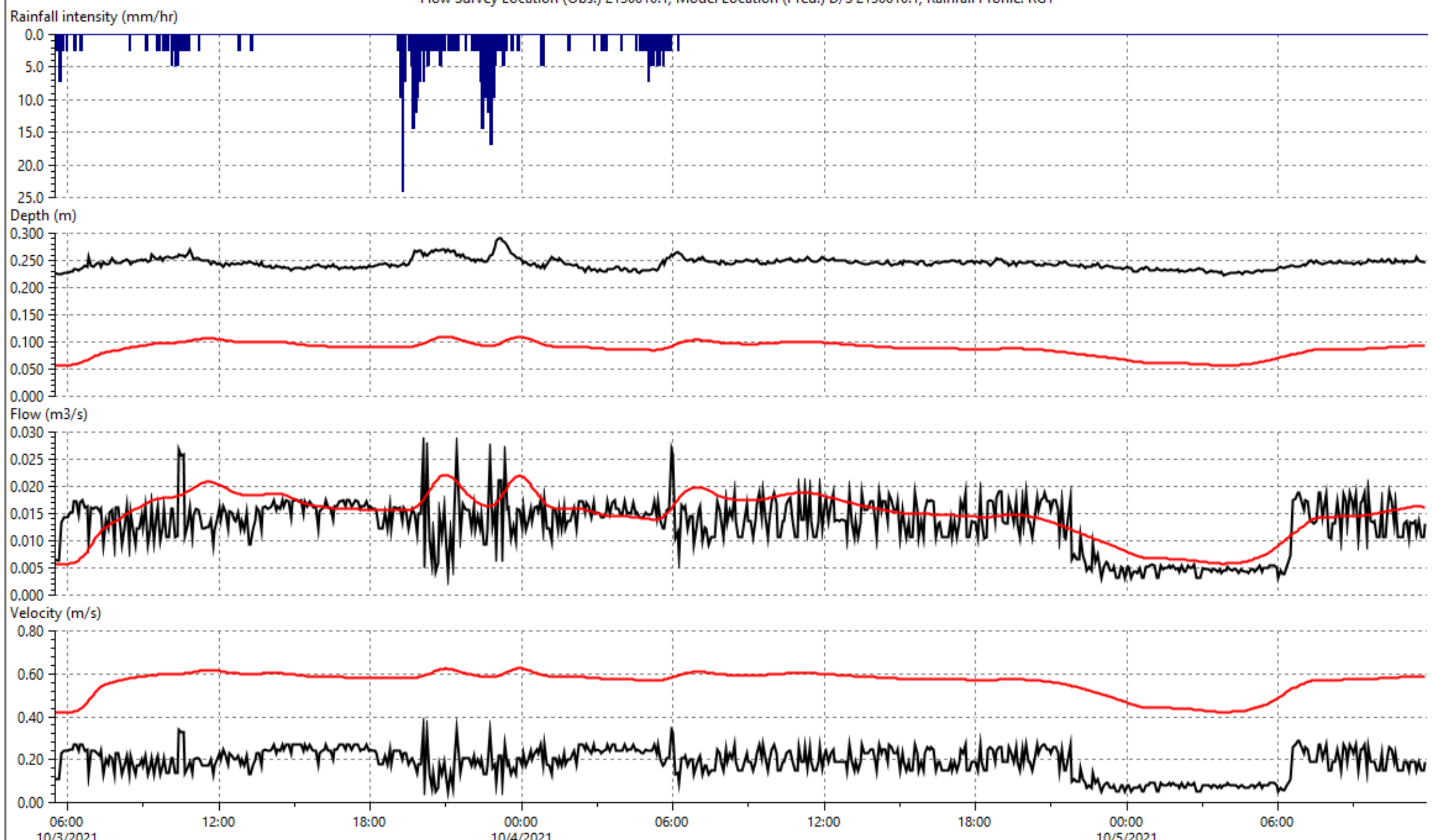
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	22.111	15.240	0.406							
Observed				0.146	0.200	0.007	0.033	3780.989	0.100	0.460
Modelled				0.103	0.144	0.016	0.033	4400.622	0.530	0.671

FM6

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 3 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 2130010.1, Model Location (Pred.) D/S 2130010.1, Rainfall Profile: RG1



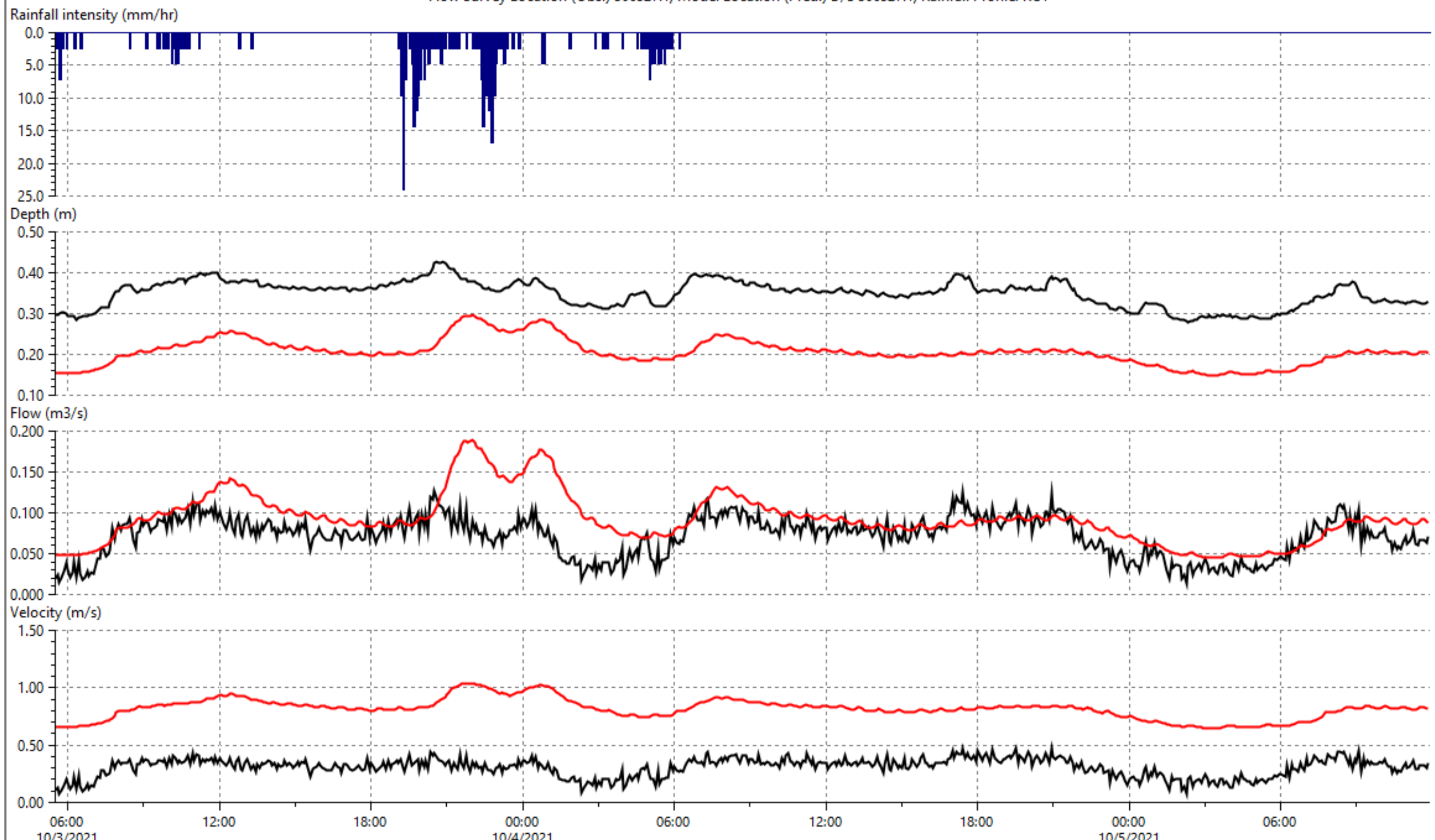
		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain		34.000	24.000	0.624							
Observed					0.224	0.290	0.003	0.027	2554.600	0.050	0.340
Modelled					0.057	0.110	0.006	0.022	2900.421	0.420	0.626

FM7

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 13 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 306527.1, Model Location (Pred.) D/S 306527.1, Rainfall Profile: RG1



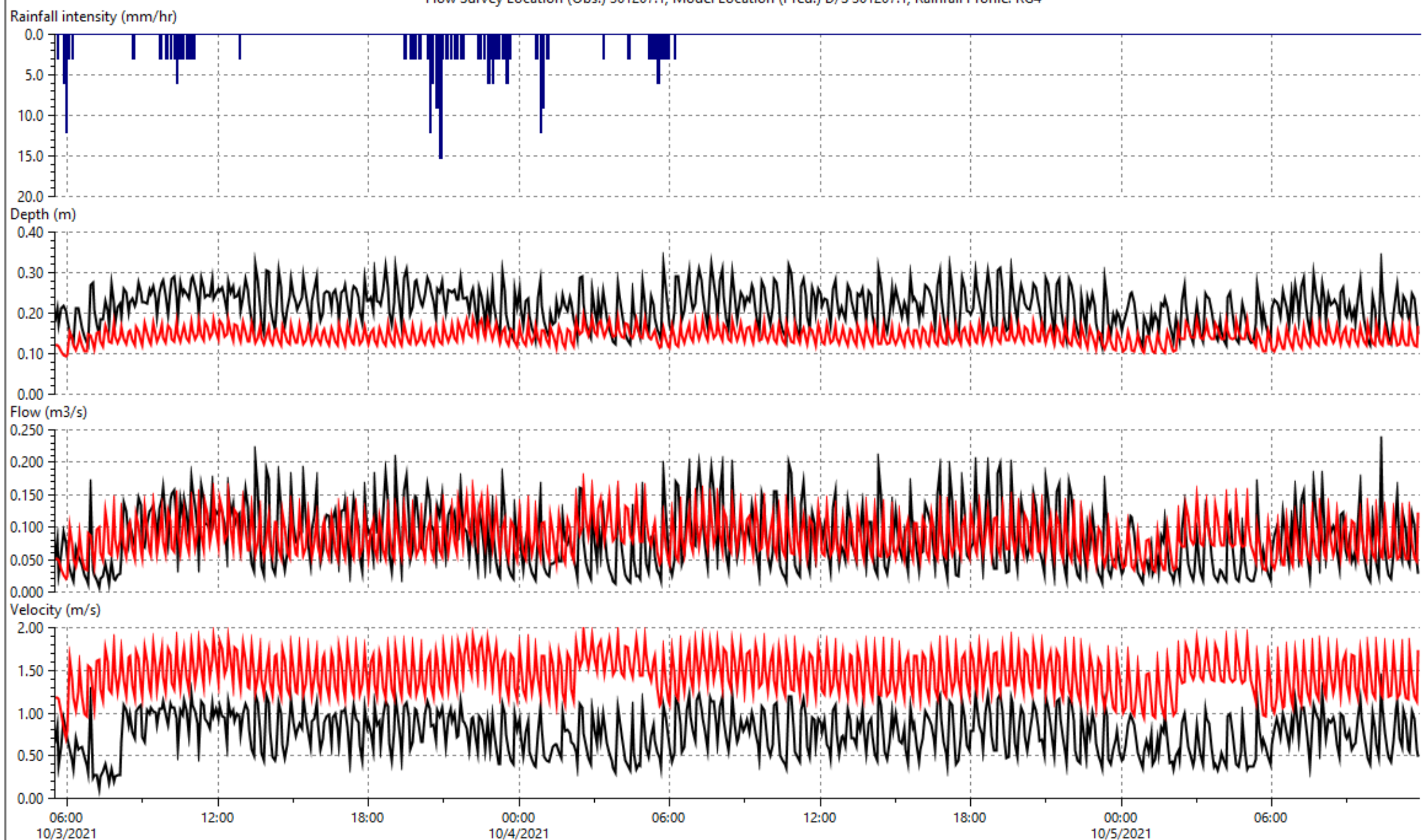
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	34.000	24.000	0.624							
Observed				0.280	0.426	0.014	0.127	14104.365	0.080	0.470
Modelled				0.150	0.296	0.045	0.189	18128.147	0.651	1.037

FM9

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 5 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 301207.1, Model Location (Pred.) D/S 301207.1, Rainfall Profile: RG4



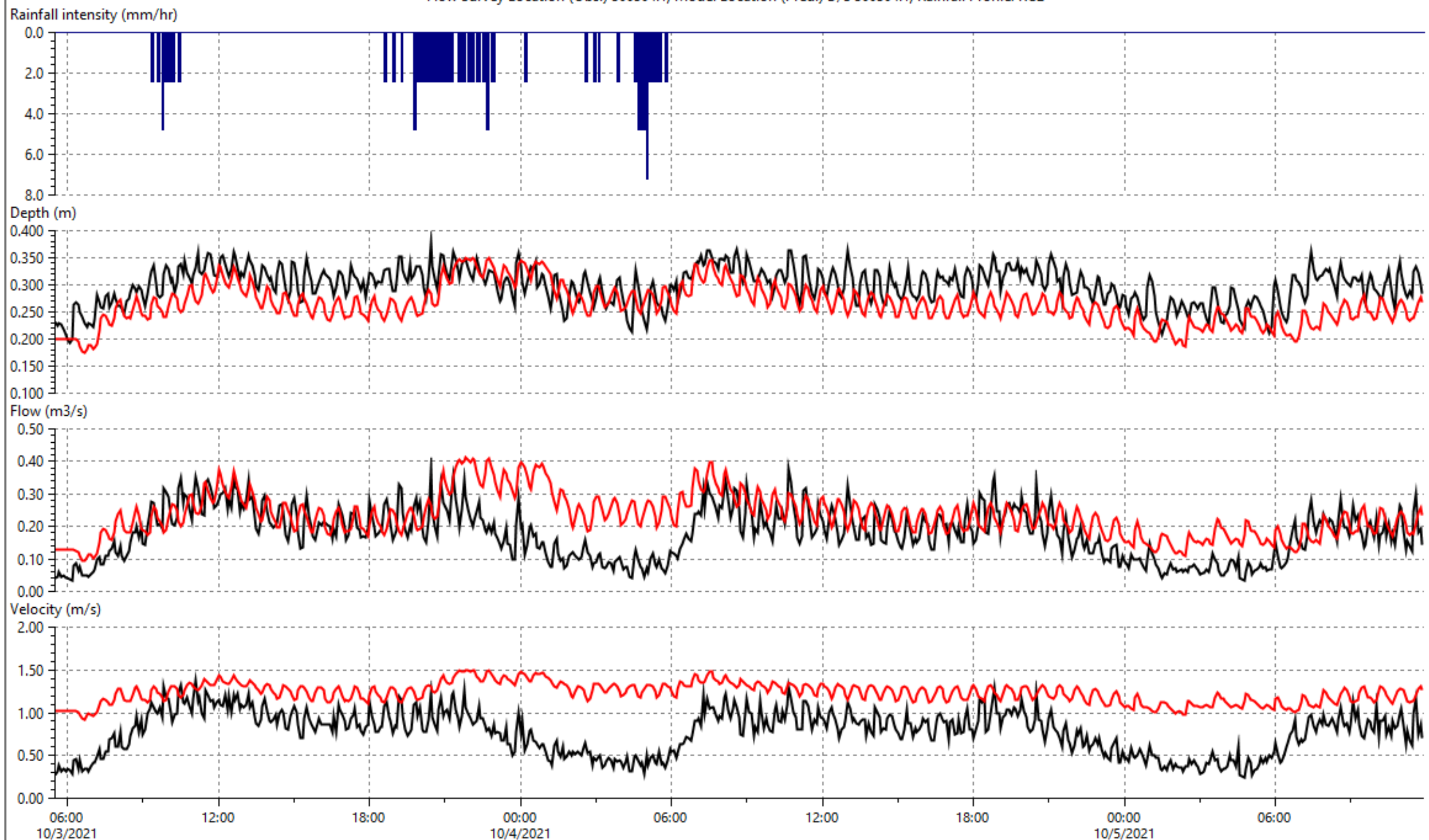
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	23.123	15.240	0.424							
Observed				0.119	0.322	0.007	0.221	16437.232	0.120	1.330
Modelled				0.093	0.193	0.021	0.166	16546.594	0.705	1.966

FM10

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 4 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

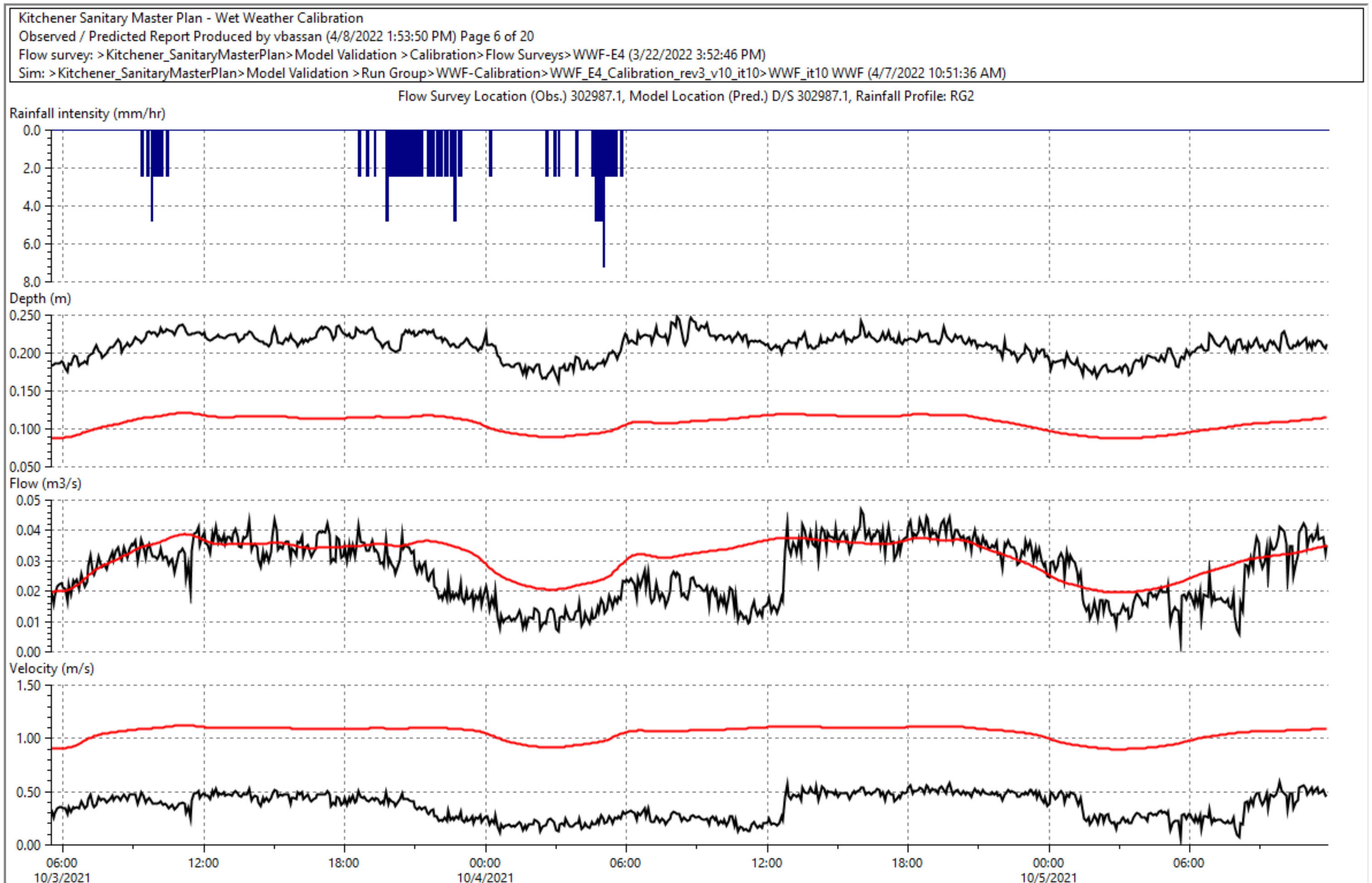
Flow Survey Location (Obs.) 300304.1, Model Location (Pred.) D/S 300304.1, Rainfall Profile: RG2



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	14.200	7.200	0.261							
Observed				0.193	0.376	0.036	0.379	34960.542	0.250	1.380
Modelled				0.174	0.350	0.094	0.412	45674.413	0.924	1.501

FM11

WWF Event 4



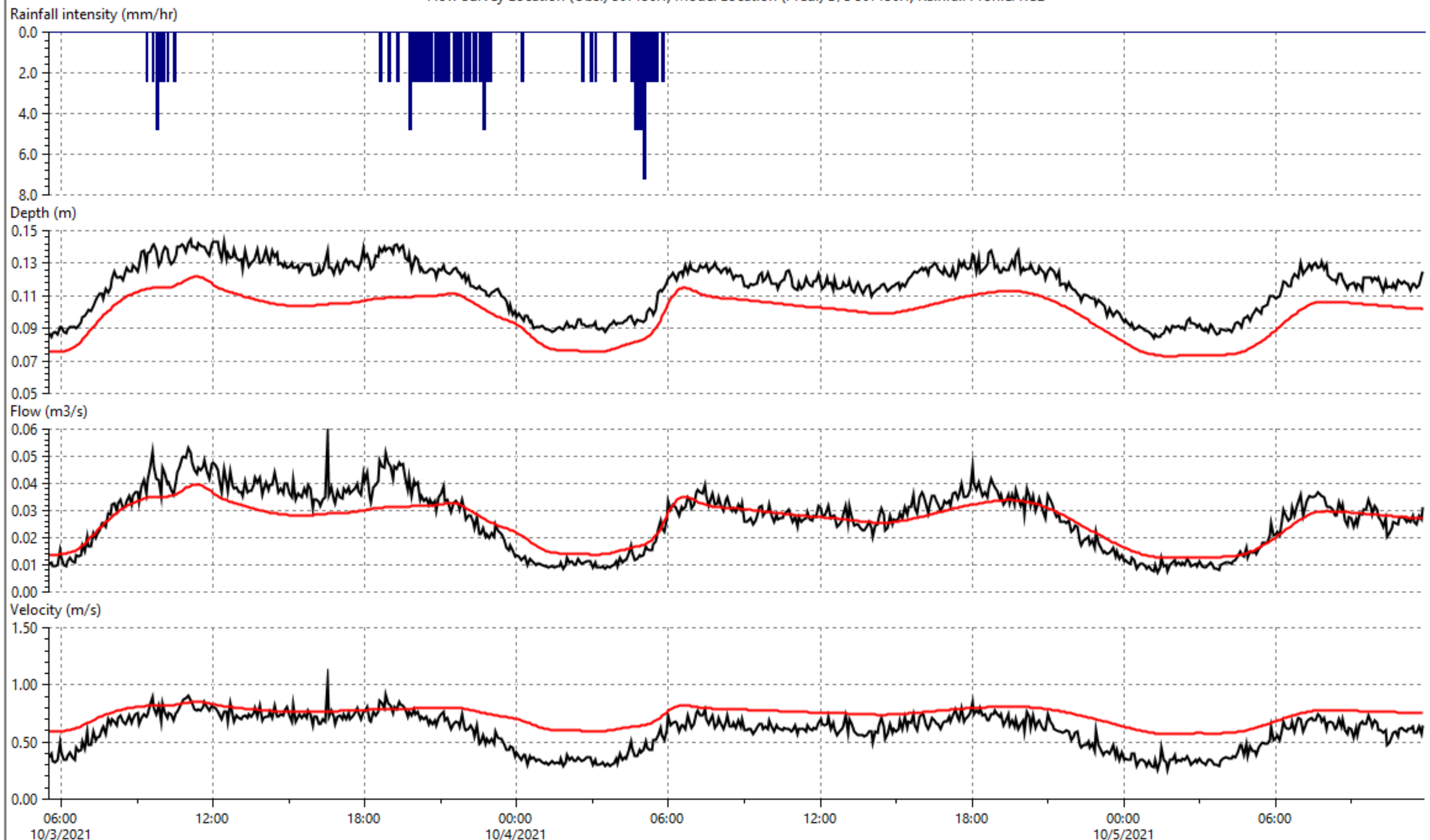
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	14.200	7.200	0.261							
Observed				0.162	0.249	0.004	0.047	5238.036	0.060	0.590
Modelled				0.088	0.121	0.020	0.039	6075.511	0.901	1.124

FM12

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 15 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 307136.1, Model Location (Pred.) D/S 307136.1, Rainfall Profile: RG2



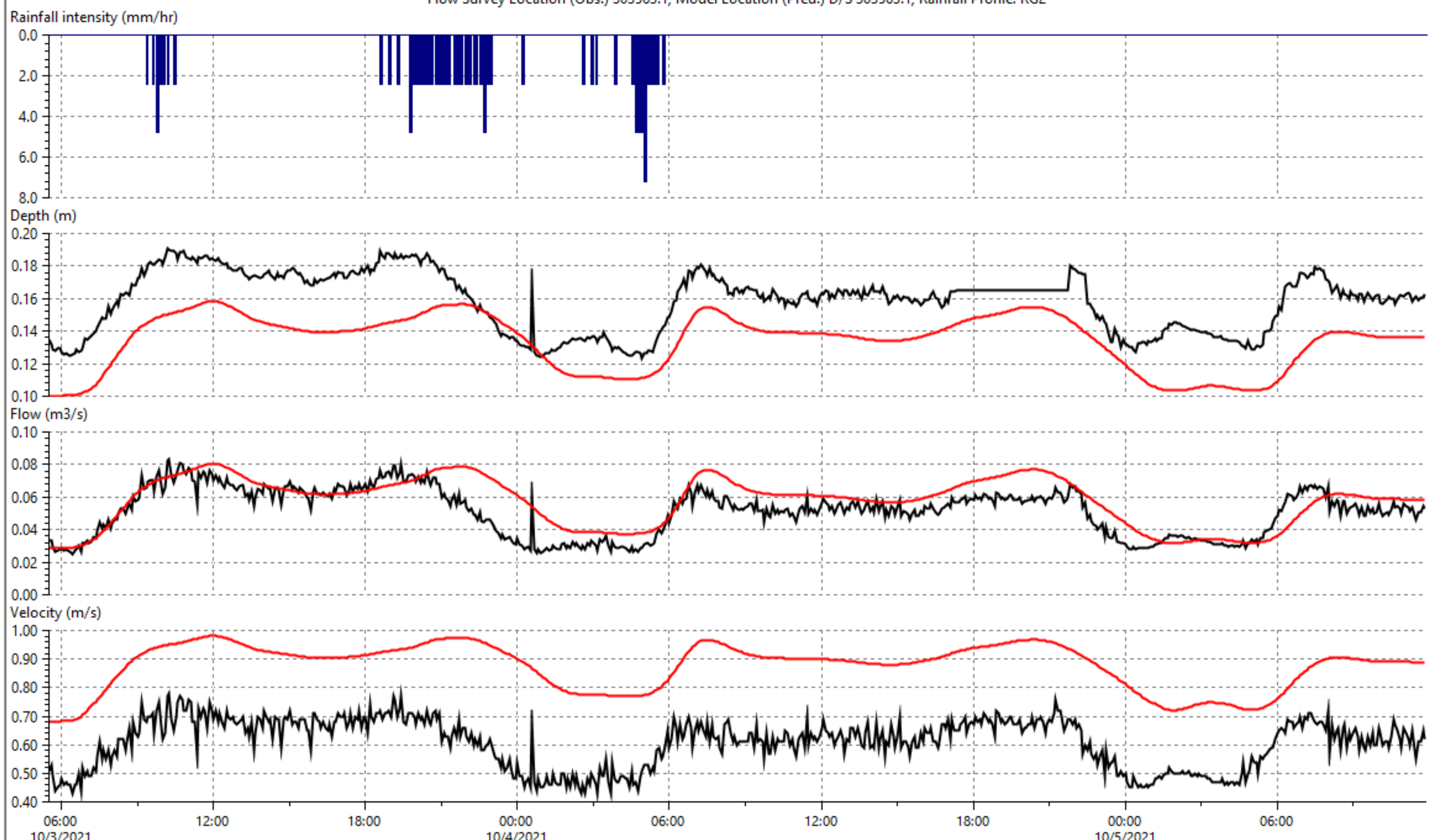
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	14.200	7.200	0.261							
Observed				0.084	0.144	0.007	0.058	5314.815	0.260	1.040
Modelled				0.073	0.122	0.013	0.040	5083.837	0.569	0.852

FM13

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 9 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 303563.1, Model Location (Pred.) D/S 303563.1, Rainfall Profile: RG2



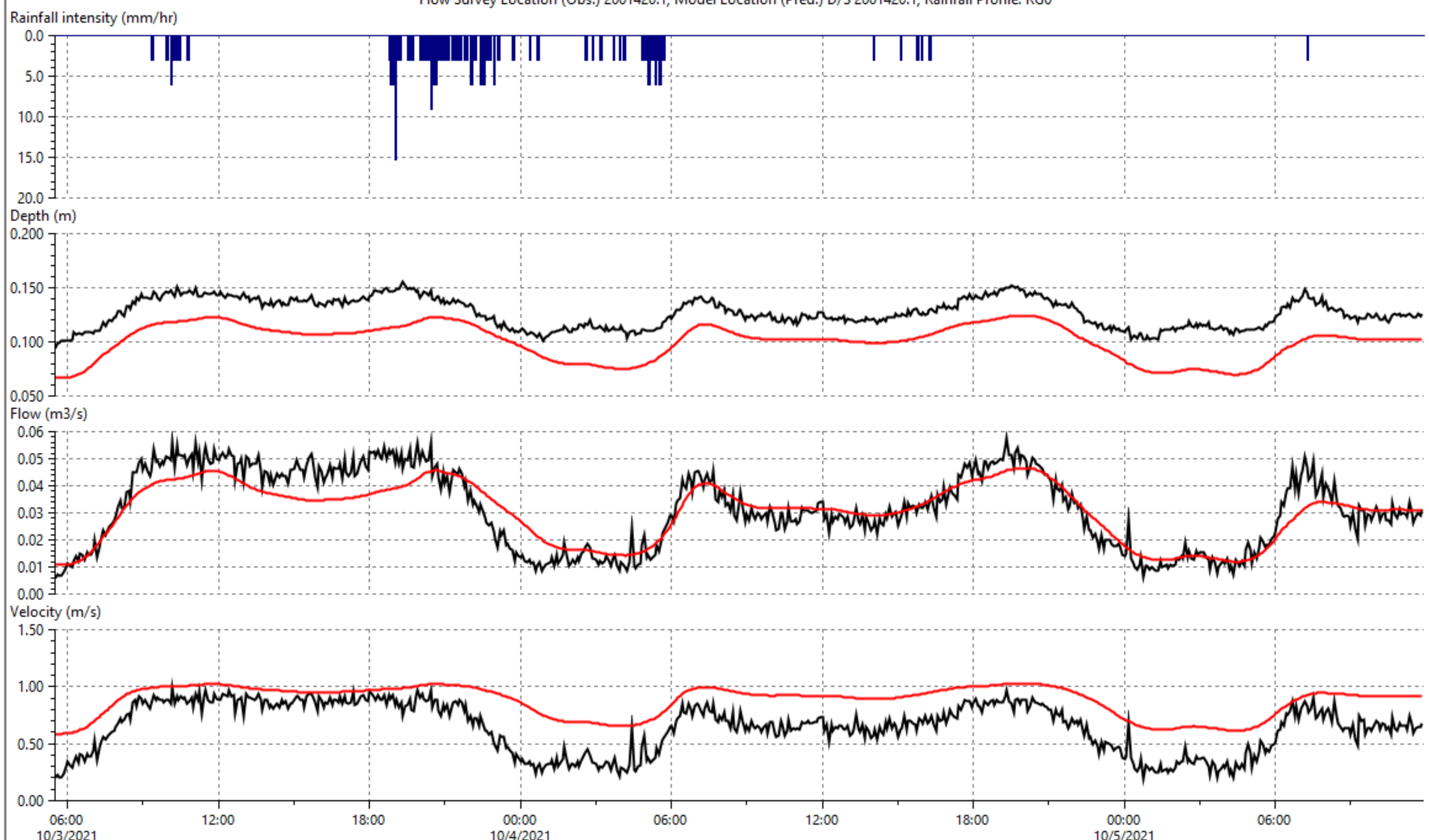
		Rainfall			Depth		Flow			Velocity	
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain		14.200	7.200	0.261							
Observed					0.123	0.191	0.025	0.083	10029.529	0.430	0.780
Modelled					0.100	0.158	0.029	0.081	11278.908	0.683	0.981

FM13b

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 1 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 2001420.1, Model Location (Pred.) D/S 2001420.1, Rainfall Profile: RG6

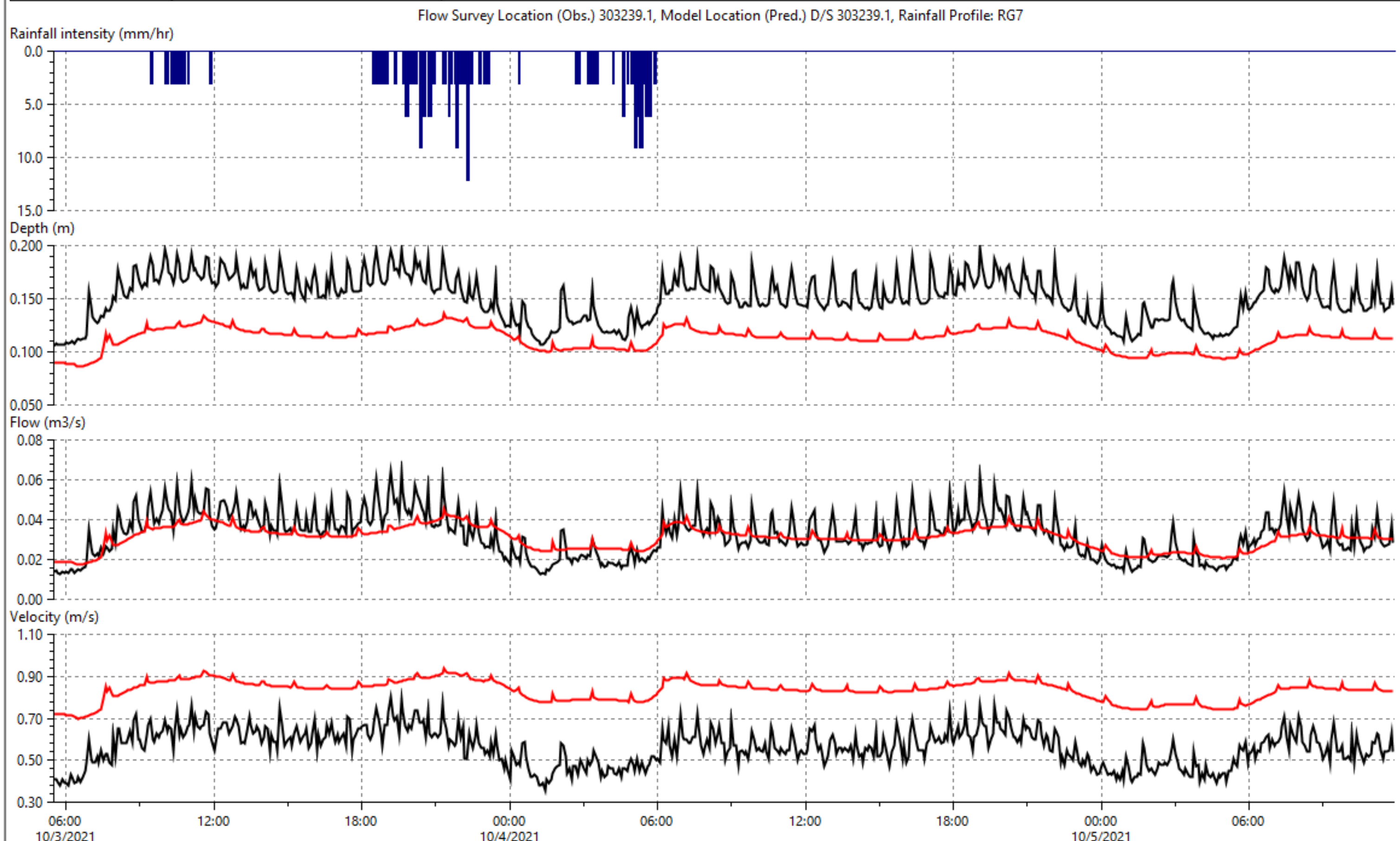


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	22.111	15.240	0.406							
Observed				0.094	0.156	0.006	0.058	6204.553	0.190	0.990
Modelled				0.067	0.124	0.011	0.047	5986.633	0.587	1.029

FM15

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 7 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)



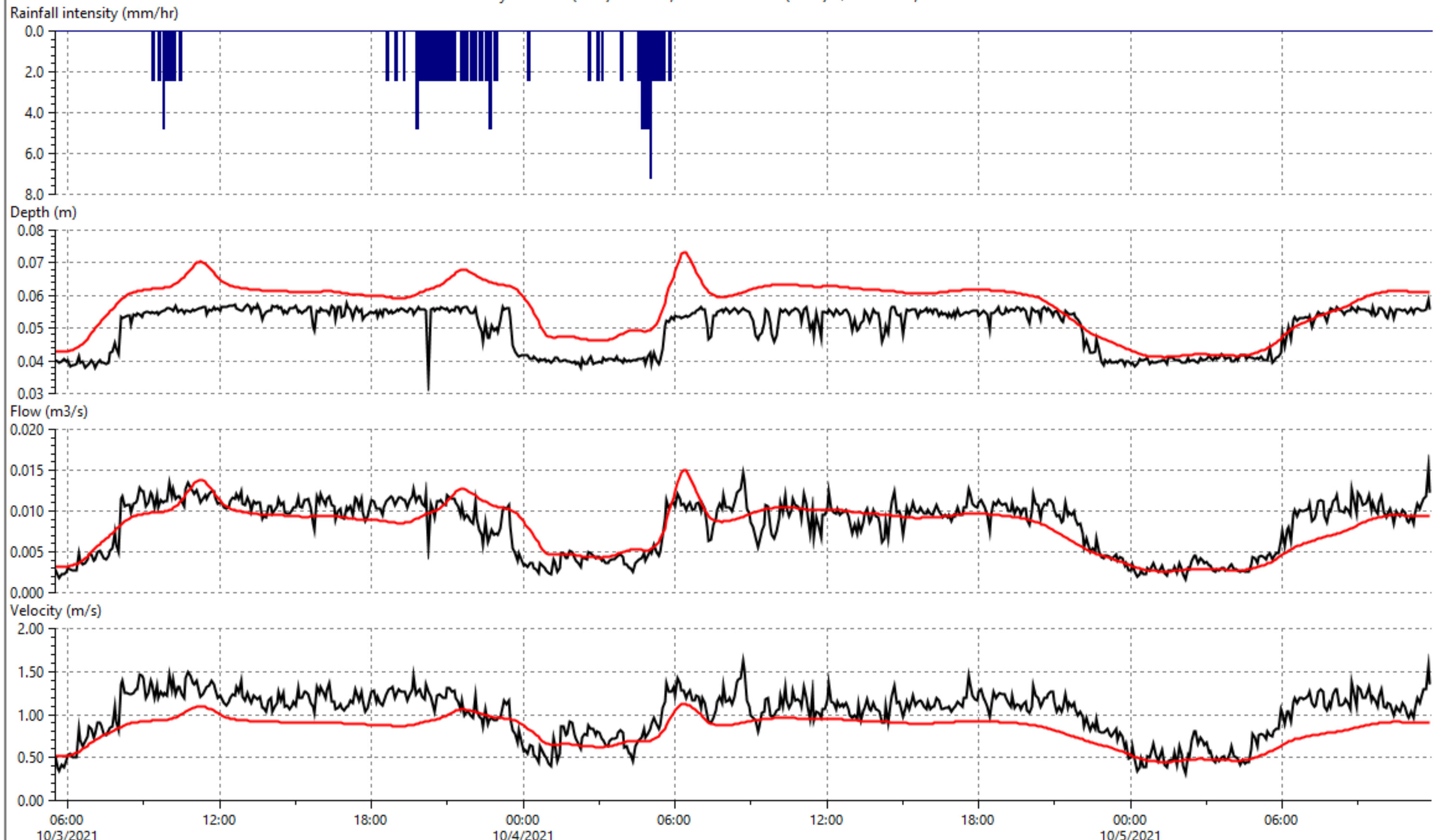
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	24.141	12.190	0.443							
Observed				0.106	0.197	0.013	0.064	6381.520	0.360	0.800
Modelled				0.086	0.137	0.017	0.045	6058.366	0.700	0.939

FM18

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 14 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 306551.1, Model Location (Pred.) D/S 306551.1, Rainfall Profile: RG2

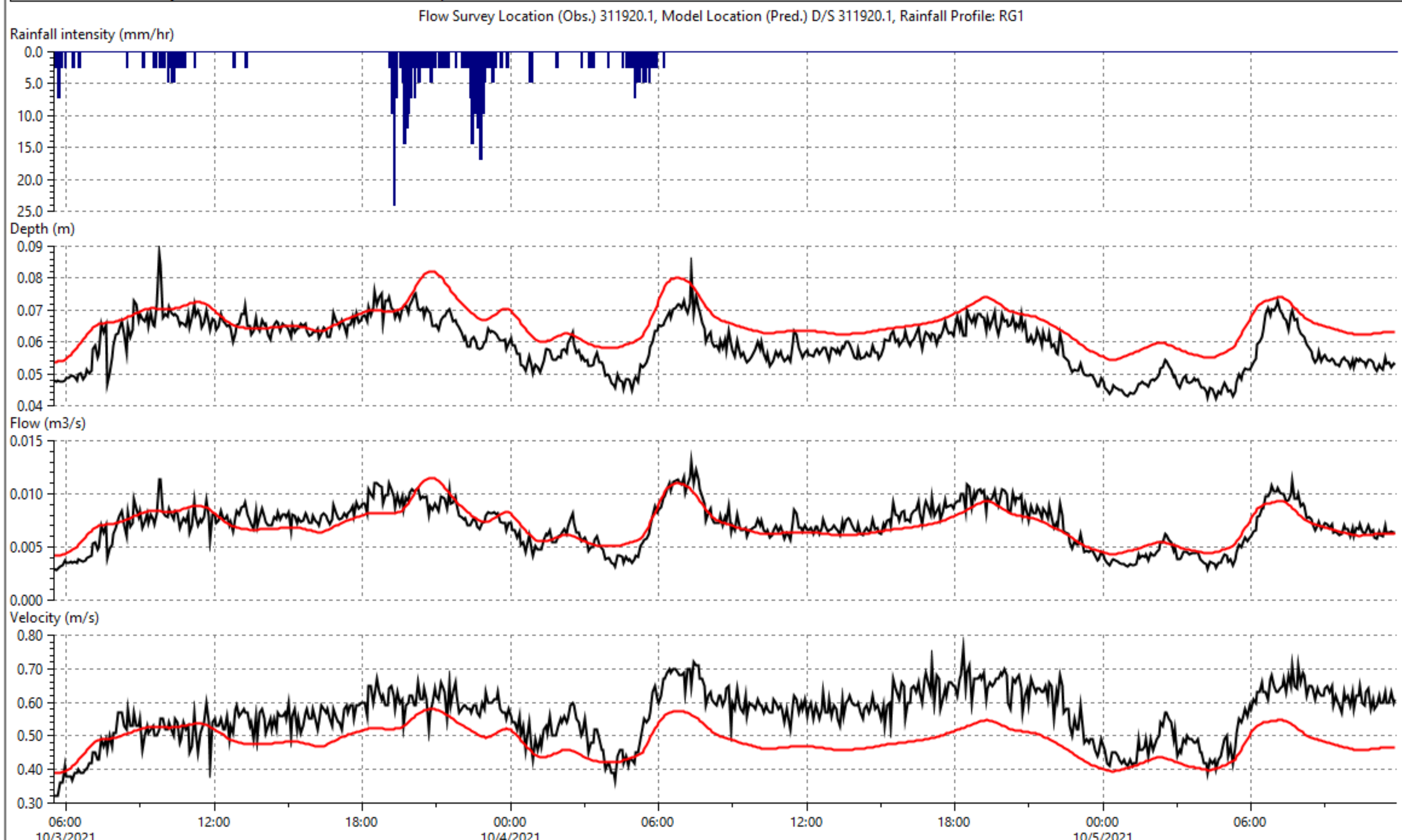


	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	14.200	7.200	0.261							
Observed				0.034	0.059	0.002	0.015	1623.771	0.310	1.620
Modelled				0.041	0.073	0.003	0.015	1563.734	0.451	1.122

FM19

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 20 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)



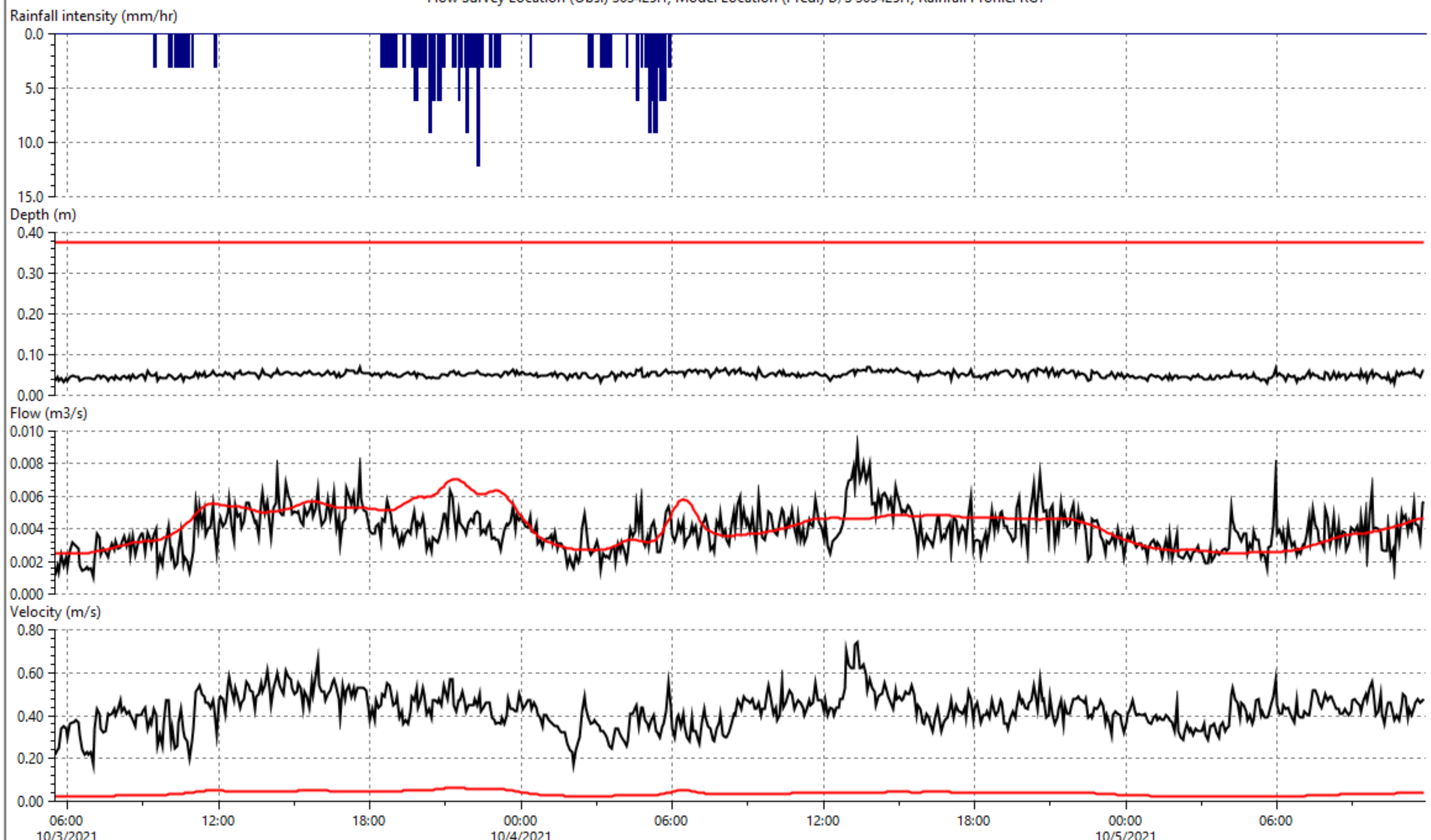
	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	34.000	24.000	0.624							
Observed				0.042	0.088	0.003	0.013	1395.070	0.320	0.760
Modelled				0.054	0.082	0.004	0.012	1377.875	0.390	0.580

FM20

WWF Event 4

Kitchener Sanitary Master Plan - Wet Weather Calibration
Observed / Predicted Report Produced by vbassan (4/8/2022 1:53:50 PM) Page 8 of 20
Flow survey: >Kitchener_SanitaryMasterPlan>Model Validation >Calibration>Flow Surveys>WWF-E4 (3/22/2022 3:52:46 PM)
Sim: >Kitchener_SanitaryMasterPlan>Model Validation >Run Group>WWF-Calibration>WWF_E4_Calibration_rev3_v10_it10>WWF_it10 WWF (4/7/2022 10:51:36 AM)

Flow Survey Location (Obs.) 303425.1, Model Location (Pred.) D/S 303425.1, Rainfall Profile: RG7



	Rainfall			Depth		Flow			Velocity	
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min (m)	Max (m)	Min (m3/s)	Max (m3/s)	Volume (m3)	Min (m/s)	Max (m/s)
Rain	24.141	12.190	0.443							
Observed				0.030	0.070	0.001	0.009	763.968	0.170	0.740
Modelled				0.375	0.375	0.002	0.007	817.751	0.022	0.064

APPENDIX F - DIURNAL PATTERNS & RTKS APPLIED FOR GROWTH

Table F-1: Diurnal Pattern for Growth with Residential Land Use (Wastewater Profile 16)

Time (hh:mm)	Factor
00:00	0.4230
01:00	0.3790
02:00	0.4460
03:00	0.3300
04:00	0.2010
05:00	0.2020
06:00	0.3550
07:00	0.7520
08:00	1.2800
09:00	1.5280
10:00	1.5750
11:00	1.5180
12:00	1.4580
13:00	1.3950
14:00	1.3190
15:00	1.2400
16:00	1.2550
17:00	1.2860
18:00	1.3880
19:00	1.4630
20:00	1.3960
21:00	1.2250
22:00	0.9260
23:00	0.6580

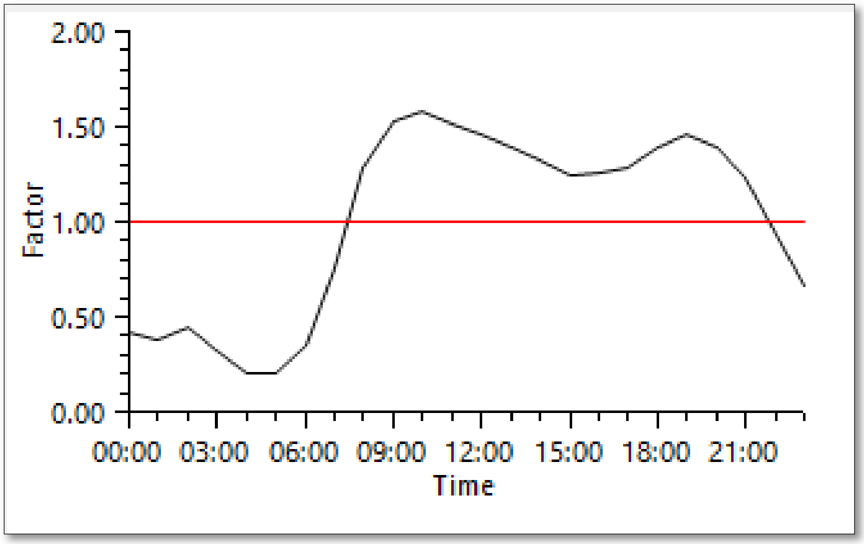


Figure F-1: Graphical Representation of the Diurnal Pattern for Growth with Residential Land Use (Wastewater Profile 16)

Table F-2: Diurnal Pattern for Growth with ICI Land Use (Wastewater Profile 20)

Time (hh:mm)	Factor
00:00	0.7480
01:00	0.6420
02:00	0.6170
03:00	0.5540
04:00	0.5470
05:00	0.5570
06:00	0.5730
07:00	0.6650
08:00	0.7770
09:00	0.8100
10:00	0.9840
11:00	1.1250
12:00	1.3340
13:00	1.3450
14:00	1.4160
15:00	1.6090
16:00	1.4580
17:00	1.4620
18:00	1.3870
19:00	1.3190
20:00	1.2170
21:00	1.0810
22:00	0.9450
23:00	0.8290

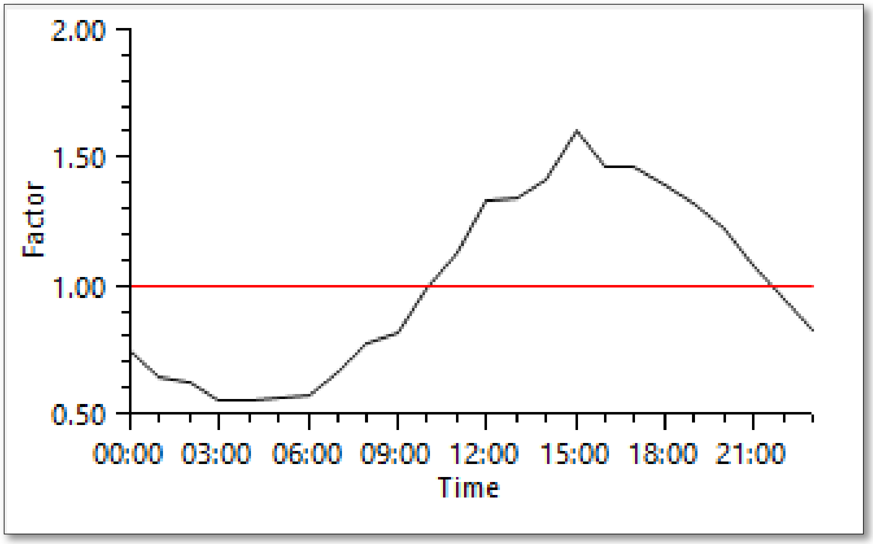


Figure F-2: Graphical Representation of the Diurnal Pattern for Growth with ICI Land Use (Wastewater Profile 20)

Table F-3: Wet Weather RTK Parameters for New Developments

RTK Hydrograph	Total R	R1	T1	K1	R2	T2	K2	R3	T3	K3
New-RES(FM13b)	1.04%	0.80%	1.1	1.6	0.24%	5.0	5.0	0%	0	0
New-ICI(FM20)	1.11%	0.71%	0.5	1.0	0.40%	1.0	1.5	0%	0	0

APPENDIX G - PLANNING DEPARTMENT CORRESPONDENCE

From:	Jean Hao
To:	Bhatia, Faiz
Cc:	Nancy Steinfield; Natalie Goss; Tim Donegani; Paul, Jeff; Nick Gollan; Eadie, Dave; LeMasurier, Ashley
Subject:	RE: population and employment forecasts for sanitary master plan
Date:	June 27, 2022 9:06:11 AM
Attachments:	image001.png image002.png image003.png image004.png image005.png image006.png image007.png

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Hi Faiz,

Please see the below email, I have uploaded the updated population and jobs forecast on Sharepoint folder "Pop and jobs forecast", please download the files and let us know if you have any questions.

Thanks,

Jean Hao, P.Eng., PMP
Design & Construction Project Manager, Utility Planning and Programs| Sanitary and Stormwater Utilities | City of Kitchener
Office: 519-741-2200 ext. 4156 | TTY 1-866-969-9994 | Jean.Hao@kitchener.ca

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From: Tim Donegani <Tim.Donegani@kitchener.ca>
Sent: Monday, June 27, 2022 8:48 AM
To: Jean Hao <Jean.Hao@kitchener.ca>
Cc: Nancy Steinfield <Nancy.Steinfield@kitchener.ca>; Natalie Goss <Natalie.Goss@kitchener.ca>
Subject: population and employment forecasts for sanitary master plan

Hi Jean,

Here is the information you requested with regard to population and employment forecasts to support the Sanitary master plan.

You can find the updated population and jobs forecast here. "O:\General\Integrated Sanitary Master Plan Document\pop and jobs forecast"

Here are some highlight and key assumptions. I will follow up with a more detailed memo in the next week or two

The 2031 population forecast is 319,500
The 2031 Jobs Forecast is 99,380

Based on initial work on Regional Official Plan, we expect:
2051 population forecast is 410,700-417,500
The 2051 Jobs forecast is 167,900-170,700

- I understand that it is important to provide a more detailed geographic breakdown of planning the sanitary conveyance system. Given the stage in Kitchener's planning cycle and the general challenges of prediction as to where intesification will occur, the sum of parcel population and jobs is at a parcel level is higher than the aggregate forecast. It is prudent to plan for larger area specific population growth as part of a sanitary master plan excessive to provide flexibility on the location of growth, and to provide opportunities for growth beyond 2051.
- The population and jobs forecasts are undertaken using the City's Parcel/Person/Jobs forecasting approach that evaluates the future population and employment based on 50% 75% or 100% of the zoned capacity for growth on a given parcel using standard assumptions based on existing or anticipated future zoning. The 50% potential fields are most comparable to the 2031 forecast and the 75% potential fields are most comparable to the 2051 forecast.
    - Updating downtown zoning assumption based on the UGC zones that were drafted in 2019, but not approved
    - Updating zoning assumptions around ION station stops west of the Conestoga expressway based on zoning that was drafted in 2019, but not approved.
    - Other intesification areas have up to date zoning

- Planning and GIS staff undertook a more detailed review of growth opportunities in constrained catchments as identified by Stantec in April 2022. This included
    - Updating assumptions based on active development applications
    - Providing more realistic zoning assumption for the Sportworld Major Transit Station Area in anticipation of secondary plan work we expect to occur in the next few years
    - No updates we made to zoning expectation in the Fairway for Block line station areas as these locations we not identified as areas of sanitary constraint

This methodology is well suited to planning for intensification. I understand that planning for greenfield opportunities are well addressed through other processes and need not be analyzed in detail here. I'd suggest other data sources be used to plan for other greenfield subadvisors such as Rosenburg, Hidden Valley, Etc.

I look forward to the opportunity to provide updated forecasts are the sani master plan is the reviewed. Please don't hesitate to contact me with any questions or concerns.
Best,
Tim

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