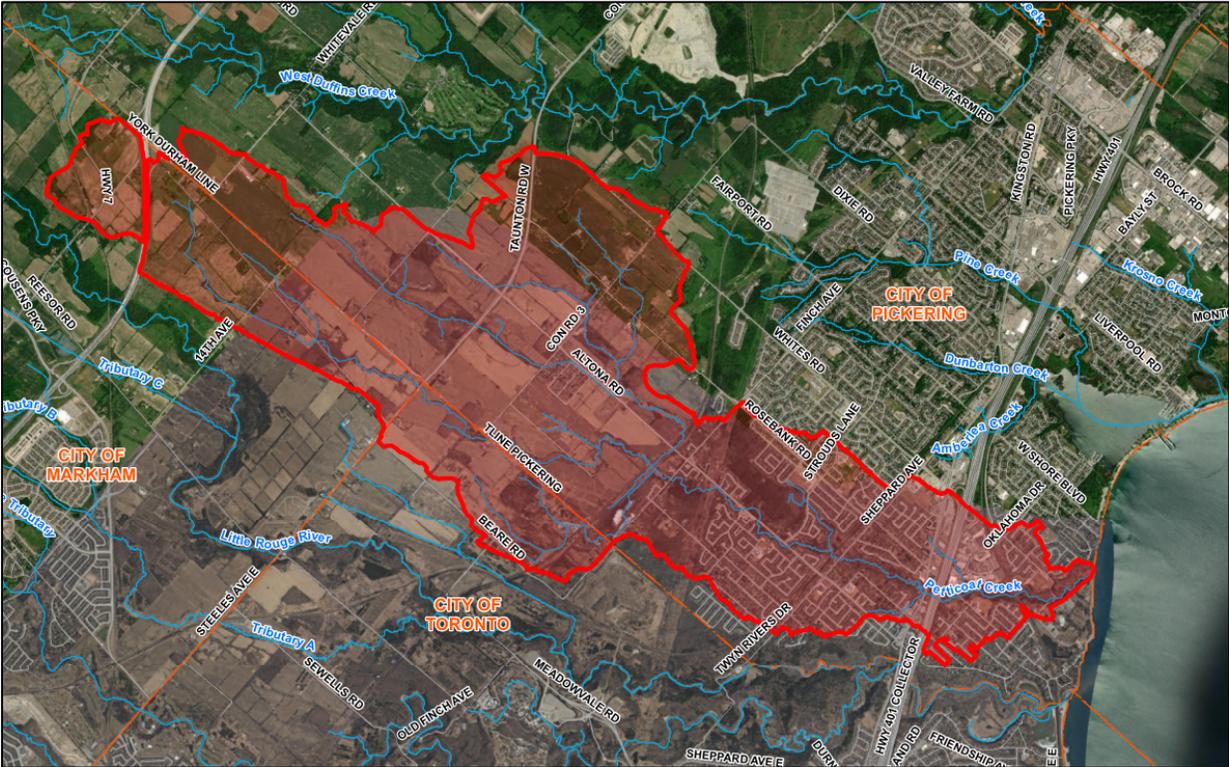


TORONTO AND REGION CONSERVATION AUTHORITY

PETTICOAT CREEK HYDROLOGY UPDATE

DECEMBER 21, 2020





PETTICOAT CREEK HYDROLOGY UPDATE

REPORT

TORONTO AND REGION CONSERVATION
AUTHORITY

PROJECT NO.: 19M-01483-00

DATE: DECEMBER 21, 2020

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December 21, 2020

Toronto and Region Conservation Authority
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Attention: Wilfred Ho, B.E.S.
Project Manager, Capital Projects Development and Engineering Services

Dear Mr. Ho:

Subject: Final Report – Petticoat Creek Hydrology Update

We are pleased to submit the Final Report to develop the updated hydrologic models for Petticoat Creek subwatershed within TRCA's area of jurisdiction.

The Final Report has been prepared in accordance with the tasks identified in the Terms of Reference (TOR), and addressed all comments received from the TRCA during the study period, including those provided to us on November 18, 2020.

We trust that our submission is complete and meets all your requirements. We wish to thank the TRCA staff for their invaluable assistance in acquiring the necessary information required to complete the study.

Very truly yours,

A handwritten signature in black ink, appearing to read 'Albert Zhuge'. The signature is stylized and includes a large, prominent 'A' at the beginning.

Albert Zhuge, M.A.Sc, P.Eng, PMP
Senior Project Manager
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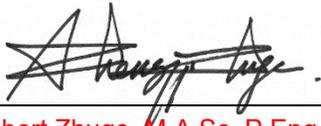
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O	CORRESPONDENCE

1 INTRODUCTION

1.1 BACKGROUND

WSP Canada Group Limited (WSP) was retained by Toronto and Region Conservation Authority (TRCA) to update the hydrologic model for the Petticoat Creek watershed by using the most up-to-date modelling technology based on the latest background data. It's our understanding that the results of the hydrology update study will be used to update the regulatory floodline, confirm the appropriateness of existing stormwater quantity control criteria, and aid in mitigating the downstream flood risk.

The original hydrology of Petticoat Creek was completed by Cosburn Patterson Wardman Limited by using HYMO in the 1990's. XCG Consultants Limited later completed an update by using Visual OTTHYMO ver. 2 model (VO2) in supporting of the Environmental Master Servicing Plan for the Rouge Park Neighbourhood.

The most recent update of the hydrologic model for the Petticoat Creek watershed was completed by Greenland Consulting Ltd. in October 2006. The VO2 model was developed as part of the study.

Since the last update, the developments within the Petticoat Creek watershed have continued. Recently collected meteorological and streamflow monitoring data can also be used to support the development of the hydrologic model for subject watershed. Therefore, the 2006 hydrologic model needs to be updated to reflect land use changes.

This report presents the methodology and results of the hydrologic model development, calibration, validation and application. Discussion on analysis of climate change is also included in the report.

1.2 DESCRIPTION OF THE STUDY AREA

The Petticoat Creek Watershed is located within the jurisdiction of the TRCA within the Regional Municipality of Durham (City of Pickering), the Regional Municipality of York (Town of Markham) and the City of Toronto. The watershed has a drainage area of approximately 25.8 km² and is surrounded by the Rouge River, Duffins Creek and the Frenchman's Bay watersheds.

The majority of the developments within the watershed is located downstream of Finch Avenue, except for a rural residential area located at the southwest quadrant of Altona Rd and Concession Rd 3. There are six (6) stormwater management facilities servicing the existing urban area.

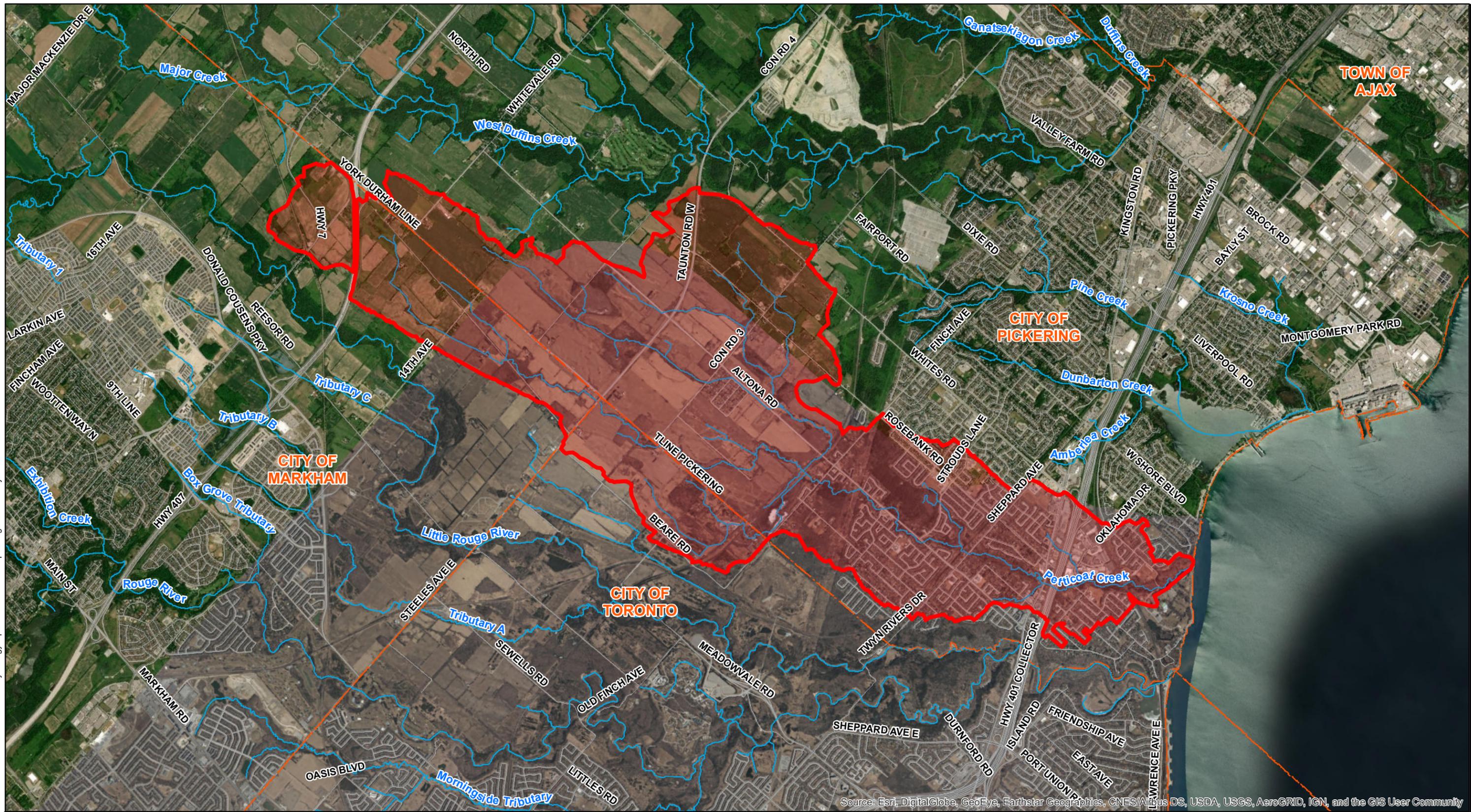
Figure 1.1 shows the map of the Petticoat Creek watershed.

1.3 RELEVANT PREVIOUS STUDIES

An extensive review of relevant studies was conducted for the present hydrologic update. The reviewed documents are summarized below:

- “*Technical Guidelines for Flood Hazard Mapping*”, prepared by Environmental Water Resources Group Ltd., dated March 2017.
- “*Petticoat Creek Watershed Hydrology Update – Final Report*” by Greenland Consulting Ltd, dated October 2006.
- “*Ontario Ministry of Natural resources Technical Guide -River & Stream Systems: Flooding Hazard Limit*” by Ministry of Natural Resources Ontario, dated 2002.
- “*MTO Drainage Management Manual*” by Ministry of Transportation Ontario, dated 1997.
- “*Hydrology of Floods in Canada, A Guide to Planning and Design*” by National Research Council Canada, Associate Committee on Hydrology, dated 1989.

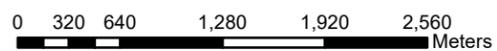
Document Path: X:\DIV\38\2019\19M-01483-00 Petticoat Creek Hydrology Update\GIS\MXD\Report Figure 1 - Study Areas.mxd



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Study Area
- Watercourse
- Municipality
- Roads



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	STUDY AREA	

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1.4 COMMENTS AND RESPONSES

Throughout the study project cycle, frequent communications have been performed between the WSP project team and TRCA staff. The communications were carried out by regular correspondences via emails and phone calls. All comments were addressed by WSP and accepted by TRCA. For reference purposes, the comment correspondence is included in **Appendix O**.

2 DEVELOPMENT OF THE HYDROLOGICAL MODEL

2.1 GENERAL

The methodology used for the study was developed with the view of achieving the objectives specified in the Terms of Reference (TOR). Background information provided by TRCA pertinent to the study was reviewed and incorporated as necessary. Furthermore, extensive discussions with TRCA have been facilitated at key milestones within the model development process to ensure that the modelling approach and the findings are in conformance with TRCA's expectation. The following sections describe the methodology used to complete different aspects of the model development.

2.2 MODEL SELECTION

Visual OTTHYMO 6.1 (VO6) was selected to model the hydrology of Petticoat Creek watershed. VO6 is based on a series of previous Visual OTTHYMO modelling platforms and has well established rural and urban catchment routines to simulate both rural and urban hydrology. VO6 provides users with the same reliable analysis of previous versions, with a new look and several improvements.

Visual OTTHYMO modeling platforms have been widely used for Watershed Studies, Sub-watershed Studies, Master Drainage Plans, Functional Stormwater Management Plans, Site Plans, and Stormwater Management Pond Design within the Credit River Watershed. Such model has also been accepted as a valid hydrologic simulation model by most municipal governments, the Association of Conservation Authorities of Ontario, Ministry of Municipal Affairs and Housing, the Ministry of Natural Resources and Forestry, the Ministry of the Environment, Conservation and Parks, and the Ministry of Transportation.

VO6 applies the following techniques (commands) to simulate the rainfall-runoff responses:

- **NASHYD** - the Nash unit hydrograph was applied to simulate runoff response from those landuse areas designated as open space or parkland;
- **STANDHYD** - the Standard unit hydrograph was applied to simulated runoff response from urban areas;
- **ROUTE CHANNEL** - was used to route hydrographs through channel elements within the model including both open channel and major flow routes through urban street system;
- **ROUTE PIPE** - was used to route hydrographs in circular or rectangular pipes. It uses a simplified form of the Route Channel input; and
- **ROUTE RESERVOIR** - was used to route hydrographs through Stormwater Management facilities;
- **DUHYD** - was used to simulate a split in runoff direction between the minor (storm sewer) system and the major (overland) system.

2.3 WATERSHED DISCRETIZATION

2.3.1 CATCHMENT DELINEATION

Catchment boundaries were carefully delineated based on the latest topographic information (LiDAR 2015), up-to-date as-built information, detailed design drawings, and City of Pickering storm sewer mapping (minor system flows).

This detailed discretization facilitates the determination of several key factors including flow nodes, road crossings/culverts, flow diversion structures and splits of minor and major systems (discussed in the following sections). A summary of the watershed discretization is presented in **Table 2.1**. **Figure 2.1** shows the frequency histogram of the catchment areas for the Petticoat Creek watershed. The watershed delineation along with the stream network and topographic information are shown on **Figure 2.2**. **Appendix A** includes the summary of the catchment areas.

Table 2.1 Watershed Discretization Summary

Subwatershed Name	Total Drainage Area (ha)	No. of Catchments	Minimum Catchment Size (ha)	Maximum Catchment Size (ha)	Average Catchment Size (ha)
Petticoat watershed	2584	99	0.1	123.1	26.1

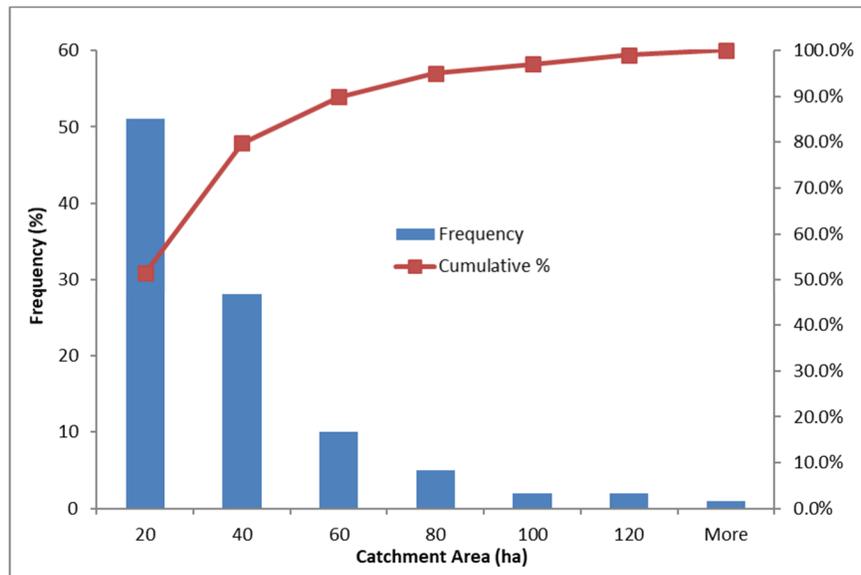


Figure 2.1 Frequency Histogram of the Catchments (Petticoat Creek)

2.3.2 SPLITS OF MAJOR AND MINOR SYSTEM

It is recognized that the diversions of the minor and the major drainage systems are critical for the subject study area by considering the scale and intensive urbanization of the subwatershed, especially for those areas located around the edge. Therefore, the developed hydrological model appropriately incorporates the diversions, where major and minor system drainage boundaries differed. DUHYD commands in VO6 model were used to simulate such diversions.

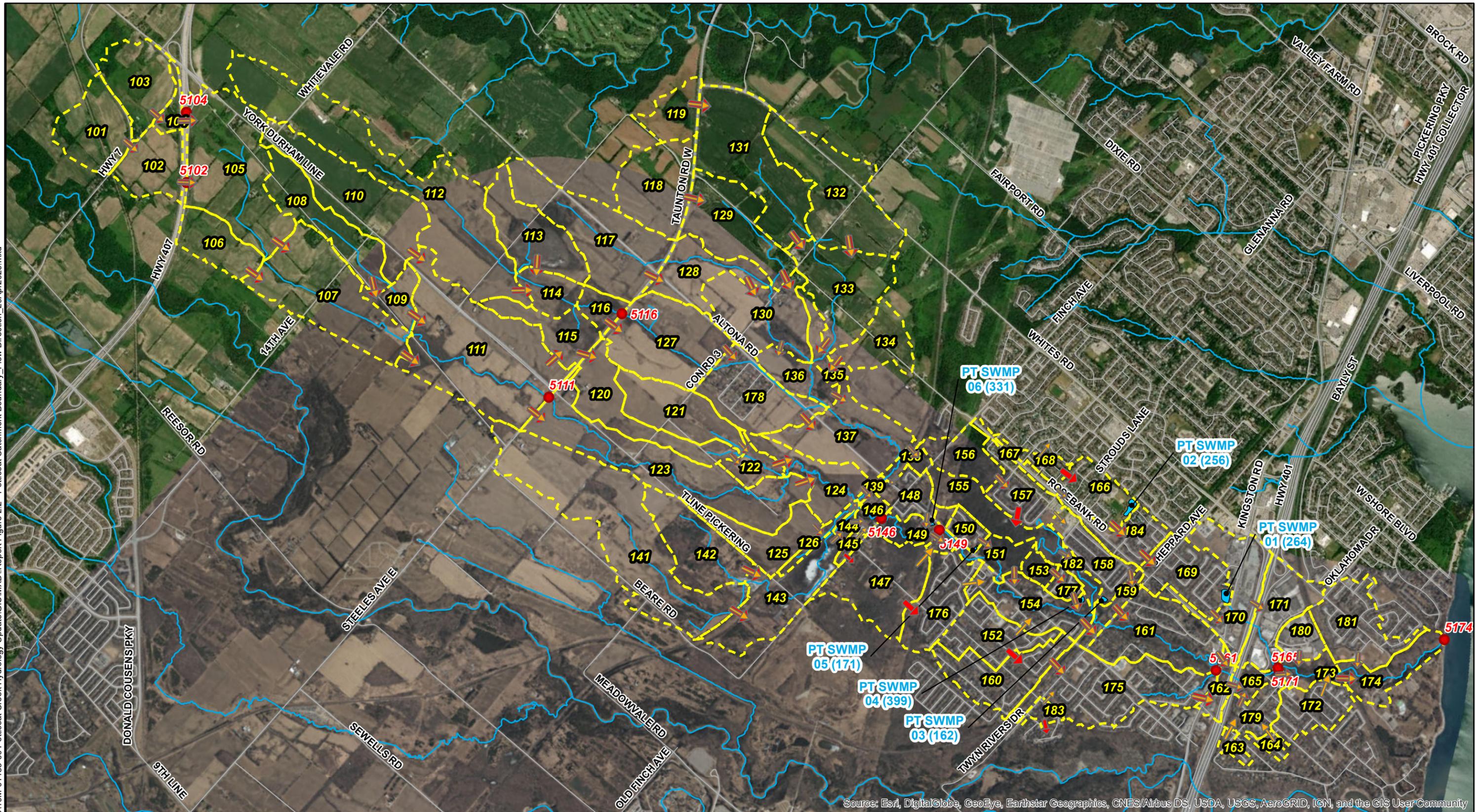
The determination of the drainage splits was carefully evaluated based on satellite imagery and topographic information (LiDAR 2015) for major system and storm sewer information from City of Pickering storm sewer index mapping for minor system. Windshield field surveys were also performed to confirm the drainage boundaries where the desktop analysis was not able to confirm the flow directions. The detailed results of the Windshield survey are included in the **Appendix B**.

Based on discussions with TRCA Staff, the capacity of the minor system was estimated to be 5-year flow rate from the associated catchments under existing conditions. Note that, for the Regional storm simulation, some DUHYD commands are removed from the model to reflect the conditions (antecedent) that the capacity of the minor (pipe) systems are full.

A summary of the DUHYD commands is included in the **Appendix C**. **Figures 2.2** shows the major and minor system diversions for the subject study watershed.

Furthermore, major flow routes through urban street system were also included in the model by using Route Channel command to reflect wave travel times and reduction in peak discharge.

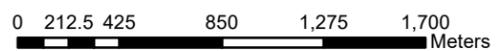
Document Path: X:\DIV38\2019\19M-01483-00 Petticoat Creek Hydrology Update\GIS\MXD\Report Figure 2.2 - Petticoat Catchment Boundary_Flow Direction_29Apr2020.mxd



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Flow Nodes
- SWM Ponds
- Petticoat Creek Catchment
- Watercourse
- Roads
- ➔ Major Flow
- ➔ Minor Flow
- ➔ Catchment Flow



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	CATCHMENT BOUNDARY, FLOW DIRECTION AND FLOW NODES	
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2.4 CATCHMENT PARAMETERS

2.4.1 GENERAL

The SCS Curve Number method was used to model the rainfall-runoff responses for the watersheds. The runoff curve number is a function of the soil type, land-use and antecedent moisture conditions (AMC). The antecedent moisture conditions of a soil are determined based on the total precipitation occurring in the five-day period preceding a storm event. Antecedent moisture condition II (AMC II) depicts the average condition, and AMC I and AMC III represent dry and wet soil conditions, respectively.

The availability of GIS data, coupled with a variety of geospatial data processing tools in GIS software, facilitated a more accurate and efficient approach to deriving model parameters. Most of the above tasks were automated by the software and a brief description of the steps involved is provided below.

2.4.2 LAND USE

Land use plays a significant role in the hydrologic response of a watershed. The existing land use map of the study area was developed and provided by TRCA staff. The land use conditions are represented in the model using different parameters such as CN, TIMP and XIMP. The existing land use map was used to estimate different parameters for inclusion in the model. The existing land uses for the subject subwatersheds are shown in **Figures 2.3**.

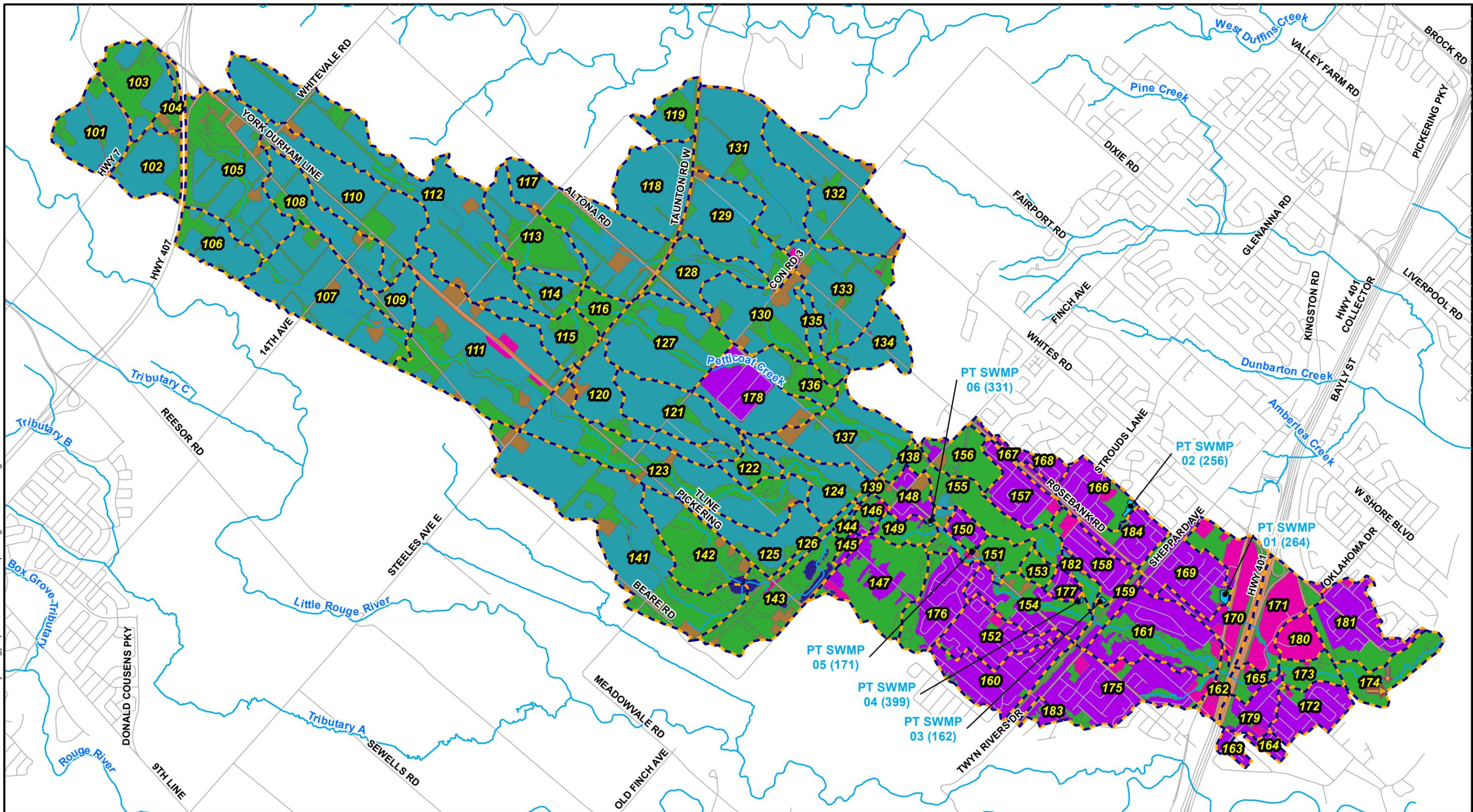
Based on discussion with TRCA staff, it is confirmed that the subject watershed is fully built in according with the current municipality's Official Plan. Therefore, there will be no changes of the land uses under future conditions.

2.4.3 SOILS MAPPING

Most of the soils within the study area had been pre-classified into one of the four hydrologic soil groups (HSG's), i.e., A, B, C and D. The HSG's are indicative of the runoff potential of particular soil types, e.g., Group A soils have the lowest runoff potential, while Group D soils have the highest runoff potential. Soils that were not classified by the mapping, such as Bottom Land, were placed in Group D to reflect their often saturated state. The overall soils maps showing the hydrologic soil groups for soil types in the study area are included in **Figures 2.4**. **Table 2.2** presents a list of the soil series with their assigned HSGs for the study area.

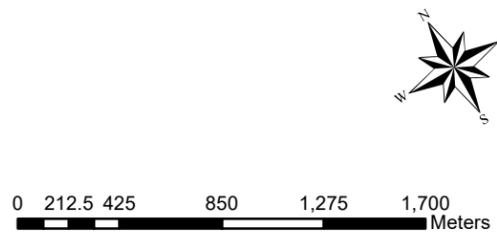
Table 2.2 Summary of Soil Information

Soil Symbol	Soil Series	Hydrologic Soil Groups (HSG)
B.L	BOTTOM LAND	D
Brsl/g	BRIGHTON GRAVELLY SANDY LOAM	A
Brsl	BRIGHTON SANDY LOAM	A
Brsvg	BRIGHTON SANDY LOAM - OVER GRAVEL	A
B.U	BUILT UP AREA	D
Cac	CASHEL CLAY	C
Gsl	GRANBY SANDY LOAM	C
LI	LYONS LOAM	C
ML	MILLIKEN LOAM	C
M	MUCK	D
Pec	PEEL CLAY LOAM	C
Wol	WOBBURN LOAM	B



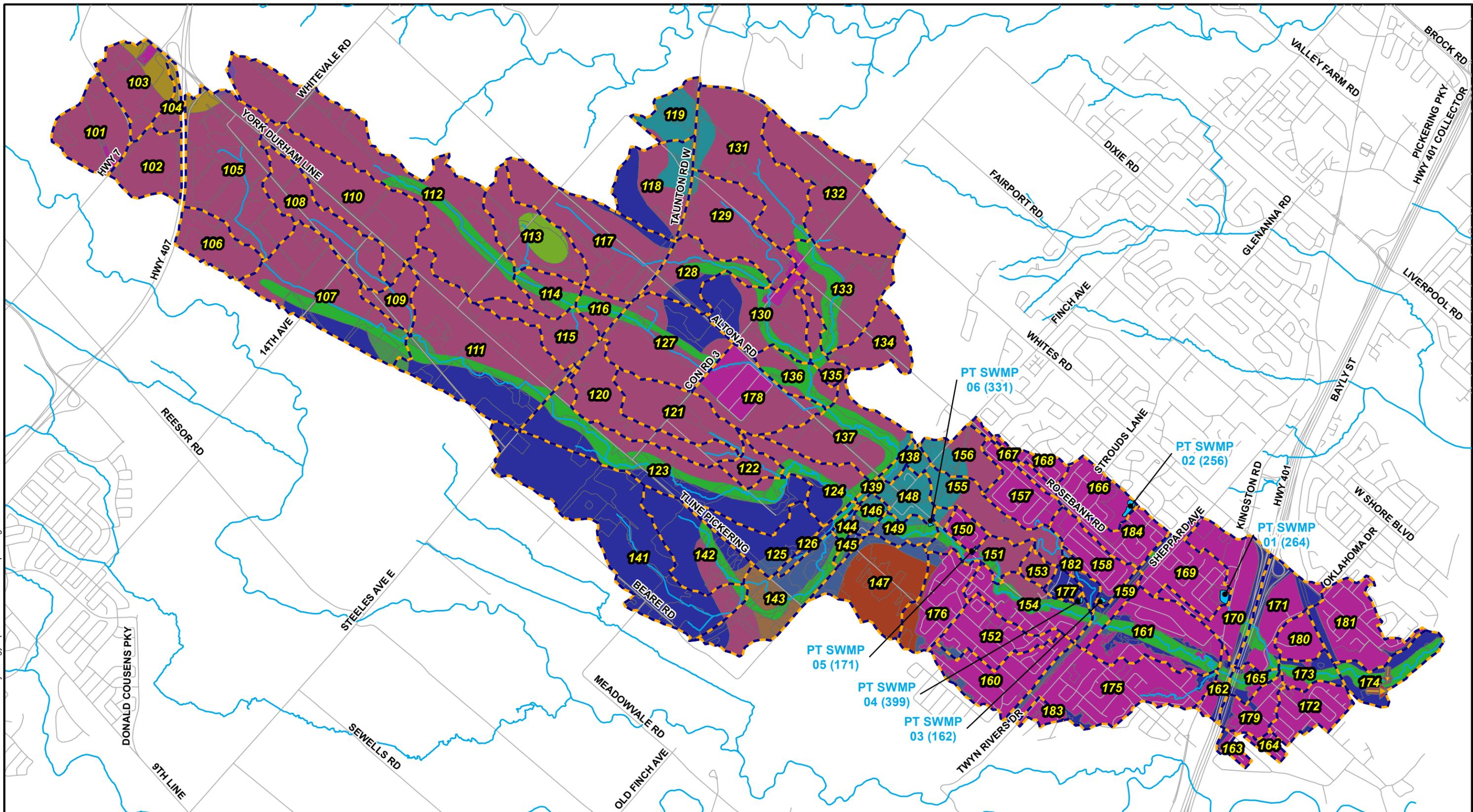
Legend

Petticoat Creek Catchment	Existing Landuse	Roads
Watercourse	Commercial/Employment/Downtown/Mixed Use	Open Space
Roads	Residential - Medium Density	Water
SWM Ponds	Residential - Low Density	Agricultural
	Railway	



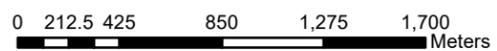
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	EXISTING LAND USES	

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Legend

Petticoat Creek Catchment	Soils (Hydrologic Soil Group)	CASHEL CLAY (C)	PEEL CLAY LOAM (C)
Watercourse	BRIGHTON GRAVELLY SANDY LOAM (A)	GRANBY SANDY LOAM (C)	BOTTOM LAND (D)
Roads	BRIGHTON SANDY LOAM (A)	LYONS LOAM (C)	BUILT UP AREA (D)
SWM Ponds	BRIGHTON SANDY LOAM - OVER GRAVEL (A)	MILLIKEN LOAM (C)	MUCK (D)
	WOBURN LOAM (B)		



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SOILS MAP	

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2.4.4 RUNOFF CURVE NUMBERS (CN)

The weighted average runoff curve number (CN) for each catchment was computed in GIS software. To do this, a “union” was created of the land-use and soils shape files in GIS software and a lookup table was created of Curve Numbers, which cross referenced land-use, hydrologic soil group and various CN values (see **Table 2.3**). The curve numbers used in the lookup table are for AMC II conditions, and were taken from “*Technical Guidelines for Hazard Mapping*” (EWRG, 2017). Using the tabulated CN values, a curve number grid was generated for the watershed. The weighted average curve number for each catchment was then determined from the curve number grid, on a cell-by-cell basis.

Table 2.3 Curve Number Lookup Table

Land Cover	AMC II CN						
	A	AB	B	BC	C	CD	D
Woods	32	46	60	67	73	76	79
Meadows	38	51	65	71	76	79	81
Cultivated	62	68	74	78	82	84	86
Lawns	49	59	69	74	79	82	84
Impervious Areas	100	100	100	100	100	100	100

The weighted average curve numbers were used to determine the initial abstraction (I_a) for each catchment. The initial abstraction is that part of the rainfall that is intercepted by vegetation or surface depressions prior to the initiation of runoff.

Appendix D includes the calculated initial watershed parameters as applied in the developed hydrological model for the Petticoat Creek watershed.

2.4.5 IMPERVIOUSNESS AND HYDRAULIC CONNECTIVITY

Two key parameters used in the VO6 model to estimate runoff response from urban watersheds are the level of impervious (TIMP) and the percentage of those lands that are directly connected (XIMP) to the urban drainage system.

To estimate impervious levels, a total of eight (8) categories for various land uses were assigned throughout the watersheds and the impervious and pervious values were determined. The analysis was performed based on the orthophotography (dated 2015) provided by TRCA.

Of the impervious surfaces, roads, driveways and parking surfaces are all commonly considered to be directly connected to the drainage system, whereas sidewalks and patios are not. In addition, the connectivity of rooftops can vary considerably. In order to establish appropriate estimates of the total imperviousness and directly connected imperviousness for the study area, a total of 14 block sites throughout the subwatersheds were selected. Based on the findings from the sample sites, the impervious levels and directly connected levels applied in the hydrological model are summarized in **Tables 2.4**. Details of the sample sites for impervious levels and connectivity levels are included in **Appendix E**.

Note that, all pervious areas greater than 3 ha were separated from the STANDHYD commands and presented by NASHYD commands in the model.

Table 2.4 Summary of the Total and Directly Connected Imperviousness for Different Land Uses

Land Use	Percent Impervious (TIMP)	Directly Connected (XIMP)	Notes
Low Density Residential	9%	4%	Sample site 1 to 3
Medium Density Residential	64%	26%	Sample site 4 to 6
Commercial/Employment/Downtown	85%	51%	Sample site 7 to 9
Road	92%	92%	Sample site 10 to 12
Railway	100%	100%	Sample site 13 to 14

2.4.6 OTHER PHYSICAL CATCHMENT PARAMETERS

Other model parameters and physical watershed characteristics were calculated according to the recommended values in the Technical Guidelines for Flood Hazard Mapping (EWRG, 2017) and VO Model Manual.

- Manning’s roughness for overland flow in urban areas
 - impervious surfaces – 0.013
 - pervious surfaces (lawns) – 0.250
- Overland flow lengths within urban lands
 - pervious surfaces (lawns) – 40 m
 - impervious surfaces = $(A/1.5)^{0.5}$
- Catchment time-to-peak was estimated for each NASHYD command by calculating its aggregate runoff coefficient, C, (MTO, 1997) and either the Airport Formula or the Bransby-Williams Formula.
 - Bransby-Williams Formula
 - For catchments where C is greater than 0.40
 - $t_c = \frac{0.057 \times L}{S_w^{0.2} \times A^{0.1}}$
 - Where: t_c = time of concentration (min)
 - L = catchment length (m)
 - S_w = catchment slope (%)
 - A = catchment area (ha)
 - Time-to-peak (Tp) = 0.67 * t_c
 - Airport Method
 - For catchments where C, is less than 0.40
 - $t_c = \frac{3.26 \times (1.1 - C) \times L^{0.5}}{S_w^{0.33}}$
 - Where: t_c = time of concentration (min)
 - L = catchment length (m)
 - S_w = catchment slope (%)
 - C = runoff coefficient
 - Time-to-peak (Tp) = 0.67 * t_c

2.5 CHANNEL ROUTING

In general, flood or channel routing is required to appropriately represent flood wave travel times (translation) and reduction in peak discharge (attenuation) as flows propagate downstream along a reach.

The routing commands available in the VO Model are the Variable Storage Coefficient (VSC) (ROUTE CHANNEL 1) and the Muskingum-Cunge (MC) (ROUTE CHANNEL 2).

The Muskingum-Cunge algorithm uses a simplification for the kinematic-wave model, which is appropriate only if the channel slope exceeds 0.002 (0.2 %) (USACE, 2000). Furthermore, the Muskingum-Cunge algorithm in VO was found to be unstable and quite unpredictable based on previous studies. Therefore, the Variable Storage Coefficient method was adopted for the subject models; however, this method also has limitations as described below.

The VSC routing algorithm is essentially a storage routing method involving the use of a storage coefficient which is a function of the time increment (or time step) and the travel time of the flow in the reach. It has two distinct characteristics: the peak of the outflow hydrograph always falls on or within one time step of the recession limb of the inflow hydrograph and, the outflow begins one time step after the inflow starts, which is typical of reservoir routing. This is because the method assumes a very short reach as noted in the Flood Routing Sensitivity Study (FRS Study) prepared by Kouwen (1984). Therefore, if applied without modification, the method is not suited for routing flows through long reaches. Similarly, the FRS Study found that the VSC method resulted in over-attenuated peak flows on long “flat” reaches.

The effects of the two limitations of the VSC method can be mitigated with some adjustments to the routing approach. The delay in outflow, required to account for the travel time of the flood wave down a long reach, can be achieved by using the Lag-and-Route methodology employed by Marshall Macklin Monaghan Limited (MMM) for the 1980 hydrology studies for the watersheds in Southern Ontario. In this approach, the inflow hydrograph is lagged by the travel time computed on the basis of the wave celerity ω (i.e., wave speed) before being routed using the VSC algorithm. The wave celerity or speed can be approximated as 1.5 times the average flow velocity within the reach (Chow, 1959). Because the average flow velocity changes with discharge, the lag time for the reaches would vary for the different calibration events.

The Lag-and-Route approach is not suitable, or necessary, for the routing of the flows along the relatively flat reaches within the study area. This is because on flat slopes (defined here as $S_o < 0.0004$), the effect of the “convective acceleration” term in the dynamic wave equation (which accounts for changes in flow velocity in the direction of flow) is pronounced and cannot be accounted for using formulas assuming uniform flow. Furthermore, the flat reaches act essentially as quasi-reservoirs, where the outflow is considered to be controlled by the channel geometry. Therefore, the Lag and Route methodology was only applied to reaches with slopes greater than 0.04% (i.e., $S_o \geq 0.0004$). The Lag-and-Route technique was applied only in those instances where the travel time was at least twice the time step.

The flat reaches (i.e., $S_o < 0.0004$) function as quasi-reservoirs for runoff events, therefore, the VSC method is directly applicable – in the sense that outflow would begin one time step after the inflow begins. The over attenuation of the peak flow observed by Kouwen (1984) can be minimized by dividing the reach into several sub reaches, where the outflow from one sub-reach becomes the inflow to the next downstream sub-reach. The FRS Study noted that the recommended routing reach lengths should be such that the travel time through the reach is smaller than 1/5th of the time to rise (Tr) of the inflow hydrograph. Though ideal, this recommendation would result in too many sub-reaches for practical applications. Therefore, in lieu of the above criterion, a maximum sub-reach length of 2.5 km was specified. The 2.5 km reach length was selected after several iterations, where the reaches were sub divided into different reach lengths to arrive at the optimum reach length that minimized both the number of required sub-reaches and peak flow attenuation.

The channel routing sections, reach lengths and reach slopes were derived directly from the DTM, while initial values for Manning’s n to denote channel roughness and typical channel cross sections were obtained based on the existing HEC-RAS hydraulic models (Greenland Consulting Ltd, October 2006) for the water courses.

As indicated previously in **Section 2.3.2**, major flow routes through urban street system were included in the model by using Route Channel command to reflect wave travel times and reduction in peak discharge. The width of the representative major flow routes was estimated based on the orthophotography.

The following parameters were applied for the ROUTE CHANNEL command representing the roads (major flows):

- Manning’s N of 0.015 for road surface;
- Manning’s N of 0.15 for the boulevards of the cross sections; and
- Set standard road cross sections with the curb height of 0.15 m.

All relevant information regarding channel routing is included in **Appendix F**.

2.6 RESERVOIR ROUTING

There are a total of six (6) Stormwater Management (SWM) facilities within the study watershed.

The storage-discharge relationships for each SWM facility were provided by TRCA and incorporated in the model. **Table 2.5** presents a brief summary of SWM control characteristics. Detailed information regarding storage elements is included in **Appendix G**. It should be noted that in accordance with provincial flood plain management guidelines, these storages were not included in the model used to simulate the Regional Storm.

Table 2.5 Summary of SWM Control in the Model

Watershed	Pond ID	VOID	Pond Name	Pond Types
Petticoat Creek	PT SWMP 06 (331)	3148	Bopa Pond (bopa Developments)	Wet
	PT SWMP 05 (171)	3150	Chickadee Ct Pond (Crystal Forest)	Wet
	PT SWMP 04 (393)	3177	Calvington Dr Pond (Timber Trails)	Wet
	PT SWMP 03 (162)	3158	Autumn Pond (Highbush)	Wet
	PT SWMP 02 (265)	3166	Braeburn Pond (Amberlea Park)	Dry
	PT SWMP 01 (264)	3169	Steeple Hill Pond	Dry

2.7 MODEL TIME STEP

In order to avoid computational instability convergence due to the inconsistent time steps during the simulations, all command elements in the model, including catchments (NASHYD, STANDHYD), ROUTE CHANNEL and ROUTE PIPE, are set to be consistent as 5 minutes. This was determined based on 1/5 of time to peak values among the smallest catchments as per Technical Guidelines (EWRG, 2017). Note that regardless of the input time steps of the rainfall events, the model will automatically convert them to the same as those of command elements (i.e., 5 minute) during the simulations.

2.8 SUMMARY OF MODEL SETUP

Table 2.7 provides a summary of the commands included in the study subwatersheds. The schematics of the models are shown in **Figure 2.5**.

Table 2.6 Summary of Model Commands

Command Elements	Count	Description
NASHYD	68	To simulate runoff from natural and open space areas, including the pervious areas greater than 3 ha, which were separated from the urban block.
STANDHYD	31	To simulate runoff from urban areas
ROUTE CHANNEL	53	To route hydrographs using the variable storage coefficient (VSC) method through open channel and major flow routes
ROUTE RESERVOIR	6	To simulate the Stormwater Management facilities
DUHYD	10	To simulate the split in flow where major and minor system drainage differs



CLIENT	TORONTO AND REGION CONSERVATION AUTHORITY	
TITLE	PETTICOAT CREEK SUBWATERSHED VO6 MODEL SCHEMATIC	



Checked	A.Z.Z.	Drawn	J.C
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Scale	N.T.S.	Figure No.	2.5

3 CALIBRATION AND VALIDATION OF BASE MODELS

3.1 METHODOLOGY

An important step in developing a hydrologic model that is capable of accurately simulating existing land use conditions is calibrating and validating the model against recorded historical streamflow data using corresponding historical rainfall data. The calibration and validation process assists in producing a reliable and representative hydrological model for a watershed.

Generally speaking, model parameters are classified into two groups: physical watershed parameters and process parameters. A physical watershed parameter represents measurable properties of the drainage system (e.g. areas of the catchment, length of channels, volumes of ponds, etc.). Process parameters represent properties of the watershed that are not directly measurable (e.g. initial abstraction, average or effective depth of surface soil moisture storage, etc.). Predictive watershed models require parameter values that produce model results closely matching recorded data. The process by which certain parameters are selected is called model calibration. There are two parts to this process: initial parameter specification and parameter adjustment.

Initial parameter specification assigns initial estimates to parameters using prior knowledge about the watershed. Physical parameters are measured from maps or from field data collection. These parameters are typically not adjusted. For “process parameters”, estimates of a range of possible values (minimum and maximum values) are made based on judgment and an understanding of the hydrology of the watershed. The process of parameter calibration reduces the uncertainty in the parameter estimates.

A typical approach is to first select an initial parameter value within an acceptable range of values. The parameter value is then adjusted to more closely match the model behaviour to that of the watershed. The process of adjustment can be done “manually” or using computer-based “optimization” methods. Manual calibration was performed for this study.

Generally, the quality of hydrologic model simulations can be evaluated by graphical comparison between measured and modelled hydrographs and by statistical methods. Graphical comparison of simulated and observed hydrographs is popular because it provides a quick and comprehensive means of assessing the accuracy of model output. ASCE (1993) and I. R. A. Green & D. Stephenson (1986) discuss statistical methods for single-event model performance evaluation. They recommend the use of a simple percentage error for peak flow, runoff volume and time-to-peak comparison. For the subject study, the widely accepted calibration criteria described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002) with adjustment to the volume errors was applied. It assumes an acceptable event calibration when the simulated volume is within +20% to -10% of the measured volume and the simulated peak flow is within +25% to -15% of the measured value. The observed and modeled hydrographs should meet the criteria for two out of three events.

3.2 STREAMFLOW AND RAIN DATA

The calibration and validation process requires concurrent streamflow and rainfall data. Model calibration relies on the quality of data available. Rainfall is the primary input of rainfall-runoff transformation of the hydrologic model. Accurate input of rainfall in time and space is key for accurately modelling and matching measured flows.

For the subject study, the streamflow and rain data used for model calibration and validation were provided by TRCA Staff. These gauges are relatively new stations and being operated and managed by TRCA. The streamflow station has about 8 years of continuous data collected since 2012.

The spatial distribution of the calibration and validation rainfall events was incorporated into the modeling by using the Thiessen Polygons method to assign the rain gauges to the different catchments, as shown in the figures included in the **Appendix H**.

Table 3.1 summarizes the details of the streamflow gauges and precipitation gauges for Petticoat Creek watershed. The locations of these streamflow and precipitation gauges are shown in **Figure 3.1**.

Table 3.1 Streamflow and Precipitation Gauges for Petticoat Creek (Provided by TRCA)

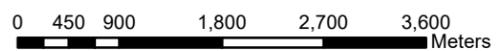
Gauge Type	Gauge ID	Location Name	Available Data From	Available Data To	Time Step
Precipitation	HY043	Little Rouge at 16th	4/25/2013	4/7/2020	5 min
	HY044	Milne Dam	1/1/2013	4/7/2020	5 min
	HY009	Brock West Landfill	7/29/2014	4/1/2020	5 min
	HY102	Petticoat Works Yard	4/22/2013	4/1/2020	5 min
Streamflow	HY051	Petticoat Creek at Whites	11/22/2012	1/25/2020	15 min



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- ▲ Streamflow Gauge
- Rain Gauges
- Petticoat Creek Catchment
- SWM Ponds
- Watercourse
- Roads



TORONTO AND REGION CONSERVATION AUTHORITY	
TITLE PETTICOAT CREEK SUBWATERSHED	
Checked A.Z.Z.	Drawn J.C
Date October 2020	Proj. No. 19M-01483-00
Scale 1:63,500	Figure No. 3.1



3.3 CALIBRATION AND VALIDATION EVENTS

Based on the available rainfall and flow data, a total of eight (8) events were selected (as shown in **Table 3.2**). Among them, four (4) events were identified for model calibration, while the rest four (4) events were used for model validation. Details of rainfall events and corresponding streamflow data used for the calibration and validation are summarized in **Appendix H**.

Table 3.2 Selected Rainfall Runoff Events

Event #	Calibration and / or Validation	Date	Period		Precipitation Depth (mm)			Streamflow Data at HY051		Total Runoff Volume ¹⁾ / Total Precipitation Volume ²⁾ (%)
			From	To	HY043	HY009	HY102	Recorded Peak Discharge Rate (cms)	Peak Discharge Rate with baseflow Subtracted (cms)	
1	Calibration	21/9/2014	9/21/14 6:00 AM	9/21/14 2:00 PM	21.0	29.7	24.8	6.8	6.7	11%
2	Validation	16/10/2014	10/16/14 4:00 PM	10/17/14 3:00 PM	16.8	33.9	27.8	6.9	5.4	25%
3	Calibration	16/6/2015	6/16/15 3:10 AM	6/16/15 11:00 AM	11.4	10.1	19.2	6.6	6.3	11%
4	Calibration	22/6/2015	6/22/15 8:55 PM	6/23/15 4:00 PM	30.4	46.9	52.8	9.5	9.4	25%
5	Validation	27/6/2015	6/27/15 1:15 PM	6/29/15 3:00 PM	46.4	49.4	48.2	8.3	8.1	46%
6	Calibration	28/10/2015	10/28/15 3:05 AM	10/29/15 12:00 PM	48.2	72.5	69.8	8.9	8.8	24%
7	Validation	26/11/2018	11/26/18 6:50 AM	11/28/18 8:00 AM	30.6	31.2	28.3	6.1	3.9	39%
8	Validation	15/4/2018	4/15/18 6:15 AM	4/17/18 10:00 AM	n/a	75.4	72.8	6.4	5.8	29%

1) Based on recorded streamflow with baseflow subtracted.

2) Based on weighted precipitation data

3.4 CALIBRATION PROCEDURE

In general, the calibration procedure for the subject study involved the following:

– **Compute initial values for catchment parameters.**

Initial values of catchment parameters were established using typical methods as discussed previously in **Section 2.4**. The initial values computed are summarized in **Appendix D**.

– **Identify suitable rainfall events.**

Identify significant rainfall events at each rain gauge. Once an event was identified, the concurrent streamflow data at the associated flow gauge was used to develop a flood (runoff) hydrograph.

If applicable, base flow was separated from the flood hydrograph to determine the direct runoff hydrograph (DRH) using the “straight line” method.

– **Calibrate watershed runoff volumes.**

For each calibration event, the runoff volume was calculated from the streamflow data at the gauges, based on the direct runoff hydrograph. The appropriate initial value of the SCS Curve Number (CN) for each catchment (NASHYD) was calculated to ensure that the modelled runoff volume would be close to that observed. This was achieved by adjusting the CN value based on the Antecedent Moisture Conditions (AMC) in the watershed prior to each calibration rainfall event. The AMC refers to the residual water storage within the watershed at the start of the rainfall event. In VO6, this is represented by the adjustment of the runoff curve number (CN) parameter. The CN is a function of the type of soil, land-use (cover conditions), and antecedent moisture conditions (AMC). The initial abstraction (Ia) is also a key parameter which presents a part of the rainfall that is intercepted by vegetation or surface depressions prior to the initiation of runoff. Estimates of initial abstraction values were set according to the Technical Guidelines for Flood Hazard Mapping (EWRG, March 2017). The adjustment of the values of initial abstraction (Ia) for the identified catchments would also be required when necessary.

The antecedent moisture conditions of a soil and surface condition have been based on the total precipitation that has occurred prior the rainfall calibration event. Antecedent Moisture Condition II (AMC II) is the average condition, and AMC I and AMC III represent dry (with lowest runoff potential) and wet soil conditions (with highest runoff potential), respectively. Chow et al. (1988) describes a CN adjustment method for dry (AMC I) or wet conditions (AMC III), using the following empirical relationships:

$$CN(I) = \frac{4.2 CN(II)}{10 - 0.058 CN(II)}$$

and

$$CN(III) = \frac{23 CN(II)}{10 + 0.13 CN(II)}$$

For urbanized catchments (STANDHYD), since the imperviousness values (TIMP and XIMP) are considered as measurable properties and were determined based on the measurement (as discussed in Section 2.4.5), no adjustments were made to the imperviousness values in the calibration process.

OTTHYMO is a single event simulation model, there is no other way of establishing antecedent conditions. The initial conditions are prescribed (AMC II or AMC III) for design event simulations, and there is no need to establish a predictive relationship for antecedent conditions.

– **Determine proper multiplication factors**

For each calibration event, the optimization was achieved by applying a multiplication factor uniformly across all catchments and/or routing reaches within the calibration watershed to the calibration parameters until an optimum multiplier was found for each type of parameter. Based on various previous hydrology studies, typical

parameters (i.e., Process Parameters) require calibration, including Time-to-peak (T_p) and Number of Linear Reservoirs (N) for NASHYD; Storage Coefficient for Impervious Areas SCI (as known as Storage Coefficient K , which is derived from overland routing by Peterson and Altera’s kinematic wave method and is a function to catchment flow length, roughness coefficient, dominant rainfall intensity, and characteristic slope) for STANDHYD; and channel roughness n for ROUTE CHANNEL command. The sensitivity analysis is typically required to identify the parameters which have the most impacts to the modelling results (i.e., peak flows, runoff volumes, etc.).

Table 3.3 shows the identified calibration parameters with their lower and upper multipliers applied for the subject watershed.

Table 3.3 Boundaries of Calibration Multiplier Coefficients

VO Command	Parameter	Lower Multiplier	Upper Multiplier
STANDHYD	$SCI - K$	0.5	1.5
NASHYD	N (Default = 3)	0.5	1.5
	T_p	0.5	1.5
ROUTE CHANNEL	Roughness (n)	0.5	3

– **Sensitivity analysis**

Sensitivity analysis was performed during the adjusting of the multiplier factors for each parameter.

– **Model validation.**

Once optimum multipliers of the identified parameters were determined, the selected validation rainfall events were applied to provide a rigorous check on the “soundness” of the calibrated hydrologic model.

4 CALIBRATION RESULTS AND DISCUSSION

4.1 CALIBRATION RESULTS

Manual calibration process was completed by implementing trial-and-error approach. **Table 4.1** presents the resulting parameter multiplier coefficients to achieve optimization. The corresponding calibration results are summarized in **Table 4.2**. As shown in **Table 4.3**, the results are generally found to be satisfied with the calibration criteria as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002):

- the simulated volume is within +20% to -10% of the measured volume
- the simulated peak flow is within +25% to -15% of the measured value, and
- At least two of the three (66%) selected storm events meet the targets.

A complete set of data including calibration results, summary tables and detailed comparisons of the hydrographs are included in **Appendix I**.

Table 4.1 Calibration Multiplier Coefficient

Event #	Description	Date	VO RUN #	CN Adjustment	Calibration Parameters			
					Multiplier - SCI	Multiplier - N	Multiplier - TP	Multiplier - Channel Manning's N
1	Calibration	9/21/2014	01.02	Decrease 12%	1.00	1.00	1.00	1.00
3	Calibration	6/16/2015	03.02	Decrease 10% (< AMC II and > AMC II)	1.00	1.00	1.00	1.00
4	Calibration	6/22/2015	04.01	AMC I	1.00	1.00	1.00	1.00
6	Calibration	10/28/2015	06.02	Decrease 30% (< AMC I)	1.00	1.00	1.00	1.00
Final (Optimum) Multipliers				N/A	1.00	1.00	1.00	1.00

Table 4.2 Calibration Results

Event #	Runoff Volume			Peak Flow Rate				
	Observed - m ³	Simulated - m ³	Difference - %	Observed with Data Gaps - m ³ /s	Observed with Data Gaps Filled* - m ³ /s	Simulated - m ³ /s	Difference with Data Gaps - %	Difference with Data Filled* - %
1	71377.20	85222.38	19%	6.72	13.00	7.44	11%	-43%
3	39676.50	44242.74	12%	6.32	7.70	6.54	3%	-15%
4	283078.50	263441.60	-7%	9.38	14.00	15.04	60%	7%
6	386063.40	407553.73	6%	8.79	n/a	8.75	0%	n/a
SUMMARY	n/a	n/a	7%	n/a	n/a	n/a	18%	-17%

* Observed flow data gaps filled by the estimated possible rate

Table 4.3 Calibration Results as per PaWUG Targets

Event #	PaWUG Target - Volume Comparison	PaWUG Target - Peak Flow Comparison with Data Gaps	PaWUG Target - Peak Flow Comparison with Data Gaps Filled
1	Meet General Target	Meet General Target	Not Meet
3	Meet General Target	Meet Target for Critical Locations	Meet General Target
4	Meet Target for Critical Locations	Not Meet	Meet Target for Critical Locations
6	Meet Target for Critical Locations	Meet Target for Critical Locations	n/a

The following are the main points and observations from the calibration process:

- Data gaps were found for Events 1, 3 and 4. Database management was completed to fill the identified gaps based on the best estimation of the hydrograph (**Appendix H**).
- The observed hydrograph shapes generally match those reproduced for all calibration events.
- All events were occurred on dry soil conditions. CN values lower than AMC II were assigned for all events.
- The results of the calibration indicate that no adjustments of any identified calibration parameters will be required (i.e., multiplier = 1.0).
- The results of the volume comparison meet the calibration criteria as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002).
- The results of peak flow comparison (either monitored flows with data gaps or data gaps filled) meet the calibration criteria as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002).
- All selected calibration events meet the targets as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002).

4.2 MODEL VALIDATION

In order to utilize a predictive watershed model for estimating the effectiveness of future potential management practices, the model must first be calibrated to measured data and should then be tested (without further parameter adjustment) against an independent set of measured data. Such testing is referred to as model validation. Model calibration determines the best and reasonable parameter set while validation ensures that these parameters performs reasonably well under an independent data set.

Model validation shall exhibit the capability of the model to produce reasonable predictions for periods outside the calibration period (Refsgaard and Knudsen, 1996). Therefore, the independently selected 4 events were used for the model validation. Since the calibration found that no adjustments of the parameters were required, the original values were used for the model validation simulations.

The validation hydrograph comparisons are included in **Appendix I**. The validation results are summarized in **Table 4.4**. **Table 4.5** shows the results based on the criteria as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002). **Figures 4.1 and 4.2** present the overall model performance for the calibrated parameterization of Petticoat Creek hydrologic model on runoff volumes and peak runoff rates respectively.

A complete set of model validations including results, summary tables and detailed comparisons of the hydrographs are included in **Appendix I**.

Table 4.4 Validation Results

Event #	Runoff Volume			Peak Flow Rate				
	Observed - m ³	Simulated - m ³	Difference - %	Observed with Data Gaps - m ³ /s	Observed with Data Gaps Filled* - m ³ /s	Simulated - m ³ /s	Difference with Data Gaps - %	Difference with Data Filled* - %
2	167694.00	92688.34	-45%	5.35	6.20	9.47	77%	53%
5	564718.80	512192.58	-9%	8.08	n/a	9.17	14%	n/a
7	303847.20	197870.18	-35%	3.89	n/a	4.18	7%	n/a
8	544352.40	506567.49	-7%	5.77	n/a	7.06	22%	n/a
SUMMARY	n/a	n/a	-24%	n/a	n/a	n/a	30%	53%

* Observed flow data gaps filled by the estimated possible rate

Table 4.5 Validation Results as per PaWUG Targets

Event #	PaWUG Target - Volume Comparison	PaWUG Target - Peak Flow Comparison with Data Gaps	PaWUG Target - Peak Flow Comparison with Data Gaps Filled
2	Not Meet	Not Meet	Not Meet
5	Meet Target for Critical Locations	Meet General Target	n/a
7	Not Meet	Meet Target for Critical Locations	n/a
8	Meet Target for Critical Locations	Meet General Target	n/a

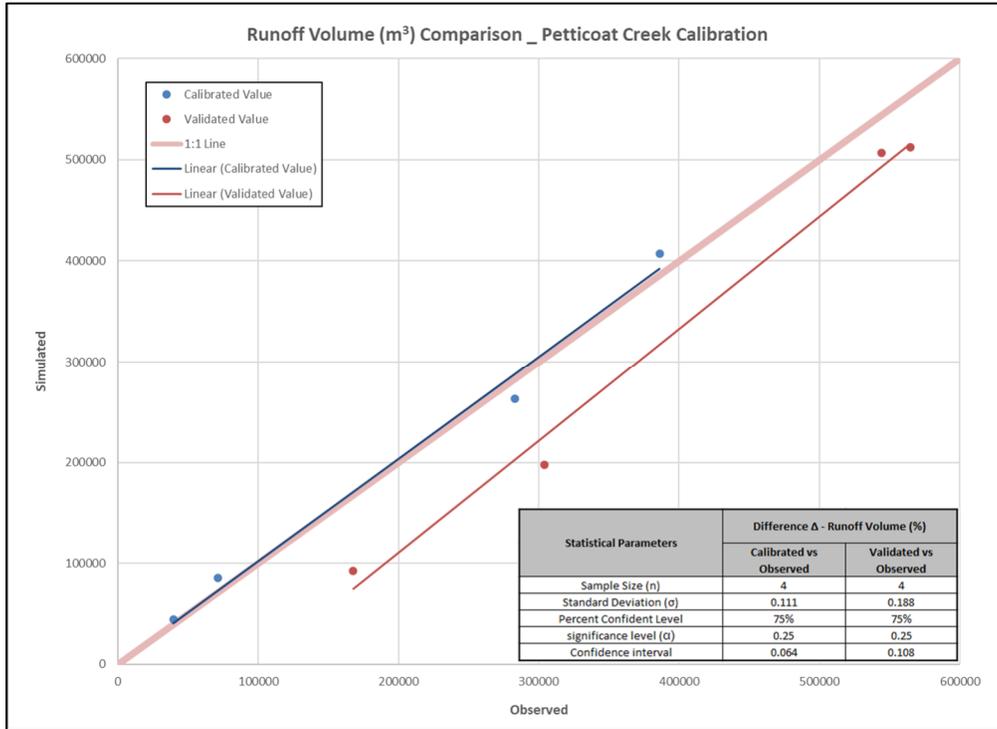


Figure 4.1 Model Parameterization Performance on Runoff Volumes

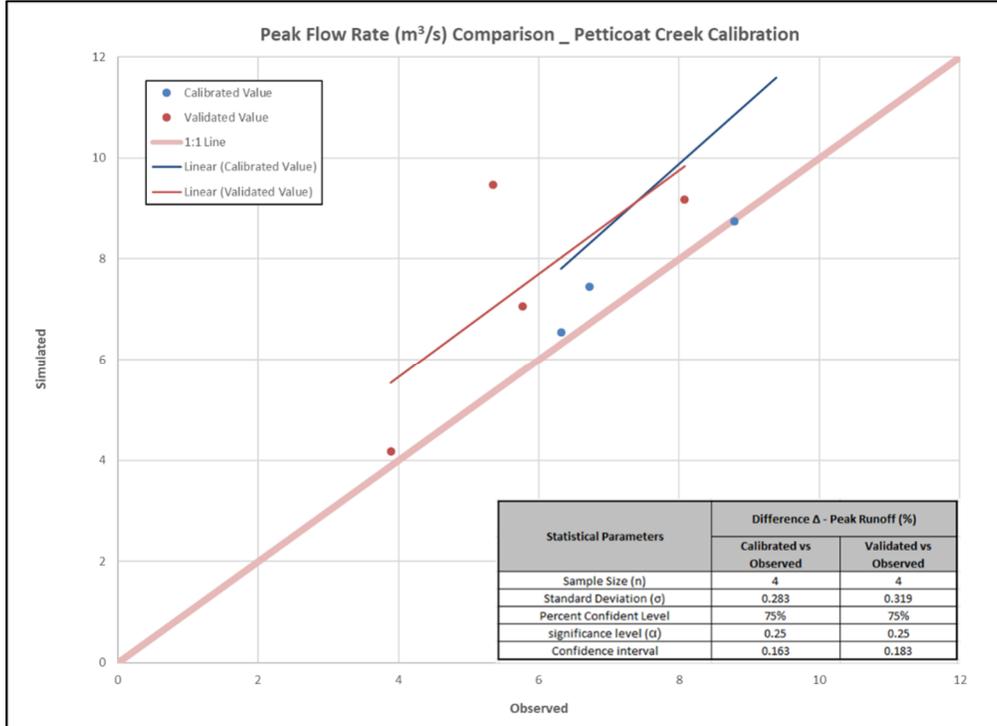


Figure 4.2 Model Parameterization Performance on Peak Flow Rates

The following are the observations and conclusion based on the results of model validation:

- The results of both volume and peak flow comparisons for Events 5 and 8 meet the calibration criteria as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002).
- The results of Event 7 meet only the peak flow comparison criteria. Based on further discussion with TRCA staff, it was found that Event 7 was a rain-on-snow event, which might cause the discrepancy between the simulated volumes and those observed. Please refer to **Appendix O** of Correspondence for more information.
- The results of Event 2 don't meet both volume and peak flow comparison criteria. Based on the discussion with TRCA staff, it was believed that the poor validation result of Event 2 might be caused by the unreliable observed streamflow data due to the limited rating curve at the streamflow gauge. Note that if a re-adjusted or "hybrid" rating curve was used, the observed flow hydrograph would generally match the simulated. Please refer to **Appendix O** of Correspondence for more information.
- Although only 2 of 4 validation events (50%) meet the targets as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002), by considering the total 8 events selected for both calibration and validation, 75% of them (6 of 8 events) meet the targets.

4.3 CONCLUSION OF MODEL CALIBRATION

The model calibration and validation process was completed for the hydrologic model developed for the Petticoat Creek watershed. In conclusion, although the calibration/validation results generally meet the targets as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002), by considering the identified data limitations (e.g., data gaps, rain-on-snow events, short period of recorded data and insignificant rainfall amounts, etc.), it is concluded that the results of model calibration and validation completed for the developed hydrologic model of Petticoat Creek watershed shall be used for reference purposes only.

Furthermore, it is strongly recommended that when the additional rainfall and stream flows data become available in the future, the calibration and validation process should be updated.

5 MODEL FOR FUTURE DEVELOPMENT CONDITIONS

As previously indicated in **Section 2.4.2**, the subject watershed is fully built in according with the current municipality's Official Plan, and there will be no changes of the land uses under future conditions. Consequently, hydrologic model for future development conditions is not included in the subject study.

6 DESIGN STORM AND REGIONAL STORM SIMULATIONS

6.1 GENERAL

The design storm approach was applied to estimate the peak flows for the 1:2 to 1:100 year return period design storms and Regional Storm (Hurricane Hazel) at the identified flow nodes (as shown in **Figure 2.2**) within the study watershed. Design storms are developed by statistical analysis of long-term historical rainfall records and the result helps to develop design storms of different return frequency that represent rainfall pattern, type and distribution of different return frequency. Under the design storm approach, a design storm is selected and applied to the calibrated model and design flows are determined by using specified antecedent moisture conditions. It is generally recognized that design storm of a given return frequency will generate a simulated runoff peak and volume that have the same return frequency. The design storm approach was used to estimate the 2-, 5-, 10-, 25-, 50-, and 100-year peak flows for the study watershed. The Regional storm in the study area for floodplain management purposes is based on Hurricane Hazel. According to the MNR Technical Guide (2002), the Regulatory flow is the greater of the Regional flow and the 100-year flow.

In order to represent the unknown antecedent moisture conditions prior to a design storm event, a curve number (CN) with average antecedent moisture conditions (AMC II) was assumed for the 2-year through 100-year design storms, while the saturated antecedent moisture conditions (AMC III) were assumed for the Regional storm event.

In addition to apply AMC III, the following adjustments were also made in the model for the Regional storm simulation.

- According to the MNR Technical Guide (2002), all SWM facilities were removed from the model for the Regional Storm simulations.
- According to the MNR Technical Guide (2002), the total rainfall depth was reduced by applying an aerial adjustment factor based on the equivalent circular area method to determine the peak flows at the downstream flow nodes.
- Some DUHYD commands were removed from the model to reflect the antecedent conditions that the capacity of the minor (pipe) systems are full.

6.2 SIMULATION OF REPRESENTATIVE DESIGN STORMS

The amount of rainfall and its representative pattern, type and distribution in time and space are usually critical inputs to the hydrologic simulation in calculating runoff characteristics. In order to determine a storm distribution appropriate for the subject watershed, various storm distributions, as shown in **Table 6.1**, were tested and simulated in the calibrated model. Based on the discussion with TRCA staff, the storm files used in the model were derived based on Toronto City (Bloor) gauge (# 6158350). A summary of the resulting 100-year peak flows at Petticoat Creek outlet to Lake Ontario (Flow Node #5174) is also presented in **Table 6.1**. The detailed results of the model simulations with their associated design storms are included in **Appendix J**.

Table 6.1 Tested Storm Distribution with Resulting Flows for Petticoat Creek watershed

Design Storm Distribution	Duration (hr)	Simulated 100-year Flows (cms) at						100-Year Unit Flow - Average (cms/ha)
		Finch Ave Main Branch	CNR Main Branch	Sheppard Ave Main Branch	Hwy 401 Main Branch	Hwy 401 West Trib	Outlet to Lake Ontario	
Southern Ontario 1 hr AES Type II	1	25.0	24.8	25.5	35.2	18.4	52.1	0.0293
	6	39.2	39.4	42.3	43.2	9.9	45.5	0.0283
	12	34.7	35.0	39.6	41.8	7.2	46.0	0.0234
	24	25.2	25.3	29.6	31.8	4.7	35.7	0.0167
30% Southern Ontario 12hr AES	12	37.4	37.7	42.5	44.8	6.4	49.7	0.0240
70% Southern Ontario 12hr AES	12	30.3	30.5	34.9	37.1	4.2	41.7	0.0187
MNR 24hr SCS Storm Type II	6	39.6	39.7	43.1	44.3	14.8	48.9	0.0332
	12	39.7	39.8	43.4	44.8	11.8	47.6	0.0304
	24	35.3	35.5	39.7	41.7	8.0	45.7	0.0252
MTO SCS Type II	6	40.2	40.3	43.4	44.5	19.8	54.4	0.0373
	12	41.6	41.7	45.0	46.1	19.0	53.5	0.0376
	24	39.9	40.0	43.3	44.4	16.9	50.2	0.0352
Chicago (Keifer and Chu)	3	35.3	35.3	36.8	37.7	20.3	55.5	0.0348
	4	36.8	36.8	39.0	39.2	20.6	56.6	0.0358
	12	41.1	41.2	44.2	45.3	21.4	60.0	0.0392

Typically, the selection of the design storm distribution for a particular watershed is based on the results of the flood frequency analysis at the downstream streamflow gauges. However, due to the limitations of the observed data which is insufficient to derive a statistically reliable flood flows of less frequent or major events (e.g., 50-, 100-year events), the best practice is to identified the design storms which produce the most conservative flows for floodplain mapping purposes. The details regarding frequency analysis are discussed in **Section 6.4**.

Consequently, the highest peak flow rates calculated were based on the 12-hr Chicago distribution. However, by considering that the Chicago method is recommended only for a very short rain event which is used to design the sewerage network or in hydrology of great dams (Musy, 1998), it is not considered appropriate for the Petticoat Creek watershed.

The next highest set of peak flows were found to be associated with the 12-hour MTO SCS Type II rainfall distribution. Therefore, it is recommended that 12-hour MTO SCS Type II distribution is applied in the Petticoat Creek watershed hydrologic model to determine the peak flows for the 2-year through 100-year design storms.

Table 6.2 summarizes the resulting 2 to 100-year peak flow rates by using the selected 12-hour MTO SCS Type II design storms. Detailed simulation results are included in **Appendix K**.

Table 6.2 Summary of Resulting 2 to 100-Year Flow Rates under Existing Conditions

Flow Node ID	Flow Node Location	Effective Drainage Area (ha) *	Existing Flow (m³/s)					
			2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr
5102	Hwy 407 (west)	61.2	0.66	1.20	1.61	2.19	2.64	3.12
5104	Hwy 407 (east)	40.7	0.37	0.66	0.86	1.16	1.38	1.61
5111	Taunton Road West East Trib	503.0	2.96	5.21	6.99	9.47	11.47	13.54
5116	Taunton Road West Main Branch	210.8	1.49	2.60	3.45	4.60	5.49	6.41
5146	Finch Ave Main Branch	1800.3	8.82	16.11	21.88	29.61	35.55	41.62
5149	CNR Main Branch	1841.3	8.78	16.08	21.82	29.58	35.57	41.74
5161	Sheppard Ave Main Branch	2138.8	9.90	17.68	23.69	31.90	38.31	44.97
5165	Hwy 401 Main Branch	2311.5	11.44	18.34	24.42	32.80	39.36	46.15
5171	Hwy 401 West Trib	157.7	6.56	9.44	11.44	14.12	16.49	18.95
5174	Outlet to Lake Ontario	2568.0	18.45	27.43	33.76	41.53	47.07	53.24

Note*. Effective drainage areas may vary from storm to storm due to minor system diversions. The values listed represent drainage areas for the 100-year event.

6.3 REGIONAL STORM

For the Petticoat Creek watershed, the final 12-hours of Hurricane Hazel was used as the Regional Storm to determine the Regional peak flows. As indicated previously, the saturated antecedent moisture condition (AMC III) was used to simulate the wet soil condition at the beginning of rainfall. This accounts for the increase in soil moisture caused by the first 36-hours of the storm. According to the MNR Technical Guide (2002), all SWM facilities were removed for a Regional Storm simulation. In addition, the total rainfall depth was reduced by applying an aerial adjustment factor (as shown in **Table 6.3**) based on the equivalent circular area method to determine the peak flows at the downstream flow nodes, and some DUHYD commands were also removed from the model to reflect the antecedent conditions that the capacity of the minor (pipe) systems are full.

Table 6.3 Areal Adjustment Factor for Regional Storm

Watershed Longest Length		Equivalent Circular Area (up to)		Reduction Factor Percentage
km	m	km ²	ha	%
5.6	5642	25	2500	100.0
7.6	7569	45	4500	99.2
9.1	9097	65	6500	98.2
10.7	10705	90	9000	97.1
12.1	12101	115	11500	96.3
13.4	13351	140	14000	95.4
14.5	14494	165	16500	94.8
15.8	15757	195	19500	94.2

Note that the equivalent circular area is different from the watershed drainage area. The equivalent circular area was determined by using the longest length of the watershed as a diameter (Page 39, Technical Guide – River and Stream Systems: Flooding Hazard Limit, MNR, 2002). It was determined that there are five (5) flow nodes where the areal reduction factors need to be applied. **Table 6.4** summarizes the resulting Regional peak flow rates under the existing conditions for the subject watershed. All detailed model results are included in **Appendix K**. The determination of the areal reduction factors for the Petticoat Creek watershed is included in **Appendix L**.

Table 6.4 Summary of Resulting Regional Flow Rates under Existing Conditions

Flow Node ID	Flow Node Location	Effective Drainage Area (ha) *	Equi. Circular Drainage Area (sq. km)	Reduction Factor	Regional Flow (m ³ /s)
5102	Hwy 407 (west)	61.2	1.2	1	6.46
5104	Hwy 407 (east)	40.7	0.6	1	4.13
5111	Taunton Road West East Trib	503.0	17.9	1	43.75
5116	Taunton Road West Main Branch	210.8	18.7	1	18.58
5146	Finch Ave Main Branch	1797.6	46.9	0.982	146.93
5149	CNR Main Branch	1874.4	53.0	0.982	151.53
5161	Sheppard Ave Main Branch	2140.0	92.1	0.963	161.34
5165	Hwy 401 Main Branch	2314.0	100.3	0.963	167.96
5171	Hwy 401 West Trib	162.8	3.0	1	21.37
5174	Outlet to Lake Ontario	2580.8	119.6	0.954	177.45

Note*. Effective drainage areas may vary from storm to storm due to minor system diversions. The values listed represent drainage areas for the Regional event.

6.4 EVALUATION OF DESIGN FLOWS

6.4.1 GENERAL

Because the results of the hydrology study will be used to update the regulatory floodline, confirm the appropriateness of existing stormwater quantity control criteria, and aid in mitigating the downstream flood risk, it is crucial to ensure that the developed hydrologic model reflects the actual hydrologic characteristics of the subject Petticoat Creek watershed.

To complete the evaluation, the non-hydrographic methods (frequency analysis) were performed by using the longest available period of streamflow data recorded at the gauges within the subject watershed. The determined flows were compared with those from the hydrological simulation. For reference purposes, the comparison also includes the results from the previous studies, so that a comprehensive evaluation can be achieved.

Note that in order to properly incorporate the possible impacts of snowpack from the upstream rural areas of Petticoat Creek watershed, annual maximum flows were applied for the frequency analysis instead of using only the summer season maximum flows.

6.4.2 NON-HYDROGRAPHIC METHODS (FREQUENCY ANALYSIS)

Single Station Frequency Analysis is one of the basic methods to determine the magnitude of a design flood at hydrometric station locations. With this method, peak annual floods recorded at these gauges are statistically analysed to provide reasonably accurate means of estimating a design flow. The computer program Consolidated Frequency Analysis (CFA) version 3.1 by Environment Canada (EC) was used to conduct a frequency analysis and calculate frequency curves and statistics characteristics of the flows at the available hydrometric station.

There is only one streamflow station within the study watershed: HY051 - Petticoat Creek at Whites. The station is being operated and maintained by TRCA. The longest continuous period of record is only 11 years of hourly runoff data (ca. 2001~2012), which was provided by TRCA and used for the purpose of frequency analysis purposes. By considering the relatively short period of the data, it is insufficient to derive statistically reliable flood flows of less frequent or major events (e.g., 50-, 100-year events).

Four theoretical distributions were examined to determine the return period peak flows, including:

- 1 General extreme value distribution (GEV),
- 2 Three-parameter lognormal distribution (3PLN),
- 3 Log Pearson type III distribution (LP3); and
- 4 Wakeby Distribution.

Table 6.5 summarizes the frequency analysis results. Detailed results including the CFA program outputs are included in **Appendix M**.

Table 6.5 Frequency Analysis Results at HY051

Flood Frequency Distribution	Resulting Flood (m3/s)					
	Generalized Extreme Value (GEV)	Three-Parameter Lognormal (3PL / HILO)	Log Pearson Type III (LP III)	Wakeby	Nonparametric Method	Average
2-Yr	19.0	19.1	19.9	18.8	20.3	19.4
5-Yr	29.2	29.2	29.0	29.6	33.7	30.1
10-Yr	36.1	36.3	34.6	36.9	40.9	37.0
25-Yr	42.8	43.3	39.6	43.5	46.6	43.2
50-Yr	51.6	52.7	45.5	51.3	52.9	50.8
100-Yr	58.3	60.0	49.7	56.5	56.8	56.3

6.4.3 FLOW COMPARISON

A comparison of the flows between those from the current hydrologic model (WSP, 2020), all available previous models and determined based on the frequency analysis was presented in **Table 6.6**.

Table 6.6 Flow Comparison Table

Source / Return Period		Drainage Area (ha)	Peak Flow Rate (cms) at Petticoat Creek Outlet to Lake Ontario / TRCA Gauge HY051 - Petticoat Ck at Whites						
			2-year	5-year	10-year	25-year	50-year	100-year	Regional
WSP 2020 Final Model	12-hr SCS Type II (MTO) ¹⁾	2568	18.5	27.5	33.9	41.7	47.3	53.5	-
	24-hr SCS Type II (MTO)	2568	18.1	26.4	32.2	39.6	44.8	50.2	-
	12-hr AES (30%)	2568	12.6	21.2	27.4	35.7	42.7	49.7	-
	24-hr SCS Type II (MNR)	2568	11.9	19.7	25.3	33.0	39.3	45.7	-
	Regional Event	-	-	-	-	-	-	-	177.0
Flood Frequency Analysis based on 8 years Data at HY051	Generalized Extreme Value (GEV)	-	19.0	29.2	36.1	42.8	51.6	58.3	-
	Three-Parameter Lognormal (3PL / HILO)	-	19.1	29.2	36.3	43.3	52.7	60.0	-
	Log Pearson Type III (LP III)	-	19.9	29.0	34.6	39.6	45.5	49.7	-
	Wakeby	-	18.8	29.6	36.9	43.5	51.3	56.5	-
	Nonparametric Method	-	20.3	33.7	40.9	46.6	52.9	56.8	-
Previous Studies	Uncalibrated INTERHYMO model (Prior to 2006)	2551	n/a	14.2	19.6	28.1	35.5	43.6	152.4
	Greenland, 2006 (Node 161, Future Committed Sc) ²⁾	2551	12.1	19.2	24.7	32.4	38.6	45.2	190.4

Note 1). Selected Design Storms for WSP 2020 Petticoat Hydrologic Model.

2). A complete set of flow comparison between WSP 2020 model and Greenland 2006 model including 2- to 100-year and Regional flows at all available flow nodes is included in **Appendix K**.

The following provides a summary of the interpretation and explanation of the results as shown in **Table 6.6**.

- The flood flows calculated based on the frequently analysis for more frequent events (i.e., 2-, 5-, 10- years) generally match those determined based on the 12-hr MTO SCS Type II design storms which were selected for the hydrologic model currently developed for Petticoat Creek watershed. Note that, as indicated previously, 11 years of continuous data (ca. 2001~2012) is typically insufficient to derive a statistically reliable flood flows of less frequent or major events (e.g., 50-, 100-events).
- The peak flows from the current model are generally higher than those calculated by the previous studies for the 2- to 100-year design storm events, however the Regional flows are slightly lower. Although there are discrepancies of the flows between the models, we believe that the current model (WSP, 2020) reflects more accurate hydrological characteristics of the Petticoat Creek watershed, and therefore predicts more reliable flows at the identified flow locations within the subject watershed. It can be explained as follows,
 - The current models for the study watershed are developed by using the most up-to-date topographic, soil, land use and other background information. Therefore, more accurate parameters (including drainage boundary, catchment area, catchment parameter, model connection, etc.) are used in the current model.
 - The current models incorporate the diversions of major and minor drainage system by using the DuHYD Commands.
 - The current models are developed by using more discretized catchments than the previous models. Furthermore, all pervious areas greater than 3 ha in the current models are separated from the STANDHYD commands and presented by NASHYD commands.
 - The current models apply major flow routes through urban street system by using Route Channel commands to reflect wave travel times and reduction in peak discharge.

7 CLIMATE CHANGE ANALYSIS

It is globally recognized that climate change has been playing an important role in our life. In order to understand how such changes impact the hydrology of our watersheds, a climate change analysis was performed by running the developed hydrological model with the revised design storms derived from the modified IDF values based on three theoretical scenarios listed as follows:

- University of Western Ontario IDF CC Tool¹ – RCP 4.5, Toronto City (6158355), 2006-2100, ensemble model approach;
- University of Western Ontario IDF CC Tool¹ – RCP 8.5, Toronto City (6158355), 2006-2100, ensemble model approach; and
- 20% increase of the current IDFs at Toronto City (6158355), 1940-2017.

The modified IDF data (i.e., intensity values) are provided in **Appendix N**. The values were input to the VO6 model to simulate the models based on the created corresponding design storms for the return periods from 2- to 100-Year. For comparison purposes, the resulting 100-Year flows from difference scenarios together with those resulted from the original design storms are summarized in **Table 7.1**. The corresponding percentage differences are also shown in **Table 7.2**.

Table 7.1 100-Year Flow Comparison – Climate Change Scenario

Flow Node ID	Flow Node Location	Flow - 100-Year Events (cms)			
		Original IDF	RCP4.5	RCP8.5	20%+ IDF
5102	Hwy 407 (west)	3.1	4.3	4.5	4.2
5104	Hwy 407 (east)	1.6	2.2	2.3	2.2
5111	Taunton Road West East Trib	13.5	19.0	19.6	18.4
5116	Taunton Road West Main Branch	6.4	8.8	9.1	8.6
5146	Finch Ave Main Branch	41.6	58.3	60.2	56.6
5149	CNR Main Branch	41.7	58.8	60.8	57.0
5161	Sheppard Ave Main Branch	45.0	63.1	65.2	61.2
5165	Hwy 401 Main Branch	46.1	64.6	66.7	62.6
5171	Hwy 401 West Trib	19.0	24.4	24.9	23.9
5174	Outlet to Lake Ontario	53.2	69.7	71.4	68.1

¹ UWO's IDF_CC Tool Program was performed, and data was collected on September 25, 2020 by WSP.
<https://www.idf-cc-uwo.ca/>

Table 7.2 100-Year Flow Comparison (Percentage Difference) – Climate Change Scenario

Flow Node ID	Flow Node Location	Flow Percentage Difference (%) - 100-Year Events			
		Original IDF	RCP4.5	RCP8.5	20%+ IDF
5102	Hwy 407 (west)	-	39%	43%	35%
5104	Hwy 407 (east)	-	38%	43%	34%
5111	Taunton Road West East Trib	-	40%	45%	36%
5116	Taunton Road West Main Branch	-	38%	42%	34%
5146	Finch Ave Main Branch	-	40%	45%	36%
5149	CNR Main Branch	-	41%	46%	37%
5161	Sheppard Ave Main Branch	-	40%	45%	36%
5165	Hwy 401 Main Branch	-	40%	45%	36%
5171	Hwy 401 West Trib	-	29%	31%	26%
5174	Outlet to Lake Ontario	-	31%	34%	28%
Average		-	38%	42%	34%

As shown in **Table 7.2**, University of Western Ontario IDF_CC Tool – RCP 8.5 results the most conservative 100-year flows than those based on other theoretical scenarios.

All related information, including the data outputs and Gumbel distribution box plots from UWO’s IDF CC Tool are included in **Appendix N**. A completed set of resulting flows (including 2- to 100-year storm events) are included in **Appendix K**.

8 CONCLUSIONS AND RECOMMENDATIONS

Hydrologic model for the Petticoat Creek watershed was developed by using the most up-to-date modelling technology based on the latest background data.

The models were calibrated and validated based on the available historical streamflow and rainfall data. Due to the limitation of historical streamflow data, it is concluded that the results of model calibration and validation process shall be used for reference purposes only.

Analysis of climate changes were also performed and included in the study.

The following summarizes the key findings of the completed study:

- A set of hydrological models was developed for the existing landuse conditions of the Petticoat Creek watershed by using the latest Visual OTTHYMO hydrological model (version 6.1). The model includes 68 NASHYDs, 31 STANDHYDs, 53 ROUGE CHANNELS, 6 ROUTE RESERVOIR and 10 DuHYDs.
- Developed hydrological model was calibrated and validated based on the selected eight (8) events from the available eight (8) years data from 2012 to 2020 at TRCA's streamflow gauge HY051 (Petticoat Creek at Whites). Although the calibration/validation results generally meet the targets as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002), by considering the data limitations (e.g., data gaps, rain-on-snow events, short period of recorded data and insignificant rainfall amounts, etc.), it is concluded that the results of model calibration and validation shall be used for reference purposes only.
- The subject watershed is fully built in according with the current municipality's Official Plan, and there will be no changes of the land uses under future conditions. Consequently, hydrologic model for future development conditions is not included in the subject study.
- Various storm distributions were tested and simulated in the calibrated model. The results recommend that 12-hour MTO SCS Type II distribution should be applied in the Petticoat Creek watershed hydrologic model to determine the peak flows for the 2-year through 100-year design storms.
- Regional Storm (Hurricane Hazel) was simulated by the developed model for the existing conditions to calculate the peak flows at the identified flow nodes along the water courses. The aerial adjustment factors based on the equivalent circular area were properly applied.
- The non-hydrographic methods (frequency analysis) were performed by using the hourly streamflow data recorded from 2001 to 2012 at the gauges within the subject watershed. The determined flows were compared with those from the hydrological simulation. The flow comparison also includes the results from the previous studies.
- Climate change analysis was performed by running developed hydrological model with the revised design storms derived from the modified IDF values based on three theoretical scenarios: UWO's CC Tool RCP 4.5 and 8.5, and 20% increase of the current IDFs at Toronto City weather station (6158355).

It is recognized that limitations associated with the model development are inevitable. By understanding the model limitations, the results of the model application can be justified and provides explanations if discrepancies occur. The recommendations are provided as follows,

- Although a generally successful calibration was achieved for the study subwatershed, by considering the data limitations, it is recommended that the results of model calibration and validation shall be used for reference purposes only.
- The majority of development within the Petticoat Creek watershed is located downstream of the watershed, while the upstream area is mainly rural. Since the only available streamflow gauge is located near the outlet of the Petticoat Creek to Lake Ontario, it brings challenge to distinguish the hydrology between the upstream rural area and downstream developed catchments. Therefore, in order to properly calibrate the parameters for the

upstream rural catchments, it is recommended to install a streamflow gauge at a proper location (e.g., main branch at Finch Avenue near Flow Node # 5146) to record the flows directly from the upstream rural area.

- Due to the unique land cover characteristics of the watershed, flood events occur during winter or spring seasons when snow melting, may provide a significant contribution to the generated runoff in the receiving water courses. Therefore, it is important to understand the effects of snowmelt in hydrological modelling of the subject watershed. One approach to evaluate the rain-on-snow events is to calculate equivalent snow water contents and add them to the rain depths. The equivalent snow water contents can be determined by a rule of thumb (1 in 10 rule) or by applying equivalent water content of snow formula (Schroeter, 2007).
- Hydrology studies should be a series within a “*living document*”. The hydrological model should be regularly updated when the new or updated material is available. It is recommended to collect more data, review and adjust the rating curves at the streamflow gauge. When the new streamflow and rainfall data are available, the calibration and validation process of the developed hydrologic model should be re-visited.

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APPENDIX

A

WATERSHED DISCRETIZATION

Petticoke

CATCH_ID	Area (ha)
101	34.43
102	26.75
103	33.79
104	6.92
105	81.92
106	24.53
107	71.90
108	38.25
109	13.17
110	62.57
111	108.72
112	123.14
113	38.83
114	15.28
115	23.61
116	9.96
117	66.19
118	42.20
119	17.74
120	37.46
121	36.38
122	11.01
123	85.46
124	28.08
125	28.41
126	5.42
127	58.40
128	29.34
129	47.30
130	46.37
131	70.58
132	65.27
133	49.59
134	22.36
135	10.91
136	17.88
137	46.43
138	3.57
139	1.79
140	0.07
141	117.59
142	40.63
143	45.23
144	2.90

Minor IN Major OUT

CATCH_ID	Area (ha)
183	4.51
163	3.97
164	3.86
172	23.16

35.50

Major IN Minor OUT

CATCH_ID	Area (ha)
168	7.30

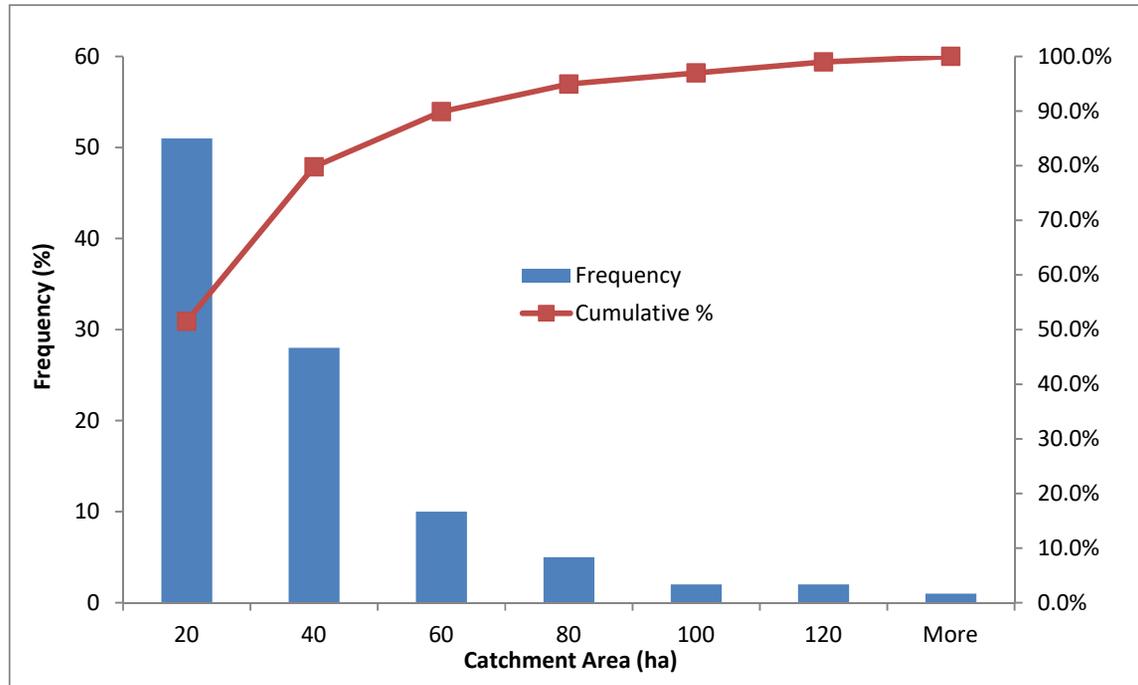
7.30

145	2.86
146	2.27
1461	4.21
147	47.69
148	11.00
1481	4.25
149	10.96
150	7.54
151	19.16
152	28.83
153	6.03
154	20.54
1541	13.63
155	31.51
156	20.00
157	23.14
158	18.49
1581	3.22
159	5.23
1591	4.15
160	35.78
161	32.30
1611	17.29
162	7.99
163	3.97
164	3.86
165	2.98
1651	5.06
166	16.52
1661	5.67
167	5.54
168	7.30
169	29.70
1691	4.31
170	31.81
1701	8.75
171	25.90
1711	6.22
172	23.16
173	11.23
174	22.50
175	55.73
1751	9.55
176	23.05
1761	8.55
177	5.72
178	24.06

1781	18.77
179	16.35
180	11.92
181	28.22
1811	9.46
182	6.07
183	4.51
184	21.11
SUM	2583.9
MIN	0.1
MAX	123.1
AVE	26.1
COUNT	99

Petticoat Creek Hydrology

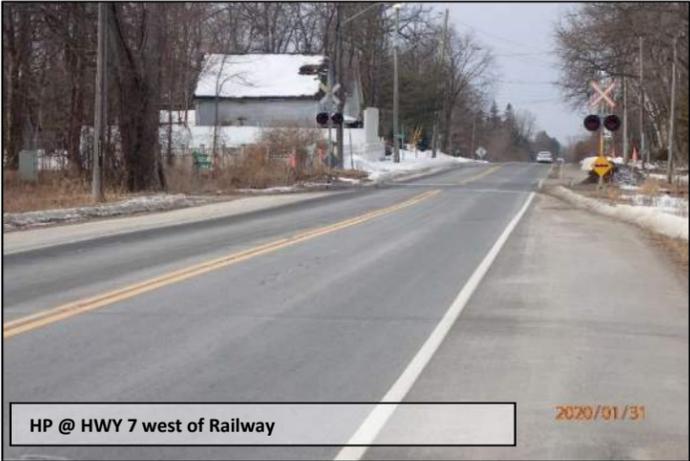
<i>Bin (Catchment Area - ha)</i>	<i>Frequency</i>	<i>Cumulative %</i>
20	51	51.5%
40	28	79.8%
60	10	89.9%
80	5	94.9%
100	2	97.0%
120	2	99.0%
More	1	100.0%



B WINDSHIELD
SURVEY

Windshield Survey

Survey Dates: January 31, 2020

ID	Location	Note	Decision / Results	Photo	
1	Drainage from HWY 407 Corridor	<ul style="list-style-type: none"> • There are no STM/CB along 407 Corridor. • 407 drainage via roadside and middle ditches/drainage swales to the west (Rouge River). • At least three culverts noted connecting Petticoat creek drainage from north to south across HWY 407 	Flows from 407 Corridor drain to Rouge River to the west.	 <p>Roadside Drainage Ditch along 407 Corridor to Rouge River</p>	 <p>Culverts at 407 HWY Connecting Petticoat Ck from N to S</p>
2	HWY 7 and Railway	<ul style="list-style-type: none"> • High Point was observed west of Railway 	Drainage area of Petticoat creek includes the portion of the Railway area (in agreement with 2006 Catchment Boundary)	 <p>HP @ HWY 7 west of Railway</p>	

3	Taunton Rd W. / Rosebank Rd. Con Rd 4 / Whites Rd.	<ul style="list-style-type: none"> • Highpoint was observed at Con Rd 4 north of Taunton Rd W. • Highpoint was observed at intersection of Whites Rd and Taunton Rd W. 	Flows from Taunton Rd W. / Rosebank Rd. Con Rd 4 / Whites Rd. area drain to Petticoat Creek.	 <p>HP at Con Rd 4 north of Taunton Rd W</p>	 <p>HP at intersection of Whites Rd and Taunton Rd W.</p>
4	Pickering Townline Rd / Railway near Finch Ave	<ul style="list-style-type: none"> • A series of online storages was observed near Finch Ave E and Pickering Townline. • Online pond (including a flow weir) was observed at northwest of Pickering Townline and Railway. • Culvert at Railway west of Pickering Townline was observed. It seems the culvert has certain capacity. The inclusion of online-storage may not be required for hydrology. • Large culvert at Pickering Townline north of Finch Ave E was observed. 	Storages may not be necessary to be included in the Petticoat Creek hydrological model, because it seems all culverts along the system have adequate capacity to convey large events.	 <p>Weir observed at online pond northwest of Pickering TL and Railway</p>	 <p>Culvert at Railway west of Pickering Townline</p>
				 <p>Large culvert at Pickering Townline north of Finch Ave E (Upstream)</p>	 <p>Large culvert at Pickering Townline north of Finch Ave E (Downstream)</p>

5	Twyn Rivers Dr and Woodview Dr	<ul style="list-style-type: none"> • Highpoint was observed at Twyn Rivers west of Ashwood Gate • Relatively flat at Woodview Dr south of Twyn Rivers Dr. 	Major system boundary at this location based on LiDAR is confirmed.	 <p>HP at Twyn Rivers west of Ashwood Gate</p>	 <p>Relatively flat at Woodview Dr south of Twyn Rivers</p>
6	Rougemount Dr area south of HWY 401	<ul style="list-style-type: none"> • Highpoint was observed at Toynevale Rd east of Rougemount Dr. • Highpoint was observed at Oakwood south of Toynevale • Highpoint was observed at Mcleod Cres • Highpoint was observed at Dahlia Cres south of Toynevale Rd. 	Major system boundary at this location based on LiDAR is confirmed.	 <p>HP at Toynevale Rd east of Rougemount Dr.</p>	 <p>HP at Oakwood south of Toynevale</p>
				 <p>HP at Mcleod Cres</p>	 <p>HP at Dahlia Cres south of Toynevale Rd.</p>

7

Rosebank Rd between
Finch Ave and Strouds
Ln

- Highpoint was observed at Amberlea Rd east of Rosebank Rd near Saugeen Dr.
- Highpoint was observed at Highview Rd east of Kirkwood Ln
- Highpoint was observed at Springview Dr. east of Greenvale Cres.
- CBs and MHs were observed at the area, however no STM information was provided.

HPs at Amberlea, Highview, and Springview confirms the major flow boundary of the Petticoat Crk at this location.
STM information need to be reviewed to confirm the boundary of minor drainage system.

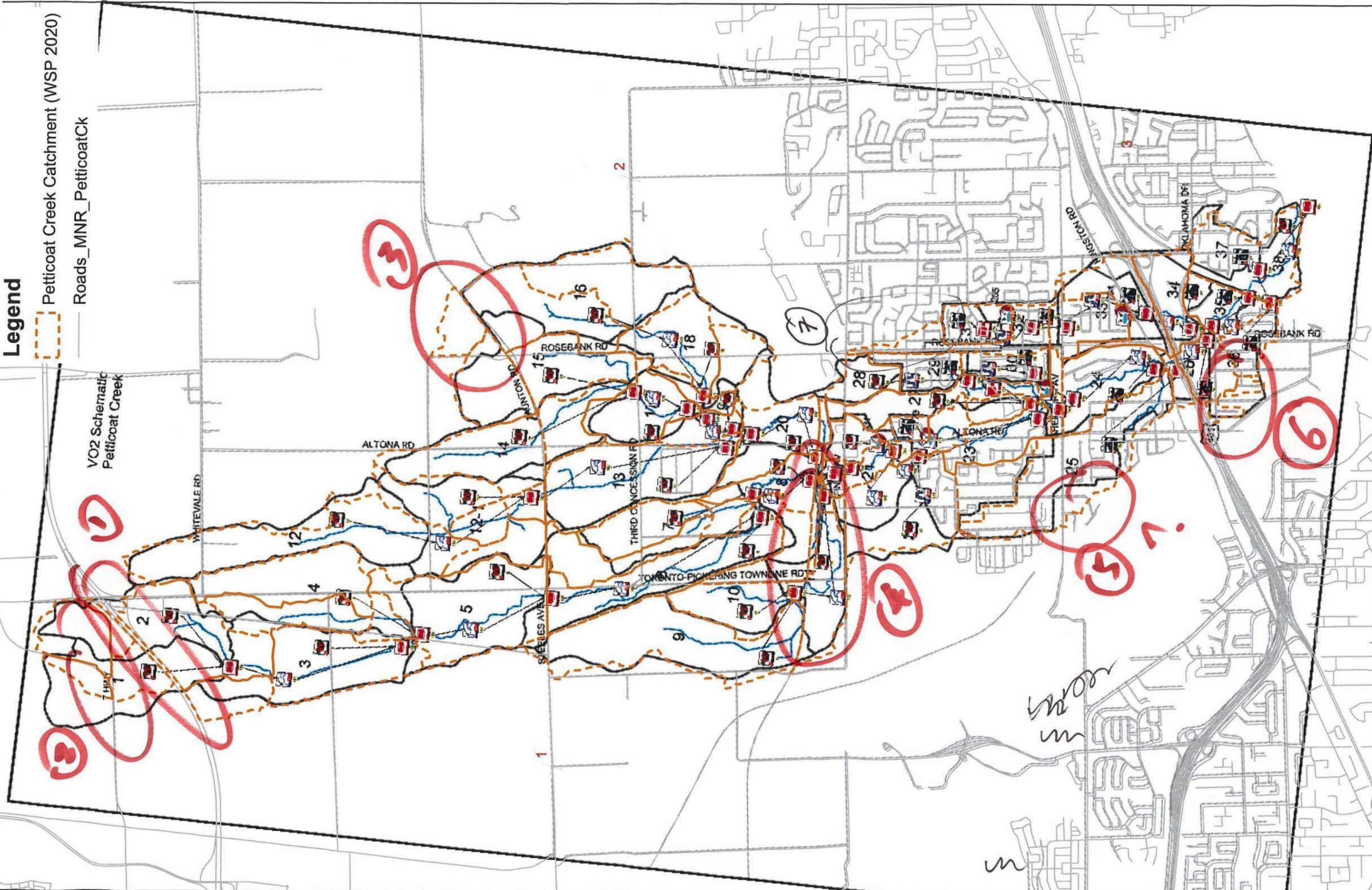


Legend

Petticoat Creek Catchment (WSP 2020)

Roads_MNR_PetticoatCk

VO2 Schematic
Petticoat Creek



WSP
m

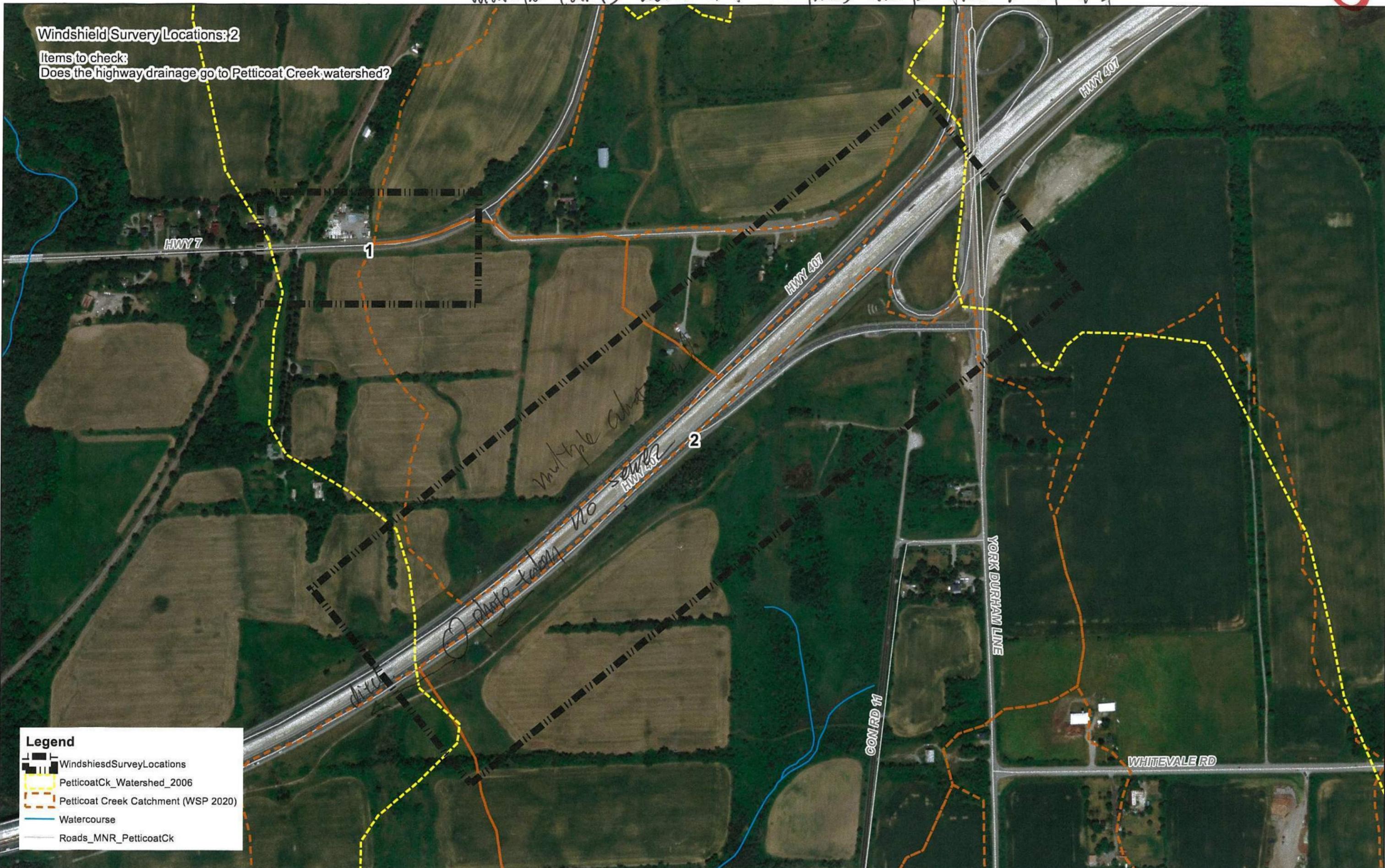


multiple culverts across 407 complex drainage from N. of 407

Windshield Survey Locations: 2

Items to check:

Does the highway drainage go to Petticoat Creek watershed?



Legend

-  WindshiedSurveyLocations
-  PetticoatCk_Watershed_2006
-  Petticoat Creek Catchment (WSP 2020)
-  Watercourse
-  Roads_MNR_PetticoatCk

Windshield Survey Locations: 1

Items to check:
Does the high point of Hwy 7 fall the catchment bouaries (WSP 2020) or catchment boundaires (2006)



Legend

- WindshiedSurveyLocations
- PetticoatCk_Watershed_2006
- Petticoat Creek Catchment (WSP 2020)
- Watercourse
- Roads_MNR_PetticoatCk

confirmed

Inter section

(3)

Windshield Survey Locations: 3

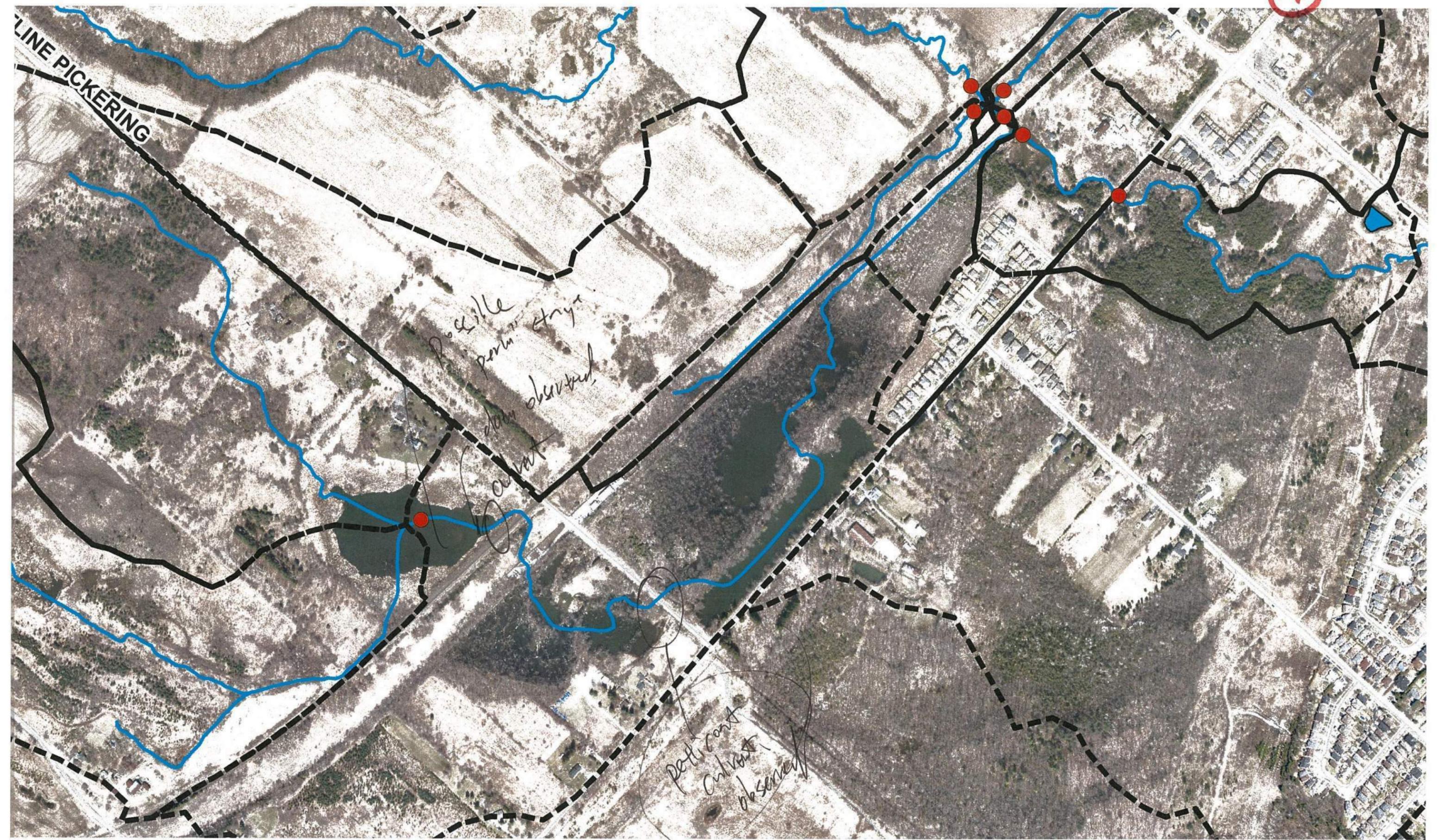
Items to check:

Does the high point of Taunton Road West fall the catchment boundaries (WSP 2020) or catchment boundaires (2006)



Legend

-  WindshiedSurveyLocations
-  PetticoatCk_Watershed_2006
-  Petticoat Creek Catchment (WSP 2020)
-  Watercourse
-  Roads_MNR_PetticoatCk



LINE PICKERING

Possible permit study done observed

Def. cont. out vent observed

5



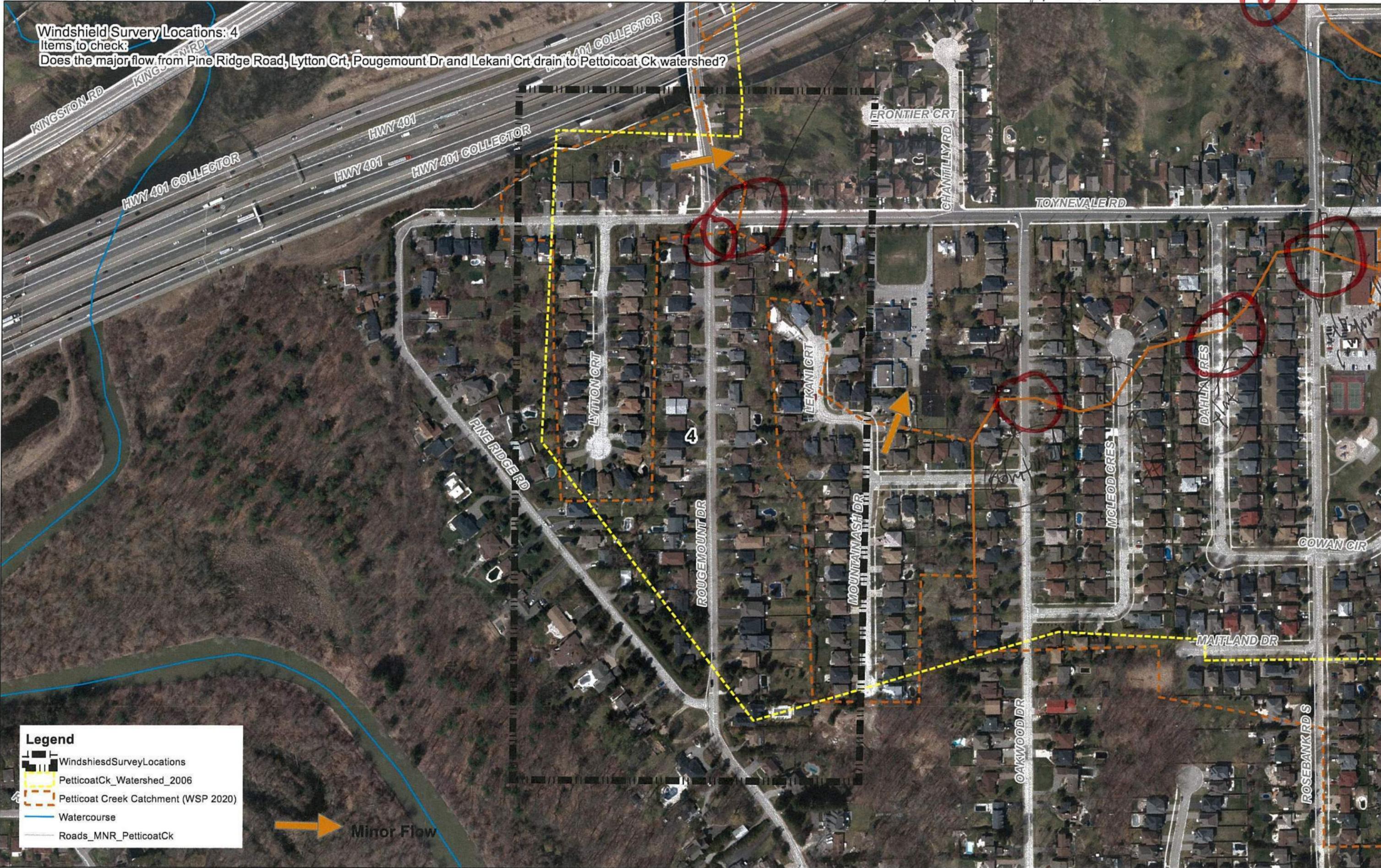
WYN RIVERS DR

low p. confirmed HHP confirmed → probably correct

MP confirmed

6

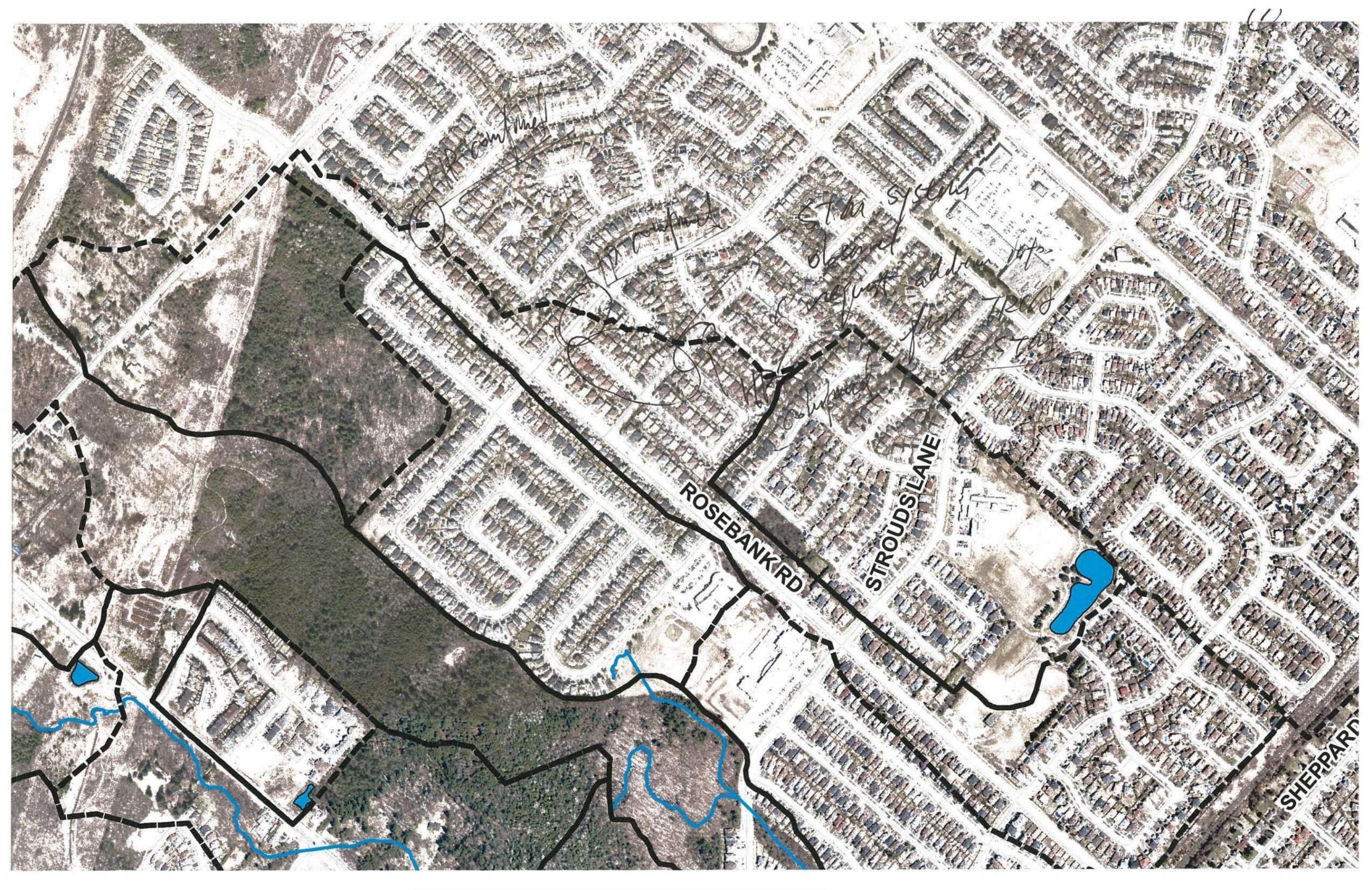
Windshield Survey Locations: 4
Items to check:
Does the major flow from Pine Ridge Road, Lytton Cr, Pougemount Dr and Lekani Cr drain to Pettoicoat Ck watershed?



Legend

- WindshiedSurveyLocations
- PettoicoatCk_Watershed_2006
- Pettoicoat Creek Catchment (WSP 2020)
- Watercourse
- Roads_MNR_PettoicoatCk

Minor Flow



SP confirmed

SP confirmed

STW system

observed

request address info

for TRS

at STW

ROSEBANK RD

STROUDS LANE

SHEPPARD

C SUMMARY OF THE DUHYD COMMANDS

DUHYD

NHYD	NAME	COMMENTS 1	COMMENTS 2	COMMENTS 3	FLOW	CINLET [m³/s]	NINLET
7145	DuHyd - 162	5-Year Storm Flow	Removed for Regional		FALSE	0.265	1
7147	DuHyd - 167	5-Year Storm Flow	Removed for Regional		FALSE	0.586	1
7176	DuHyd - 174	5-Year Storm Flow	Removed for Regional		FALSE	2.142	1
7152	DuHyd - 188	5-Year Storm Flow	Removed for Regional		FALSE	2.442	1
7183	DuHyd - 205	5-Year Storm Flow	Minor Flow in - Keep for Regional		FALSE	0.485	1
7157	DuHyd - 217	5-Year Storm Flow	Removed for Regional		FALSE	1.879	1
7163	DuHyd - 244	5-Year Storm Flow	Minor Flow in - Keep for Regional		FALSE	0.408	1
7164	DuHyd - 245	5-Year Storm Flow	Minor Flow in - Keep for Regional		FALSE	0.406	1
7168	DuHyd - 252	5-Year Storm Flow	Removed for Regional		FALSE	0.731	1
7172	DuHyd - 278	5-Year Storm Flow	Minor Flow in - Keep for Regional		FALSE	1.95	1

↑
5 Yr Chicago 4hr Duration

	145	5147	5176	152	183	157	163	164	168	172
5Yr 1 hr AES	0.217	0.501	2.387	2.617	0.455	2.004	0.386	0.39	0.729	2.072
5Yr 12 hr AES	0.09	0.642	1.405	1.392	0.225	1.098	0.202	0.205	0.379	1.116
5Yr 24 hr AES	0.059	0.551	0.91	0.883	0.141	0.7	0.124	0.125	0.237	0.709
5Yr 6 hr AES	0.126	0.673	1.902	1.917	0.314	1.502	0.275	0.298	0.529	1.532
5Yr Chicago 12hr	0.193	0.724	2.381	2.511	0.435	1.946	0.374	0.379	0.706	2.002
5Yr Chicago 3hr	0.236	0.371	1.774	1.99	0.416	1.522	0.35	0.346	0.62	1.583
5Yr Chicago 4hr	0.265	0.586	2.142	2.442	0.485	1.879	0.408	0.406	0.731	1.95
5Yr SCS 12hr	0.14	0.73	2.089	2.1	0.346	1.646	0.323	0.329	0.617	1.677
5Yr SCS 24hr	0.063	0.565	0.981	0.949	0.152	0.752	0.134	0.136	0.256	0.761
5Yr SCS 6hr	0.129	0.629	1.913	1.932	0.317	1.51	0.295	0.303	0.532	1.543

D HYDROLOGICAL
MODEL
PARAMETERS

Petticoat Creek Subwatershed - Existing Conditions

Catchment #	Catchment (NYHD)									CN - AMC II		XIMP	TIMP	TIMP	XIMP	Runoff C	COMMAND
			ha	m	m	m	%	%	%	CN - AMC II	IA (Nashyd) / DPSP (Standhyd)						
			Area	LENGTH	US_Elev	DS_Elev	Slope	SLPP	SLPI								
101	101	0	34.43	750.70	208.00	201.00	0.37	0.37	1.00	81.05	8.91	5.14	5.94	0.06	0.05	0.36	NASHYD
102	102	0	26.75	291.70	200.50	197.00	1.20	1.20	1.00	80.95	8.96	4.77	4.83	0.05	0.05	0.35	NASHYD
103	103	0	33.79	838.90	208.00	203.50	0.54	0.54	1.00	78.21	7.08	1.63	1.63	0.02	0.02	0.24	NASHYD
104	104	0	6.92	543.90	207.00	201.50	1.01	1.01	1.00	78.09	7.13	15.96	17.26	0.17	0.16	0.37	NASHYD
105	105	0	81.92	1565.30	204.50	190.50	0.89	0.89	1.00	79.03	6.74	4.42	4.67	0.05	0.04	0.30	NASHYD
106	106	0	24.53	826.90	198.50	190.00	1.03	1.03	1.00	80.50	9.23	1.50	1.50	0.02	0.02	0.31	NASHYD
107	107	0	71.90	1397.00	189.70	182.50	0.52	0.52	1.00	80.20	9.41	1.00	1.23	0.01	0.01	0.32	NASHYD
108	108	0	38.25	1630.60	199.50	188.50	0.67	0.67	1.00	80.76	9.08	4.17	4.30	0.04	0.04	0.35	NASHYD
109	109	0	13.17	398.00	185.70	182.70	0.75	0.75	1.00	80.76	9.07	4.86	4.86	0.05	0.05	0.35	NASHYD
110	110	0	62.57	1917.60	201.50	186.50	0.78	0.78	1.00	80.97	8.95	2.96	3.06	0.03	0.03	0.34	NASHYD
111	111	0	108.72	1505.00	181.50	176.51	0.33	0.33	1.00	77.78	7.25	7.90	9.14	0.09	0.08	0.36	NASHYD
112	112	0	123.14	3062.70	202.00	182.00	0.65	0.65	1.00	81.33	8.74	0.64	0.79	0.01	0.01	0.33	NASHYD
113	113	0	38.83	982.84	193.00	182.50	1.07	1.07	1.00	79.76	6.45	0.14	0.31	0.00	0.00	0.25	NASHYD
114	114	0	15.28	569.00	181.70	177.70	0.70	0.70	1.00	80.98	8.95	0.00	0.00	0.00	0.00	0.28	NASHYD
115	115	0	23.61	1050.10	189.00	179.50	0.90	0.90	1.00	78.46	6.98	1.80	1.90	0.02	0.02	0.28	NASHYD
116	116	0	9.96	425.00	177.70	169.40	1.95	1.95	1.00	76.36	7.86	3.94	3.94	0.04	0.04	0.19	NASHYD
117	117	0	66.19	1622.50	194.50	174.50	1.23	1.23	1.00	79.41	6.59	5.63	5.90	0.06	0.06	0.34	NASHYD
118	118	0	42.20	644.80	185.50	168.50	2.64	2.64	1.00	73.39	9.21	3.00	3.00	0.03	0.03	0.36	NASHYD
119	119	0	17.74	562.70	170.00	169.00	0.18	0.25	1.00	54.45	15.93	3.86	3.86	0.04	0.04	0.30	NASHYD
120	120	0	37.46	1723.50	181.50	150.50	1.80	1.80	1.00	81.01	8.93	1.62	1.81	0.02	0.02	0.34	NASHYD
121	121	0	36.38	1279.40	182.50	150.50	2.50	2.50	1.00	81.37	8.72	0.94	0.94	0.01	0.01	0.34	NASHYD
122	122	0	11.01	386.90	150.50	143.50	1.81	1.81	1.00	79.08	6.72	0.00	0.00	0.00	0.00	0.25	NASHYD
123	123	0	85.46	2995.00	176.33	143.40	1.10	1.10	1.00	76.12	7.97	3.14	3.35	0.03	0.03	0.30	NASHYD
124	124	0	28.08	980.00	143.40	136.78	0.68	0.68	1.00	78.81	6.83	0.84	0.84	0.01	0.01	0.30	NASHYD
125	125	0	28.41	1084.90	169.50	145.00	2.26	2.26	1.00	69.45	8.38	2.29	2.32	0.02	0.02	0.33	NASHYD
126	126	0	5.42	558.00	144.50	137.00	1.34	1.34	1.00	60.50	12.44	6.95	7.25	0.07	0.07	0.21	NASHYD
127	127	0	58.40	914.00	167.90	155.12	1.40	1.40	1.00	78.01	7.16	2.10	2.10	0.02	0.02	0.30	NASHYD
128	128	0	29.34	965.00	169.00	155.70	1.38	1.38	1.00	79.30	6.63	3.96	3.96	0.04	0.04	0.33	NASHYD
129	129	0	47.30	1208.00	165.50	156.50	0.75	0.75	1.00	80.04	9.50	2.34	2.57	0.03	0.02	0.34	NASHYD
130	130	0	46.37	901.00	154.70	147.50	0.80	0.80	1.00	78.21	7.08	2.13	2.71	0.03	0.02	0.31	NASHYD
131	131	0	70.58	1245.90	165.00	156.00	0.72	0.72	1.00	79.04	6.74	2.92	2.95	0.03	0.03	0.35	NASHYD
132	132	0	65.27	1282.90	164.50	156.50	0.62	0.62	1.00	81.23	8.80	3.37	3.60	0.04	0.03	0.36	NASHYD
133	133	0	49.59	1221.98	154.66	148.50	0.50	0.50	1.00	81.39	8.71	2.87	3.68	0.04	0.03	0.32	NASHYD
134	134	0	22.36	923.20	160.50	149.00	1.25	1.25	1.00	81.76	8.50	1.99	2.10	0.02	0.02	0.36	NASHYD
135	135	0	10.91	111.00	148.50	147.50	0.90	0.90	1.00	79.79	6.43	0.00	0.00	0.00	0.00	0.28	NASHYD
136	136	0	17.88	496.97	147.50	143.50	0.80	0.80	1.00	79.42	6.58	1.88	1.88	0.02	0.02	0.22	NASHYD
137	137	0	46.43	936.00	142.50	140.50	0.21	0.25	1.00	80.81	9.05	3.08	3.35	0.03	0.03	0.33	NASHYD
138	138	0	3.57	197.00	139.73	138.46	0.64	0.64	1.00	44.75	23.52	6.64	6.64	0.07	0.07	0.20	NASHYD
139	139	0	1.79	291.00	138.30	136.60	0.58	0.58	1.00	65.27	10.14	12.21	12.21	0.12	0.12	0.25	NASHYD
140	140	0	0.07	34.00	136.40	135.96	1.29	1.29	1.00	81.00	8.94	0.00	0.00	0.00	0.00	0.15	NASHYD
141	141	0	117.59	2736.90	187.00	145.00	1.53	1.53	1.00	64.50	10.49	2.07	2.43	0.02	0.02	0.30	NASHYD
142	142	0	40.63	1230.10	179.50	141.50	3.09	3.09	1.00	57.05	14.34	1.63	1.87	0.02	0.02	0.21	NASHYD
143	143	0	45.23	1306.00	142.30	139.90	0.18	0.25	1.00	53.01	16.89	5.05	5.78	0.06	0.05	0.22	NASHYD
144	144	0	2.90	279.00	139.60	137.80	0.65	0.65	1.00	61.35	12.00	0.79	1.93	0.02	0.01	0.16	NASHYD
145	145	0	2.86	0.00	0.00	0.00	0.00	0.25	1.00	60.22	12.58	25.99	54.62	0.55	0.26	0.47	STANDHYD
146	146	0	2.27	0.00	0.00	0.00	0.00	0.25	1.00	51.13	18.21	39.19	70.01	0.70	0.39	0.64	STANDHYD
146	1461	0	4.21	220.00	136.00	134.41	0.72	0.72	1.00	56.57	14.62	0.00	0.00	0.00	0.00	0.15	NASHYD
147	147	0	47.69	675.70	138.50	131.50	1.04	1.04	1.00	68.12	8.91	8.81	19.28	0.19	0.09	0.26	NASHYD
148	148	0	11.00	0.00	0.00	0.00	0.00	0.25	1.00	49.00	19.83	32.59	59.68	0.60	0.33	0.56	STANDHYD
148	1481	0	4.25	207.20	142.00	138.50	1.69	1.69	1.00	34.40	36.33	0.00	0.00	0.00	0.00	0.15	NASHYD
149	149	0	10.96	702.00	134.39	129.40	0.71	0.71	1.00	57.52	14.07	4.62	8.70	0.09	0.05	0.21	NASHYD
150	150	0	7.54	0.00	0.00	0.00	0.00	0.25	1.00	83.38	7.60	21.99	50.01	0.50	0.22	0.44	STANDHYD
151	151	0	19.16	801.98	128.40	120.30	1.01	1.01	1.00	72.19	9.79	5.80	8.15	0.08	0.06	0.24	NASHYD
152	152	0	28.83	0.00	0.00	0.00	0.00	0.25	1.00	82.47	8.10	25.98	62.29	0.62	0.26	0.50	STANDHYD
153	153	0	6.03	298.20	125.50	124.00	0.50	0.50	1.00	72.83	9.48	0.03	0.08	0.00	0.00	0.15	NASHYD

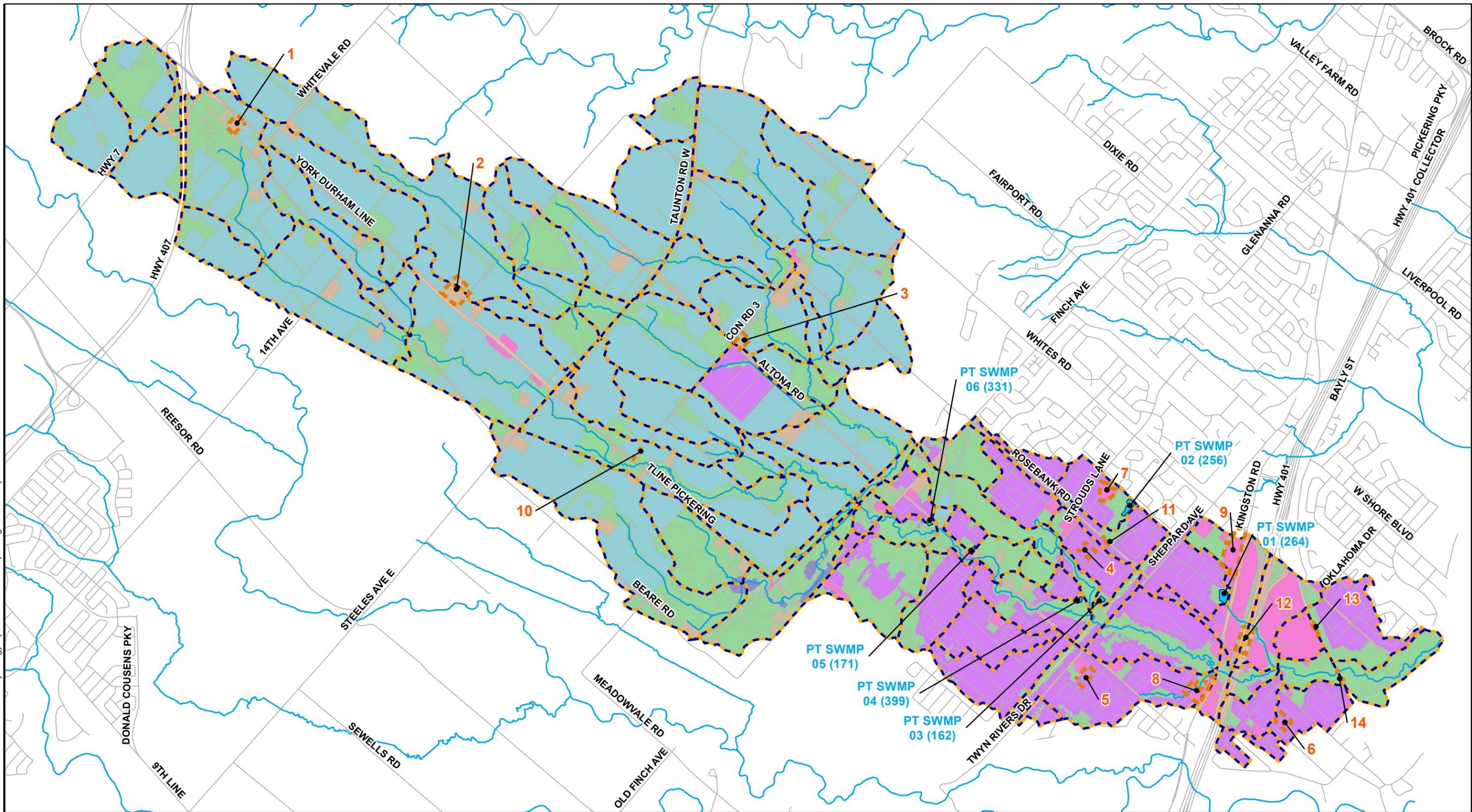
154	154	0	20.54	0.00	0.00	0.00	0.00	0.25	1.00	83.17	7.71	29.61	63.47	0.63	0.30	0.53	STANDHYD
154	1541	0	13.63	922.00	119.30	106.30	1.41	1.41	1.00	76.21	7.93	0.00	0.00	0.00	0.00	0.15	NASHYD
155	155	0	31.51	1678.40	141.50	121.50	1.19	1.19	1.00	61.43	11.96	1.55	2.93	0.03	0.02	0.18	NASHYD
156	156	0	20.00	825.80	143.00	127.50	1.88	1.88	1.00	60.39	12.50	3.87	6.95	0.07	0.04	0.21	NASHYD
157	157	0	23.14	0.00	0.00	0.00	0.00	0.25	1.00	83.65	7.45	24.31	57.63	0.58	0.24	0.48	STANDHYD
158	158	0	18.49	0.00	0.00	0.00	0.00	0.25	1.00	83.87	7.33	29.12	66.37	0.66	0.29	0.54	STANDHYD
158	1581	0	3.22	996.50	125.00	113.50	1.15	1.15	1.00	73.87	8.99	0.00	0.00	0.00	0.00	0.15	NASHYD
159	159	0	5.23	0.00	0.00	0.00	0.00	0.25	1.00	80.39	9.29	41.99	71.18	0.71	0.42	0.60	STANDHYD
159	1591	0	4.15	91.00	105.30	103.30	2.20	2.20	1.00	63.64	10.89	0.00	0.00	0.00	0.00	0.15	NASHYD
160	160	0	35.78	0.00	0.00	0.00	0.00	0.25	1.00	81.16	8.85	25.23	61.26	0.61	0.25	0.49	STANDHYD
161	161	0	32.30	0.00	0.00	0.00	0.00	0.25	1.00	83.21	7.69	28.50	64.76	0.65	0.28	0.52	STANDHYD
161	1611	0	17.29	1231.00	102.53	91.30	0.91	0.91	1.00	73.97	8.94	0.00	0.00	0.00	0.00	0.15	NASHYD
162	162	0	7.99	0.00	0.00	0.00	0.00	0.25	1.00	78.39	7.00	57.50	73.02	0.73	0.58	0.74	STANDHYD
163	163	0	3.97	0.00	0.00	0.00	0.00	0.25	1.00	81.45	8.68	25.88	63.48	0.63	0.26	0.50	STANDHYD
164	164	0	3.86	0.00	0.00	0.00	0.00	0.25	1.00	83.63	7.46	25.99	63.74	0.64	0.26	0.50	STANDHYD
165	165	0	2.98	0.00	0.00	0.00	0.00	0.25	1.00	80.62	9.16	61.22	81.20	0.81	0.61	0.77	STANDHYD
165	1651	0	5.06	412.00	89.36	86.20	0.77	0.77	1.00	74.61	8.64	0.00	0.00	0.00	0.00	0.15	NASHYD
166	166	0	16.52	0.00	0.00	0.00	0.00	0.25	1.00	84.00	7.26	28.39	65.85	0.66	0.28	0.53	STANDHYD
166	1661	0	5.67	830.70	123.50	113.50	1.20	1.20	1.00	83.69	7.43	0.00	0.00	0.00	0.00	0.15	NASHYD
167	167	0	5.54	0.00	0.00	0.00	0.00	0.25	1.00	83.45	7.56	39.23	64.38	0.64	0.39	0.57	STANDHYD
168	168	0	7.30	0.00	0.00	0.00	0.00	0.25	1.00	84.00	7.26	26.01	63.79	0.64	0.26	0.50	STANDHYD
169	169	0	29.70	0.00	0.00	0.00	0.00	0.25	1.00	83.82	7.35	29.03	65.24	0.65	0.29	0.52	STANDHYD
169	1691	0	4.31	777.50	111.50	98.50	1.67	1.67	1.00	75.93	8.05	0.00	0.00	0.00	0.00	0.15	NASHYD
170	170	0	31.81	0.00	0.00	0.00	0.00	0.25	1.00	81.97	8.38	55.90	83.00	0.83	0.56	0.78	STANDHYD
170	1701	0	8.75	207.90	98.50	96.00	1.20	1.20	1.00	78.35	7.02	0.00	0.00	0.00	0.00	0.15	NASHYD
171	171	0	25.90	0.00	0.00	0.00	0.00	0.25	1.00	79.93	6.38	61.81	86.83	0.87	0.62	0.83	STANDHYD
171	1711	0	6.22	355.00	94.00	88.00	1.69	1.69	1.00	69.93	8.19	0.00	0.00	0.00	0.00	0.15	NASHYD
172	172	0	23.16	0.00	0.00	0.00	0.00	0.25	1.00	83.52	7.52	24.61	59.63	0.60	0.25	0.48	STANDHYD
173	173	0	11.23	487.00	86.20	81.80	0.90	0.90	1.00	74.33	8.77	4.86	7.14	0.07	0.05	0.20	NASHYD
174	174	0	22.50	1175.00	81.67	74.70	0.59	0.59	1.00	71.38	10.19	0.94	0.97	0.01	0.01	0.16	NASHYD
175	175	0	55.73	0.00	0.00	0.00	0.00	0.25	1.00	83.09	7.76	31.53	66.99	0.67	0.32	0.55	STANDHYD
175	1751	0	9.55	757.00	110.60	91.90	2.47	2.47	1.00	64.44	10.51	0.00	0.00	0.00	0.00	0.15	NASHYD
176	176	0	23.05	0.00	0.00	0.00	0.00	0.25	1.00	83.74	7.40	26.05	63.81	0.64	0.26	0.50	STANDHYD
176	1761	0	8.55	422.10	131.50	128.50	0.71	0.71	1.00	65.37	10.09	0.00	0.00	0.00	0.00	0.15	NASHYD
177	177	0	5.72	0.00	0.00	0.00	0.00	0.25	1.00	68.92	8.59	23.59	57.86	0.58	0.24	0.47	STANDHYD
178	178	0	24.06	0.00	0.00	0.00	0.00	0.25	1.00	83.36	7.61	27.96	60.82	0.61	0.28	0.52	STANDHYD
178	1781	0	18.77	1123.00	155.35	143.50	1.06	1.06	1.00	81.35	8.73	0.00	0.00	0.00	0.00	0.32	NASHYD
179	179	0	16.35	0.00	0.00	0.00	0.00	0.25	1.00	81.16	8.84	28.64	58.34	0.58	0.29	0.50	STANDHYD
180	180	0	11.92	0.00	0.00	0.00	0.00	0.25	1.00	83.35	7.61	51.76	85.47	0.85	0.52	0.80	STANDHYD
181	181	0	28.22	0.00	0.00	0.00	0.00	0.25	1.00	83.49	7.53	29.95	65.90	0.66	0.30	0.53	STANDHYD
181	1811	0	9.46	242.80	105.00	92.50	5.15	5.00	1.00	75.78	8.12	0.00	0.00	0.00	0.00	0.15	NASHYD
182	182	0	6.07	656.00	119.93	105.50	2.20	2.20	1.00	67.37	9.23	7.24	17.76	0.18	0.07	0.25	NASHYD
183	183	0	4.51	0.00	0.00	0.00	0.00	0.25	1.00	83.51	7.52	27.52	59.28	0.59	0.28	0.49	STANDHYD
184	184	0	21.11	0.00	0.00	0.00	0.00	0.25	1.00	83.86	7.33	27.32	57.90	0.58	0.27	0.49	STANDHYD

CATCHMENT VOID	hr	hr	hr	hr	hr	Soil Storage, s	mm	mm	n, Roughness - Pervious	Number of Linear Reservoir N	n, Roughness - Imp.	Initial K - Pervious	Initial K - Imp.	m	m	CN - AMC III			CN - AMC I		
	Tc - Airport Method	Tp - Airport Method	Tc - Bransby Williams	Tp - Bransby Williams	Tp - in Model		la / DPSP	DPSI								CN - AMC III	Soil Storage, S	la / DPSP	CN - AMC I	Soil Storage, S	la / DPSP
101	1.55	1.04	0.61	0.41	1.04	59.37	8.91	1.00	0.25	3.00	0.013	24.21	4.11	40	479.11	90.8	26	5.16	64.2	141	10.60
102	0.65	0.44	0.19	0.13	0.44	59.76	8.96	1.00	0.25	3.00	1.013	9.61	22.25	40	422.32	90.7	26	5.20	64.1	142	10.67
103	1.67	1.12	0.63	0.43	1.12	70.76	7.08	1.00	0.25	3.00	2.013	23.06	80.62	40	474.64	89.2	31	4.61	60.1	168	12.64
104	0.92	0.61	0.42	0.28	0.61	71.28	7.13	1.00	0.25	3.00	3.013	14.70	65.46	40	214.75	89.1	31	4.65	59.9	170	12.73
105	1.78	1.19	0.98	0.66	1.19	67.38	6.74	1.00	0.25	3.00	4.013	28.76	152.10	40	739.01	89.7	29	4.39	61.3	160	12.03
106	1.22	0.82	0.57	0.38	0.82	61.54	9.23	1.00	0.25	3.00	5.013	18.81	113.68	40	404.38	90.5	27	5.35	63.4	147	10.99
107	1.96	1.32	0.99	0.66	1.32	62.72	9.41	1.00	0.25	3.00	6.013	31.69	213.63	40	692.35	90.3	27	5.45	63.0	149	11.20
108	1.88	1.26	1.16	0.78	1.26	60.51	9.08	1.00	0.25	3.00	7.013	32.08	237.12	40	504.95	90.6	26	5.26	63.8	144	10.81
109	0.89	0.60	0.31	0.21	0.60	60.50	9.07	1.00	0.25	3.00	8.013	13.31	106.60	40	296.32	90.6	26	5.26	63.8	144	10.80
110	1.95	1.31	1.27	0.85	1.31	59.68	8.95	1.00	0.25	3.00	9.013	33.82	290.61	40	645.87	90.7	26	5.19	64.1	142	10.66
111	2.24	1.50	1.12	0.75	1.50	72.54	7.25	1.00	0.25	3.00	10.013	37.83	346.28	40	851.35	89.0	32	4.73	59.5	173	12.95
112	2.67	1.79	1.96	1.31	1.79	58.29	8.74	1.00	0.25	3.00	11.013	47.28	458.21	40	906.06	90.9	25	5.07	64.7	139	10.41
113	1.42	0.95	0.64	0.43	0.95	64.47	6.45	1.00	0.25	3.00	12.013	20.62	210.58	40	508.81	90.1	28	5.61	62.3	153	11.51
114	1.19	0.80	0.44	0.30	0.80	59.67	8.95	1.00	0.25	3.00	13.013	16.85	180.45	40	319.21	90.7	26	5.19	64.1	142	10.66
115	1.50	1.01	0.74	0.50	1.01	69.75	6.98	1.00	0.25	3.00	14.013	22.56	252.61	40	396.71	89.3	30	4.55	60.5	166	12.46
116	0.82	0.55	0.28	0.19	0.55	78.62	7.86	1.00	0.25	3.00	15.013	10.41	121.46	40	257.66	88.1	34	5.13	57.6	187	14.04
117	1.54	1.03	0.97	0.65	1.03	65.87	6.59	1.00	0.25	3.00	16.013	26.69	323.80	40	664.29	89.9	29	4.30	61.8	157	11.76
118	0.74	0.50	0.35	0.23	0.50	92.10	9.21	1.00	0.25	3.00	17.013	12.21	153.66	40	530.41	86.4	40	6.01	53.7	219	16.45
119	1.83	1.22	0.57	0.38	1.22	212.45	15.93	1.00	0.25	3.00	18.013	25.28	329.11	40	343.92	73.3	92	9.24	33.4	506	37.94
120	1.41	0.95	1.01	0.68	0.95	59.55	8.93	1.00	0.25	3.00	19.013	24.71	332.30	40	499.73	90.8	26	5.18	64.2	142	10.63
121	1.10	0.73	0.71	0.47	0.73	58.15	8.72	1.00	0.25	3.00	20.013	18.72	259.59	40	492.46	90.9	25	5.06	64.7	138	10.38
122	0.75	0.50	0.26	0.17	0.50	67.21	6.72	1.00	0.25	3.00	21.013	10.06	143.73	40	270.96	89.7	29	4.38	61.3	160	12.00
123	2.31	1.55	1.79	1.20	1.55	79.69	7.97	1.00	0.25	3.00	22.013	39.90	585.90	40	754.81	88.0	35	5.20	57.2	190	14.23
124	1.55	1.04	0.72	0.48	1.04	68.31	6.83	1.00	0.25	3.00	23.013	23.62	356.26	40	432.66	89.5	30	4.46	61.0	163	12.20
125	1.05	0.70	0.63	0.42	0.70	111.74	8.38	1.00	0.25	3.00	24.013	17.48	270.46	40	435.18	83.9	49	7.29	48.8	266	19.95
126	1.04	0.70	0.42	0.28	0.70	165.86	12.44	1.00	0.25	3.00	25.013	13.71	217.32	40	190.09	77.9	72	7.21	39.1	395	29.62
127	1.17	0.78	0.54	0.36	0.78	71.59	7.16	1.00	0.25	3.00	26.013	18.21	295.63	40	623.94	89.1	31	4.67	59.8	170	12.78
128	1.17	0.78	0.61	0.41	0.78	66.32	6.63	1.00	0.25	3.00	27.013	18.90	313.76	40	442.27	89.8	29	4.32	61.7	158	11.84
129	1.59	1.06	0.83	0.55	1.06	63.34	9.50	1.00	0.25	3.00	28.013	26.01	441.31	40	561.52	90.2	28	5.51	62.7	151	11.31
130	1.39	0.93	0.61	0.41	0.93	70.75	7.08	1.00	0.25	3.00	29.013	21.36	370.12	40	555.99	89.2	31	4.61	60.1	168	12.63
131	1.60	1.07	0.83	0.55	1.07	67.35	6.74	1.00	0.25	3.00	30.013	26.74	472.92	40	685.98	89.7	29	4.39	61.3	160	12.03
132	1.69	1.13	0.88	0.59	1.13	58.68	8.80	1.00	0.25	3.00	31.013	28.44	512.99	40	659.63	90.9	26	5.10	64.5	140	10.48
133	1.85	1.24	0.90	0.60	1.24	58.09	8.71	1.00	0.25	3.00	32.013	29.44	541.28	40	575.00	91.0	25	5.05	64.7	138	10.37
134	1.14	0.76	0.62	0.41	0.76	56.65	8.50	1.00	0.25	3.00	33.013	18.97	355.23	40	386.09	91.2	25	4.93	65.3	135	10.12
135	0.49	0.33	0.08	0.06	0.33	64.33	6.43	1.00	0.25	3.00	34.013	5.87	111.82	40	269.66	90.1	28	5.59	62.4	153	11.49
136	1.14	0.76	0.37	0.25	0.76	65.80	6.58	1.00	0.25	3.00	35.013	14.91	289.31	40	345.27	89.9	29	4.29	61.9	157	11.75
137	2.14	1.43	0.82	0.55	1.43	60.31	9.05	1.00	0.25	3.00	36.013	32.46	640.40	40	556.35	90.6	26	5.24	63.9	144	10.77
138	0.79	0.53	0.18	0.12	0.53	313.59	23.52	1.00	0.25	3.00	37.013	9.15	183.50	40	154.32	65.1	136	10.23	25.4	747	56.00
139	0.94	0.63	0.29	0.19	0.63	135.15	10.14	1.00	0.25	3.00	38.013	11.91	242.70	40	109.38	81.2	59	8.81	44.1	322	24.13
140	0.28	0.19	0.04	0.03	0.19	59.58	8.94	1.00	0.25	3.00	39.013	2.59	53.55	40	21.03	90.7	26	5.18	64.2	142	10.64
141	1.98	1.32	1.48	0.99	1.32	139.80	10.49	1.00	0.25	3.00	40.013	34.20	718.82	40	885.39	80.7	61	9.12	43.3	333	24.96
142	1.16	0.78	0.64	0.43	0.78	191.26	14.34	1.00	0.25	3.00	41.013	17.16	366.02	40	520.44	75.3	83	8.32	35.8	455	34.15
143	3.04	2.04	1.19	0.80	2.04	225.15	16.89	1.00	0.25	3.00	42.013	41.48	897.54	40	549.13	72.2	98	9.79	32.1	536	40.21
144	0.99	0.66	0.26	0.17	0.66	160.03	12.00	1.00	0.25	3.00	43.013	11.27	247.38	40	138.94	78.5	70	6.96	40.0	381	28.58
145	n/a	n/a	n/a	n/a	n/a	167.75	12.58	1.00	0.25	N/A	44.013	#DIV/0!	#DIV/0!	40	138.08	77.7	73	7.29	38.9	399	29.96
146	n/a	n/a	n/a	n/a	n/a	242.79	18.21	1.00	0.25	N/A	45.013	#DIV/0!	#DIV/0!	40	122.99	70.6	106	10.56	30.5	578	43.36
1461	0.85	0.57	0.19	0.13	0.57	195.00	14.62	1.00	0.25	3.00	46.013	9.45	215.89	40	167.44	75.0	85	8.48	35.4	464	34.82
147	1.17	0.78	0.43	0.29	0.78	118.85	8.91	1.00	0.25	3.00	47.013	16.62	384.87	40	563.86	83.1	52	7.75	47.3	283	21.22
148	n/a	n/a	n/a	n/a	n/a	264.36	19.83	1.00	0.25	N/A	48.013	#DIV/0!	#DIV/0!	40	270.84	68.8	115	8.62	28.8	629	47.21
1481	0.62	0.42	0.15	0.10	0.42	484.38	36.33	1.00	0.25	3.00	49.013	7.06	167.67	40	168.38	54.7	211	15.80	18.0	1153	86.50
149	1.44	0.97	0.56	0.38	0.97	187.57	14.07	1.00	0.25	3.00	50.013	19.04	457.58	40	270.31	75.7	82	8.16	36.3	447	33.49
150	n/a	n/a	n/a	n/a	n/a	50.63	7.60	1.00	0.25	N/A	51.013	#DIV/0!	#DIV/0!	40	224.19	92.0	22	4.40	67.8	121	9.04
151	1.32	0.88	0.57	0.38	0.88	97.87	9.79	1.00	0.25	3.00	52.013	18.57	456.68	40	357.39	85.7	43	6.38	52.2	233	17.48
152	n/a	n/a	n/a	n/a	n/a	53.99	8.10	1.00	0.25	N/A	53.013	#DIV/0!	#DIV/0!	40	438.37	91.5	23	4.69	66.4	129	9.64
153	1.12	0.75	0.27	0.18	0.75	94.78	9.48	1.00	0.25	3.00	54.013	12.64	318.03	40	200.56	86.0	41	6.18	53.0	226	16.93

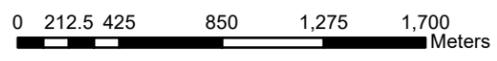
154	n/a	n/a	n/a	n/a	n/a	51.40	7.71	1.00	0.25	N/A	55.013	#DIV/0!	#DIV/0!	40	370.04	91.9	22	4.47	67.5	122	9.18
1541	1.40	0.94	0.63	0.42	0.94	79.30	7.93	1.00	0.25	3.00	56.013	18.26	469.66	40	301.39	88.0	34	5.17	57.4	189	14.16
155	1.93	1.30	1.09	0.73	1.30	159.48	11.96	1.00	0.25	3.00	57.013	27.52	715.19	40	458.34	78.6	69	6.93	40.1	380	28.48
156	1.13	0.76	0.51	0.34	0.76	166.61	12.50	1.00	0.25	3.00	58.013	15.69	412.04	40	365.12	77.8	72	7.24	39.0	397	29.75
157	n/a	n/a	n/a	n/a	n/a	49.66	7.45	1.00	0.25	N/A	59.013	#DIV/0!	#DIV/0!	40	392.78	92.2	22	4.32	68.2	118	8.87
158	n/a	n/a	n/a	n/a	n/a	48.86	7.33	1.00	0.25	N/A	60.013	#DIV/0!	#DIV/0!	40	351.12	92.3	21	4.25	68.6	116	8.73
1581	1.55	1.04	0.82	0.55	1.04	89.87	8.99	1.00	0.25	3.00	61.013	20.32	550.06	40	146.49	86.7	39	5.86	54.3	214	16.05
159	n/a	n/a	n/a	n/a	n/a	61.94	9.29	1.00	0.25	N/A	62.013	#DIV/0!	#DIV/0!	40	186.65	90.4	27	5.39	63.3	147	11.06
1591	0.38	0.25	0.06	0.04	0.25	145.15	10.89	1.00	0.25	3.00	63.013	3.98	109.96	40	166.26	80.1	63	9.47	42.4	346	25.92
160	n/a	n/a	n/a	n/a	n/a	58.98	8.85	1.00	0.25	N/A	64.013	#DIV/0!	#DIV/0!	40	488.38	90.8	26	5.13	64.4	140	10.53
161	n/a	n/a	n/a	n/a	n/a	51.24	7.69	1.00	0.25	N/A	65.013	#DIV/0!	#DIV/0!	40	464.06	91.9	22	4.46	67.6	122	9.15
1611	1.87	1.25	0.90	0.60	1.25	89.37	8.94	1.00	0.25	3.00	66.013	24.75	702.48	40	339.50	86.7	39	5.83	54.4	213	15.96
162	n/a	n/a	n/a	n/a	n/a	70.03	7.00	1.00	0.25	N/A	67.013	#DIV/0!	#DIV/0!	40	230.80	89.3	30	4.57	60.4	167	12.51
163	n/a	n/a	n/a	n/a	n/a	57.85	8.68	1.00	0.25	N/A	68.013	#DIV/0!	#DIV/0!	40	162.78	91.0	25	5.03	64.8	138	10.33
164	n/a	n/a	n/a	n/a	n/a	49.71	7.46	1.00	0.25	N/A	69.013	#DIV/0!	#DIV/0!	40	160.41	92.2	22	4.32	68.2	118	8.88
165	n/a	n/a	n/a	n/a	n/a	61.06	9.16	1.00	0.25	N/A	70.013	#DIV/0!	#DIV/0!	40	140.95	90.5	27	5.31	63.6	145	10.90
1651	1.14	0.77	0.35	0.24	0.77	86.44	8.64	1.00	0.25	3.00	71.013	13.52	400.91	40	183.70	87.1	38	5.64	55.2	206	15.44
166	n/a	n/a	n/a	n/a	n/a	48.38	7.26	1.00	0.25	N/A	72.013	#DIV/0!	#DIV/0!	40	331.87	92.4	21	4.21	68.8	115	8.64
1661	1.40	0.94	0.64	0.43	0.94	49.51	7.43	1.00	0.25	3.00	73.013	17.99	542.35	40	194.38	92.2	22	4.31	68.3	118	8.84
167	n/a	n/a	n/a	n/a	n/a	50.38	7.56	1.00	0.25	N/A	74.013	#DIV/0!	#DIV/0!	40	192.24	92.1	22	4.38	67.9	120	9.00
168	n/a	n/a	n/a	n/a	n/a	48.38	7.26	1.00	0.25	N/A	75.013	#DIV/0!	#DIV/0!	40	220.58	92.4	21	4.21	68.8	115	8.64
169	n/a	n/a	n/a	n/a	n/a	49.01	7.35	1.00	0.25	N/A	76.013	#DIV/0!	#DIV/0!	40	444.98	92.3	21	4.26	68.5	117	8.75
1691	1.21	0.81	0.58	0.39	0.81	80.53	8.05	1.00	0.25	3.00	77.013	15.67	487.67	40	169.43	87.9	35	5.25	57.0	192	14.38
170	n/a	n/a	n/a	n/a	n/a	55.87	8.38	1.00	0.25	N/A	78.013	#DIV/0!	#DIV/0!	40	460.50	91.3	24	4.86	65.6	133	9.98
1701	0.70	0.47	0.15	0.10	0.47	70.20	7.02	1.00	0.25	3.00	79.013	7.84	247.77	40	241.57	89.3	31	4.58	60.3	167	12.54
171	n/a	n/a	n/a	n/a	n/a	63.78	6.38	1.00	0.25	N/A	80.013	#DIV/0!	#DIV/0!	40	415.50	90.2	28	5.55	62.6	152	11.39
1711	0.82	0.55	0.25	0.17	0.55	109.21	8.19	1.00	0.25	3.00	81.013	9.76	313.06	40	203.65	84.2	47	7.12	49.4	260	19.50
172	n/a	n/a	n/a	n/a	n/a	50.11	7.52	1.00	0.25	N/A	82.013	#DIV/0!	#DIV/0!	40	392.94	92.1	22	4.36	68.0	119	8.95
173	1.11	0.75	0.37	0.25	0.75	87.74	8.77	1.00	0.25	3.00	83.013	14.23	463.41	40	273.62	86.9	38	5.72	54.9	209	15.67
174	2.09	1.40	0.91	0.61	1.40	101.86	10.19	1.00	0.25	3.00	84.013	27.39	898.28	40	387.26	85.2	44	6.64	51.2	243	18.19
175	n/a	n/a	n/a	n/a	n/a	51.71	7.76	1.00	0.25	N/A	85.013	#DIV/0!	#DIV/0!	40	609.55	91.9	22	4.50	67.4	123	9.23
1751	1.05	0.71	0.48	0.32	0.71	140.14	10.51	1.00	0.25	3.00	86.013	13.71	456.15	40	252.34	80.7	61	9.14	43.2	334	25.03
176	n/a	n/a	n/a	n/a	n/a	49.32	7.40	1.00	0.25	N/A	87.013	#DIV/0!	#DIV/0!	40	392.04	92.2	21	4.29	68.4	117	8.81
1761	1.19	0.80	0.35	0.23	0.80	134.56	10.09	1.00	0.25	3.00	88.013	14.04	473.37	40	238.71	81.3	59	8.78	44.2	320	24.03
177	n/a	n/a	n/a	n/a	n/a	114.53	8.59	1.00	0.25	N/A	89.013	#DIV/0!	#DIV/0!	40	195.33	83.6	50	7.47	48.2	273	20.45
178	n/a	n/a	n/a	n/a	n/a	50.71	7.61	1.00	0.25	N/A	90.013	#DIV/0!	#DIV/0!	40	400.49	92.0	22	4.41	67.8	121	9.06
1781	1.40	0.94	0.79	0.53	0.94	58.22	8.73	1.00	0.25	3.00	91.013	22.42	771.66	40	353.76	90.9	25	5.06	64.7	139	10.40
179	n/a	n/a	n/a	n/a	n/a	58.95	8.84	1.00	0.25	N/A	92.013	#DIV/0!	#DIV/0!	40	330.20	90.8	26	5.13	64.4	140	10.53
180	n/a	n/a	n/a	n/a	n/a	50.74	7.61	1.00	0.25	N/A	93.013	#DIV/0!	#DIV/0!	40	281.84	92.0	22	4.41	67.8	121	9.06
181	n/a	n/a	n/a	n/a	n/a	50.22	7.53	1.00	0.25	N/A	94.013	#DIV/0!	#DIV/0!	40	433.75	92.1	22	4.37	68.0	120	8.97
1811	0.47	0.31	0.13	0.09	0.31	81.16	8.12	1.00	0.25	3.00	95.013	5.56	196.36	40	251.15	87.8	35	5.29	56.8	193	14.49
182	0.91	0.61	0.44	0.30	0.61	123.04	9.23	1.00	0.25	3.00	96.013	13.03	462.99	40	201.16	82.6	53	8.02	46.4	293	21.97
183	n/a	n/a	n/a	n/a	n/a	50.15	7.52	1.00	0.25	N/A	97.013	#DIV/0!	#DIV/0!	40	173.30	92.1	22	4.36	68.0	119	8.96
184	n/a	n/a	n/a	n/a	n/a	48.88	7.33	1.00	0.25	N/A	98.013	#DIV/0!	#DIV/0!	40	375.17	92.3	21	4.25	68.6	116	8.73

E

DEVELOPMENT OF
IMPERVIOUSNESS
AND HYDRAULIC
CONNECTIVITY



Legend		
ImpSites	Existing Landuse	Roads
SWM Ponds	Commercial/Employment/Downtown/Mixed Use	Open Space
Petticoat Creek Catchment	Residential - Medium Density	Water
Watercourse	Residential - Low Density	Agricultural
Roads	Railway	



CLIENT	TORONTO AND REGION CONSERVATION AUTHORITY	
TITLE	PETTICOAT CREEK SUBWATERSHED	
	DEVELOPMENT OF IMPERVIOUSNESS AND HYDRAULIC CONNECTIVITY	

Date October 2020	Proj. No. 19M-01483-00
Scale 1:30,000	Figure No. E.1

Petticoat Ck

Percent Impervious and Directly Connected Estimates Sampling:

Low Density Residential Sample Sites:

	cover	calculation	Site 1	Site 2	Site 3	Average
	Roof	a	350.7	1600.0	445.9	
	Driveway/Parking	b	652.8	1745.8	289.3	
	Other Imp surface	c	293.5	90.9	18.1	
	Lawn/Boulevard	d	13200.4	29137.7	8537.0	
	Total	$T=r+a+b+s+c+d$	13191.8	32574.5	9290.3	
	% Roof Connectivity	A	0%	0%	0%	
	% imp (TIMP)	$(a+b+c)/T$	10%	11%	8%	9%
	% D.C. (XIMP)	$((a \times A\%)+b)/T$	5%	5%	3%	4%

Medium Density Residential Sample Sites:

	cover	calculation	Site 4	Site 5	Site 6	Average
	Roof	a	3203.0	4205.1	3202.6	
	Driveway/Parking	b	2705.6	3441.4	2852.3	
	Other Imp surface	c	665.2	740.7	1056.3	
	Lawn/Boulevard	d	3237.1	5454.3	4041.1	
	Total	$T=r+a+b+s+c+d$	9810.9	13841.5	11152.3	
	% Roof Connectivity	A	0%	0%	0%	
	% imp (TIMP)	$(a+b+c)/T$	67%	61%	64%	64%
	% D.C. (XIMP)	$((a \times A\%)+b)/T$	28%	25%	26%	26%

Commercial/Employment/Downtown Areas Sample Sites:

	cover	calculation	Site 7	Site 8	Site 9	Average
	Roof	a	3737.7	5928.1	8789.4	
	Driveway/Parking	b	5531.3	11921.0	30336.7	
	Sidewalk/Path	s	4439.0	583.9	1695.9	
	Lawn/Boulevard	d	1983.0	4726.2	4816.1	
	Total	$T=r+a+b+s+c+d$	15691.0	23159.1	45638.0	
	% Roof Connectivity	A	0%	0%	0%	
	% imp (TIMP)	$(+a+b+s+c)/T$	87%	80%	89%	85%
	% D.C. (XIMP)	$((a \times A\%)+b)/T$	35%	51%	66%	51%

Road Sample Sites:

	cover	calculation	Site 10	Site 11	Site 12	Average
Road	Roadway	a	788.5	1089.0	18752.9	
	Sidewalk	c	0.0	0.0	0.0	
	Lawn/Boulevard	d	147.7	11.3	1471.8	
	Total	$T=a+c+d$	936.3	1100.2	20224.7	
	% imp (TIMP)	$(a+b)/T$	84%	99%	93%	92%
	% D.C. (XIMP)	a/T	84%	99%	93%	92%

CN Railway Sample Sites:

	cover	calculation	Site 13	Site 14	Average
CN Railway	Railway Track	a	958.6	720.4	
	Gravel	c	332.8	429.6	
	Total	$T=a+c$	1291.4	1150.0	
	% imp (TIMP)	$(a+c)/T$	100%	100%	100%
	% D.C. (XIMP)	$(a+c)/T$	100%	100%	100%

Petticoat Creek

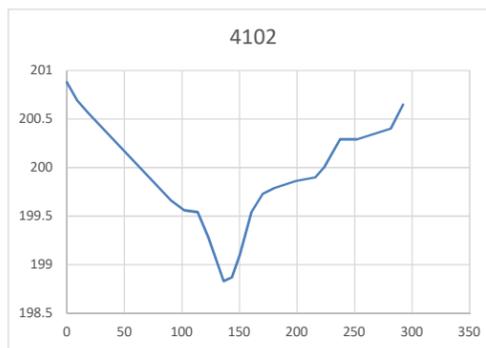
Landuse	Percent Impervious (TIMP)	Directly Connected (XIMP)	Notes
<i>Low Density Residential</i>	9%	4%	Sample site 1 to 3
<i>Medium Density Residential</i>	64%	26%	Sample site 4 to 6
<i>Commercial/Employment/Downtown</i>	85%	51%	Sample site 7 to 9
<i>Road</i>	92%	92%	Sample site 10 to 12
<i>Railway</i>	100%	100%	Sample site 13 to 14

F CHANNEL ROUTING

NHYD	NAME	COMMENTS 1	COMMENTS 2	COMMENTS 3	Outlet	Erosion Index	DT [min]	CHLGTH [m]	CHSLOPE [%]	FPSLOPE [%]	VSN	NSEG	DIST/ELEV
4102	RouteChannel - 4	n/a	n/a		5102	FALSE	5	291.7	1.199862873	1.199862873	1.1	3	7
4104	RouteChannel - 7	n/a	n/a		5104	FALSE	5	543.9	1.011215297	1.011215297	1.1	3	7
4105	RouteChannel - 11	n/a	n/a		5105	FALSE	5	1565.3	0.89439724	0.89439724	1.1	3	7
4107	RouteChannel - 16	Reach 1 Main Channel G	XS 13813.03		5107	FALSE	5	1397.0	0.515390122	0.515390122	1.1	3	7
4109	RouteChannel - 20	Reach 10 Tributary 9	XS 206.04		5109	FALSE	5	398.0	0.753768844	0.753768844	1.1	3	7
4111	RouteChannel - 25	Reach 1 Main Channel G	XS 11677.05		5111	FALSE	5	1505.0	0.331561462	0.331561462	1.1	3	7
4123	RouteChannel - 30	Reach 1 Main Channel F	XS 9369.06		51231	FALSE	5	2995.0	1.099499165	1.099499165	1.1	3	7
4122	RouteChannel - 32	n/a	n/a		5122	FALSE	5	386.9	1.809253037	1.809253037	1.1	3	7
4124	RouteChannel - 36	Reach 1 Main Channel F	XS 7368.08		5124	FALSE	5	980.0	0.675510204	0.675510204	1.1	3	7
4114	RouteChannel - 40	Reach 5 Tributary 4B	XS 4425.121		5114	FALSE	5	569.0	0.702987698	0.702987698	1.1	3	7
4116	RouteChannel - 46	Reach 5 Tributary 4B	XS 3893.121		5116	FALSE	5	425.0	1.952941176	1.952941176	1.1	3	7
4127	RouteChannel - 50	Reach 5 Tributary 4B	XS 2966.13		5127	FALSE	5	914.0	1.398249453	1.398249453	1.1	3	7
4178	RouteChannel - 53	Reach 5 Tributary 4B	XS 2431.13		5178	FALSE	5	1123.0	1.055209261	1.055209261	1.1	3	7
4128	RouteChannel - 60	Reach 6 Tributary 5B	XS 1865.14		5128	FALSE	5	965.0	1.378238342	1.378238342	1.1	3	7
4129	RouteChannel - 61	n/a	n/a		5129	FALSE	5	1208.0	0.745033113	0.745033113	1.1	3	7
4131	RouteChannel - 62	n/a	n/a		5131	FALSE	5	1245.9	0.722369372	0.722369372	1.1	3	7
4130	RouteChannel - 68	Reach 6 Tributary 5B	XS 941.17		5130	FALSE	5	901.0	0.799112098	0.799112098	1.1	3	7
4133	RouteChannel - 75	Reach 7 Tributary 6	XS 940.18		5133	FALSE	5	1222.0	0.504099903	0.504099903	1.1	3	7
4135	RouteChannel - 80	Reach 7 Tributary 6	XS 75.18		5135	FALSE	5	111.0	0.900900901	0.900900901	1.1	3	7
4136	RouteChannel - 84	Reach 6 Tributary 5A	XS 353.19		5136	FALSE	5	497.0	0.804877558	0.804877558	1.1	3	7
4137	RouteChannel - 88	Reach 5 Tributary 4A	XS 1283.20		5137	FALSE	5	936.0	0.213675214	0.213675214	1.1	3	7
4138	RouteChannel - 91	Reach 5 Tributary 4A	XS 419.20		5138	FALSE	5	197.0	0.644670051	0.644670051	1.1	3	7
4139	RouteChannel - 94	Reach 5 Tributary 4A	XS 209.20		5139	FALSE	5	291.0	0.58419244	0.58419244	1.1	3	7
4143	RouteChannel - 100	Reach 8 Tributary 7A	XS 892.11		5143	FALSE	5	1306.0	0.183767228	0.183767228	1.1	3	7
4126	RouteChannel - 140	n/a	n/a		5126	FALSE	5	558.0	1.344086022	1.344086022	1.1	3	7
4140	RouteChannel - 147	Reach 1 Main Channel E	XS 6985.21		5140	FALSE	5	34.0	1.294117647	1.294117647	1.1	3	7
4144	RouteChannel - 150	Reach 8 Tributary 7A	XS 279.11		5144	FALSE	5	279.0	0.64516129	0.64516129	1.1	3	7
4146	RouteChannel - 154	Reach 1 Main Channel D	XS 6824.21		5146	FALSE	5	220.0	0.722727273	0.722727273	1.1	3	7
4147	RouteChannel - 164	n/a	n/a	Route Road	5147	FALSE	5	675.7	1.035962705	1.035962705	1.1	3	7
4149	RouteChannel - 168	Reach 1 Main Channel D	XS 6400.21		5149	FALSE	5	702.0	0.710826211	0.710826211	1.1	3	7
4176	RouteChannel - 171	n/a	n/a	Route Road	5176	FALSE	5	422.1	0.710732054	0.710732054	1.1	3	7
4151	RouteChannel - 179	Reach 1 Main Channel D	XS 5354.23		5151	FALSE	5	802.0	1.010000249	1.010000249	1.1	3	7
4154	RouteChannel - 184	Reach 1 Main Channel D	XS 4422.23		5154	FALSE	5	922.0	1.409978308	1.409978308	1.1	3	7
4152	RouteChannel - 185	n/a	n/a	Route Road	5152	FALSE	5	541.5	0.738688827	0.738688827	1.1	3	7
4177	RouteChannel - 196	n/a	n/a	Route Road	5177	FALSE	5	364.9	1.370238421	1.370238421	1.1	3	7
4160	RouteChannel - 199	n/a	n/a	Route Road	5160	FALSE	5	330.6	0.756200847	0.756200847	1.1	3	7
4175	RouteChannel - 203	Reach 3 Tributary 2	XS 485.25		5175	FALSE	5	757.0	2.470277411	2.470277411	1.1	3	7
4159	RouteChannel - 209	Reach 1 Main Channel C	XS 3928.24		5159	FALSE	5	91.0	2.197802198	2.197802198	1.1	3	7
4157	RouteChannel - 213	n/a	n/a	Route Road	5157	FALSE	5	843.9	0.710984714	0.710984714	1.1	3	7
4155	RouteChannel - 220	n/a	n/a	Route Road	5155	FALSE	5	1678.4	1.191611058	1.191611058	1.1	3	7
4158	RouteChannel - 221	n/a	n/a	Route Road	5158	FALSE	5	996.5	1.154039137	1.154039137	1.1	3	7
4182	RouteChannel - 226	Reach 4 Tributary 3	XS 549.27		5182	FALSE	5	656.0	2.199695122	2.199695122	1.1	3	7
4161	RouteChannel - 229	Reach 1 Main Channel C	XS 3092.24		5161	FALSE	5	1231.0	0.91226645	0.91226645	1.1	3	7
4162	RouteChannel - 233	Reach 1 Main Channel C	XS 2406.26		5162	FALSE	5	39.0	0.666666667	0.666666667	1.1	3	7
4165	RouteChannel - 237	Reach 1 Main Channel B	XS 2141.26		5165	FALSE	5	412.0	0.766990291	0.766990291	1.1	3	7
4179	RouteChannel - 247	n/a	n/a	Route Road	5197	FALSE	5	594.8	1.513113652	1.513113652	1.1	3	7
4184	RouteChannel - 254	n/a	n/a	Route Road	5184	FALSE	5	929.2	0.269048644	0.269048644	1.1	3	7
4166	RouteChannel - 255	n/a	n/a	Route Road	5166	FALSE	5	830.7	1.203804021	1.203804021	1.1	3	7
4169	RouteChannel - 263	n/a	n/a	Route Road	5169	FALSE	5	777.5	1.672025723	1.672025723	1.1	3	7
4170	RouteChannel - 267	n/a	n/a	Route Road	5170	FALSE	5	207.9	1.202501203	1.202501203	1.1	3	7
4171	RouteChannel - 270	Reach 2 Tributary 1	XS 256.34		5171	FALSE	5	355.0	1.690140845	1.690140845	1.1	3	7
4173	RouteChannel - 274	Reach 1 Main Channel A	XS 1321.35		5173	FALSE	5	487.0	338.3059548	338.3059548	1.1	3	7
4174	RouteChannel - 281	Reach 1 Main Channel A	XS 500.38		5174	FALSE	5	1175.0	0.593191489	0.593191489	1.1	3	7

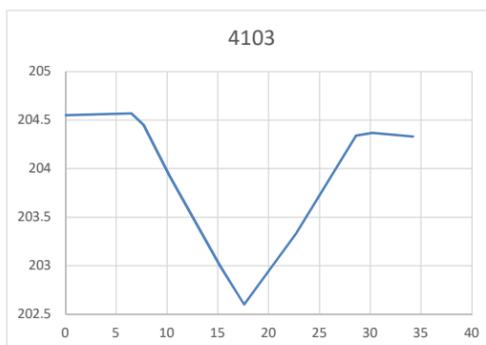
Catchment
4102

X	Y	Manning's n	
0	200.88	113.7	0.08
9.1	200.69	160.3	-0.035
18.6	200.56	292.076	0.08
90.5	199.66		
102.1	199.56		
113.7	199.54		
123	199.28		
136.3	198.83		
143.4	198.87		
150.3	199.1		
160.3	199.54		
170.3	199.73		
180.3	199.79		
198.9	199.86		
215.9	199.9		
223.2	200		
237.4	200.29		
252.2	200.29		
281.3	200.4		
292.076	200.65		



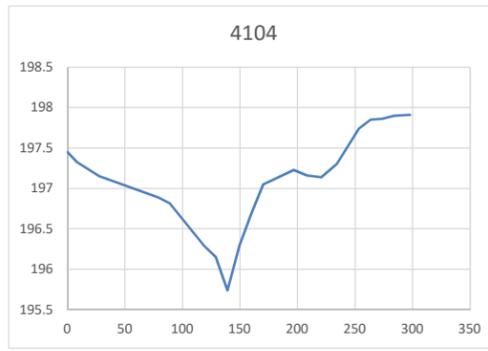
Catchment
4104

X	Y	Manning's n	
0	204.55	7.7	0.08
6.5	204.57	28.6	-0.035
7.7	204.45	34.2	0.08
10.3	203.92		
15.2	203		
17.6	202.6		
22.7	203.33		
24.2	203.59		
28.6	204.34		
30.2	204.37		
34.2	204.33		



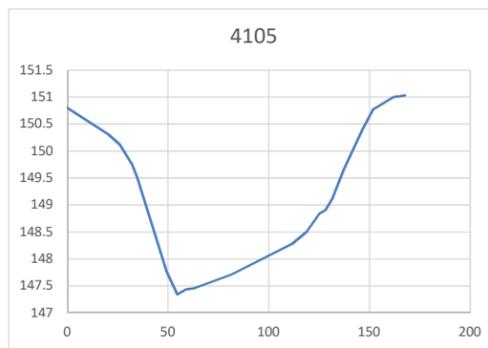
Catchment
4105

X	Y	Manning's n	
0	197.45	89	0.08
8	197.33	159.8	-0.035
28.3	197.15	297.7	0.08
78.8	196.89		
89	196.82		
119.1	196.29		
129.1	196.15		
139.1	195.74		
149.5	196.29		
159.8	196.69		
170.2	197.05		
196.7	197.23		
208.1	197.16		
220.5	197.14		
233.9	197.3		
253.3	197.74		
263.4	197.85		
273.6	197.86		
284.2	197.9		
297.7	197.91		



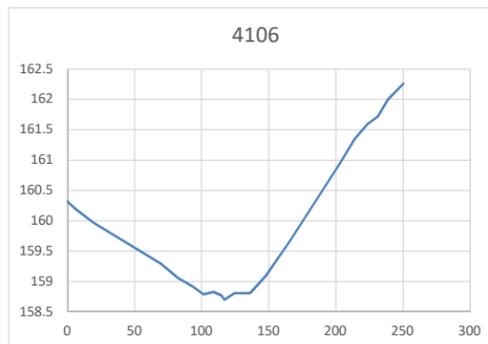
Catchment
4122

X	Y	Manning's n	
0	150.8	49.3	0.08
20.3	150.31	81.5	-0.035
26.3	150.11	167.6	0.08
32.1	149.76		
34.8	149.5		
49.3	147.76		
54.6	147.34		
59.2	147.44		
63.4	147.46		
81.5	147.71		
111.7	148.28		
118.8	148.5		
125.1	148.84		
128	148.9		
131.7	149.13		
137.3	149.66		
146.5	150.4		
151.8	150.77		
161.8	151		
167.6	151.03		



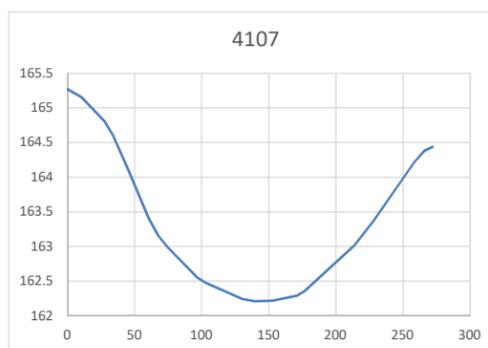
Catchment
4129

X	Y	Manning's n	
0	160.32	93.9	0.08
6.4	160.19	136	-0.035
19.6	159.97	250.3	0.08
69.6	159.29		
82.9	159.05		
93.9	158.91		
101.2	158.79		
109.1	158.83		
114.6	158.77		
117	158.7		
124.8	158.81		
136	158.81		
147.8	159.09		
165.9	159.67		
202.2	160.92		
213.6	161.34		
224	161.6		
231.2	161.72		
238.5	161.99		
250.3	162.26		



Catchment
4131

X	Y	Manning's n	
0	165.27	103.7	0.08
10.3	165.16	176.8	-0.035
28.1	164.8	272	0.08
34.2	164.6		
46.3	164.07		
60.5	163.41		
67.7	163.16		
74.9	162.99		
96.5	162.56		
103.7	162.47		
130.8	162.24		
139.7	162.21		
152.9	162.22		
170.7	162.29		
176.8	162.36		
213.4	163.01		
228.1	163.37		
258.5	164.22		
266.1	164.38		
272.0	164.44		

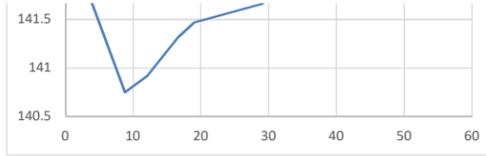


Catchment
4126

X	Y	Manning's n	
0	142.36	3.7	0.08
3.7	141.71	19	-0.035
8.8	140.75	49.6	0.08
12.1	140.92		
16.7	141.32		
19	141.47		

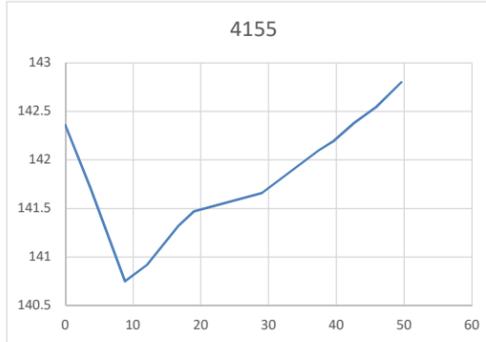


29	141.66
37.4	142.1
39.5	142.19
42.6	142.38
45.8	142.54
49.6	142.8



Catchment
4155

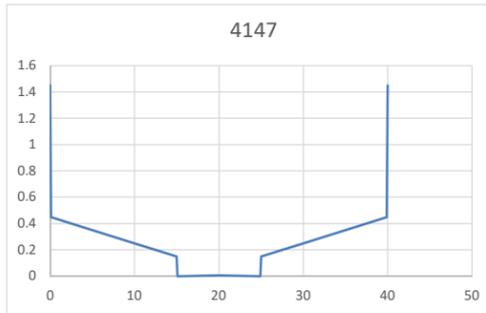
X	Y	Manning's n	
0	125.18	14.6	0.08
1.8	125.11	14.7	-0.035
3.3	125.09	90.5	0.08
14.6	124.21		
20.2	124.02		
24	123.82		
31.4	123.59		
37.3	123.47		
47.7	124.09		
56.5	124.77		
57.5	124.83		
67.7	125.12		
71	125.21		
74	125.27		
77.8	125.38		
90.5	126.31		



Catchment
4147 Road XS width

Estimate Road Width (m)
10

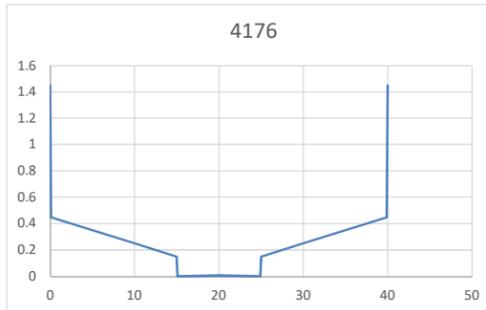
	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	25	-0.015
10	10	0.25	40	0.15
15	15	0.15		
15.1	15.1	0		
21.6	20	0.0065		
28.1	24.9	0		
28.2	25	0.15		
33.2	30	0.25		
43.1	39.9	0.448		
43.2	40	1.448		



Catchment
4176 Road XS width

Estimate Road Width (m)
10

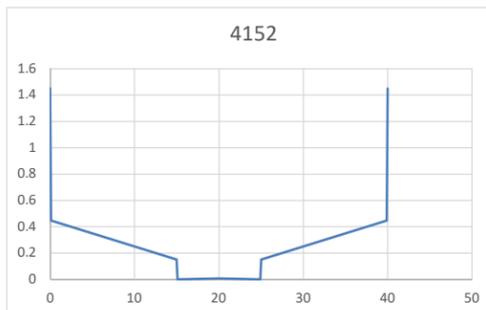
	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	25	-0.015
10	10	0.25	40	0.15
15	15	0.15		
15.1	15.1	0		
21.6	20	0.0065		
28.1	24.9	0		
28.2	25	0.15		
33.2	30	0.25		
43.1	39.9	0.448		
43.2	40	1.448		



Catchment
4152 Road XS width

Estimate Road Width (m)
10

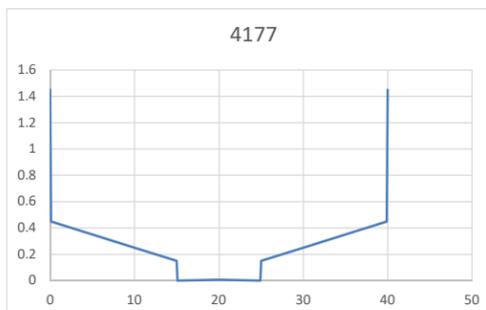
	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	25	-0.015
10	10	0.25	40	0.15
15	15	0.15		
15.1	15.1	0		
21.6	20	0.0065		
28.1	24.9	0		
28.2	25	0.15		
33.2	30	0.25		
43.1	39.9	0.448		
43.2	40	1.448		



Catchment
4177 Road XS width

Estimate Road Width (m)
10

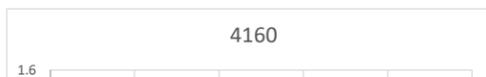
	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	25	-0.015
10	10	0.25	40	0.15
15	15	0.15		
15.1	15.1	0		
21.6	20	0.0065		
28.1	24.9	0		
28.2	25	0.15		
33.2	30	0.25		
43.1	39.9	0.448		
43.2	40	1.448		



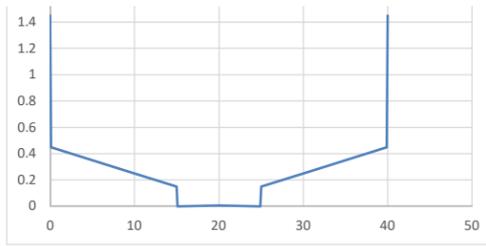
Catchment
4160 Road XS width

Estimate Road Width (m)
10

	X	Y	Manning's n	
0	0	1.448	15	0.15

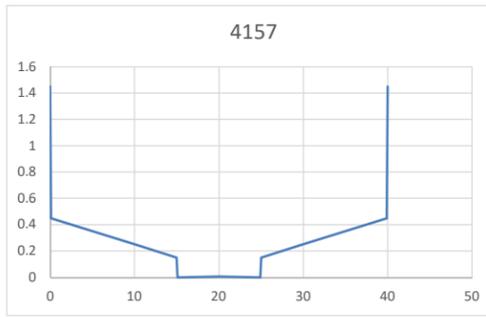


0.1	0.1	0.448	25	-0.015
10	10	0.25	40	0.15
15	15	0.15		
15.1	15.1	0		
21.6	20	0.0065		
28.1	24.9	0		
28.2	25	0.15		
33.2	30	0.25		
43.1	39.9	0.448		
43.2	40	1.448		



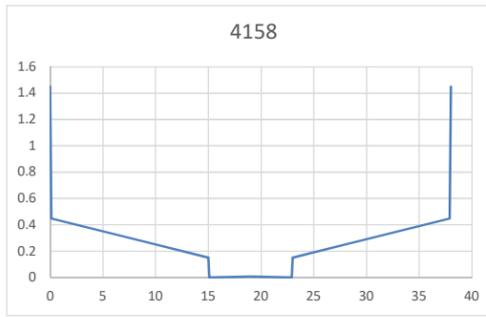
Catchment 4157 Road XS width Estimate Road Width (m) 10

	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	25	-0.015
10	10	0.25	40	0.15
15	15	0.15		
15.1	15.1	0		
21.6	20	0.0065		
28.1	24.9	0		
28.2	25	0.15		
33.2	30	0.25		
43.1	39.9	0.448		
43.2	40	1.448		



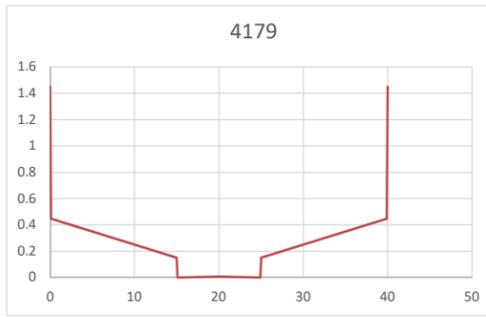
Catchment 4158 Road XS width Estimate Road Width (m) 8

	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	23	-0.015
10	10	0.25	38	0.15
15	15	0.15		
15.1	15.1	0		
21.6	19	0.0065		
28.1	22.9	0		
28.2	23	0.15		
33.2	28	0.25		
43.1	37.9	0.448		
43.2	38	1.448		



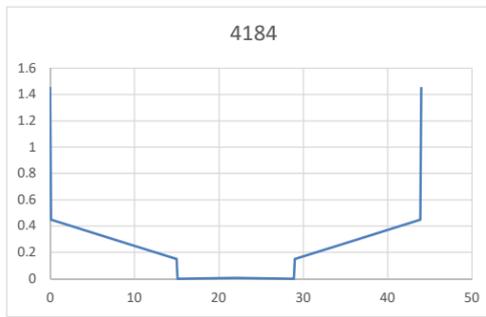
Catchment 4179 Road XS width Estimate Road Width (m) 10

	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	25	-0.015
10	10	0.25	40	0.15
15	15	0.15		
15.1	15.1	0		
21.6	20	0.0065		
28.1	24.9	0		
28.2	25	0.15		
33.2	30	0.25		
43.1	39.9	0.448		
43.2	40	1.448		



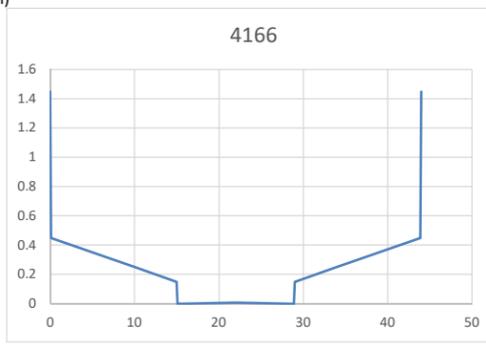
Catchment 4184 Road XS width Estimate Road Width (m) 14

	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	29	-0.015
10	10	0.25	44	0.15
15	15	0.15		
15.1	15.1	0		
21.6	22	0.0065		
28.1	28.9	0		
28.2	29	0.15		
33.2	34	0.25		
43.1	43.9	0.448		
43.2	44	1.448		



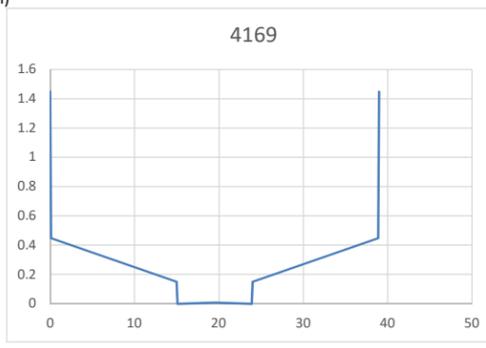
Catchment 4166 Road XS width Estimate Road Width (m) 14

	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	29	-0.015
10	10	0.25	44	0.15
15	15	0.15		
15.1	15.1	0		
21.6	22	0.0065		
28.1	28.9	0		
28.2	29	0.15		
33.2	34	0.25		
43.1	43.9	0.448		
43.2	44	1.448		



Catchment 4169 Road XS width Estimate Road Width (m) 9

	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	24	-0.015
10	10	0.25	39	0.15
15	15	0.15		
15.1	15.1	0		
21.6	19.5	0.0065		
28.1	23.9	0		
28.2	24	0.15		
33.2	29	0.25		
43.1	38.9	0.448		
43.2	39	1.448		

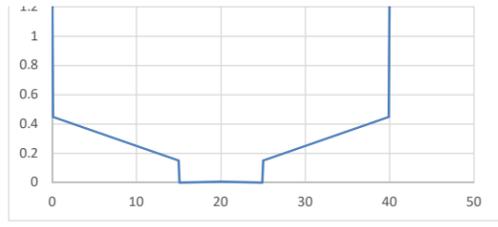


Catchment 4170 Road XS width Estimate Road Width (m) 10

	X	Y	Manning's n	
0	0	1.448	15	0.15
0.1	0.1	0.448	25	-0.015



10	10	0.25	40	0.15
15	15	0.15		
15.1	15.1	0		
21.6	20	0.0065		
28.1	24.9	0		
28.2	25	0.15		
33.2	30	0.25		
43.1	39.9	0.448		
43.2	40	1.448		



G RESERVOIR ROUTING

NHYD	NAME	COMMENTS 1	COMMENTS 2	COMMENTS 3	Outlet	DT [min]	Rating Curve
3148	PT SWMP 06 (331)	Bopa Pond (bopa Developments)			51491	5	4
3150	PT SWMP 05 (171)	Chickadee Ct Pond (Crystal Forest)			51511	5	4
3177	PT SWMP 04 (393)	Calvington Dr Pond (Timber Trails)			5177	5	4
3158	PT SWMP 03 (162)	Autumn Pond (Highbush)			51591	5	4
3166	PT SWMP 02 (265)	Braeburn Pond (Amberlea Park)			51841	5	4
3169	PT SWMP 01 (264)	Steeple Hill Pond			4170	5	4

GIS			TRCA Provide (2019)	Previous Hydrology (2006)	Pond Drainage Area (ha)	Pond Drainage Area (ha)	Report Name
Pond ID	Assetname	Type	Pond ID file	Report Figure 2.2	Appendix D (2006)	WSP Model (2019)	
PT SWMP 06	Bopa Pond (bopa Developments)	Wet	331	331	15.3	15.3 (Catchment 148)	SWM Report - BOPA Developments Inc (2001)
PT SWMP 05	Chickadee Ct Pond (Crystal Forest)	Wet	n/a	173	7.5	7.5 (Catchment 150)	
PT SWMP 04	Calvington Dr Pond (Timber Trails)	Wet	393	n/a		11.8 (Catchment 153)	SWM Report - Silver Lane Estates Inc (2005)
PT SWMP 03	Autumn Pond (Highbush)	Wet	162	162	64.8	64.8 (Catchment 156,157,158)	SWM Report - Bramalea Highbush Subdivision (1994)
PT SWMP 02	Braeburn Pond (Amberlea Park)	Dry	265	265	22.2	22.2 (Catchment 166)	SWM Report - Modifications to the RES. 6 (1984)
PT SWMP 01	Steeple Hill Pond	Dry	264	264	80.8	33.7 (Catchment 167)	SWM Report - Steeple Hill Subdivision (1986)

PT SWMP 06

PT SWMP 06 (331) from 2005 Petticoke Creek Report	
Flow (cms)	Storage (ha*m)
0.000	0.000
0.040	0.134
0.100	0.176
0.140	0.208
0.200	0.254
0.25	0.2914
0.3	0.3314

PT SWMP 06 (331) from SWM Report , June 2001	
Flow (cms)	Storage (ha*m)
0.000	0.000
0.152	0.095
0.251	0.207
0.320	0.335
0.379	0.481

PT SWMP 05

PT SWMP 05 (171) from 2005 Petticoke Creek Report	
Flow (cms)	Storage (ha*m)
0.000	0.000
0.150	0.123
0.220	0.128
0.260	0.132
0.330	0.136
0.38	0.1393
0.49	0.145

PT SWMP 04

PT SWMP 04 (393) from SWM Report Silver Lane Estates (2005)	
Flow (cms)	Storage (ha*m)
0.000	0.000
0.002	0.009
0.005	0.018
0.007	0.028
0.008	0.037
0.01	0.0473
0.011	0.0575
0.012	0.0679
0.013	0.0794
0.014	0.0892
0.014	0.1004
0.015	0.1116
0.016	0.1231
0.017	0.1346
0.017	0.1464
0.018	0.1583
0.019	0.1703

0.019	0.1825
0.020	0.1949
0.020	0.2074
0.021	0.2201
0.022	0.2329
0.022	0.246
0.023	0.2592

PT SWMP 03

PT SWMP 03 (162) from 2005 Petticoke Creek Report	
Flow (cms)	Storage (ha*m)
0.000	0.000
0.56	0.4786
1.46	0.4887
1.78	0.4913
1.97	0.4933
2.12	0.4948
2.28	0.4964

PT SWMP 02

PT SWMP 02 (265) from 2005 Petticoke Creek Report	
Flow (cms)	Storage (ha*m)
0.000	0.000
0.05	0.0026
0.23	0.0131
0.37	0.0215
0.46	0.0333

PT SWMP 02 (265) from SWM Report , June 2001	
Flow (cms)	Storage (ha*m)
0.000	0.000
0.450	0.025
0.500	0.056
0.560	0.175
0.610	0.395
0.66	0.713
0.670	0.814

PT SWMP 01

PT SWMP 01 (264) from 2005 Petticoke Creek Report	
Flow (cms)	Storage (ha*m)
0.000	0.000
1.570	0.101
2.160	0.151
2.600	0.199
3.220	0.268
3.68	0.3171
4.12	0.3679

PT SWMP 01 (264) from SWM Report 1986	
Flow (cms)	Storage (ha*m)
0.000	0.000
0.010	0.001
0.910	0.017
1.980	0.129
4.190	0.374
6.45	0.7168
8.500	1.990
10.030	1.473
10.200	1.500

*approx number, the PDF quality bad and cannot read the number clearly

H CALIBRATION AND VALIDATION EVENTS

Gauge Type	ID#	Name	Used for	Interval	All Available		In Review		Approved		Corrected		Working		Unverified	
					From	To	From	To	From	To	From	To	From	To	From	To
Precipitation	HY043	Little Rouge at 16th	Events 1, 2, 5	5 min	4/25/2013	4/7/2020									4/25/2013	4/7/2020
	HY044	Milne Dam	Used When HY043 is not available (Events 3, 4 and 6)	5 min	1/1/2013	4/7/2020										
	HY009	Brock West Landfill	All Events	5 min	7/29/2014	4/1/2020									7/29/2014	4/1/2020
	HY102	Petticoat Works Yard	All Events	5 min	4/22/2013	4/1/2020			4/22/2013	1/1/2018	1/2/2018	12/31/2018	1/1/2019	12/31/2019	1/1/2020	4/1/2020
Streamflow	HY051	Petticoat Creek at Whites	All Events	15 min	11/22/2012	1/25/2020	11/22/2012	12/31/2012	1/1/2013	1/11/2018	1/11/2018	12/31/2018	1/1/2019	4/11/2019	4/12/2019	1/25/2020

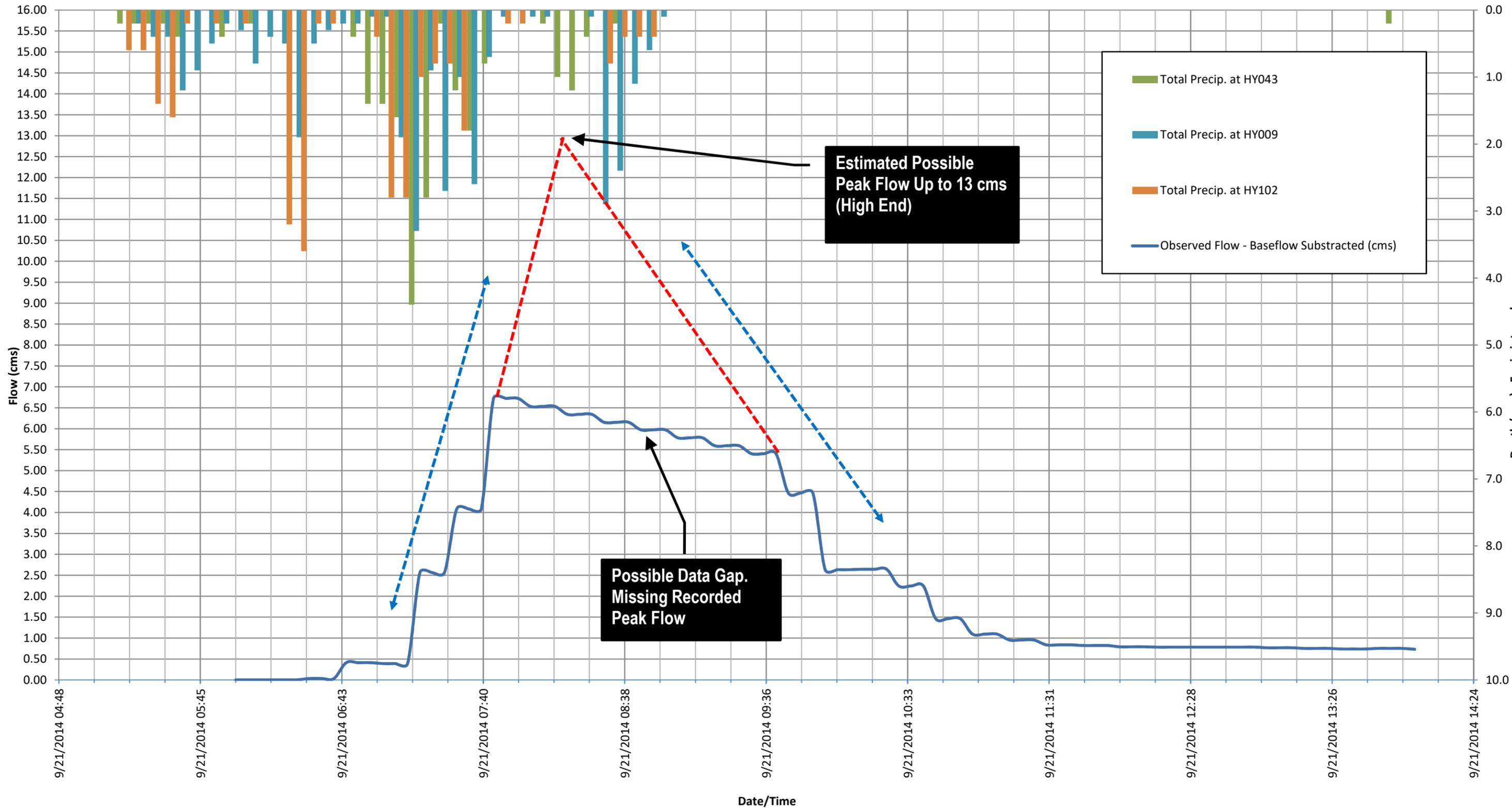
HY051 Petticoat Creek at Whites
Peak Flows > 6 cms

Date	Peak (cms)	at	Description	Selected	Notes	Rainfall Gauge Used	
9/21/2014	6.780	9/21/2014 7:45 AM	good runoff hydrograph, possible peak data missing, Interpolating used to fill the gaps.	Yes_Event 1	Good event	HY043, HY009, HY102	
10/17/2014	6.847	10/17/2014 2:45 AM	good runoff hydrograph, possible peak data missing, Interpolating used to fill the gaps.	Yes_Event 2	delayed runoff response	HY043, HY009, HY102	
11/24/2014	6.734	11/24/2014 8:45 AM	good runoff hydrograph - possible ice condition	No	Ice Conditions		
3/11/2015	6.776	3/11/2015 5:45 AM	multiple peaks, possible snow melt event, not proper	No	Snowmelt		
3/17/2015	6.838	3/17/2015 7:15 AM	multiple peaks, possible snow melt event, not proper	No	Snowmelt		
6/16/2015	6.581	6/16/2015 6:00 AM	good runoff hydrograph	Yes_Event 3	Good event	HY044, HY009, HY102	
6/23/2015	9.465	6/23/2015 1:30 AM	Excellent Event, Significant Event	Yes_Event 4	Good event	HY044, HY009, HY102	Good for Cali. Highest Peak, Normal Estimated AMC Conditions
6/28/2015	8.288	6/28/2015 8:30 AM	Significant Event, good event	Yes_Event 5	Multiple Peaks	HY043, HY009, HY102	
10/28/2015	8.855	10/28/2015 9:45 AM	Significant Event, good event, double peak	Yes_Event 6	Multiple Peaks	HY044, HY009, HY102	
1/10/2016	10.054	1/10/16 4:15 AM	Excellent Event, Significant Event, possible ice condition	No	Ice Conditions		
4/16/2018	6.370	4/16/2018 6:30 AM	good runoff hydrograph	Yes_Event 8	Two Gauges Only. Snowmelt	HY009, HY102	Radar coverage received. Added Event
11/27/2018	6.140	11/27/2018 12:30 PM	good runoff hydrograph	Yes_Event 7	High Baseflow	HY043, HY009, HY102	
2/5/2019	6.245	2/5/2019 9:30 AM	good runoff hydrograph, possible ice condition	No	Ice Conditions		
3/15/2019	6.353	3/15/2019 12:45 PM	double peak, possible ice condition, possible snow melt, not proper	No	Snowmelt		

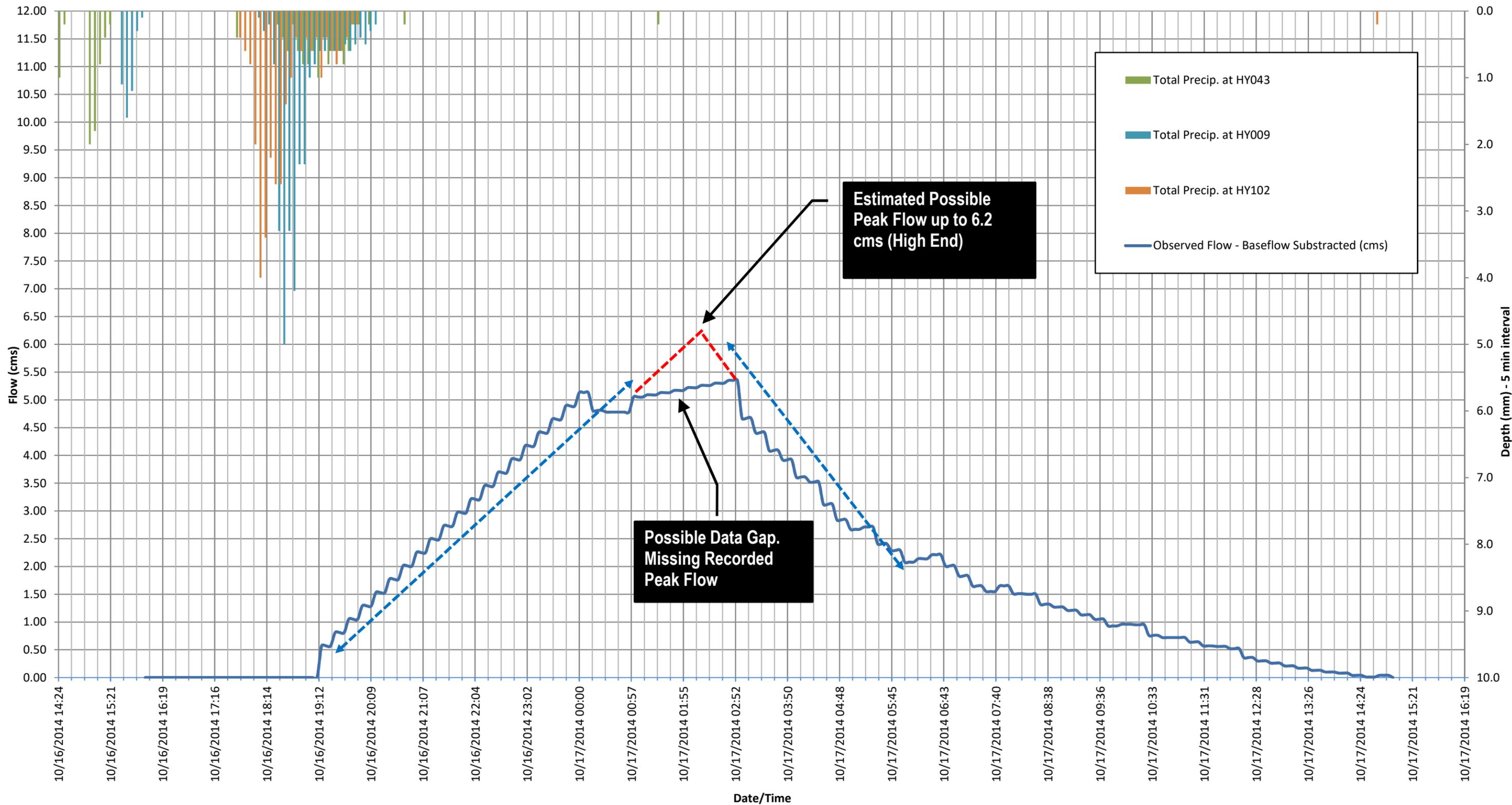
Petticoat Creek Hydrology
 2020.07.21
 Summary of Calibration/Validation Events - Rainfall

Event #	Description	Date	Period		Observed Runoff					Precipitation											Note	Rank by Peak Flow	Rank by Rainfall Intensity	Rank by Rainfall Depth			
					Recorded Peak Discharge Rate	Baseflow Subtracted from Runoff for Calibration and Validation	Recorded Peak Discharge Rate - Baseflow Subtracted	Total Runoff Depth - Baseflow Subtracted	Total Runoff Volume - Baseflow Subtracted	Recorded Time to Peak	Peak Precip. Intensity @ HY043	Total Precipitation Depth @ HY043	Total Precipitation Volume @ HY043	Peak Precip. Intensity @ HY009	Total Precipitation Depth @ HY009	Total Precipitation Volume @ HY009	Peak Precip. Intensity @ HY102	Total Precipitation Depth @ HY102	Total Precipitation Volume @ HY102	Peak Precip. Intensity - Weighted					Total Precipitation Depth - Weighted	Total Precipitation Volume - Weighted	Observed Runoff / Total Weighted Precipitation
			cms	cms	cms	mm	1000 m3	Hr	mm/hr	mm	1000 m3	mm/hr	mm	1000 m3	mm/hr	mm	1000 m3	mm/hr	mm	1000 m3					mm/hr	mm	1000 m3
1	Calibration	21/9/2014	9/21/14 6:00 AM	9/21/14 2:00 PM	6.8	0.1	6.7	2.8	71.6	1.8	52.8	21.0	542.4	39.6	29.7	767.2	43.2	24.8	640.6	45.2	25.2	650.1	11%	Good event	4	2	7
2	Validation	16/10/2014	10/16/14 4:00 PM	10/17/14 3:00 PM	6.9	1.5	5.4	6.5	167.7	10.8	24.0	16.8	433.9	60.0	33.9	875.6	48.0	27.8	718.1	44.0	26.2	675.9	25%	delayed runoff response	7	3	6
3	Calibration	16/6/2015	6/16/15 3:10 AM	6/16/15 11:00 AM	6.6	0.3	6.3	1.5	39.8	2.8	21.6	11.4	294.5	14.4	10.1	260.9	36.0	19.2	495.9	24.0	13.6	350.4	11%	Good event	5	5	8
4	Calibration	22/6/2015	6/22/15 8:55 PM	6/23/15 4:00 PM	9.5	0.1	9.4	11.0	284.5	4.6	50.4	30.4	785.2	54.0	46.9	1211.4	57.6	52.8	1363.8	54.0	43.4	1120.2	25%	Good event	1	1	4
5	Validation	27/6/2015	6/27/15 1:15 PM	6/29/15 3:00 PM	8.3	0.2	8.1	21.9	566.2	19.3	16.8	46.4	1198.5	21.6	49.4	1276.0	14.4	48.2	1245.0	17.6	48.0	1239.8	46%	Multiple Peaks	3	6	3
6	Calibration	28/10/2015	10/28/15 3:05 AM	10/29/15 12:00 PM	8.9	0.1	8.8	14.9	386.1	6.7	14.4	48.2	1245.0	19.2	72.5	1872.7	19.2	69.8	1802.9	17.6	63.5	1640.2	24%	Multiple Peaks	2	7	2
7	Validation	26/11/2018	11/26/18 6:50 AM	11/28/18 8:00 AM	6.1	2.3	3.9	11.8	303.8	17.7	7.2	30.6	790.4	4.8	31.2	805.9	4.8	28.3	731.0	5.6	30.0	775.8	39%	High Baseflow	8	8	5
8	Validation	15/4/2018	4/15/18 6:15 AM	4/17/18 10:00 AM	6.4	0.6	5.8	21.3	549.7	6.4	0.0	0.0	0.0	44.4	75.4	1947.6	16.8	72.8	1880.4	30.6	74.1	1914.0	29%	Two Gauges Only. Snowmelt	6	4	1

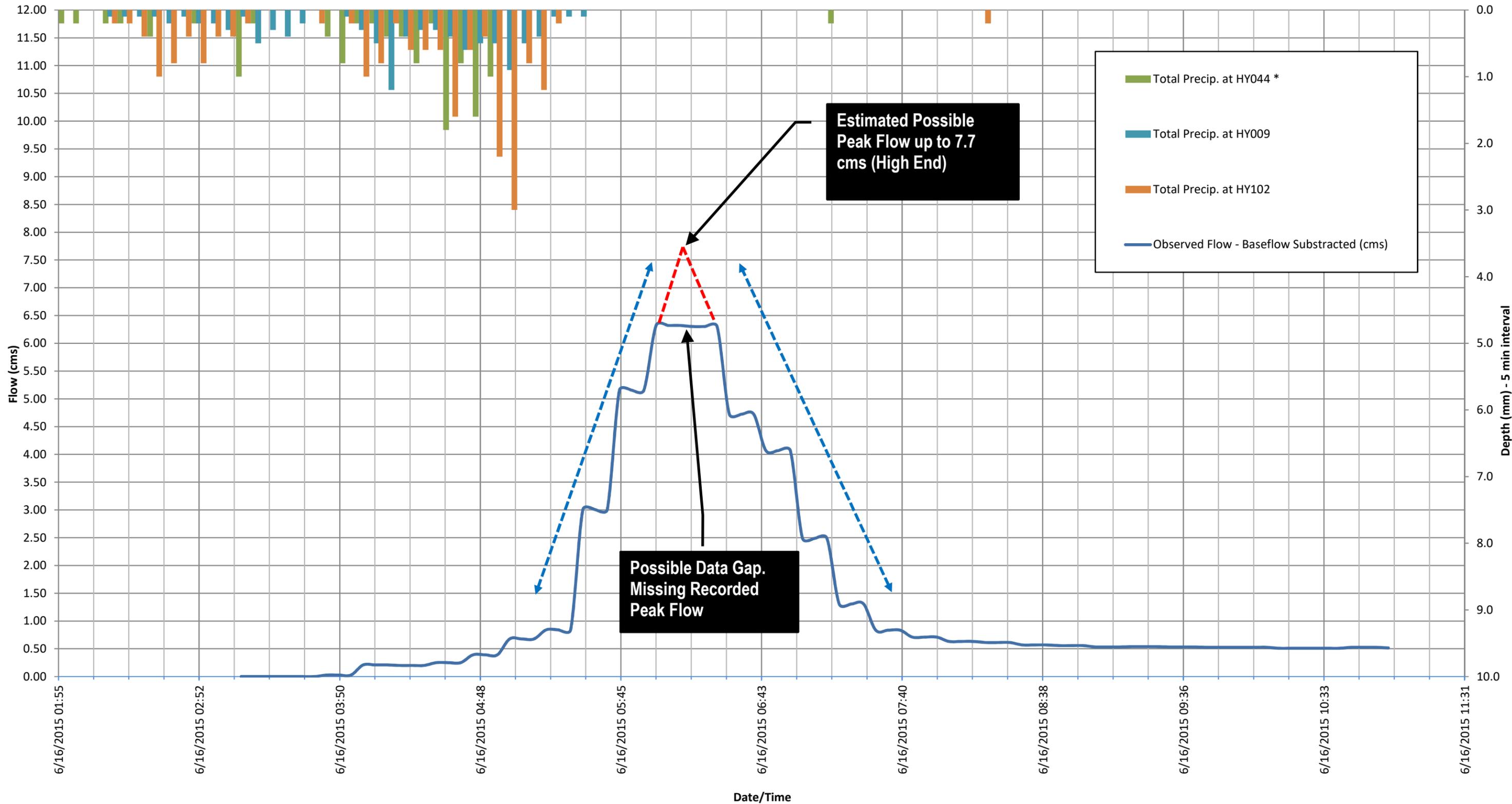
Petticoat Creek - Event 1 - 9/21/2014
Calibration



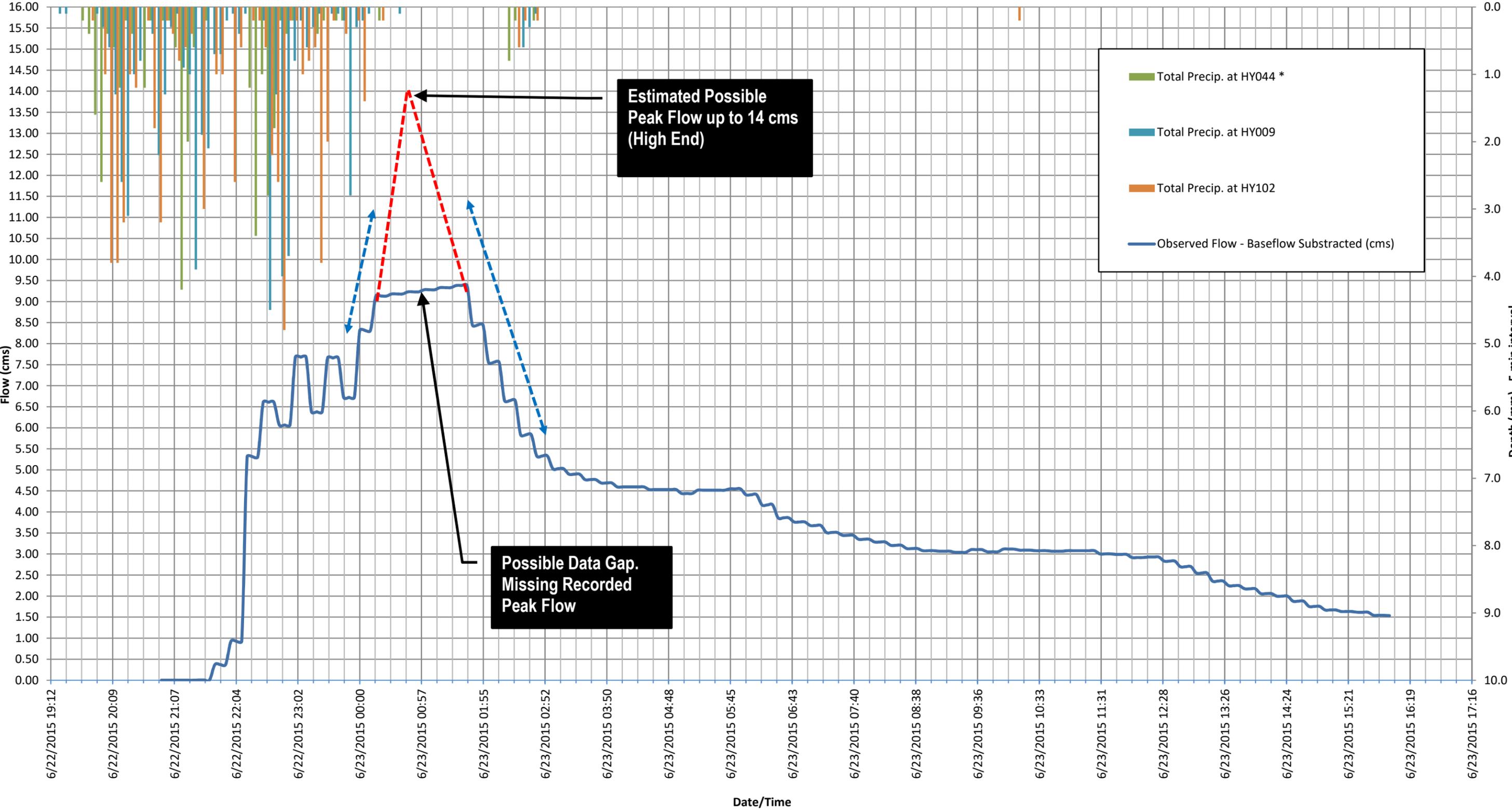
Petticoat Creek - Event 2 - 10/16/2014 Calibration



Petticoat Creek - Event 3 - 6/16/2015
Calibration



Petticoat Creek - Event 4 - 6/22/2015
Calibration

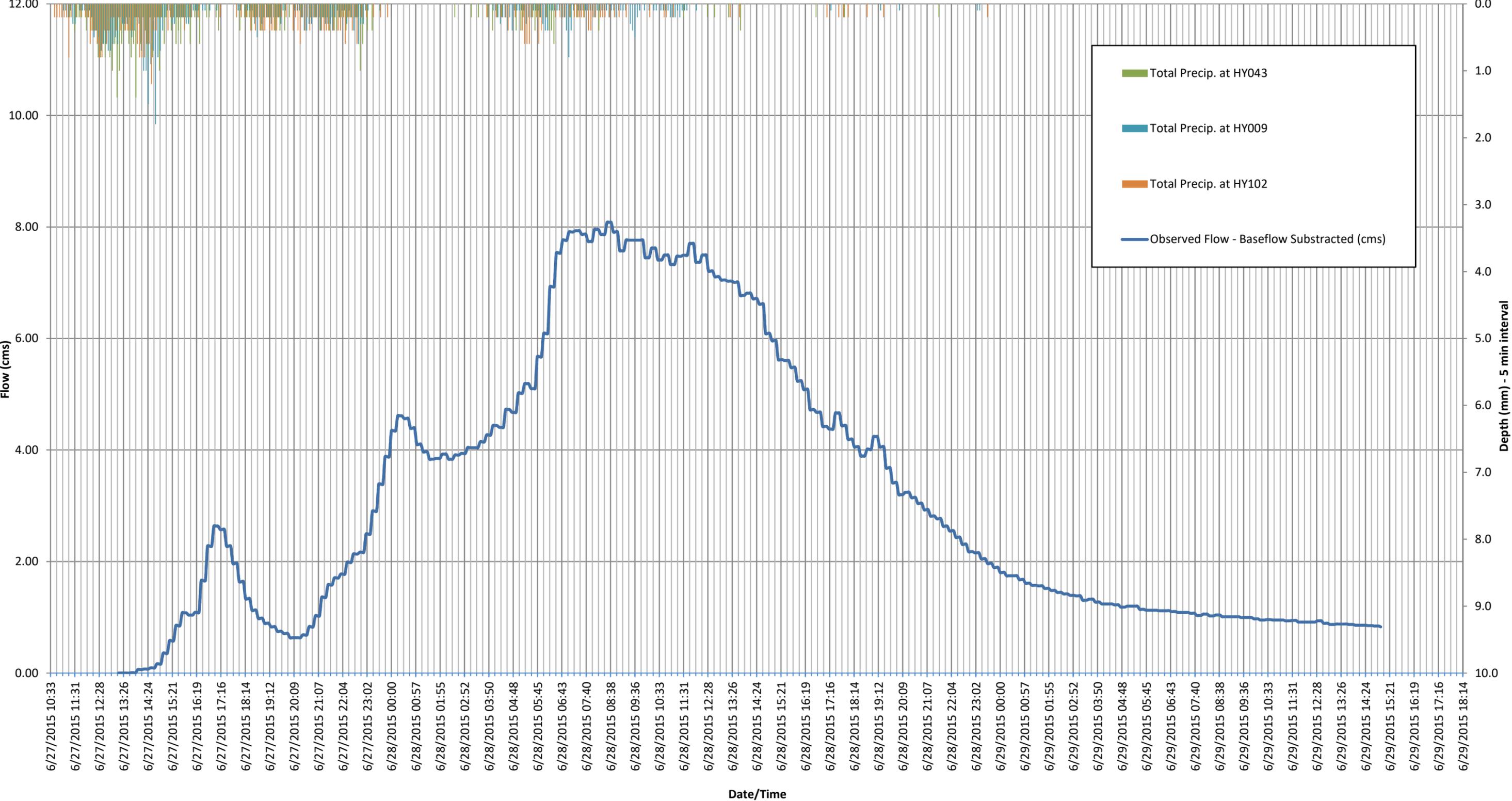


Estimated Possible Peak Flow up to 14 cms (High End)

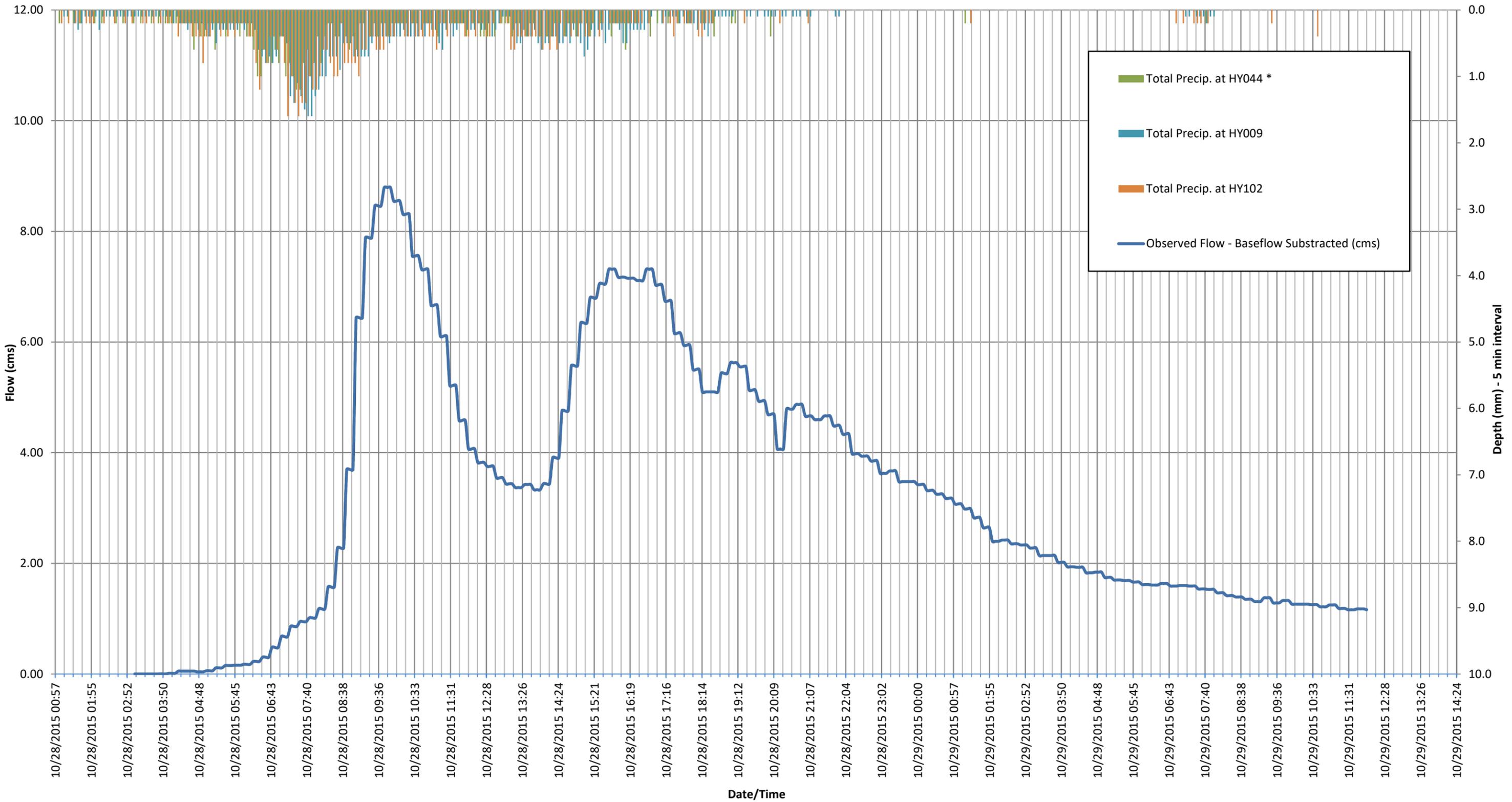
Possible Data Gap. Missing Recorded Peak Flow

- Total Precip. at HY044 *
- Total Precip. at HY009
- Total Precip. at HY102
- Observed Flow - Baseflow Substracted (cms)

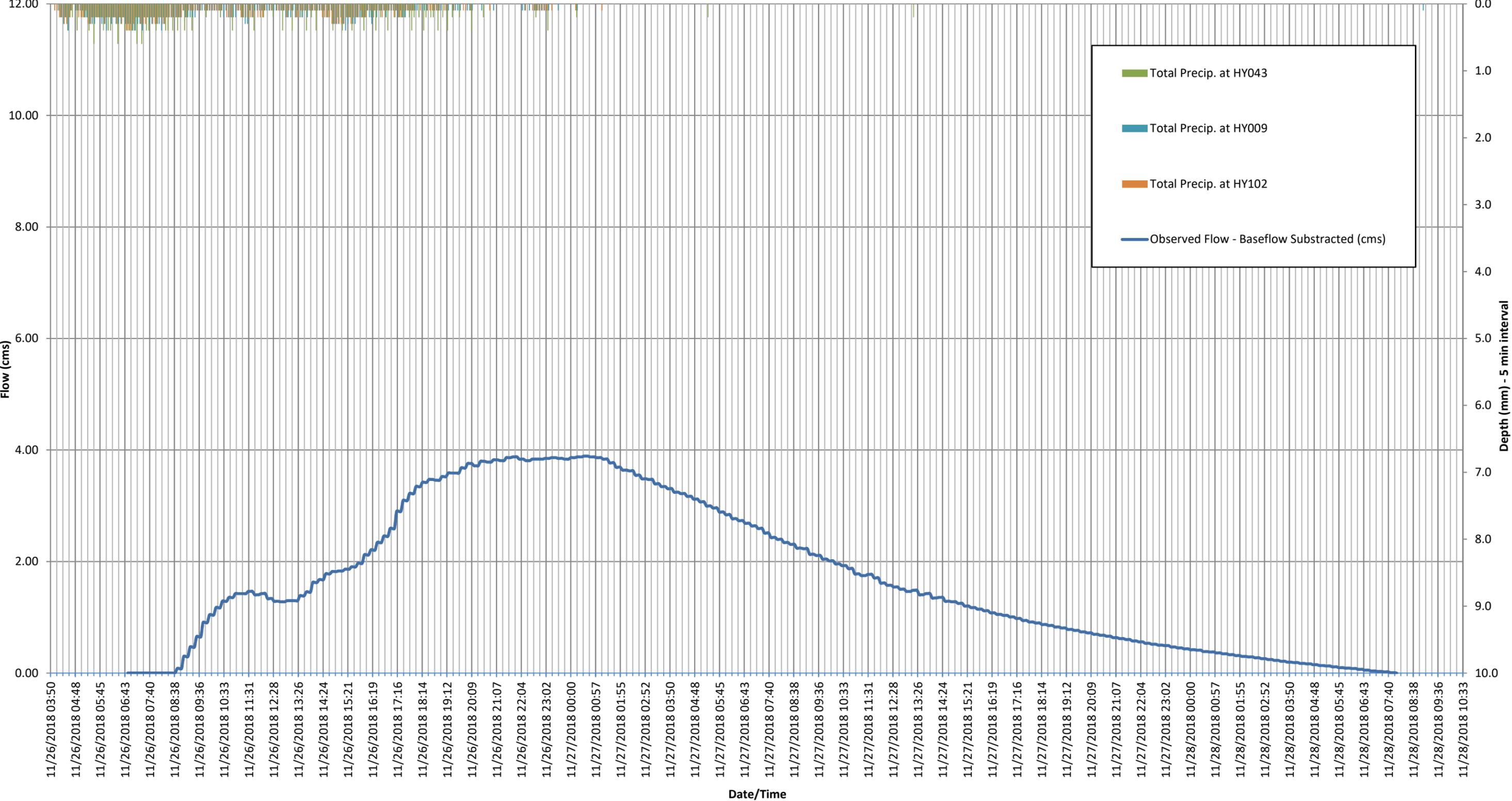
Petticoat Creek - Event 5 - 6/27/2015
Calibration



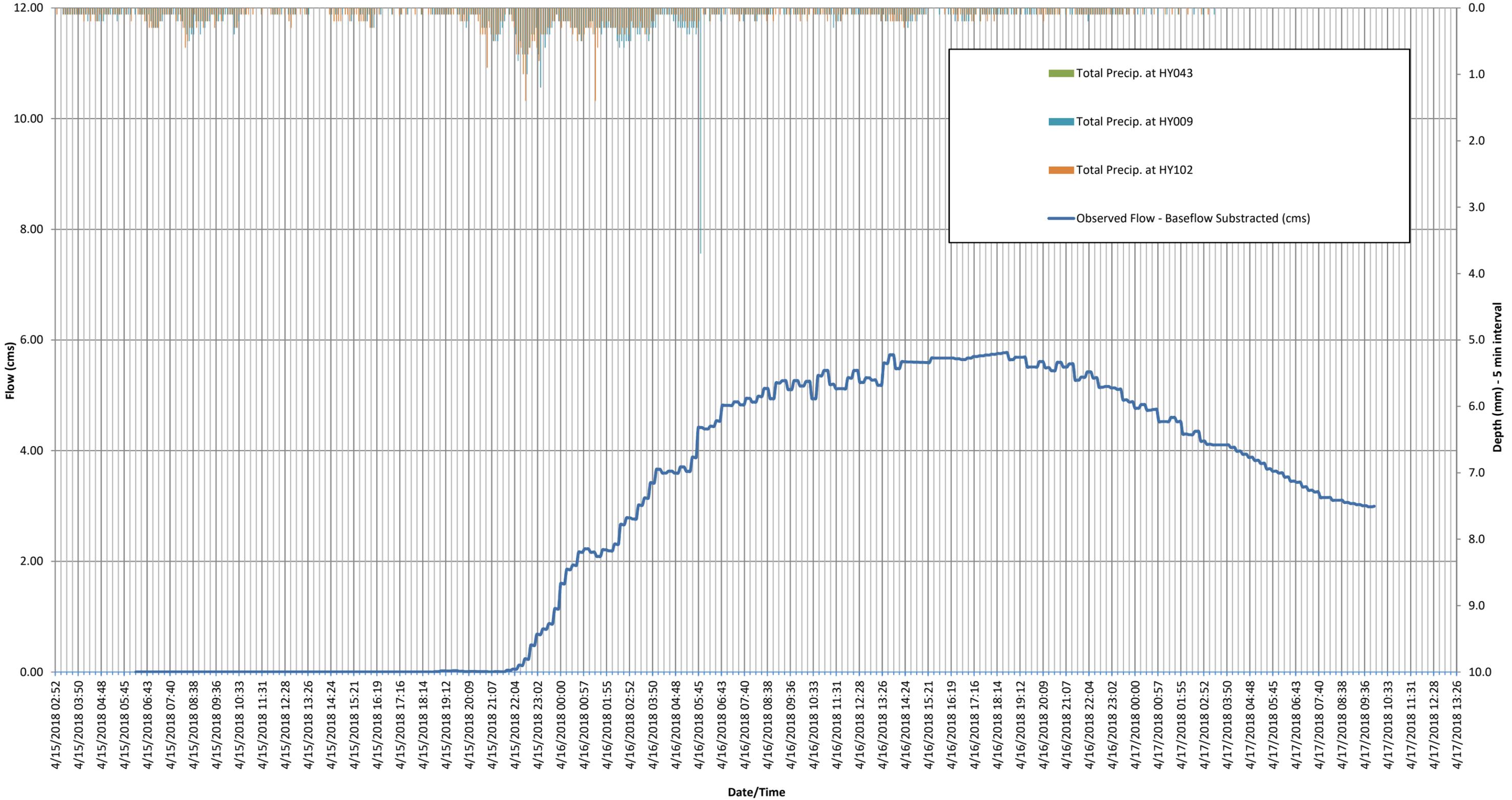
Petticoat Creek - Event 6 - 10/28/2015 Calibration



Petticoat Creek - Event 6 - 10/28/2015 Calibration



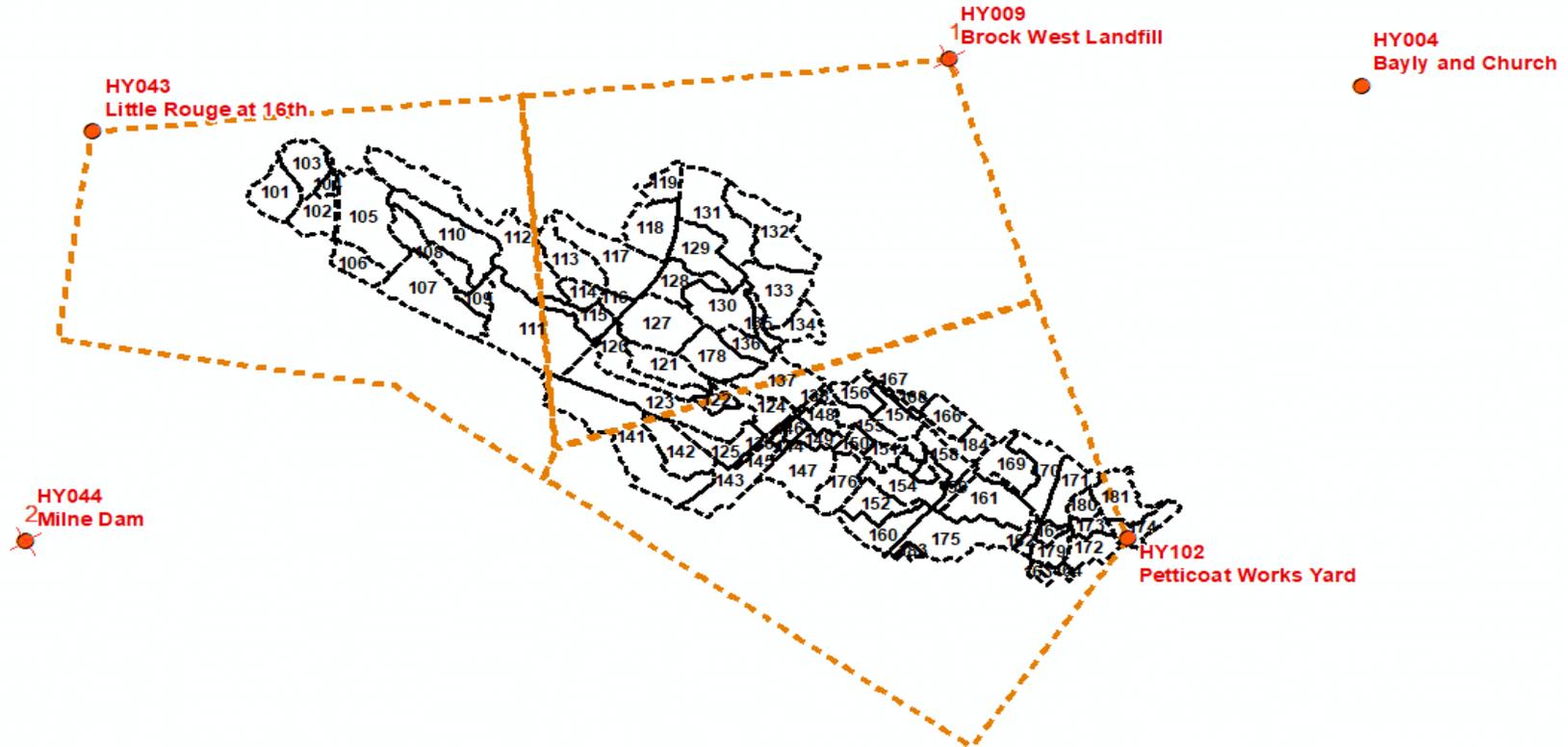
Petticoat Creek - Event 8 - 04/16/2015 Calibration



Event 01, 02, 05, 07

Gauge Used: HY043; HY009; HY102.

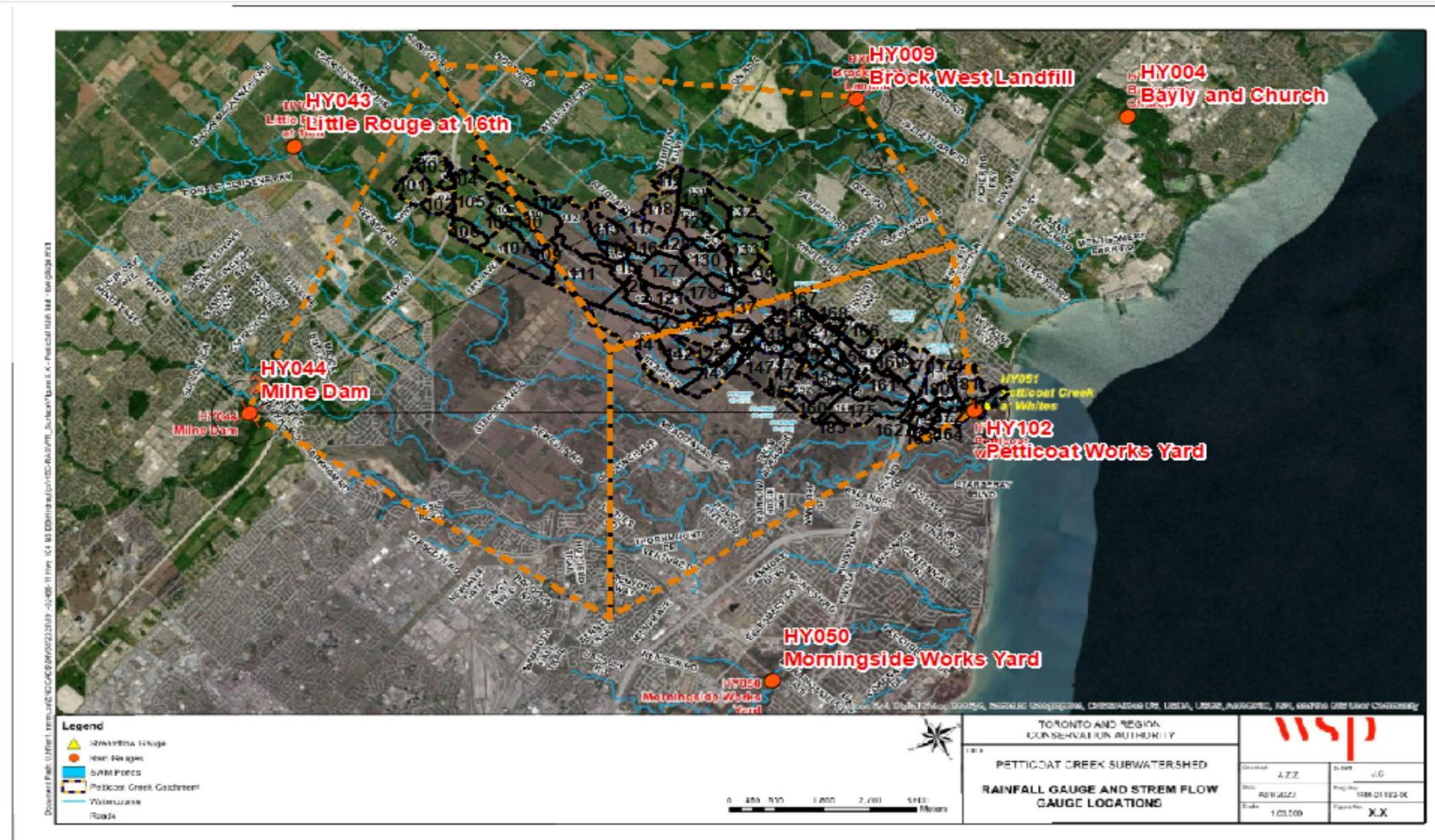
Gauge Unavailable for the Selected Event: HY044



Event 03, 04, 06

Gauge Used: HY044; HY009; HY102.

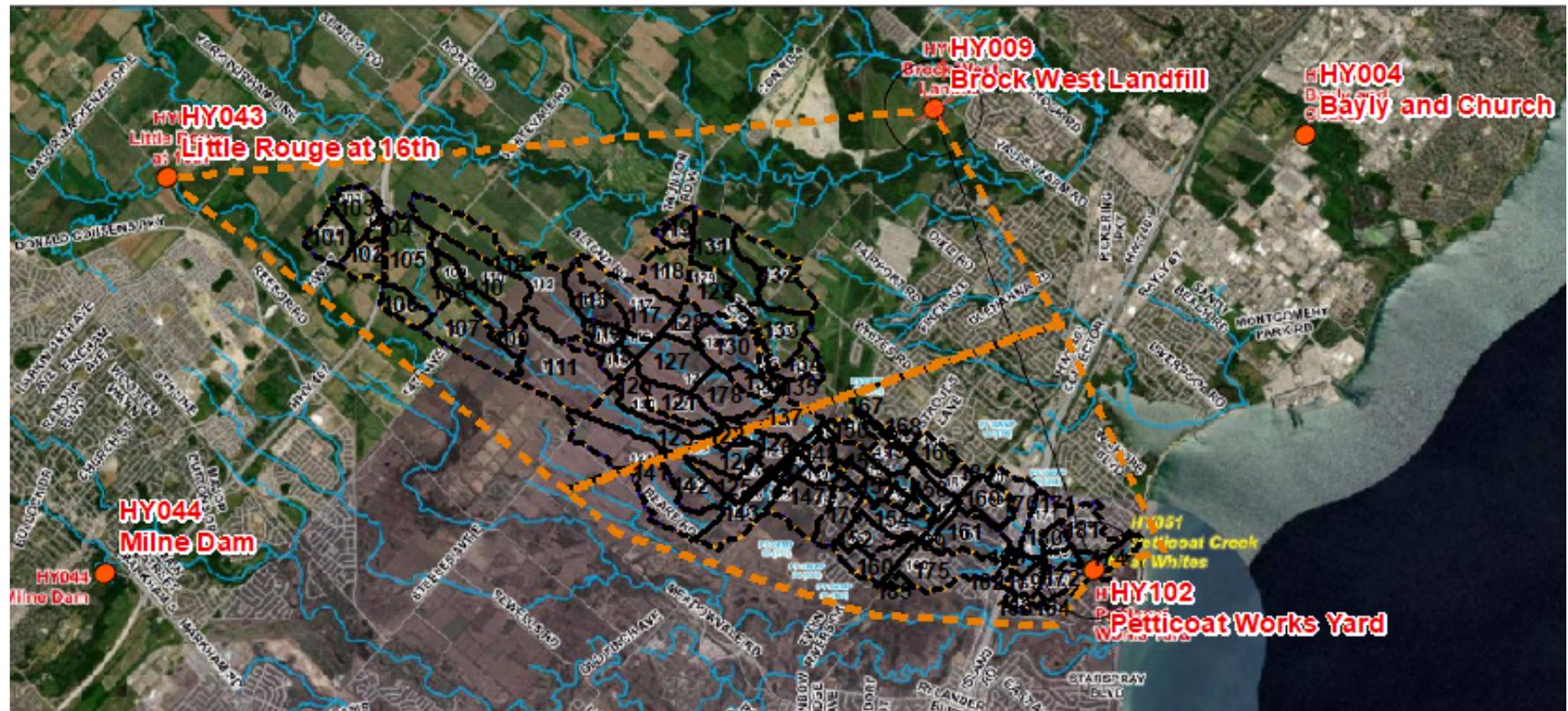
Gauge Unavailable for the Selected Event: HY043



Event 08

Gauge Used: HY009; HY102.

Gauge Unavailable for the Selected Event: HY043; HY044





MODEL
CALIBRATION
AND
VALIDATION

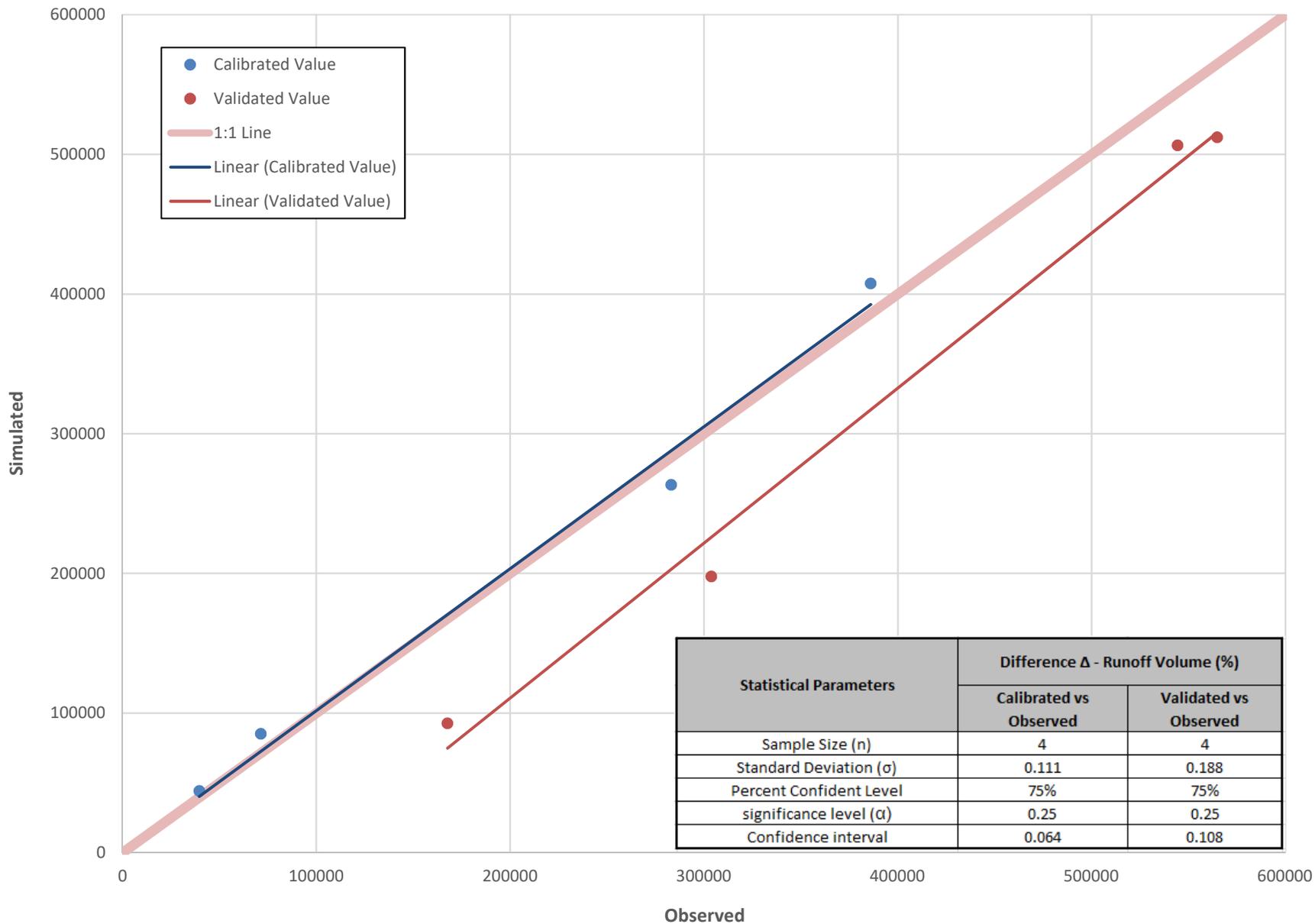
CALIBRATION SUMMARY				NASHYD			STANDHYD					ROUTE CHANNEL	COMPARISON - RUNOFF VOLUME			COMPARISON - PEAK FLOW						Notes				
Event #	Description	Date	RUN ¹⁾	CN ²⁾	N	TP	CN (for Pervious Area) ³⁾	TMIP	XIMP	DPSI (Depression Storage for Impervious Area)	SCI (Storage Coefficient for Impervious Area)	Manning's N	Runoff Volume - cu. M. (Observed)	Runoff Volume - cu.m. (Simulated)	Runoff Volume Difference	Peak Flow - cms (Observed)	Peak Flow - cms (Simulated)	Peak Flow Difference	Peak Flow - cms (Estimated Possible High End Rate due to Data Gap)	Peak Flow - cms (Simulated)	Peak Flow Difference		PaWUG Target - Volume ⁴⁾	PaWUG Target - Peak ³⁾ (with Observed)	PaWUG Target - Peak ³⁾ (with Estimated Possible High End Rate)	
1	Calibration	9/21/2014	01.02	Decrease 12%	1.00	1.00	Decrease 12%	1.00	1.00	1.00	1.00	1.00	71377.20	85222.38	19.4%	6.72	7.44	11%	13.00	7.44	-43%	Meet General Target	Meet General Target	Not Meet	- Fall Event. - Possible data gap and missing recorded peak flow. - Estimated possible peak flow up to 13 cms. - Good Fit (with observed peak). Hydrograph comparison in agreement.	
3	Calibration	6/16/2015	03.02	Decrease 10% (< AMC II and > AMC II)	1.00	1.00	Decrease 10% (< AMC II and > AMC II)	1.00	1.00	1.00	1.00	1.00	39676.50	44242.74	11.5%	6.32	6.54	3%	7.70	6.54	-15%	Meet General Target	Meet Target for Critical Locations	Meet General Target	- Summer Event. - Multiple peaks simulated, while single peak observed. - Possible data gap and missing recorded peak flow. - Estimated possible peak flow up to 7.7 cms.	
4	Calibration	6/22/2015	04.01	AMC I	1.00	1.00	AMC I	1.00	1.00	1.00	1.00	1.00	283078.50	263441.60	-6.9%	9.38	15.04	60%	14.00	15.04	7%	Meet Target for Critical Locations	Not Meet	Meet Target for Critical Locations	- Summer Event. Most Significant Event. - Possible data gap and missing recorded peak flow. - Estimated possible peak flow up to 13 cms. - Good Fit (with Estimated Possible Peak). Hydrograph comparison in agreement.	
6	Calibration	10/28/2015	06.02	Decrease 30% (< AMC I)	1.00	1.00	Decrease 30% (< AMC I)	1.00	1.00	1.00	1.00	1.00	386063.40	407553.73	5.6%	8.79	8.75	0%	n/a	n/a	n/a	Meet Target for Critical Locations	Meet Target for Critical Locations	n/a	- Late Fall / Early Winter Event. - Good Fit. - Multiple peaks during the event. Difficult to determine the direct rainfall-runoff response. - Time to peak not in agreement.	
CALIBRATION SUMMARY					1.00	1.00		1.00	1.00	1.00	1.00	1.00			7%			18%								

1) Results from Final Run are retrieved from detailed hydrograph comparison.
a) Base AMC Conditions: AMC II
b) Dry AMC Conditions: AMC I (Equivalent to Decrease 20% from AMC II)
c) Wet AMC Conditions: AMC III (Equivalent to Increase 17% from AMC II)
2) PaWUG (2002) Target for Flow Volume: +20% to -10% for General Target; +10% to -10% for Critical Locations
3) PaWUG (2002) Target for Peak Flow: +25% to -15% for General Target; +10% to -10% for Critical Locations
4) PaWUG (2002) Targets for at least two of the three (66%) selected storm events.

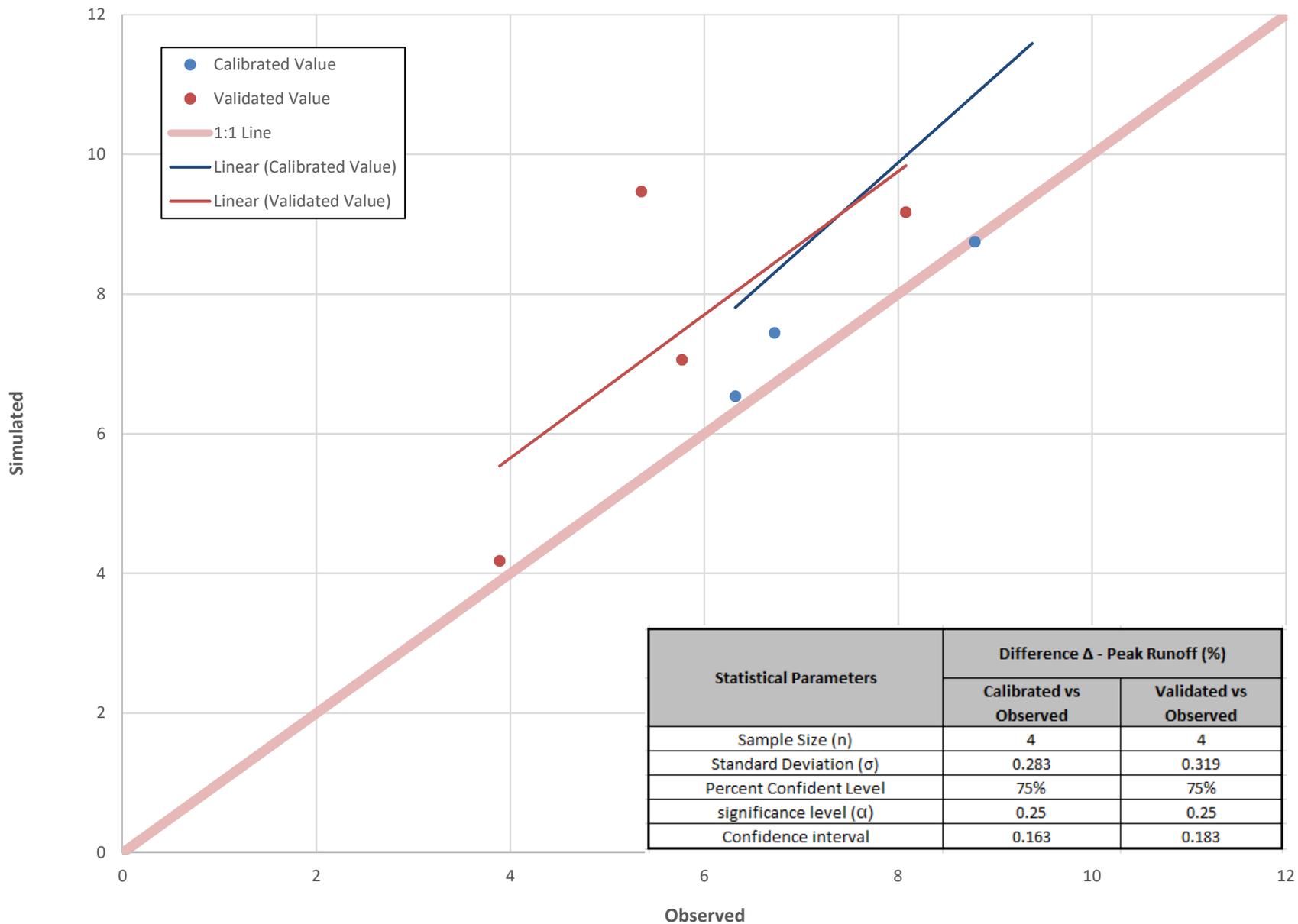
VALIDATION SUMMARY				NASHYD			STANDHYD					ROUTE CHANNEL	COMPARISON - RUNOFF VOLUME			COMPARISON - PEAK FLOW						Notes				
Event #	Description	Date	RUN ¹⁾	CN ²⁾	N	TP	CN (for Pervious Area) ³⁾	TMIP	XIMP	DPSI (Depression Storage for Impervious Area)	SCI (Storage Coefficient for Impervious Area)	Manning's N	Runoff Volume - cu. M. (Observed)	Runoff Volume - cu.m. (Simulated)	Runoff Volume Difference	Peak Flow - cms (Observed)	Peak Flow - cms (Simulated)	Peak Flow Difference	Peak Flow - cms (Estimated Possible High End Rate due to Data Gap)	Peak Flow - cms (Simulated)	Peak Flow Difference		PaWUG Target - Volume ⁴⁾	PaWUG Target - Peak ³⁾ (with Observed)	PaWUG Target - Peak ³⁾ (with Estimated Possible High End Rate)	
2	Validation	10/16/2014	02.01	AMC I			AMC I						167694.00	92688.34	-44.7%	5.35	9.47	77%	6.20	9.47	53%	Not Meet	Not Meet	Not Meet	- Late Fall / Early Winter Event. - Peak intensity occur significantly earlier than the peak runoff. - Unreliable streamflow data expected. - Multiple peaks simulated, while single peak observed. - Possible data gap and missing recorded peak flow. - Estimated possible peak flow up to 6.2 cms.	
5	Validation	6/27/2015	05.01	Increase 5% (> AMC II and < AMC III)	1.00	1.00	Increase 5% (> AMC II and < AMC III)	1.00	1.00	1.00	1.00	1.00	564718.80	512192.58	-9.3%	8.08	9.17	14%	n/a	n/a	n/a	Meet Target for Critical Locations	Meet General Target	n/a	- Summer Event. - Good Fit. - Multiple peaks during the event. Difficult to determine the direct rainfall-runoff response. - Time to peak not in agreement.	
7	Validation	11/26/2018	07.00	AMCII			AMCII						303847.20	197870.18	-34.9%	3.89	4.18	7%	n/a	n/a	n/a	Not Meet	Meet Target for Critical Locations	n/a	- Early Winter Event. - Runoff Volume not in agreement due to possible snow melt amount. - Good Fit with Observed Peak / Hydrograph comparison in agreement.	
8	Validation	4/15/2018	08.04	Decrease 27% (< AMC I)			Decrease 27% (< AMC I)						544352.40	506567.49	-6.9%	5.77	7.06	22%	n/a	n/a	n/a	Meet Target for Critical Locations	Meet General Target	n/a	- Early Spring Event. - General Fit with Observed Peak / Hydrograph comparison in agreement.	
VALIDATION SUMMARY					1.00	1.00		1.00	1.00	1.00	1.00	1.00			-24%			30%								

1) Results from Final Run are retrieved from detailed hydrograph comparison.
a) Base AMC Conditions: AMC II
b) Dry AMC Conditions: AMC I (Equivalent to Decrease 20% from AMC II)
c) Wet AMC Conditions: AMC III (Equivalent to Increase 17% from AMC II)
2) PaWUG (2002) Target for Flow Volume: +20% to -10% for General Target; +10% to -10% for Critical Locations
3) PaWUG (2002) Target for Peak Flow: +25% to -15% for General Target; +10% to -10% for Critical Locations
4) PaWUG (2002) Targets for at least two of the three (66%) selected storm events.

Runoff Volume (m³) Comparison _ Petticoat Creek Calibration



Peak Flow Rate (m³/s) Comparison _ Petticoat Creek Calibration



Code of Practice for the Hydraulic Modelling of Urban Drainage Systems

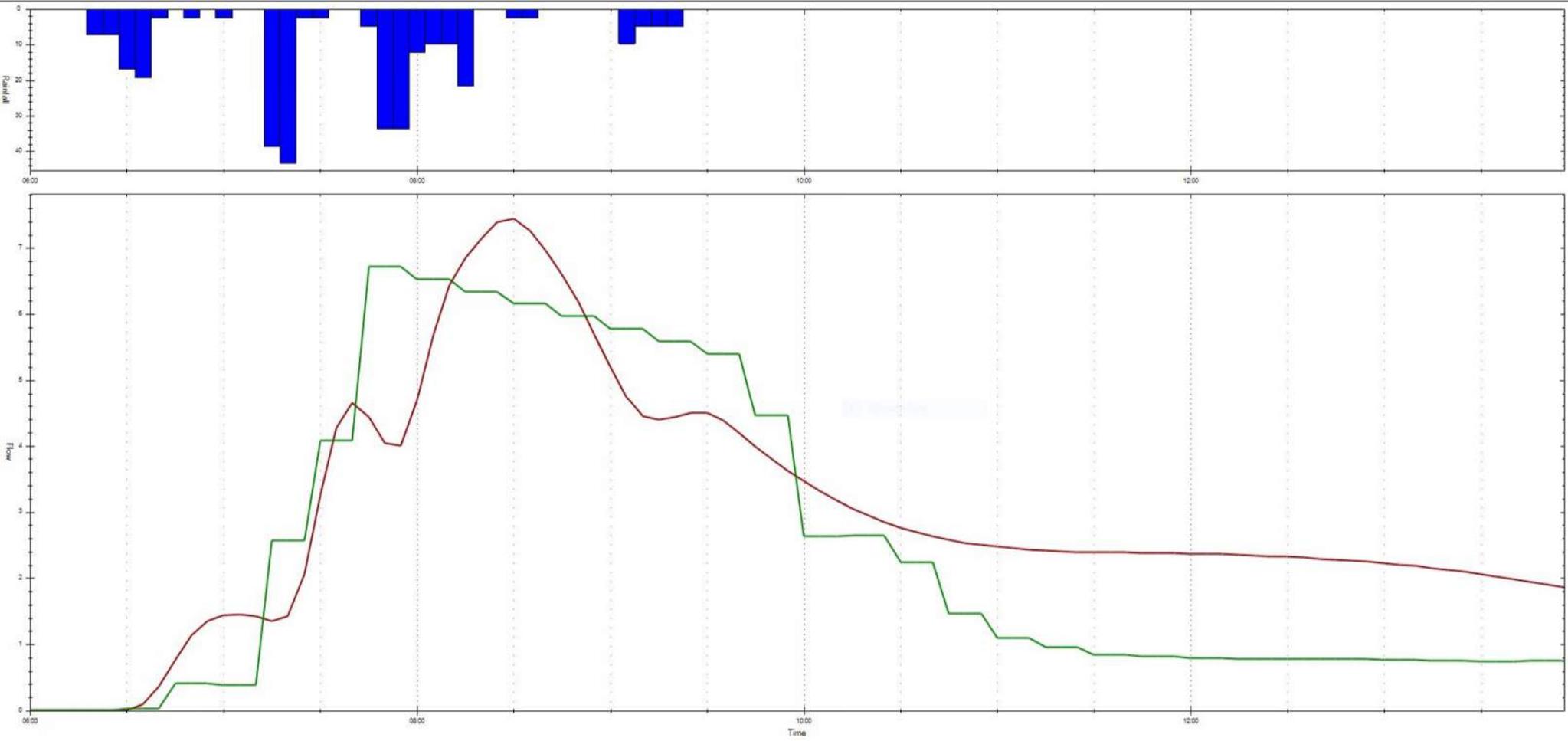
Version 01

In addition to the shape, the observed and predicted hydrographs should aim to meet the targets in Table 5-1 for **at least two of the three selected storm events**. This comparison can be applied to more than three events to improve confidence. At locations that are critical to the use of the model a higher standard of verification should be aimed for as detailed in Table 5-1. Critical locations will be agreed with the Commissioning Body and will typically include flooding locations, CSOs and WwTWs where the accuracy of the model is important in the replication of the system. Modellers should not lose sight of the model's purpose and project scope in undertaking verification against the targets set in Table 5-1. Each site must be viewed in context, and the implications of the achievement or non-achievement of targets should be assessed against the effect that this will have on the model's purpose and use. Implications of non-achievement of targets is discussed later in **section 5.5**.

Table 5-1 Storm Verification Targets

Parameter	General	Critical Locations	Comments
Shape	Good match (NSEC if used >0.5)	Good match (NSEC if used >0.5)	An evaluation technique may be used to compare the shape such as the Nash-Sutcliffe Efficiency Co-efficient (NSEC) method together with a visual check. More information on this approach is included in Appendix G
Time of peaks and troughs	±0.5 hour	±0.5 hour	The timing of the peaks and troughs should be similar having regard to the duration of the event
Peak depth (un-surcharged)	±0.1m or ±10% whichever is greater	±0.1m	
Peak depth (surcharged)	+0.5m to - 0.1m	±0.1m	Relaxation may be appropriate in deep sewers. Where coupled 1D-2D models are used the 'critical locations' criteria should apply
Peak flow	+ 25% to -15%	±10%	
Flow volume	+20% to -10%	±10%	Excluding poor / missing data

Observed/Simulation Plot



	Min	Max	Volume
Observed - FLOW_01_20140921.csv	0.000	6.724	71377.200
Modeled - 5174 - Outlet to Lake Ontario (Gauge)	0.000	7.444	85222.377
% Difference	-	10.710	19.397

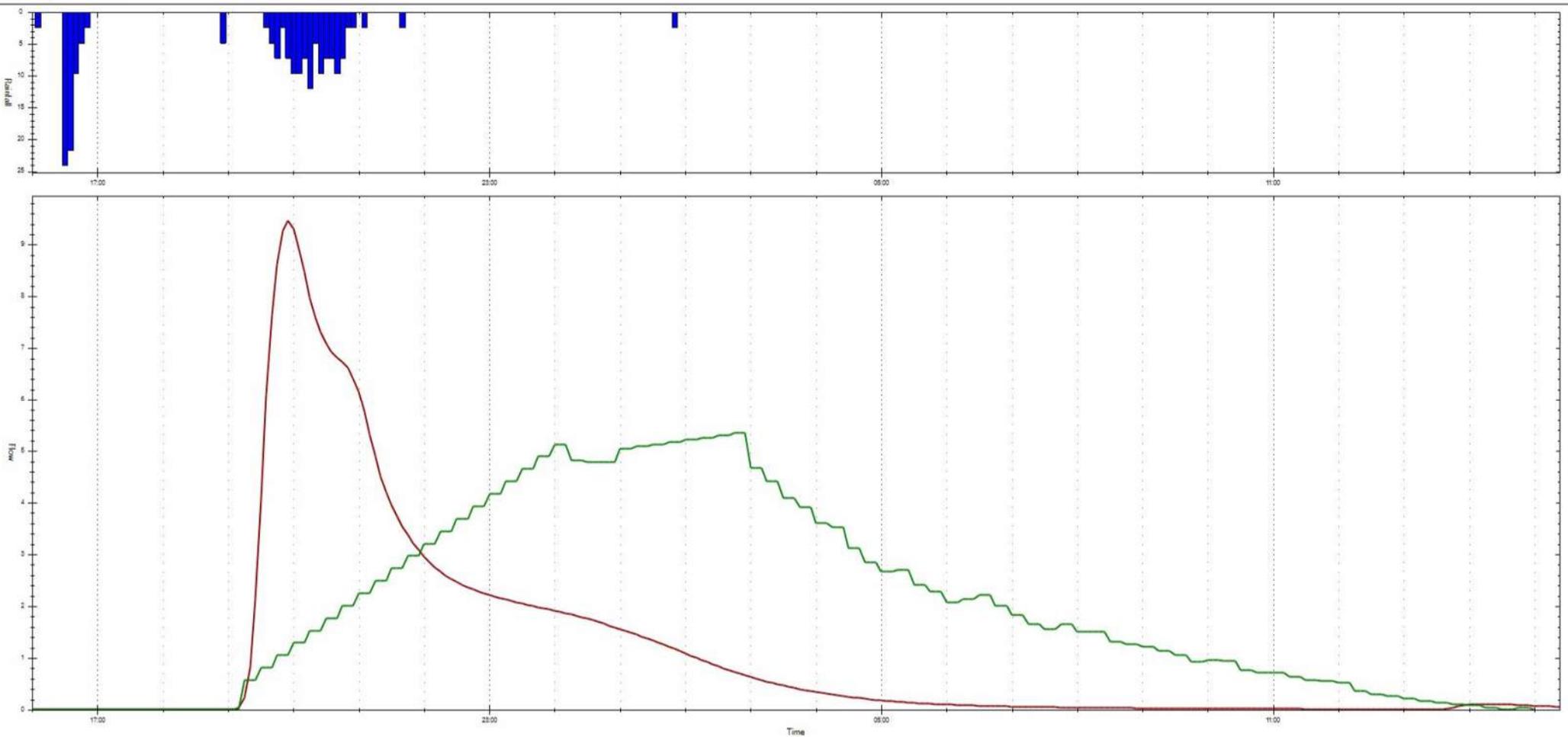
← Observed Flow: FLOW_01_20140921.csv

Run: Event 01

Gauge Location: 5174 - Outlet to Lake Ontario (Gauge)

Hyetograph: HY102 →

Observed/Simulation Plot



	Min	Max	Volume
Observed - FLOW_02_20141016.csv	0.000	5.350	167706.000
Modeled - 5174 - Outlet to Lake Ontario (Gauge)	0.000	9.469	92688.338
% Difference	-	76.989	-44.732

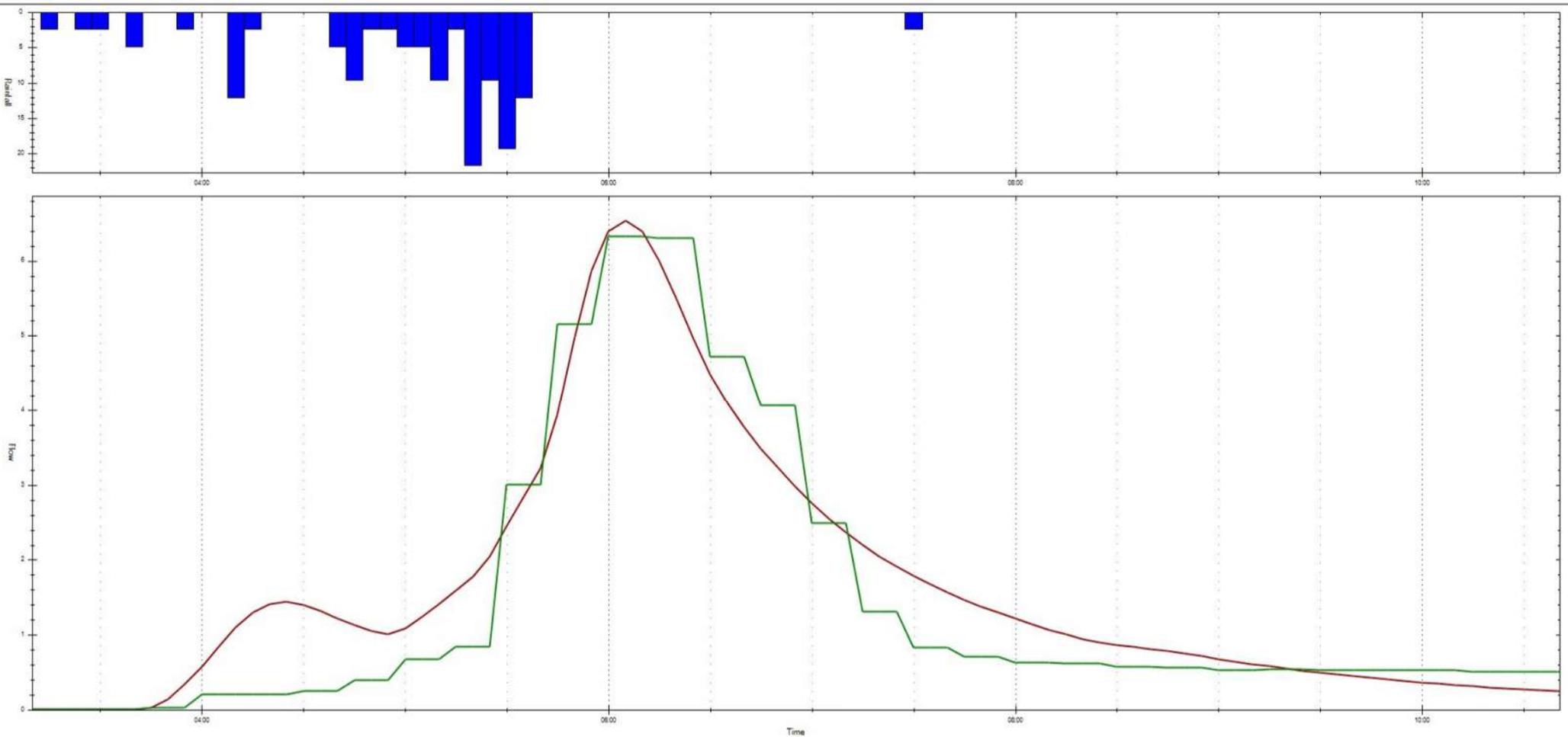
← Observed Flow: FLOW_02_20141016.csv

Run: Event 02

Gauge Location: 5174 - Outlet to Lake Ontario (Gauge)

Hyetograph: HY043 →

Observed/Simulation Plot



	Min	Max	Volume
Observed - FLOW_03_20150616.csv	0.000	6.321	39202.200
Modeled - 5174 - Outlet to Lake Ontario (Gauge)	0.000	6.538	44242.736
% Difference	-	3.431	12.858

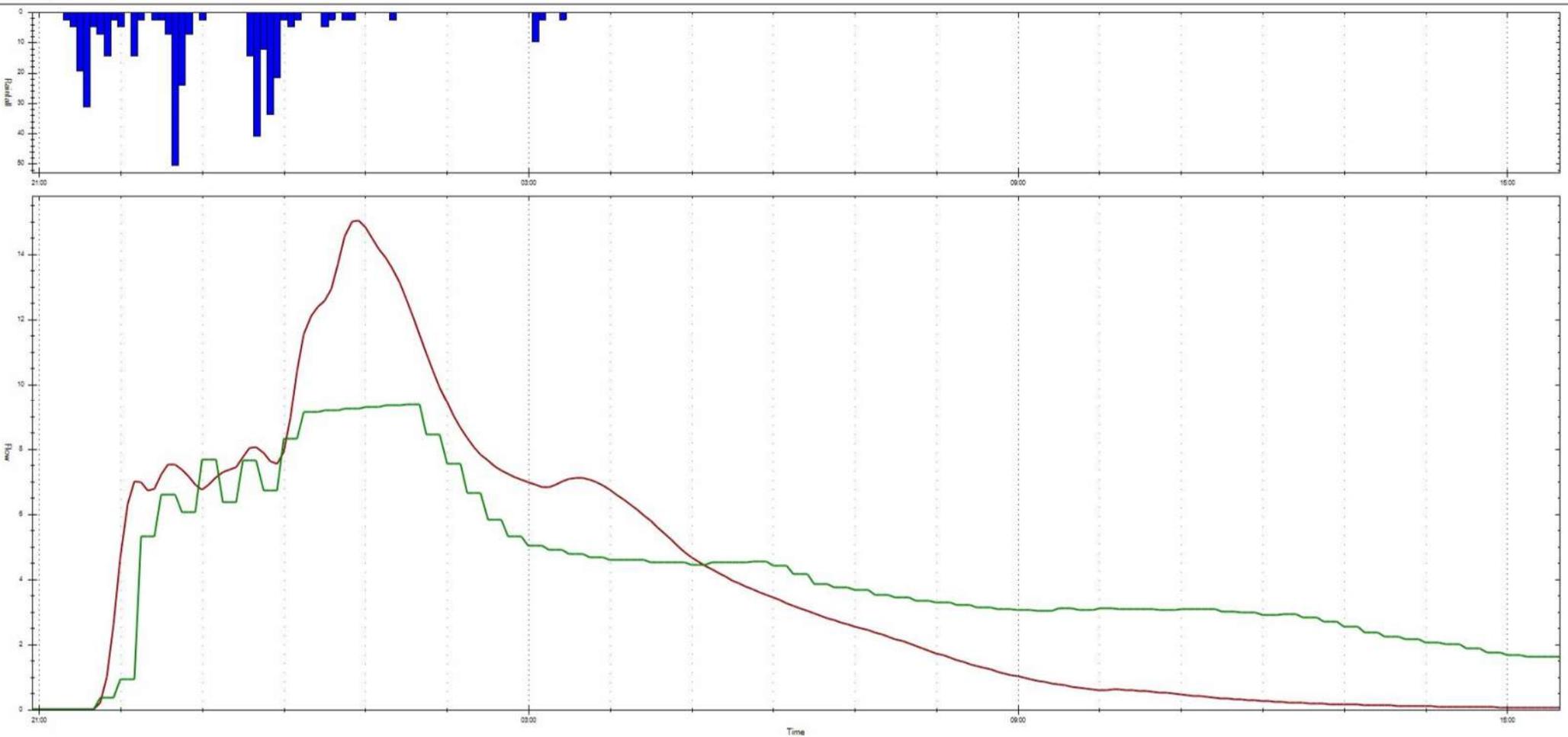
← Observed Flow: FLOW_03_20150616.csv

Run: Event 03

Gauge Location: 5174 - Outlet to Lake Ontario (Gauge)

Hyetograph: HY044 →

Observed/Simulation Plot



	Min	Max	Volume
Observed - FLOW_04_20150622.csv	0.000	9.382	282130.500
Modeled - 5174 - Outlet to Lake Ontario (Gauge)	0.000	15.041	263441.596
% Difference	-	60.313	-6.624

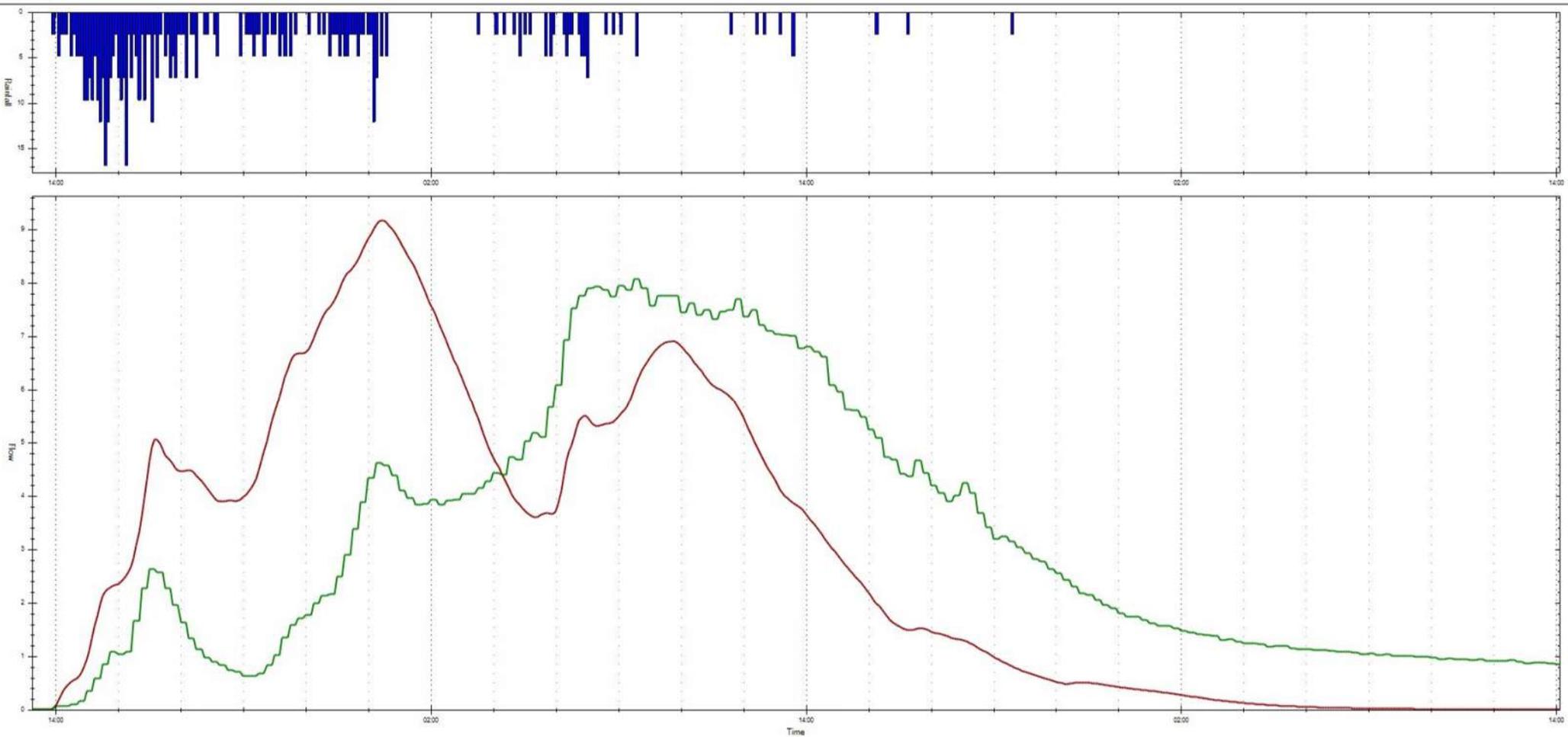
Observed Flow: FLOW_04_20150622.csv

Run: Event 04

Gauge Location: 5174 - Outlet to Lake Ontario (Gauge)

Hytograph: HY044

Observed/Simulation Plot



	Min	Max	Volume
Observed - FLOW_05_20150627.csv	0.000	8.080	563435.400
Modeled - 5174 - Outlet to Lake Ontario (Gauge)	0.000	9.173	512192.584
% Difference	-	13.529	-9.095

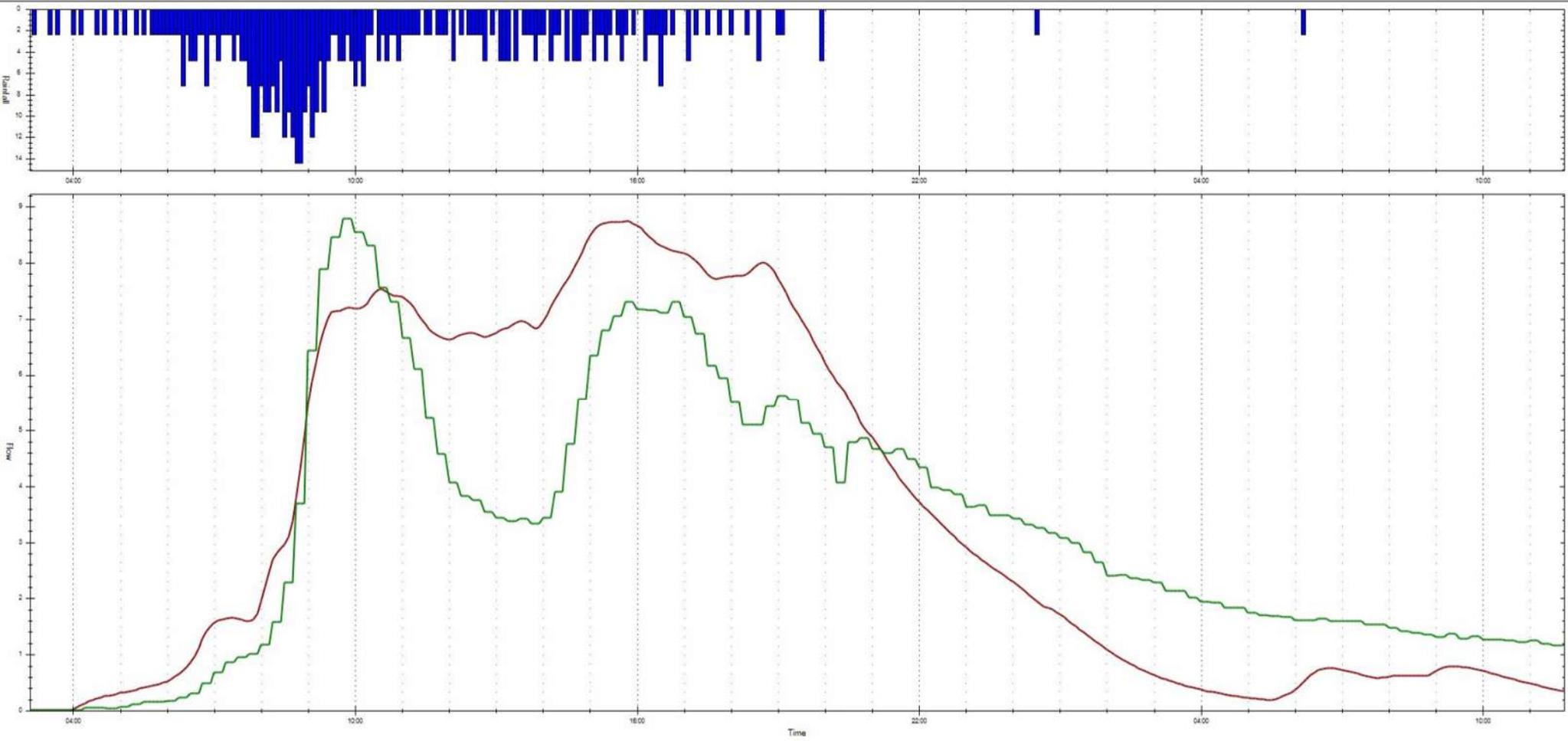
Observed Flow: FLOW_05_20150627.csv

Run: Event 05

Gauge Location: 5174 - Outlet to Lake Ontario (Gauge)

Hyetograph: HY043

Observed/Simulation Plot



	Min	Max	Volume
Observed - FLOW_06_20151028.csv	0.000	8.791	384655.500
Modeled - 5174 - Outlet to Lake Ontario (Gauge)	0.000	8.748	407553.732
% Difference	-	-0.492	5.953

← Observed Flow: FLOW_06_20151028.csv

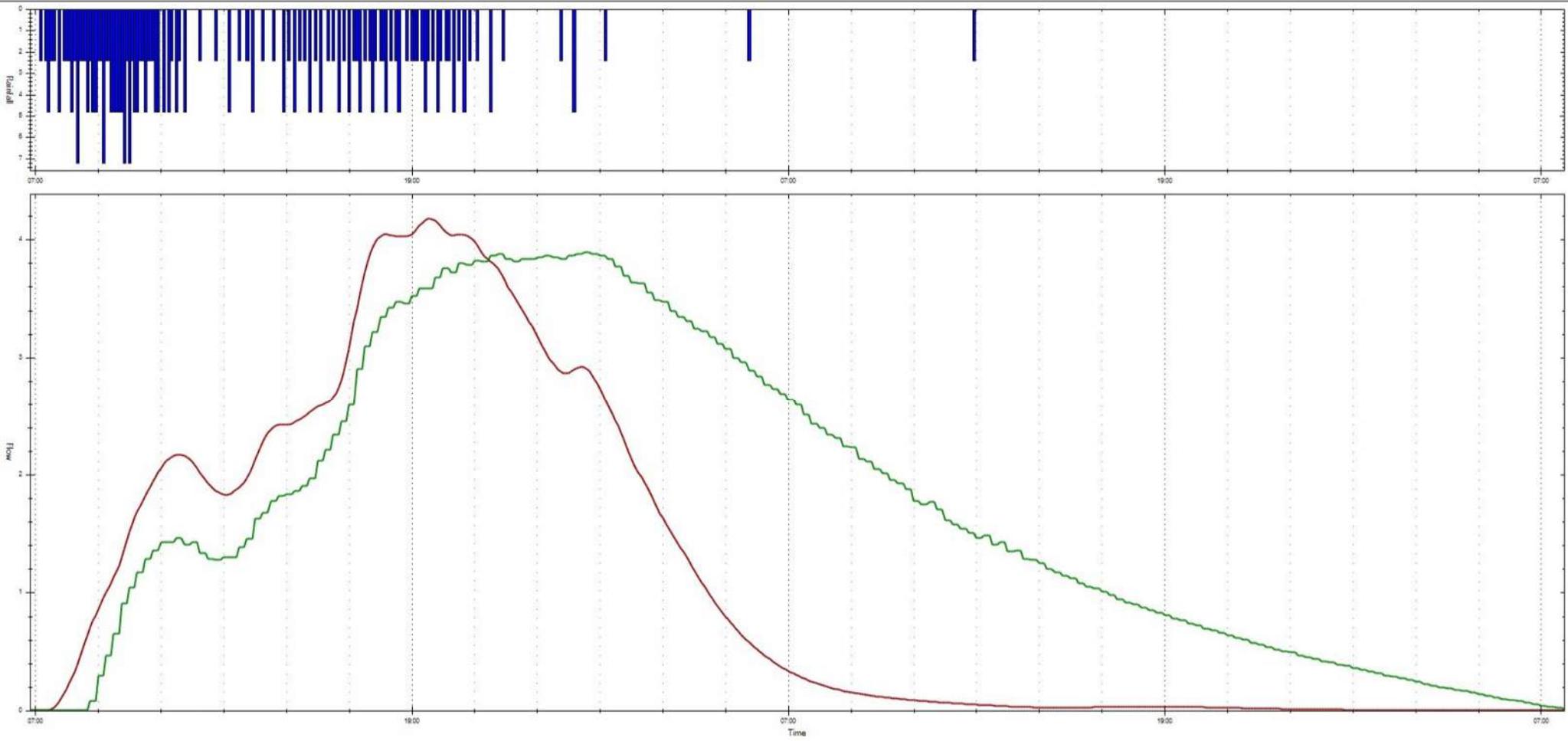
Run: Event 06

Gauge Location: 5174 - Outlet to Lake Ontario (Gauge)

Hyetograph: HY044



Observed/Simulation Plot



	Min	Max	Volume
Observed - FLOW_07_20181126.csv	0.000	3.890	303847.200
Modeled - 5174 - Outlet to Lake Ontario (Gauge)	0.000	4.178	197870.181
% Difference	--	7.404	-34.878

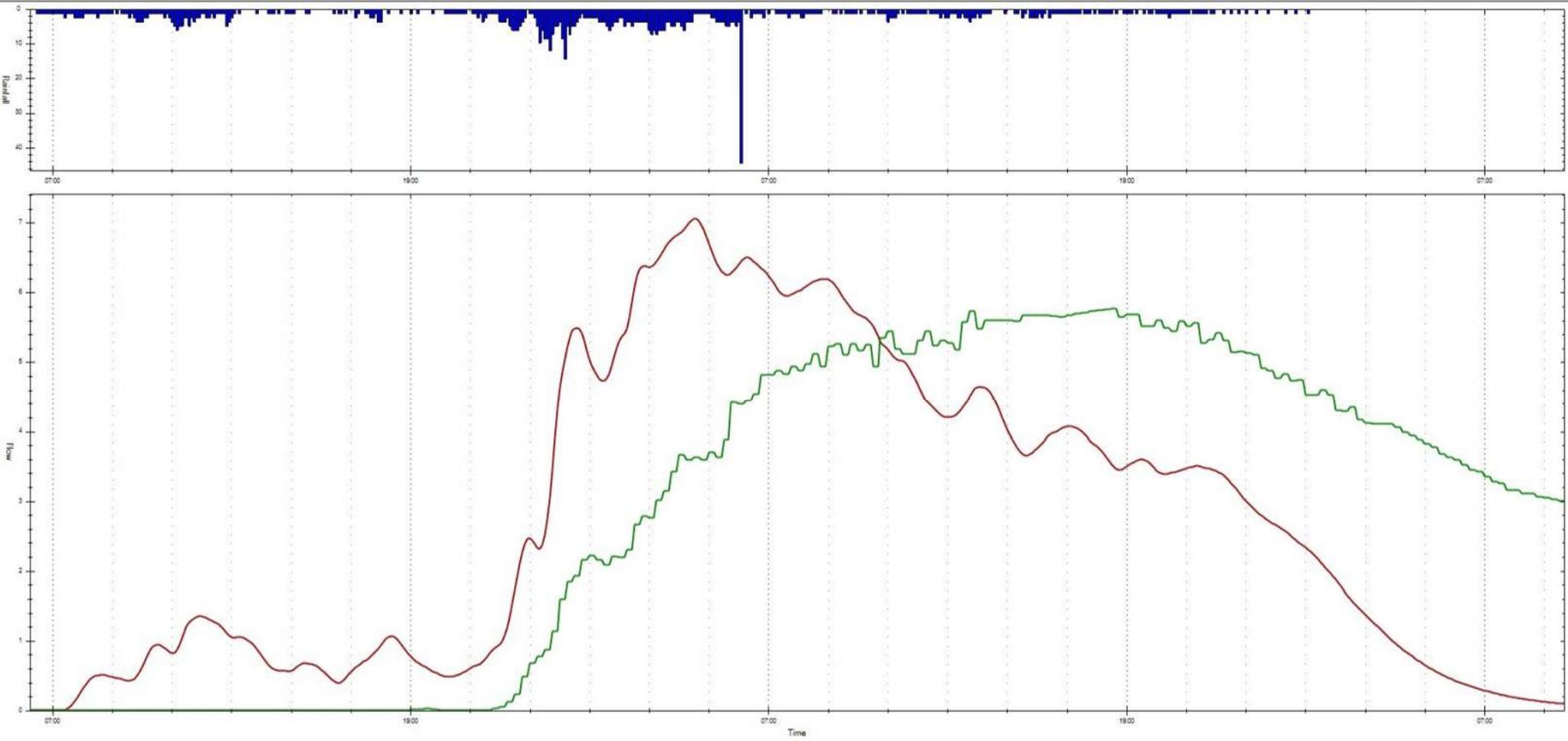
Observed Flow: FLOW_07_20181126.csv

Run: Event 07

Gauge Location: 5174 - Outlet to Lake Ontario (Gauge)

Hyetograph: HY043

Observed/Simulation Plot



	Min	Max	Volume
Observed - FLOW_08_20180415.csv	0.000	5.769	546156.000
Modeled - 5174 - Outlet to Lake Ontario (Gauge)	0.000	7.060	506567.486
% Difference	--	22.376	-7.249

← Observed Flow: FLOW_08_20180415.csv

Run: Event 08

Gauge Location: 5174 - Outlet to Lake Ontario (Gauge)

Hyetograph: HY009



J

SELECTION OF
RAINFALL
DISTRIBUTION

A. Existing Model - Design Storm Selection

WATERSHED	NODE	VO NHYD	NAME	Effective Drainage Area (ha)	1	2	3	4
					01. 100-Yr _ AES 1hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	02. 100-Yr _ AES 6hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	03. 100-Yr _ AES 12hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	04. 100-Yr _ AES 24hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City
Petticoat	5102	5102	Hwy 407	61.2	2.31	2.24	1.64	1.21
	5104	5104	Hwy 407	40.7	1.13	1.33	1.01	0.71
	5111	5111	Taunton Road West East Trib	503.0	8.13	12.56	10.76	7.62
	5116	5116	Taunton Road West Main Branch	210.8	4.26	5.76	4.77	3.36
	5146	5146	Finch Ave Main Branch	1800.3	24.95	39.22	34.70	25.15
	5149	5149	CNR Main Branch	1841.3	24.79	39.35	34.95	25.32
	5161	5161	Sheppard Ave Main Branch	2138.8	25.51	42.32	39.57	29.57
	5165	5165	Hwy 401 Main Branch	2311.5	35.25	43.21	41.78	31.77
	5171	5171	Hwy 401 West Trib	157.7	18.38	9.86	7.20	4.68
5174	5174	Outlet to Lake Ontario	2568.0	52.11	45.53	46.05	35.66	

UNIT RATES

WATERSHED	NODE	VO NHYD	NAME	Effective Drainage Area (ha)	1	2	3	4
					01. 100-Yr _ AES 1hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	02. 100-Yr _ AES 6hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	03. 100-Yr _ AES 12hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	04. 100-Yr _ AES 24hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City
Petticoat	5102	5102	Hwy 407	61.2	0.03774	0.03661	0.02686	0.01978
	5104	5104	Hwy 407	40.7	0.02781	0.03267	0.02481	0.01751
	5111	5111	Taunton Road West East Trib	503.0	0.01616	0.02497	0.02139	0.01514
	5116	5116	Taunton Road West Main Branch	210.8	0.02021	0.02733	0.02260	0.01591
	5146	5146	Finch Ave Main Branch	1800.3	0.01386	0.02178	0.01928	0.01397
	5149	5149	CNR Main Branch	1841.3	0.01347	0.02137	0.01898	0.01375
	5161	5161	Sheppard Ave Main Branch	2138.8	0.01193	0.01979	0.01850	0.01382
	5165	5165	Hwy 401 Main Branch	2311.5	0.01525	0.01870	0.01807	0.01374
	5171	5171	Hwy 401 West Trib	157.7	0.11655	0.06252	0.04569	0.02970
5174	5174	Outlet to Lake Ontario	2568.0	0.02029	0.01773	0.01793	0.01389	
				Average	0.02933	0.02835	0.02341	0.01672

A. Existing Model - Design Storm Selection - PEAK FLOW (CMS)

05. 100yr - 30% Southern Ontario 12hr AES - Toronto City	06. 100yr - 70% Southern Ontario 12hr AES - Toronto City	07. 100Yr - 6hr - Based on MNR 24hr SCS Storm Type II - Toronto City	08. 100Yr - 12hr - Based on MNR 24hr SCS Storm Type II - Toronto City	09. 100Yr - 24hr - Based on MNR 24hr SCS Storm Type II - Toronto City	10. 100yr _ 6hr _ MTO SCS Type II _ Toronto City	11. 100yr _ 12hr _ MTO SCS Type II _ Toronto City	12. 100yr _ 24hr _ MTO SCS Type II _ Toronto City	13. 100yr 3hr 5min Chicago _ Toronto City	14. 100yr 4hr 5min Chicago _ Toronto City	15. 100yr 12hr 5min Chicago _ Toronto City
1.65	1.31	2.78	2.45	2.04	2.98	3.12	3.00	2.60	2.70	3.08
1.04	0.80	1.50	1.40	1.16	1.56	1.61	1.55	1.39	1.44	1.61
11.56	9.15	12.82	12.76	11.05	13.07	13.54	12.88	11.47	11.92	13.40
5.09	4.02	6.05	5.92	5.01	6.19	6.41	6.17	5.53	5.71	6.39
37.40	30.27	39.59	39.69	35.30	40.22	41.62	39.85	35.32	36.83	41.12
37.73	30.46	39.70	39.82	35.50	40.31	41.74	39.95	35.28	36.84	41.20
42.46	34.87	43.06	43.39	39.73	43.43	44.97	43.25	36.78	39.00	44.24
44.79	37.09	44.32	44.82	41.74	44.51	46.15	44.44	37.73	39.24	45.29
6.43	4.17	14.84	11.76	7.99	19.85	18.95	16.86	20.29	20.58	21.42
49.65	41.67	48.95	47.64	45.66	54.35	53.53	50.15	55.49	56.57	60.04

A. Existing Model - Design Storm Selection - UNIT FLOW RATE (CMS/ha)

05. 100yr - 30% Southern Ontario 12hr AES - Toronto City	06. 100yr - 70% Southern Ontario 12hr AES - Toronto City	07. 100Yr - 6hr - Based on MNR 24hr SCS Storm Type II - Toronto City	08. 100Yr - 12hr - Based on MNR 24hr SCS Storm Type II - Toronto City	09. 100Yr - 24hr - Based on MNR 24hr SCS Storm Type II - Toronto City	10. 100yr _ 6hr _ MTO SCS Type II _ Toronto City	11. 100yr _ 12hr _ MTO SCS Type II _ Toronto City	12. 100yr _ 24hr _ MTO SCS Type II _ Toronto City	13. 100yr 3hr 5min Chicago _ Toronto City	14. 100yr 4hr 5min Chicago _ Toronto City	15. 100yr 12hr 5min Chicago _ Toronto City
0.02700	0.02136	0.04539	0.04006	0.03341	0.04876	0.05103	0.04908	0.04245	0.04407	0.05031
0.02542	0.01965	0.03687	0.03444	0.02842	0.03825	0.03957	0.03800	0.03417	0.03525	0.03957
0.02298	0.01819	0.02549	0.02537	0.02197	0.02599	0.02691	0.02562	0.02281	0.02370	0.02665
0.02413	0.01906	0.02870	0.02810	0.02375	0.02938	0.03040	0.02928	0.02625	0.02707	0.03029
0.02077	0.01681	0.02199	0.02204	0.01961	0.02234	0.02312	0.02214	0.01962	0.02046	0.02284
0.02049	0.01654	0.02156	0.02163	0.01928	0.02189	0.02267	0.02170	0.01916	0.02001	0.02238
0.01985	0.01630	0.02013	0.02029	0.01858	0.02031	0.02103	0.02022	0.01720	0.01824	0.02068
0.01938	0.01605	0.01917	0.01939	0.01806	0.01926	0.01996	0.01922	0.01632	0.01698	0.01959
0.04075	0.02644	0.09409	0.07459	0.05070	0.12587	0.12021	0.10691	0.12871	0.13052	0.13588
0.01934	0.01623	0.01906	0.01855	0.01778	0.02117	0.02085	0.01953	0.02161	0.02203	0.02338
0.02401	0.01866	0.03325	0.03044	0.02516	0.03732	0.03758	0.03517	0.03483	0.03583	0.03916

APPENDIX

K

RESULTS OF DESIGN STORM AND REGIONAL STORM SIMULATION

Petticoat Hydrology Updates
Scenario Summary
2020.10.05

Model File Name	Model Scenario Name	Run Name	Watershed	Land Use	AMC	SWM Pond	Design Storms
A. Existing Model - Design Storm Selection	01. Existing Condition-Design Storm Selection	1	Petticoat	Existing	II	Yes	01. 100-Yr _ AES 1hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City
		2					02. 100-Yr _ AES 6hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City
		3					03. 100-Yr _ AES 12hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City
		4					04. 100-Yr _ AES 24hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City
		5					05. 100yr - 30% Southern Ontario 12hr AES - Toronto City - Updated
		6					06. 100yr - 70% Southern Ontario 12hr AES - Toronto City - Updated
		7					07. 100Yr - 6hr - Based on MNR 24hr SCS Storm Type II - Toronto City
		8					08. 100Yr - 12hr - Based on MNR 24hr SCS Storm Type II - Toronto City
		9					09. 100Yr - 24hr - Based on MNR 24hr SCS Storm Type II - Toronto City
		10					10. 100yr _ 6hr _ MTO SCS Type II _ Toronto City
		11					11. 100yr _ 12hr _ MTO SCS Type II _ Toronto City
		12					12. 100yr _ 24hr _ MTO SCS Type II _ Toronto City
		13					13. 100yr 3hr 5min Chicago _ Toronto City
		14					14. 100yr 4hr 5min Chicago _ Toronto City
		15					15. 100yr 12hr 5min Chicago _ Toronto City
B. Final Existing Model	02. Existing Condition-Design Storm	21	Petticoat	Existing	II	Yes	2-Yr 12-Hr MTO SCS Type II Toronto City
		22					5-Yr 12-Hr MTO SCS Type II Toronto City
		23					10-Yr 12-Hr MTO SCS Type II Toronto City
		24					25-Yr 12-Hr MTO SCS Type II Toronto City
		25					50-Yr 12-Hr MTO SCS Type II Toronto City
		26					100-Yr 12-Hr MTO SCS Type II Toronto City
	03. Existing Condition-Regional (AMCIII)	27	Petticoat	Existing	III	No	Hazel (100%)
		28					Hazel (98.2%)
		29					Hazel (96.3%)
		30					Hazel (95.4%)
	04. Existing Condition-Design Storm-Climate Change	31	Petticoat	Existing	II	Yes	RCP 4.5 - 2-Yr 12-Hr
		32					RCP 4.5 - 5-Yr 12-Hr
		33					RCP 4.5 - 10-Yr 12-Hr
		34					RCP 4.5 - 25-Yr 12-Hr
		35					RCP 4.5 - 50-Yr 12-Hr
		36					RCP 4.5 - 100-Yr 12-Hr
		41					RCP 8.5 - 2-Yr 12-Hr
		42					RCP 8.5 - 5-Yr 12-Hr
		43					RCP 8.5 - 10-Yr 12-Hr
		44					RCP 8.5 - 25-Yr 12-Hr
		45					RCP 8.5 - 50-Yr 12-Hr
		46					RCP 8.5 - 100-Yr 12-Hr
		51					20% increased Rainfall Depth - 2-Yr 12-Hr
		52					20% increased Rainfall Depth - 5-Yr 12-Hr
53	20% increased Rainfall Depth - 10-Yr 12-Hr						
54	20% increased Rainfall Depth - 25-Yr 12-Hr						
55	20% increased Rainfall Depth - 50-Yr 12-Hr						
56	20% increased Rainfall Depth - 100-Yr 12-Hr						

A. Existing Model - Design Storm Selection

WATERSHED	NODE	VO NHYD	NAME	Effective Drainage Area (ha)	SC 01. Existing Condition-Design Storm Selection - Peak Flow Rate (cms)											
					01. 100-Yr _ AES 1hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	02. 100-Yr _ AES 6hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	03. 100-Yr _ AES 12hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	04. 100-Yr _ AES 24hr _ based on Southern Ontario 1 hr AES Type II _ Toronto City	05. 100yr - 30% Southern Ontario 12hr AES - Toronto City	06. 100yr - 70% Southern Ontario 12hr AES - Toronto City	07. 100Yr - 6hr - Based on MNR 24hr SCS Storm Type II - Toronto City	08. 100Yr - 12hr - Based on MNR 24hr SCS Storm Type II - Toronto City	09. 100Yr - 24hr - Based on MNR 24hr SCS Storm Type II - Toronto City	10. 100yr _ 6hr _ MTO SCS Type II _ Toronto City	11. 100yr _ 12hr _ MTO SCS Type II _ Toronto City	12. 100yr _ 24hr _ MTO SCS Type II _ Toronto City
Petticoat	5102	5102	Hwy 407 (west)	61.2	2.31	2.24	1.64	1.21	1.65	1.31	2.78	2.45	2.04	2.98	3.12	3.00
	5104	5104	Hwy 407 (east)	40.7	1.13	1.33	1.01	0.71	1.04	0.80	1.50	1.40	1.16	1.56	1.61	1.55
	5111	5111	Taunton Road West East Trib	503.0	8.13	12.56	10.76	7.62	11.56	9.15	12.82	12.76	11.05	13.07	13.54	12.88
	5116	5116	Taunton Road West Main Branch	210.8	4.26	5.76	4.77	3.36	5.09	4.02	6.05	5.92	5.01	6.19	6.41	6.17
	5146	5146	Finch Ave Main Branch	1800.3	24.95	39.22	34.70	25.15	37.40	30.27	39.59	39.69	35.30	40.22	41.62	39.85
	5149	5149	CNR Main Branch	1841.3	24.79	39.35	34.95	25.32	37.73	30.46	39.70	39.82	35.50	40.31	41.74	39.95
	5161	5161	Sheppard Ave Main Branch	2138.8	25.51	42.32	39.57	29.57	42.46	34.87	43.06	43.39	39.73	43.43	44.97	43.25
	5165	5165	Hwy 401 Main Branch	2311.5	35.25	43.21	41.78	31.77	44.79	37.09	44.32	44.82	41.74	44.51	46.15	44.44
	5171	5171	Hwy 401 West Trib	157.7	18.38	9.86	7.20	4.68	6.43	4.17	14.84	11.76	7.99	19.85	18.95	16.86
	5174	5174	Outlet to Lake Ontario	2568.0	52.11	45.53	46.05	35.66	49.65	41.67	48.95	47.64	45.66	54.35	53.53	50.15

B. Final Existing Model

WATERSHED	NODE	VO NHYD	NAME	Effective Drainage Area (ha)	SC 02. Existing Condition-Design Storm - Peak Flow Rate (cms)					
					2-Yr 12-Hr	5-Yr 12-Hr	10-Yr 12-Hr	25-Yr 12-Hr	50-Yr 12-Hr	100-Yr 12-Hr
Petticoat	5102	5102	Hwy 407 (west)	61.2	0.66	1.20	1.61	2.19	2.64	3.12
	5104	5104	Hwy 407 (east)	40.7	0.37	0.66	0.86	1.16	1.38	1.61
	5111	5111	Taunton Road West East Trib	503.0	2.96	5.21	6.99	9.47	11.47	13.54
	5116	5116	Taunton Road West Main Branch	210.8	1.49	2.60	3.45	4.60	5.49	6.41
	5146	5146	Finch Ave Main Branch	1800.3	8.82	16.11	21.88	29.61	35.55	41.62
	5149	5149	CNR Main Branch	1841.3	8.78	16.08	21.82	29.58	35.57	41.74
	5161	5161	Sheppard Ave Main Branch	2138.8	9.90	17.68	23.69	31.90	38.31	44.97
	5165	5165	Hwy 401 Main Branch	2311.5	11.44	18.34	24.42	32.80	39.36	46.15
	5171	5171	Hwy 401 West Trib	157.7	6.56	9.44	11.44	14.12	16.49	18.95
	5174	5174	Outlet to Lake Ontario	2568.0	18.45	27.43	33.76	41.53	47.07	53.24

B. Final Existing Model

WATERSHED	NODE	VO NHYD	NAME	Effective Drainage Area (ha)	Equi. Circular Drainage Area (sq. km)	Reduction Factor Percentage	SC 03. Existing Condition-Regional (AMCIII) - Peak Flow Rate (cms)			
							Final Regional Flow	Hazel (100%)	Hazel (98.2%)	Hazel (96.3%)
Petticoat	5102	5102	Hwy 407 (west)	61.2	1.2	100%	6.46	6.46	6.34	6.21
	5104	5104	Hwy 407 (east)	40.7	0.6	100%	4.13	4.13	4.05	3.97
	5111	5111	Taunton Road West East Trib	503.0	17.9	100%	43.75	43.75	42.89	41.97
	5116	5116	Taunton Road West Main Branch	210.8	18.7	100%	18.58	18.58	18.22	17.84
	5146	5146	Finch Ave Main Branch	1797.6	46.9	98.2%	146.93	149.98	146.93	143.70
	5149	5149	CNR Main Branch	1874.4	53.0	98.2%	151.53	154.64	151.53	148.20
	5161	5161	Sheppard Ave Main Branch	2140.0	92.1	96.3%	161.34	168.41	165.13	161.34
	5165	5165	Hwy 401 Main Branch	2314.0	100.3	96.3%	167.96	175.24	171.97	166.05
	5171	5171	Hwy 401 West Trib	162.8	3.0	100%	21.37	21.37	20.98	20.34
	5174	5174	Outlet to Lake Ontario	2580.8	119.6	95.4%	177.45	187.19	183.58	179.38

B. Final Existing Model

WATERSHED	NODE	VO NHYD	NAME	Effective Drainage Area (ha)	SC 04. Existing Condition-Design Storm-Climate Change - RCP4.5 - Peak Flow Rate (cms)					
					RCP4.5 2-Yr 12-Hr	RCP4.5 5-Yr 12-Hr	RCP4.5 10-Yr 12-Hr	RCP4.5 25-Yr 12-Hr	RCP4.5 50-Yr 12-Hr	RCP4.5 100-Yr 12-Hr
Petticoat	5102	5102	Hwy 407 (west)	61.2	0.76	1.40	1.92	2.72	3.51	4.33
	5104	5104	Hwy 407 (east)	40.7	0.43	0.75	1.02	1.42	1.80	2.23
	5111	5111	Taunton Road West East Trib	503.0	3.40	6.08	8.34	11.81	15.17	18.97
	5116	5116	Taunton Road West Main Branch	210.8	1.71	3.02	4.08	5.64	7.14	8.84
	5146	5146	Finch Ave Main Branch	1800.3	10.24	18.92	26.13	36.54	46.42	58.28
	5149	5149	CNR Main Branch	1841.3	10.19	18.87	26.10	36.58	46.71	58.81
	5161	5161	Sheppard Ave Main Branch	2138.8	11.42	20.59	28.18	39.40	50.32	63.08
	5165	5165	Hwy 401 Main Branch	2311.5	12.63	21.28	28.97	40.45	51.60	64.58
	5171	5171	Hwy 401 West Trib	157.7	6.68	10.43	12.91	16.85	20.71	24.37
	5174	5174	Outlet to Lake Ontario	2568.0	20.13	30.54	38.05	48.11	58.13	69.67

B. Final Existing Model

WATERSHED	NODE	VO NHYD	NAME	Effective Drainage Area (ha)	SC 04. Existing Condition-Design Storm-Climate Change - RCP8.5 - Peak Flow Rate (cms)					
					RCP8.5 2-Yr 12-Hr	RCP8.5 5-Yr 12-Hr	RCP8.5 10-Yr 12-Hr	RCP8.5 25-Yr 12-Hr	RCP8.5 50-Yr 12-Hr	RCP8.5 100-Yr 12-Hr
Petticoat	5102	5102	Hwy 407 (west)	61.2	0.86	1.56	2.13	3.00	3.75	4.46
	5104	5104	Hwy 407 (east)	40.7	0.48	0.83	1.13	1.55	1.92	2.30
	5111	5111	Taunton Road West East Trib	503.0	3.78	6.74	9.23	13.02	16.24	19.58
	5116	5116	Taunton Road West Main Branch	210.8	1.90	3.33	4.49	6.18	7.62	9.11
	5146	5146	Finch Ave Main Branch	1800.3	11.50	21.07	28.86	40.08	49.66	60.16
	5149	5149	CNR Main Branch	1841.3	11.46	21.01	28.82	40.16	50.00	60.76
	5161	5161	Sheppard Ave Main Branch	2138.8	12.77	22.84	31.10	43.29	53.83	65.16
	5165	5165	Hwy 401 Main Branch	2311.5	13.69	23.56	31.97	44.44	55.17	66.69
	5171	5171	Hwy 401 West Trib	157.7	7.31	11.17	13.86	18.44	21.84	24.91
	5174	5174	Outlet to Lake Ontario	2568.0	21.66	32.92	40.80	51.54	61.65	71.35

B. Final Existing Model

WATERSHED	NODE	VO NHYD	NAME	Effective Drainage Area (ha)	SC 04. Existing Condition-Design Storm-Climate Change - 20% Increased Rainfall Depth - Peak Flow Rate (cms)					
					20% increased Rainfall Depth - 2-Yr 12-Hr	20% increased Rainfall Depth - 5-Yr 12-Hr	20% increased Rainfall Depth - 10-Yr 12-Hr	20% increased Rainfall Depth - 25-Yr 12-Hr	20% increased Rainfall Depth - 50-Yr 12-Hr	20% increased Rainfall Depth - 100-Yr 12-Hr
Petticoat	5102	5102	Hwy 407 (west)	61.2	0.98	1.73	1.61	3.04	3.64	4.22
	5104	5104	Hwy 407 (east)	40.7	0.54	0.92	0.86	1.57	1.86	2.16
	5111	5111	Taunton Road West East Trib	503.0	4.30	7.49	6.99	13.18	15.76	18.42
	5116	5116	Taunton Road West Main Branch	210.8	2.15	3.68	3.45	6.25	7.41	8.59
	5146	5146	Finch Ave Main Branch	1800.3	13.25	23.50	21.88	40.56	48.17	56.55
	5149	5149	CNR Main Branch	1841.3	13.18	23.44	21.82	40.66	48.49	57.02
	5161	5161	Sheppard Ave Main Branch	2138.8	14.58	25.38	23.69	43.81	52.24	61.18
	5165	5165	Hwy 401 Main Branch	2311.5	15.19	26.12	24.42	44.97	53.55	62.65
	5171	5171	Hwy 401 West Trib	157.7	8.05	11.99	11.44	18.60	21.38	23.87
	5174	5174	Outlet to Lake Ontario	2568.0	23.74	35.38	33.76	52.17	60.17	68.10

Comparison between WSP, 2020 with Greenland, 2006

WATERSHED	NODE	VO NYHD	NAME	Effective Drainage Area (ha)	WSP, 2020 (SC 02. Existing Condition-Design Storm - Peak Flow Rate - cms)							NODE	Greenland, 2006 Petticoat Creek Watershed Report (Future committed)							
					2-Yr 12-Hr	5-Yr 12-Hr	10-Yr 12-Hr	25-Yr 12-Hr	50-Yr 12-Hr	100-Yr 12-Hr	Final Regional Flow		Drainage Areas	2-Yr 12-Hr	5-Yr 12-Hr	10-Yr 12-Hr	25-Yr 12-Hr	50-Yr 12-Hr	100-Yr 12-Hr	Final Regional Flow
Petticoat	5102	5102	Hwy 407 (west)	61.2	0.66	1.20	1.61	2.19	2.64	3.12	6.46									
	5104	5104	Hwy 407 (east)	40.7	0.37	0.66	0.86	1.16	1.38	1.61	4.13									
	5111	5111	Taunton Road West East Trib	503.0	2.96	5.21	6.99	9.47	11.47	13.54	43.75	105	492.50	2.71	4.47	5.84	7.71	9.21	10.82	43.63
	5116	5116	Taunton Road West Main Branch	210.8	1.49	2.60	3.45	4.60	5.49	6.41	18.58	142	215.40	1.06	1.76	2.31	3.06	3.67	4.31	18.26
	5146	5146	Finch Ave Main Branch	1800.3	8.82	16.11	21.88	29.61	35.55	41.62	146.93	128	1774.90	8.83	14.79	19.45	25.84	30.99	34.49	153.71
	5149	5149	CNR Main Branch	1841.3	8.78	16.08	21.82	29.58	35.57	41.74	151.53									
	5161	5161	Sheppard Ave Main Branch	2138.8	9.90	17.68	23.69	31.90	38.31	44.97	161.34	149	2163.60	10.1	16.61	21.71	28.74	34.42	40.4	168.97
	5165	5165	Hwy 401 Main Branch	2311.5	11.44	18.34	24.42	32.80	39.36	46.15	167.96	152	2276.90	10.61	17.3	22.51	29.72	35.52	41.66	172.69
	5171	5171	Hwy 401 West Trib	157.7	6.56	9.44	11.44	14.12	16.49	18.95	21.37	154	146.40	3.93	5.28	6.23	7.58	8.55	9.48	19.15
5174	5174	Outlet to Lake Ontario	2568.0	18.53	27.52	33.94	41.74	47.25	53.53	177.01	161	2551.30	12.05	19.2	24.74	32.44	38.63	45.2	190.4	

Percentage Difference

NODE	NAME	Percentage Flow Changes of WSP, 2020 from Greenland, 2006							
		Drainage Area	2-Yr Flow	5-Yr Flow	10-Yr Flow	25-Yr Flow	50-Yr Flow	100-Yr Flow	Regional Flow
5111	Taunton Road West East Trib	2%	9%	14%	16%	19%	20%	20%	0%
5116	Taunton Road West Main Branch	-2%	29%	32%	33%	33%	33%	33%	2%
5146	Finch Ave Main Branch	1%	0%	8%	11%	13%	13%	17%	-5%
5161	Sheppard Ave Main Branch	-1%	-2%	6%	8%	10%	10%	10%	-5%
5165	Hwy 401 Main Branch	1%	7%	6%	8%	9%	10%	10%	-3%
5171	Hwy 401 West Trib	7%	40%	44%	46%	46%	48%	50%	10%
5174	Outlet to Lake Ontario	1%	35%	30%	27%	22%	18%	16%	-8%
Total / Average		1%	17%	20%	21%	22%	22%	22%	-1%

L AREAL
REDUCTION
FACTORS

Aerial Reduction Factor for Petticoat Creek

Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Areas (km ²)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.3%
5165	11.3	5.7	100.35	96.3%
5171				100%
5174	12.3	6.2	119.63	95.4%

Technical Guidelines For Flood Hazard Mapping

Table 3.2 Hydrologic Standard Parameters continued

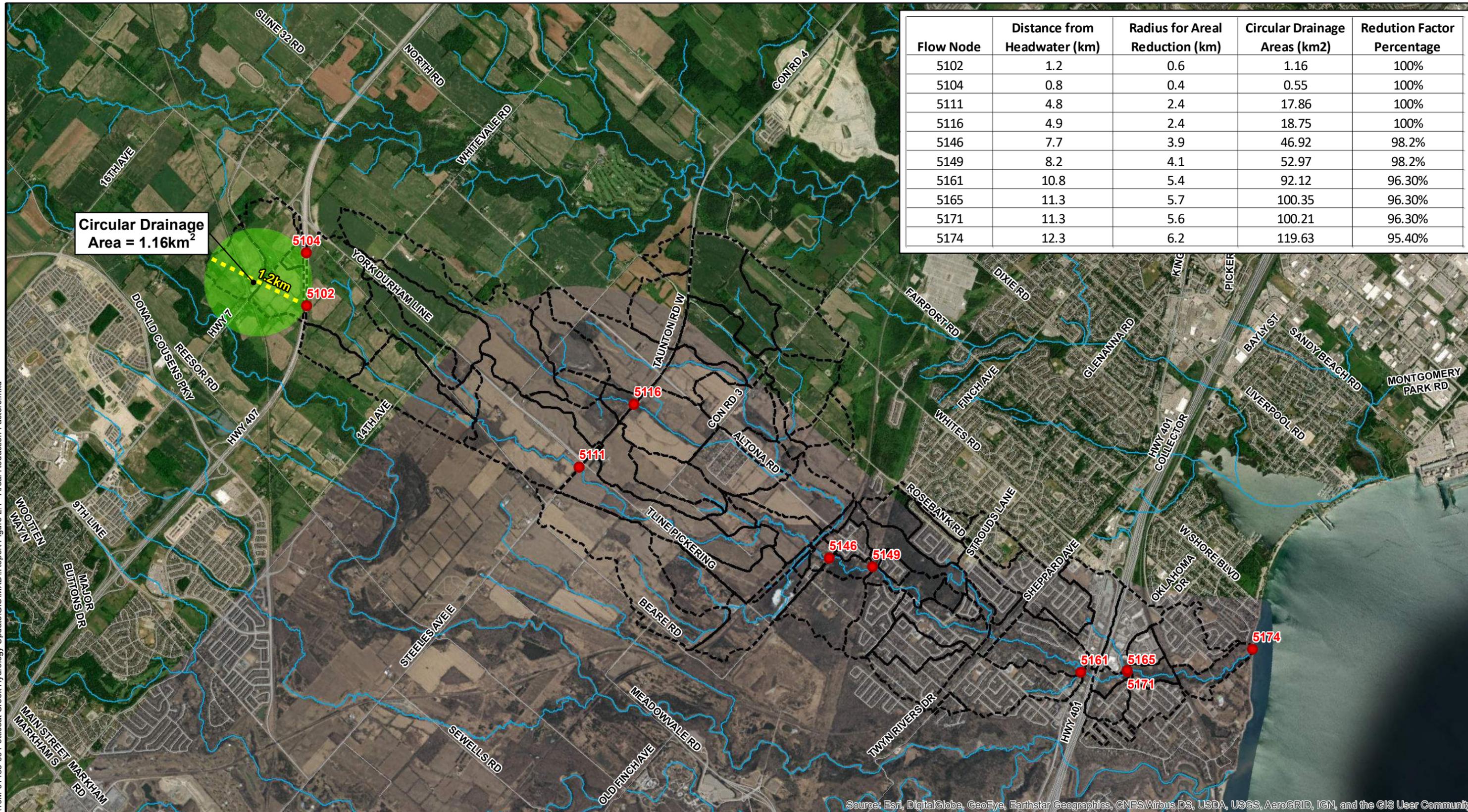
Table 3.2.12 Hurricane Hazel Storm

In the first 36 hours the total rainfall recorded was 73 mm. The following 12 hour rainfall represents the Ontario Ministry of Natural Resources Storm:

	Depth (mm)	Percent of Total
37th hour	6	3
38th hour	4	2
39th hour	6	3
40th hour	13	6
41st hour	17	8
42nd hour	13	6
43rd hour	23	11
44th hour	13	6
45th hour	13	6
46th hour	53	25
47th hour	38	18
48th hour	13	6
Total	212 mm	100

Table 3.2.13 Hurricane Hazel - Areal Reduction Factors

Circular Drainage Area (km ²)	Total Percentage of Rainfall
0 to 25	100
26 to 45	99.2
46 to 65	98.2
66 to 90	97.1
91 to 115	96.3
116 to 140	95.4
141 to 165	94.8
166 to 195	94.2
196 to 220	93.5
221 to 245	92.7
246 to 270	92.0
271 to 450	89.4
451 to 575	86.7
576 to 700	84.0
701 to 850	82.4
851 to 1000	80.8
1001 to 1200	79.3
1201 to 1500	76.6



Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Circular Drainage Areas (km ²)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.30%
5165	11.3	5.7	100.35	96.30%
5171	11.3	5.6	100.21	96.30%
5174	12.3	6.2	119.63	95.40%

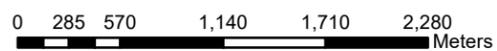
Circular Drainage Area = 1.16km²

1.2km

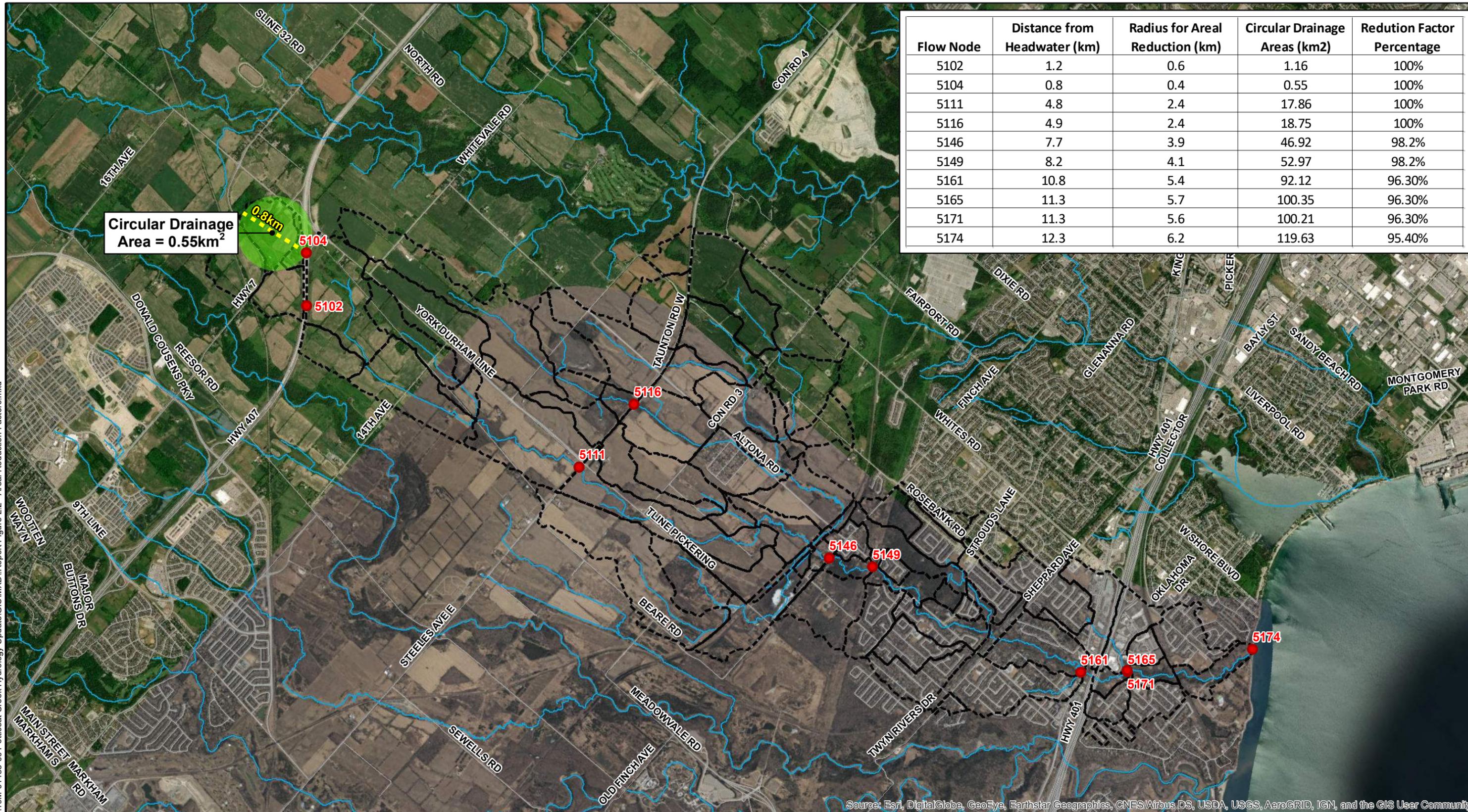
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Flow Nodes
- Petticoke Creek Catchment
- Distance from Headwater
- Watercourse
- Equivalent Circular Area
- Roads



CLIENT	TORONTO AND REGION CONSERVATION AUTHORITY		
TITLE	PETTICOAT CREEK SUBWATERSHED		
	AREAL REDUCTION FACTORS (#5102)		
Checked	A.Z.Z.	Drawn	J.C
Date	November 2020	Proj. No.	19M-01483-00
Scale	1:40,000	Figure No.	L.1



Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Circular Drainage Areas (km ²)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.30%
5165	11.3	5.7	100.35	96.30%
5171	11.3	5.6	100.21	96.30%
5174	12.3	6.2	119.63	95.40%

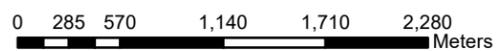
Circular Drainage Area = 0.55km²

0.8km

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Flow Nodes
- Petticoke Creek Catchment
- Distance from Headwater
- Watercourse
- Equivalent Circular Area
- Roads

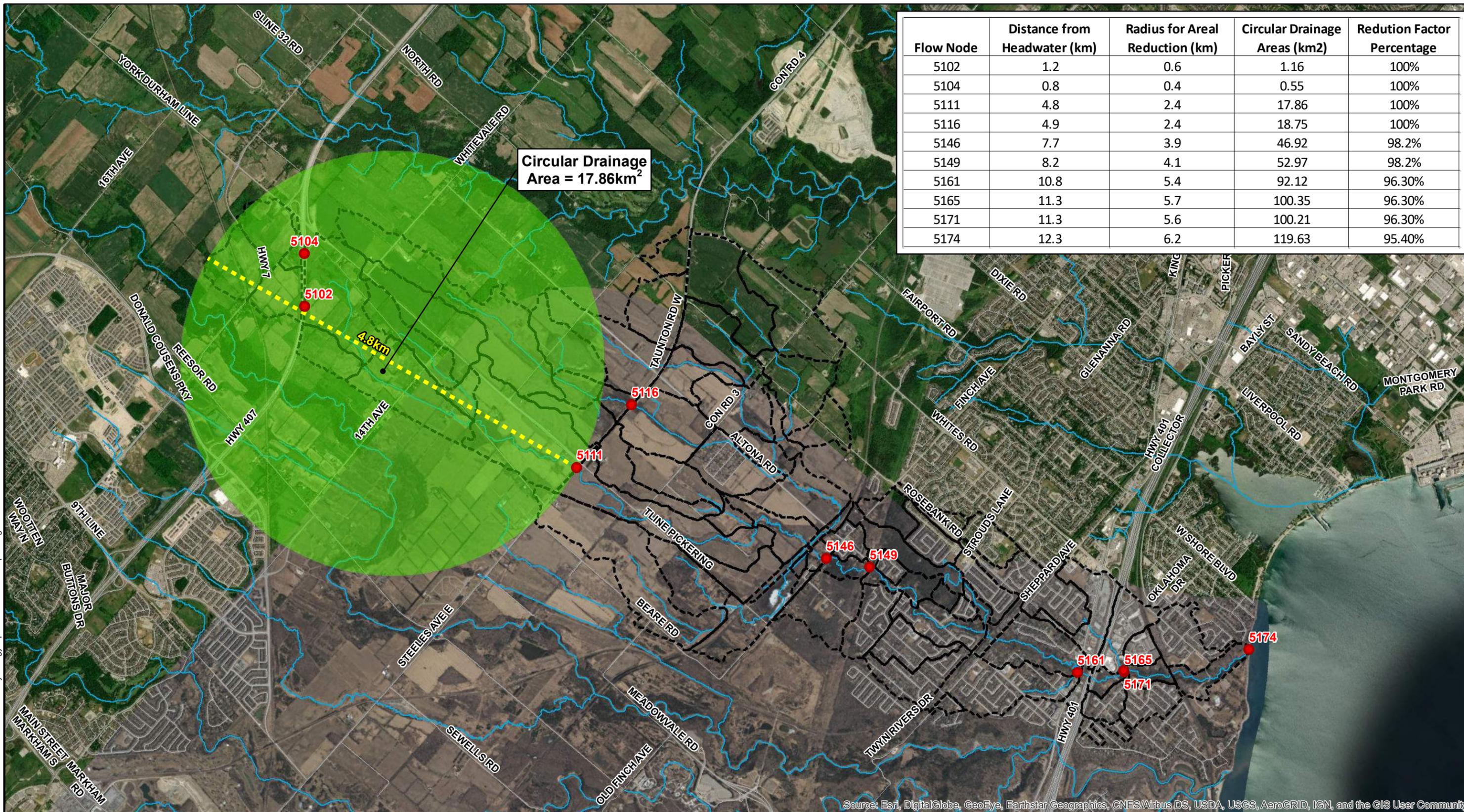


CLIENT: TORONTO AND REGION CONSERVATION AUTHORITY

TITLE: PETTICOAT CREEK SUBWATERSHED

AREAL REDUCTION FACTORS (#5104)

Checked: A.Z.Z.	Drawn: J.C.
Date: November 2020	Proj. No.: 19M-01483-00
Scale: 1:40,000	Figure No.: L.2



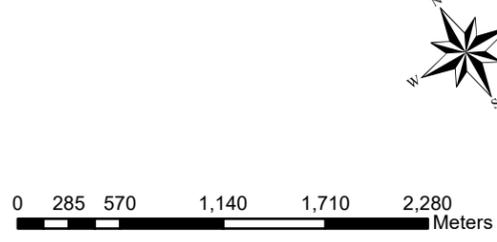
Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Circular Drainage Areas (km2)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.30%
5165	11.3	5.7	100.35	96.30%
5171	11.3	5.6	100.21	96.30%
5174	12.3	6.2	119.63	95.40%

Circular Drainage Area = 17.86km²

Legend

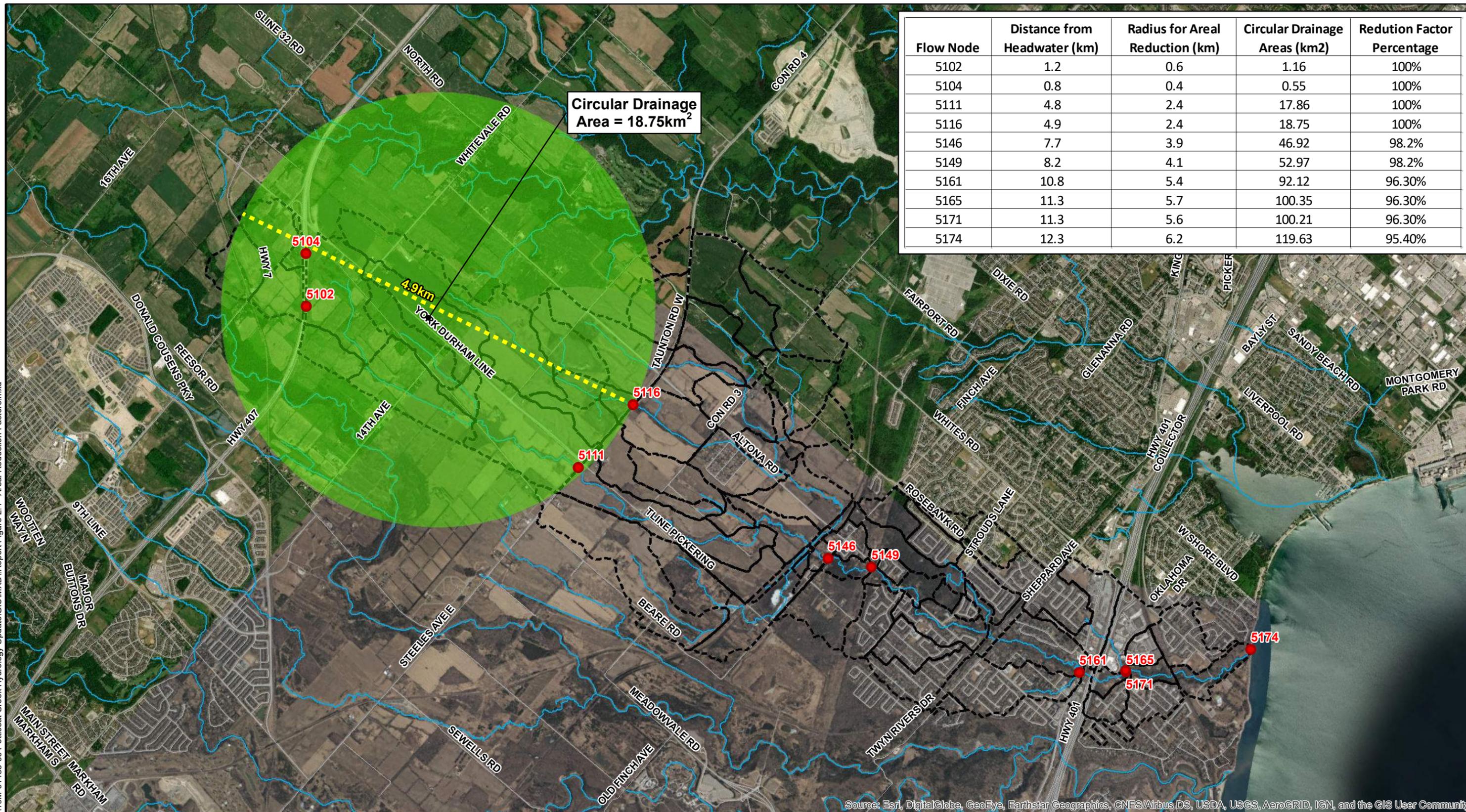
- Flow Nodes
- Petticoke Creek Catchment
- Distance from Headwater
- Watercourse
- Equivalent Circular Area
- Roads

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



CLIENT	TORONTO AND REGION CONSERVATION AUTHORITY	
TITLE	PETTICOAT CREEK SUBWATERSHED	
	AREAL REDUCTION FACTORS (#5111)	

Checked	A.Z.Z.
Drawn	J.C
Date	November 2020
Proj. No.	19M-01483-00
Scale	1:40,000
Figure No.	L.3



Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Circular Drainage Areas (km2)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.30%
5165	11.3	5.7	100.35	96.30%
5171	11.3	5.6	100.21	96.30%
5174	12.3	6.2	119.63	95.40%

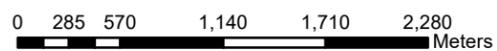
Circular Drainage Area = 18.75km²

4.9km

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Flow Nodes
- Distance from Headwater
- Equivalent Circular Area
- Petticoke Creek Catchment
- Watercourse
- Roads

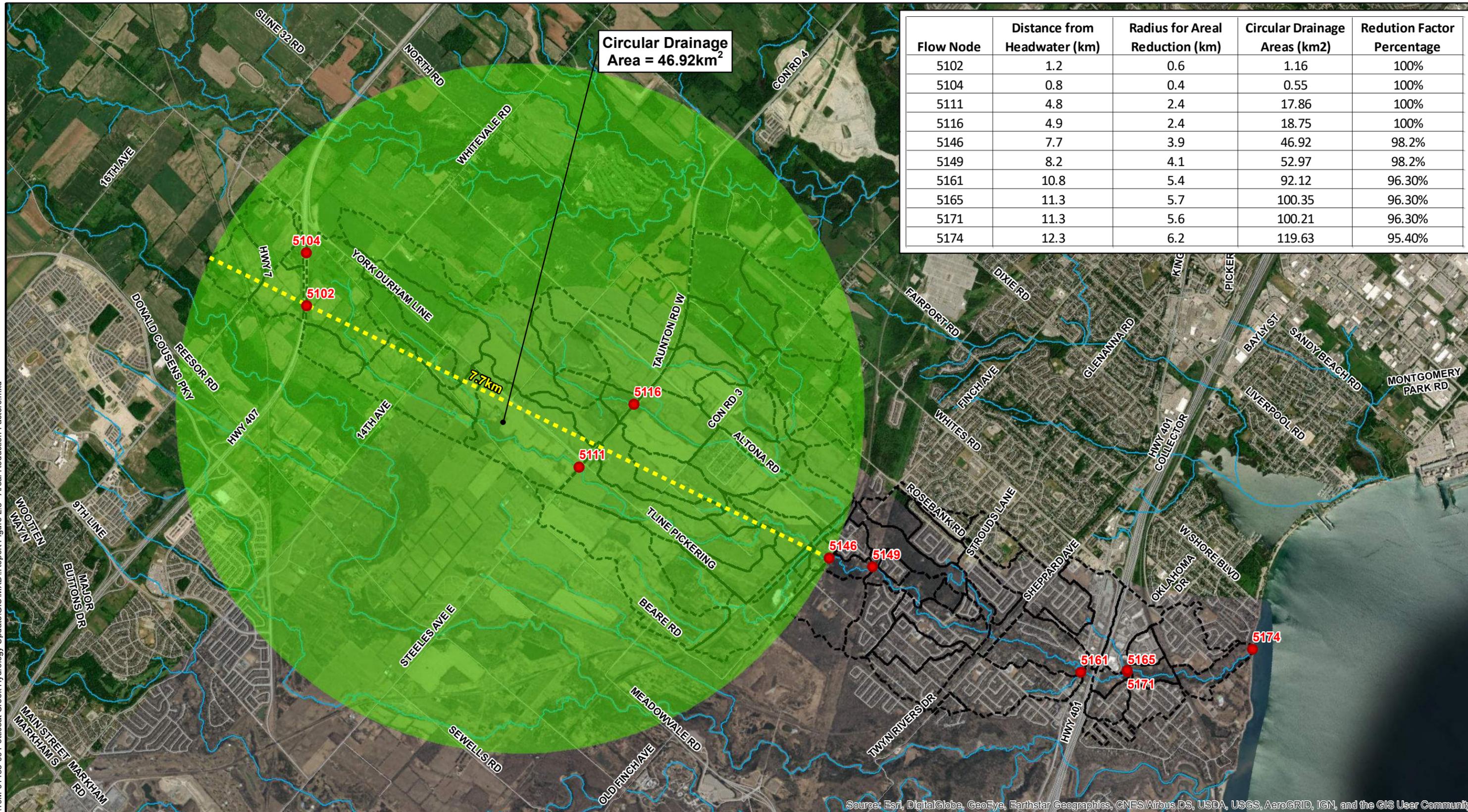


CLIENT: TORONTO AND REGION CONSERVATION AUTHORITY

TITLE: PETTICOAT CREEK SUBWATERSHED

AREAL REDUCTION FACTORS (#5116)

Checked	A.Z.Z.	Drawn	J.C
Date	November 2020	Proj. No.	19M-01483-00
Scale	1:40,000	Figure No.	L.4



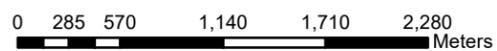
Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Circular Drainage Areas (km ²)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.30%
5165	11.3	5.7	100.35	96.30%
5171	11.3	5.6	100.21	96.30%
5174	12.3	6.2	119.63	95.40%

Circular Drainage Area = 46.92km²

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Flow Nodes
- Petticoke Creek Catchment
- Distance from Headwater
- Watercourse
- Equivalent Circular Area
- Roads

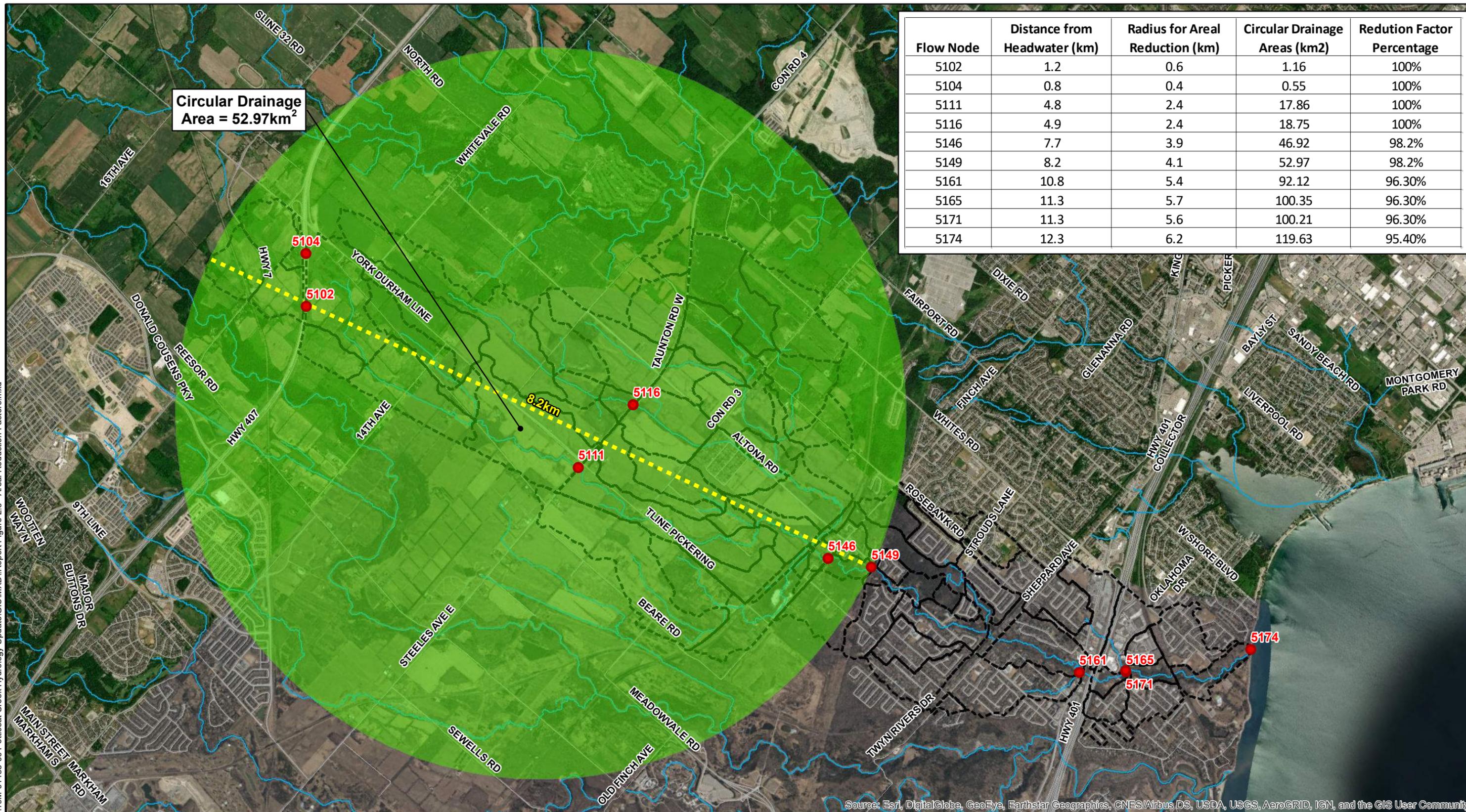


CLIENT: TORONTO AND REGION CONSERVATION AUTHORITY

TITLE: PETTICOAT CREEK SUBWATERSHED

AREAL REDUCTION FACTORS (#5146)

Checked	A.Z.Z.	Drawn	J.C
Date	November 2020	Proj. No.	19M-01483-00
Scale	1:40,000	Figure No.	L.5

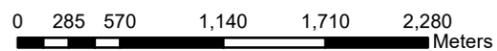


Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Circular Drainage Areas (km ²)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.30%
5165	11.3	5.7	100.35	96.30%
5171	11.3	5.6	100.21	96.30%
5174	12.3	6.2	119.63	95.40%

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

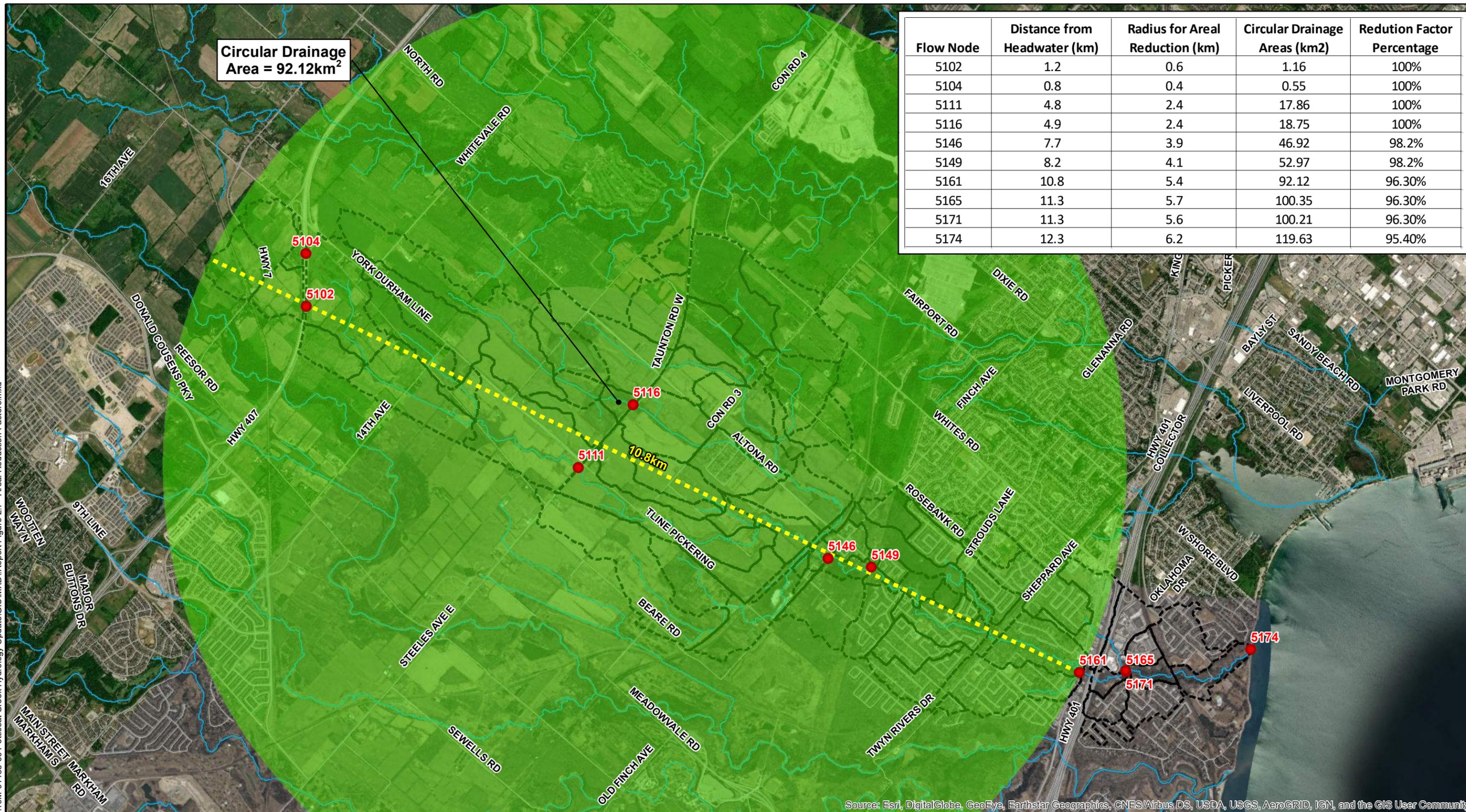
Legend

- Flow Nodes
- Distance from Headwater
- Equivalent Circular Area
- Petticoke Creek Catchment
- Watercourse
- Roads



CLIENT	TORONTO AND REGION CONSERVATION AUTHORITY	
TITLE	PETTICOAT CREEK SUBWATERSHED	
	AREAL REDUCTION FACTORS (#5149)	

Checked A.Z.Z.	Drawn J.C.
Date November 2020	Proj. No. 19M-01483-00
Scale 1:40,000	Figure No. L.6



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Flow Nodes
- Distance from Headwater
- Equivalent Circular Area
- Petticoke Creek Catchment
- Watercourse
- Roads

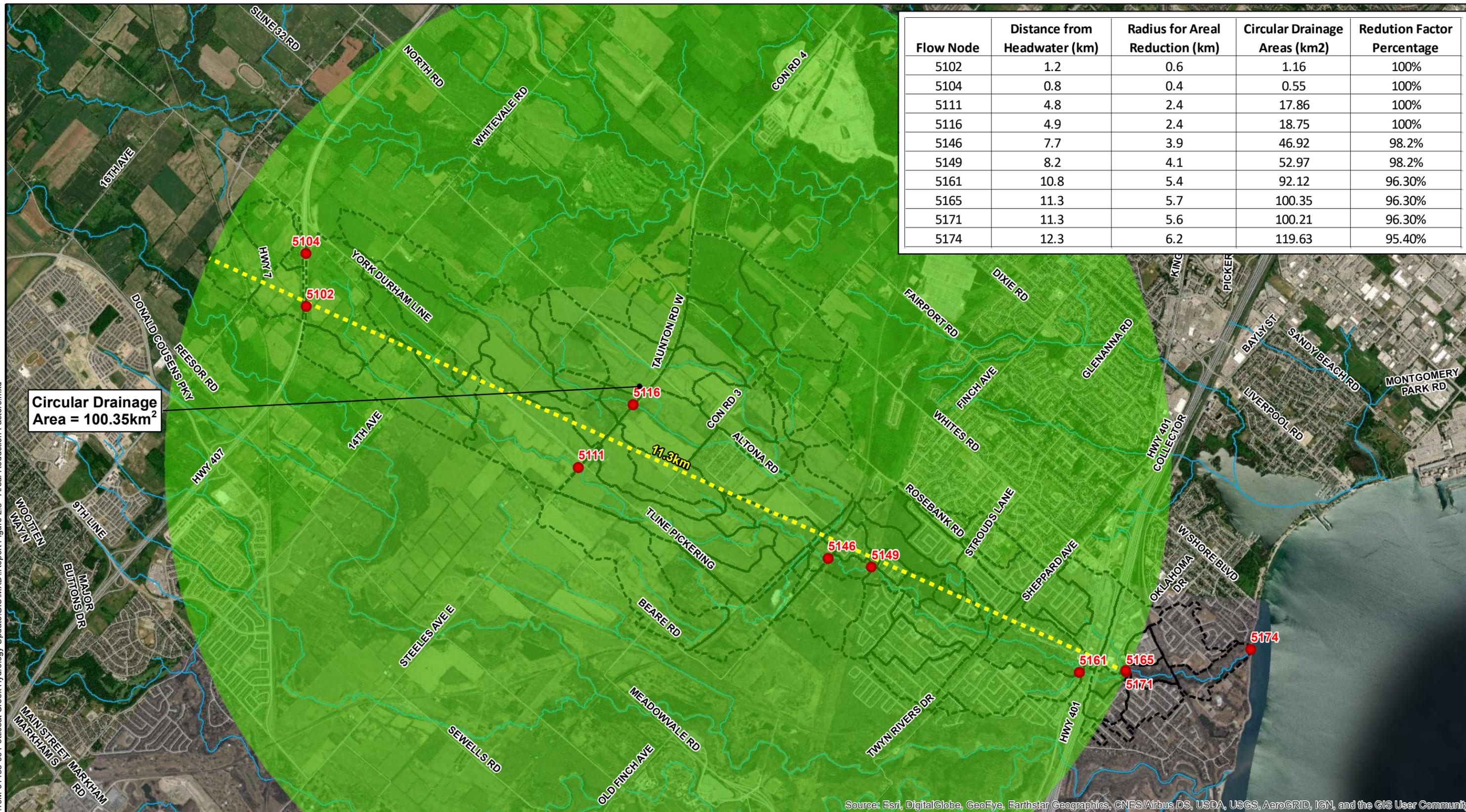
0 285 570 1,140 1,710 2,280 Meters

CLIENT: TORONTO AND REGION CONSERVATION AUTHORITY

TITLE: PETTICOAT CREEK SUBWATERSHED

AREAL REDUCTION FACTORS (#5161)

Checked	A.Z.Z.	Drawn	J.C
Date	November 2020	Proj. No.	19M-01483-00
Scale	1:40,000	Figure No.	L.7



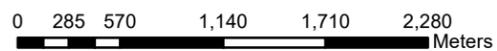
Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Circular Drainage Areas (km2)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.30%
5165	11.3	5.7	100.35	96.30%
5171	11.3	5.6	100.21	96.30%
5174	12.3	6.2	119.63	95.40%

Circular Drainage Area = 100.35km²

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Flow Nodes
- - - Distance from Headwater
- Equivalent Circular Area
- Petticoke Creek Catchment
- Watercourse
- Roads

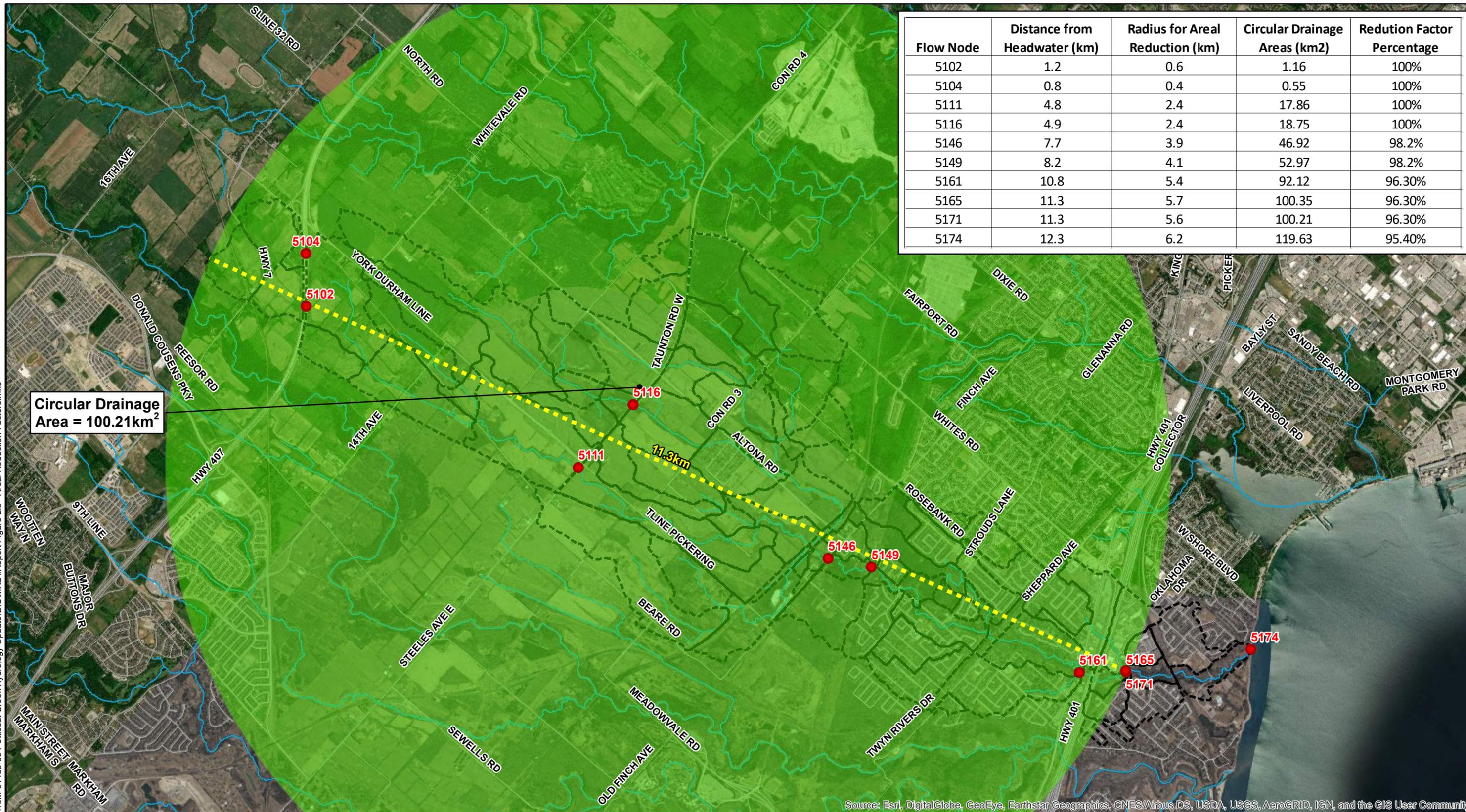


CLIENT: TORONTO AND REGION CONSERVATION AUTHORITY

TITLE: PETTICOAT CREEK SUBWATERSHED

AREAL REDUCTION FACTORS (#5165)

Checked: A.Z.Z.	Drawn: J.C.
Date: November 2020	Proj. No.: 19M-01483-00
Scale: 1:40,000	Figure No.: L.8



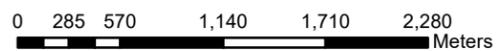
Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Circular Drainage Areas (km ²)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.30%
5165	11.3	5.7	100.35	96.30%
5171	11.3	5.6	100.21	96.30%
5174	12.3	6.2	119.63	95.40%

Circular Drainage Area = 100.21km²

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Flow Nodes
- Petticoke Creek Catchment
- Distance from Headwater
- Watercourse
- Equivalent Circular Area
- Roads



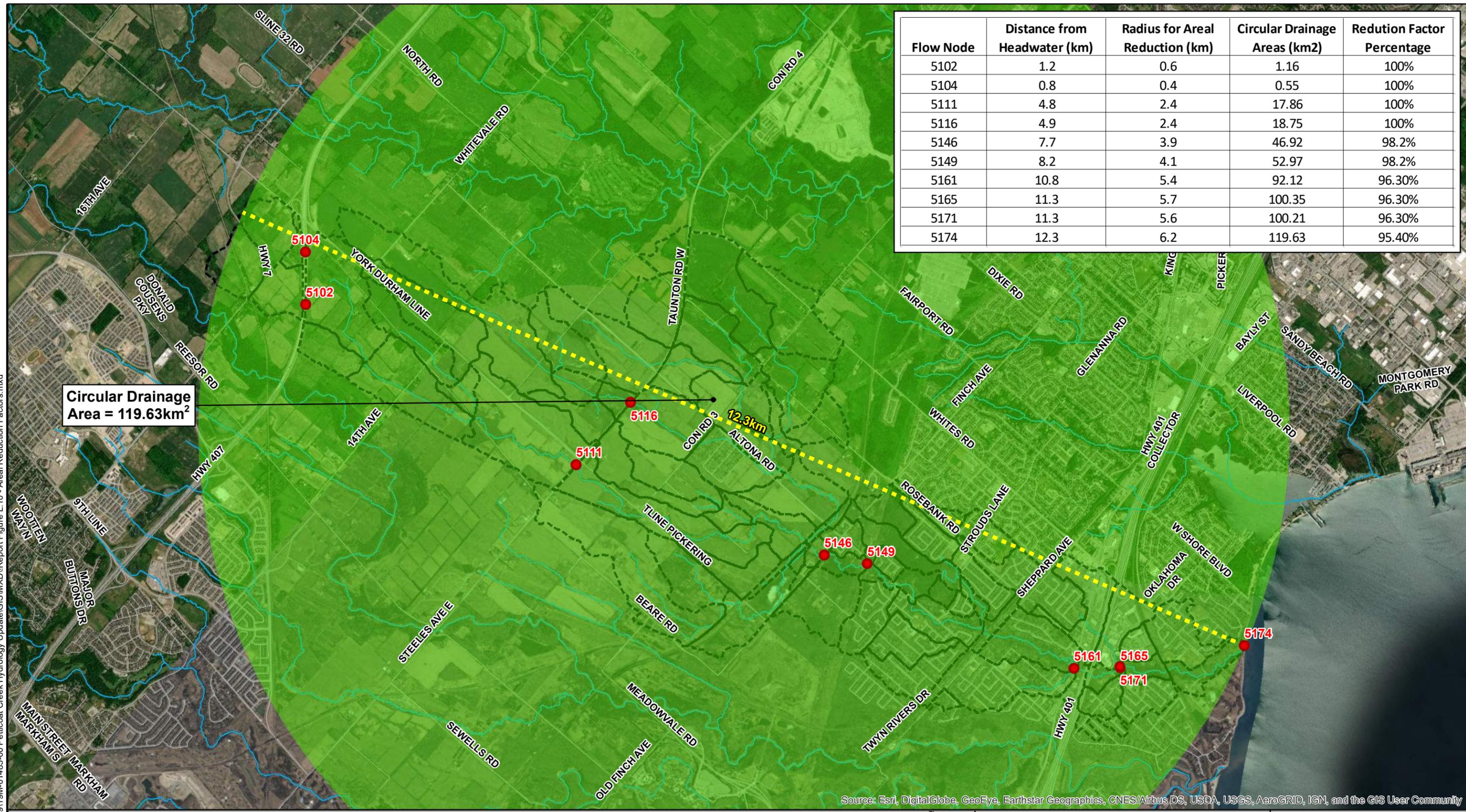
CLIENT: TORONTO AND REGION CONSERVATION AUTHORITY

TITLE: PETTICOAT CREEK SUBWATERSHED

AREAL REDUCTION FACTORS (#5171)

Checked A.Z.Z.	Drawn J.C.
Date November 2020	Proj. No. 19M-01483-00
Scale 1:40,000	Figure No. L.9

Document Path: X:\DIV\38\2019\19M-01483-00 Petticoat Creek Hydrology Update\GIS\MXD\Report Figure L.10 - Areal Reduction Factors.mxd



Flow Node	Distance from Headwater (km)	Radius for Areal Reduction (km)	Circular Drainage Areas (km2)	Redution Factor Percentage
5102	1.2	0.6	1.16	100%
5104	0.8	0.4	0.55	100%
5111	4.8	2.4	17.86	100%
5116	4.9	2.4	18.75	100%
5146	7.7	3.9	46.92	98.2%
5149	8.2	4.1	52.97	98.2%
5161	10.8	5.4	92.12	96.30%
5165	11.3	5.7	100.35	96.30%
5171	11.3	5.6	100.21	96.30%
5174	12.3	6.2	119.63	95.40%

Circular Drainage Area = 119.63km²

Legend

- Flow Nodes
- Petticoke Creek Catchment
- Distance from Headwater
- Watercourse
- Equivalent Circular Area
- Roads

CLIENT: TORONTO AND REGION CONSERVATION AUTHORITY

TITLE: PETTICOAT CREEK SUBWATERSHED

AREAL REDUCTION FACTORS (#5174)

Checked	A.Z.Z.	Drawn	J.C
Date	November 2020	Proj. No.	19M-01483-00
Scale	1:40,000	Figure No.	L.10

M FREQUENCY ANALYSIS

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual Max - Hourly Data	Annual Max - Hourly Data -
2001						0.346	18.077	0.819	1.434	1.262	4.477	1.338	18.08	07
2002	0.729	2.465	3.155	2.518	2.492	1.918	7.776	1.475	2.241	0.660	11.178	0.249	11.18	11
2003	3.107	9.299	14.694	2.042	23.378	3.115	4.634	6.593	2.100	1.536	4.458	3.103	23.38	05
2004	1.521	1.824	8.958	1.581	3.343	2.606	2.161	13.990	3.563	0.866	1.639	4.962	13.99	08
2005	4.465	12.510	2.764	8.874	0.673	1.558	0.707	29.440	4.490	1.785	5.552	2.296	29.44	08
2006	5.401	16.400	10.748	5.254	2.758	3.514	11.486	3.510	2.754	5.324	6.530	18.033	18.03	12
2007	1.755	5.091	8.949	3.434	3.298	2.239	3.340	0.854	1.135	0.937	1.570	4.551	8.95	03
2008	3.203	5.645	4.385	34.277	2.054	7.028	4.837	4.670	2.358	1.251	7.187	16.349	34.28	04
2009	6.558	20.930	9.508	21.222	10.271	2.327	42.356	4.408	0.903	1.930	1.023	7.023	42.36	07
2010	6.831	2.023	7.397	2.053	9.426	18.011	11.379	7.375	3.683	3.470	9.249	15.315	18.01	06
2011	1.934	18.385	27.636	8.102	10.066	13.982	11.930	11.267	1.632	7.147	8.432	5.065	27.64	03
2012	4.258	1.360	1.446	1.079	1.206	2.327	2.954	3.634	3.309	4.067	2.241	4.625	4.63	12

Flood Frequency Distribution	Resulting Flood (m3/s)					
	Generalized Extreme Value (GEV)	Three-Parameter Lognormal (3PL / HILO)	Log Pearson Type III (LPIII)	Wakeby	Nonparametric Method	Average
2-Yr	19.0	19.1	19.9	18.8	20.3	19.4
5-Yr	29.2	29.2	29.0	29.6	33.7	30.1
10-Yr	36.1	36.3	34.6	36.9	40.9	37.0
25-Yr	42.8	43.3	39.6	43.5	46.6	43.2
50-Yr	51.6	52.7	45.5	51.3	52.9	50.8
100-Yr	58.3	60.0	49.7	56.5	56.8	56.3

```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
WSC STATION NO=HY051
WSC STATION NAME=TRCA - Petticoat Creek at Whites
-----
MONTH      YEAR      DATA      ORDERED    RANK      PROB.      RET. PERIOD
-----
(1)        (2)        (3)        (4)        (5)        (6)        (7)
              (%)        (YEARS)
7          2001      18.080     42.360     1          4.92      20.333
11         2002      11.180     34.280     2          13.11     7.625
5          2003      23.380     29.440     3          21.31     4.692
8          2004      13.990     27.640     4          29.51     3.389
8          2005      29.440     23.380     5          37.70     2.652
12         2006      18.030     18.080     6          45.90     2.179
3          2007      8.950      18.030     7          54.10     1.848
4          2008      34.280     18.010     8          62.30     1.605
7          2009      42.360     13.990     9          70.49     1.419
6          2010      18.010     11.180     10         78.69     1.271
3          2011      27.640     8.950      11         86.89     1.151
12         2012      4.630      4.630*     12         95.08     1.052

Press <RETURN> to continue █

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DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
HY051          TRCA - Petticoat Creek at Whites

                SAMPLE STATISTICS
                MEAN      S.D.      C.U.      C.S.      C.K.
X SERIES      20.831    11.030    .530      .501      3.780
LN X SERIES   2.882     .623     .216     -.794     4.659
L-MOM RATIO   20.831    6.479    .311     .125     .133

X(MIN)=       4.630                TOTAL SAMPLE SIZE= 12
X(MAX)=       42.360                NO. OF LOW OUTLIERS= 1
LOWER OUTLIER LIMIT OF X= 4.733    NO. OF ZERO FLOWS= 0

                AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                MEAN      S.D.      C.U.      C.S.      C.K.
X SERIES      22.304    10.257    .460      .650      3.954
LN X SERIES   3.005     .477     .159     -.174     3.502
L-MOM RATIO   22.304    6.007    .269     .173     .115

Press <RETURN> to continue , <CTRL> P to obtain hard copy_

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```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

SOLUTION OBTAINED VIA L - MOMENTS

```

PARAMETERS OF THE GEV WHICH DUPLICATES THE CONDITIONAL FUNCTION:

U= 15.80 A= 8.820 K= -.020

FLOOD FREQUENCY REGIME

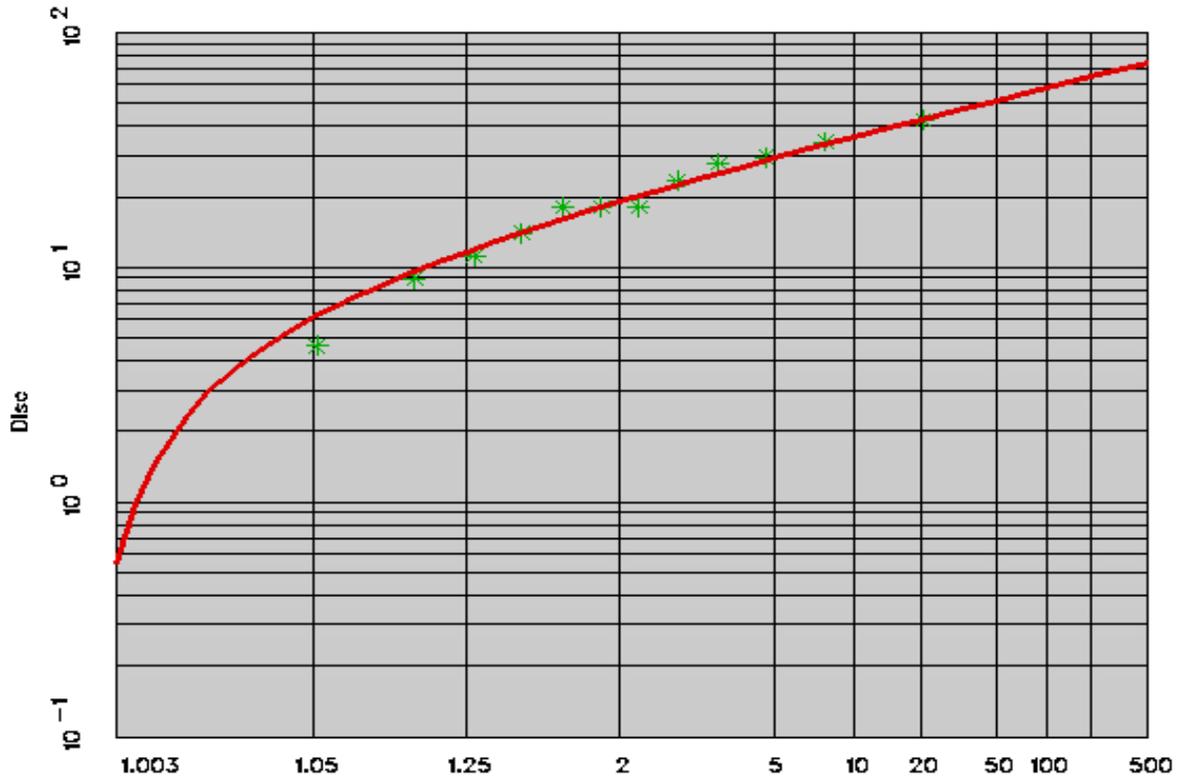
RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	.550
1.050	.952	6.09
1.250	.800	11.6
2.000	.500	19.0
5.000	.200	29.2
10.000	.100	36.1
20.000	.050	42.8
50.000	.020	51.6
100.000	.010	58.3
200.000	.005	65.1
500.000	.002	74.2

Press <RETURN> to continue , <CTRL> P to obtain hard copy_

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

Flood Frequency – Generalized Extreme Value Distribution

HY051 TRCA – Petticoat Creek at Whites



```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
WSC STATION NO=HY051
WSC STATION NAME=TRCA - Petticoat Creek at Whites
-----
MONTH      YEAR      DATA      ORDERED    RANK      PROB.      RET. PERIOD
-----
(1)        (2)        (3)        (4)        (5)        (6)        (7)
              (%)        (YEARS)
7          2001      18.080     42.360     1          4.92      20.333
11         2002      11.180     34.280     2          13.11     7.625
5          2003      23.380     29.440     3          21.31     4.692
8          2004      13.990     27.640     4          29.51     3.389
8          2005      29.440     23.380     5          37.70     2.652
12         2006      18.030     18.080     6          45.90     2.179
3          2007      8.950      18.030     7          54.10     1.848
4          2008      34.280     18.010     8          62.30     1.605
7          2009      42.360     13.990     9          70.49     1.419
6          2010      18.010     11.180     10         78.69     1.271
3          2011      27.640     8.950      11         86.89     1.151
12         2012      4.630      4.630*    12         95.08     1.052

Press <RETURN> to continue █

```

```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
HY051          TRCA - Petticoat Creek at Whites

                SAMPLE STATISTICS
                MEAN      S.D.      C.U.      C.S.      C.K.
X SERIES      20.831    11.030    .530      .501      3.780
LN X SERIES    2.882      .623     .216     -.794     4.659

X(MIN)=       4.630
X(MAX)=       42.360
LOWER OUTLIER LIMIT OF X= 4.733

TOTAL SAMPLE SIZE= 12
NO. OF LOW OUTLIERS= 1
NO. OF ZERO FLOWS= 0

AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                MEAN      S.D.      C.U.      C.S.      C.K.
X SERIES      22.304    10.257    .460      .650      3.954
LN X SERIES    3.005      .477     .159     -.174     3.502
LN(X-A) SERIES 3.122      .425     .136     -.082     3.447

Press <RETURN> to continue , <CTRL> P to obtain hard copy_

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```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

```

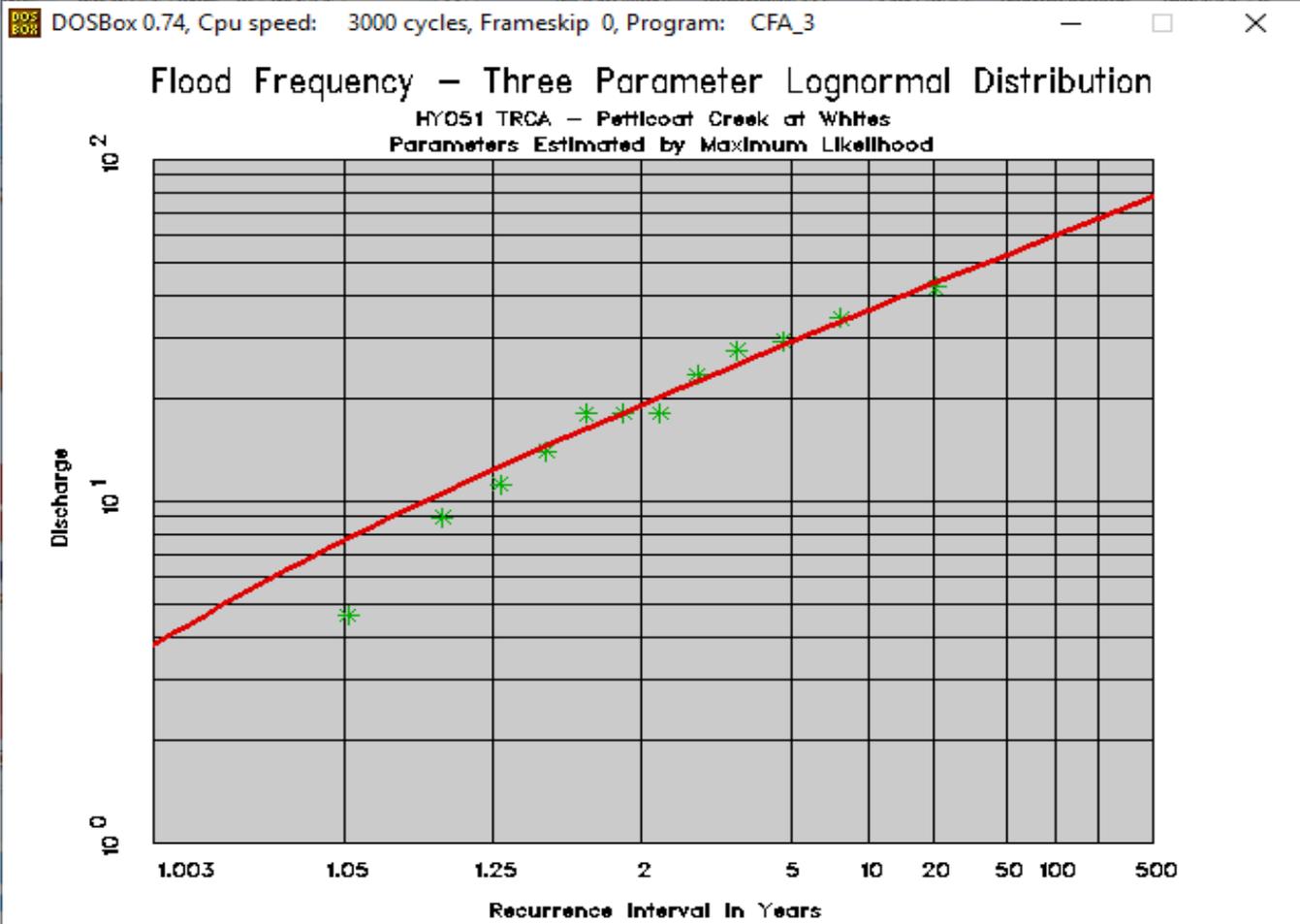
PARAMETERS OF THE 3LN WHICH DUPLICATES THE CONDITIONAL FUNCTION:

A= -2.286 M= 3.065 S= .459

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	3.79
1.050	.952	7.68
1.250	.800	12.3
2.000	.500	19.1
5.000	.200	29.2
10.000	.100	36.3
20.000	.050	43.3
50.000	.020	52.7
100.000	.010	60.0
200.000	.005	67.6
500.000	.002	78.0

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```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
WSC STATION NO=HY051
WSC STATION NAME=TRCA - Petticoat Creek at Whites
-----
MONTH      YEAR      DATA      ORDERED    RANK      PROB.      RET. PERIOD
-----
(1)        (2)        (3)        (4)        (5)        (6)        (7)
              (%)        (YEARS)
7          2001      18.080     42.360     1          4.92      20.333
11         2002      11.180     34.280     2          13.11     7.625
5          2003      23.380     29.440     3          21.31     4.692
8          2004      13.990     27.640     4          29.51     3.389
8          2005      29.440     23.380     5          37.70     2.652
12         2006      18.030     18.080     6          45.90     2.179
3          2007      8.950      18.030     7          54.10     1.848
4          2008      34.280     18.010     8          62.30     1.605
7          2009      42.360     13.990     9          70.49     1.419
6          2010      18.010     11.180     10         78.69     1.271
3          2011      27.640     8.950      11         86.89     1.151
12         2012      4.630      4.630*    12         95.08     1.052

Press <RETURN> to continue █

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```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
HY051      TRCA - Petticoat Creek at Whites

                SAMPLE STATISTICS
                MEAN      S.D.      C.U.      C.S.      C.K.
X SERIES      20.831    11.030    .530      .501      3.780
LN X SERIES    2.882     .623     .216     -.794     4.659

X(MIN)=       4.630
X(MAX)=       42.360
LOWER OUTLIER LIMIT OF X= 4.733

TOTAL SAMPLE SIZE= 12
NO. OF LOW OUTLIERS= 1
NO. OF ZERO FLOWS= 0

AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                MEAN      S.D.      C.U.      C.S.      C.K.
X SERIES      22.304    10.257    .460      .650      3.954
LN X SERIES    3.005     .477     .159     -.174     3.502

Press <RETURN> to continue , <CTRL> P to obtain hard copy_

```

```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

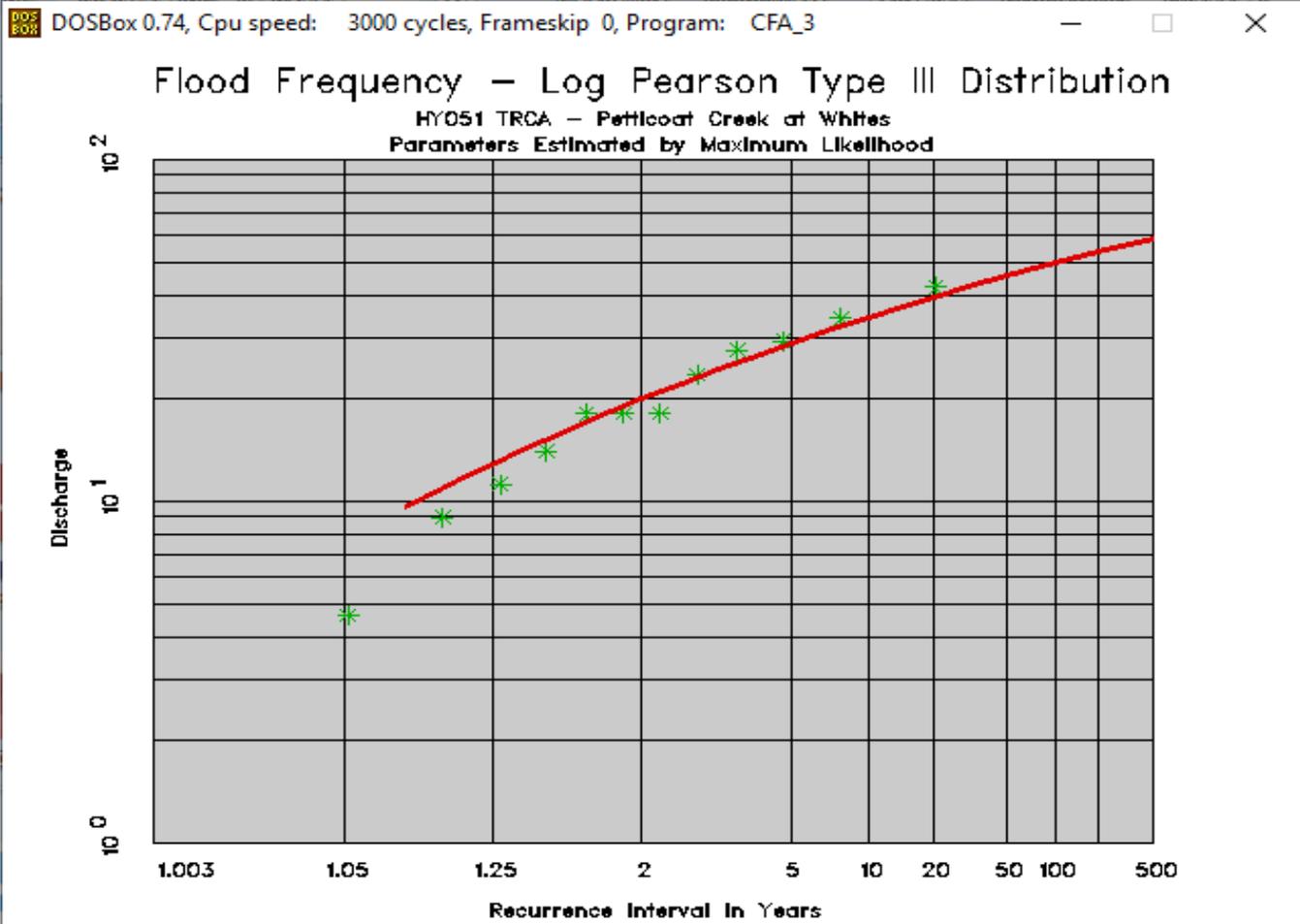
```

DISTRIBUTION IS UPPER BOUNDED AT M= 131.0
 PARAMETERS OF THE LP3 WHICH DUPLICATES THE CONDITIONAL FUNCTION:
 A= -.1249 B= 15.42 LOG(M)= 4.875 M = 131.0
 SYNTHETIC STATISTICS: MEAN= 2.948 S.D.= .491 C.S.= -.509

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	-
1.050	.952	-
1.250	.800	12.8
2.000	.500	19.9
5.000	.200	29.0
10.000	.100	34.6
20.000	.050	39.6
50.000	.020	45.5
100.000	.010	49.7
200.000	.005	53.6
500.000	.002	58.4

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```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
WSC STATION NO=HY051
WSC STATION NAME=TRCA - Petticoat Creek at Whites
-----
MONTH      YEAR      DATA      ORDERED    RANK      PROB.      RET. PERIOD
-----
(1)        (2)        (3)        (4)        (5)        (6)        (7)
              (%)        (YEARS)
7          2001      18.080     42.360     1          4.92      20.333
11         2002      11.180     34.280     2          13.11     7.625
5          2003      23.380     29.440     3          21.31     4.692
8          2004      13.990     27.640     4          29.51     3.389
8          2005      29.440     23.380     5          37.70     2.652
12         2006      18.030     18.080     6          45.90     2.179
3          2007      8.950      18.030     7          54.10     1.848
4          2008      34.280     18.010     8          62.30     1.605
7          2009      42.360     13.990     9          70.49     1.419
6          2010      18.010     11.180     10         78.69     1.271
3          2011      27.640     8.950      11         86.89     1.151
12         2012      4.630      4.630*     12         95.08     1.052

Press <RETURN> to continue █

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DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
HY051          TRCA - Petticoat Creek at Whites

                SAMPLE STATISTICS
                MEAN      S.D.      C.U.      C.S.      C.K.
X SERIES      20.831    11.030    .530      .501      3.780
LN X SERIES   2.882     .623     .216     -.794     4.659
L-MOM RATIO   20.831    6.479    .311     .125     .133

X(MIN)=      4.630
X(MAX)=      42.360
LOWER OUTLIER LIMIT OF X= 4.733

TOTAL SAMPLE SIZE= 12
NO. OF LOW OUTLIERS= 1
NO. OF ZERO FLOWS= 0

AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                MEAN      S.D.      C.U.      C.S.      C.K.
X SERIES      22.304    10.257    .460      .650      3.954
LN X SERIES   3.005     .477     .159     -.174     3.502
L-MOM RATIO   22.304    6.007    .269     .173     .115

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```

```

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

```

THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M= 1.957 A= 8.930 B= 15.42 C= -97.214 D= -.140
DISTRIBUTION IS UPPER BOUNDED AT E= .1081E+03

FLOOD FREQUENCY REGIME

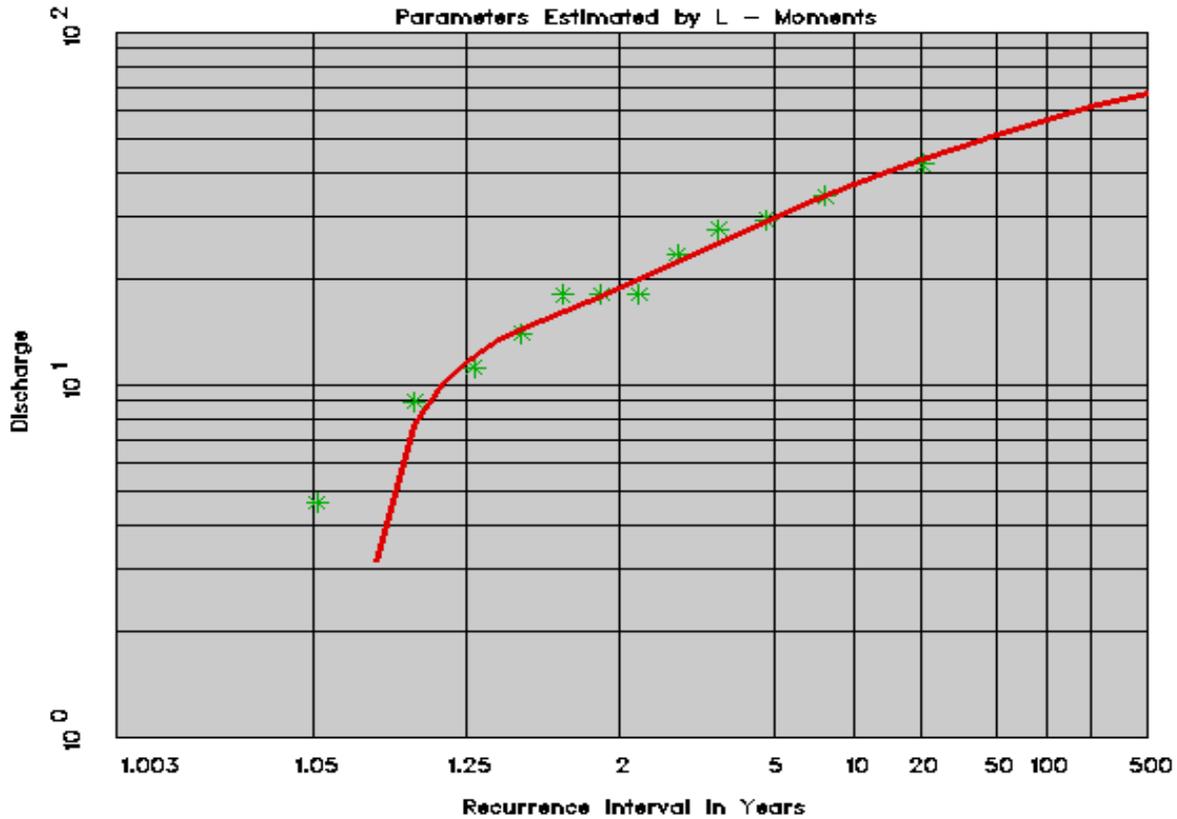
RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	-
1.050	.952	-
1.250	.800	11.6
2.000	.500	18.8
5.000	.200	29.6
10.000	.100	36.9
20.000	.050	43.5
50.000	.020	51.3
100.000	.010	56.5
200.000	.005	61.3
500.000	.002	66.9

Press <RETURN> to continue , <CTRL> P to obtain hard copy

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

Flood Frequency - Wakeby Distribution

HY051 TRCA - Petticoat Creek at Whites
Parameters Estimated by L - Moments



```
DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

*** FREQUENCY ANALYSIS PROGRAM ***
--- SAMPLE STATISTICS ---

WSC STATION NO.=HY051
WSC STATION NAME=TRCA - Petticoat Creek at Whites
DRAINAGE AREA= 25.84
NUMBER OF OBSERVATIONS= 12

      X series   lnX series
MEAN   20.831   2.8824
S.D.   11.030   .6226
C.U.   .5295   .2160
C.S.   .5015   -.7941
C.K.   3.7803   4.6588

You should always check :
> that the data are accurate
> for historic information
> that the data and historic information are up to date

Press <RETURN> to continue
```

```
DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

FREQUENCY ANALYSIS - NONPARAMETRIC METHOD
HY051      TRCA - Petticoat Creek at Whites

              SAMPLE STATISTICS
              MEAN      S.D.      C.U.      C.S.      C.K.
X SERIES      20.831    11.030    .530     .501     3.780
LN X SERIES   2.882     .623     .216     -.794     4.659

X(MIN)=      4.630
X(MAX)=      42.360

TOTAL SAMPLE SIZE= 12
NO. OF ZERO FLOWS= 0

Press <RETURN> to continue , <CTRL> P to obtain hard copy_
```

```
DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
```

SMOOTHING PARAMETER H = 10.830

FLOOD FREQUENCY REGIME

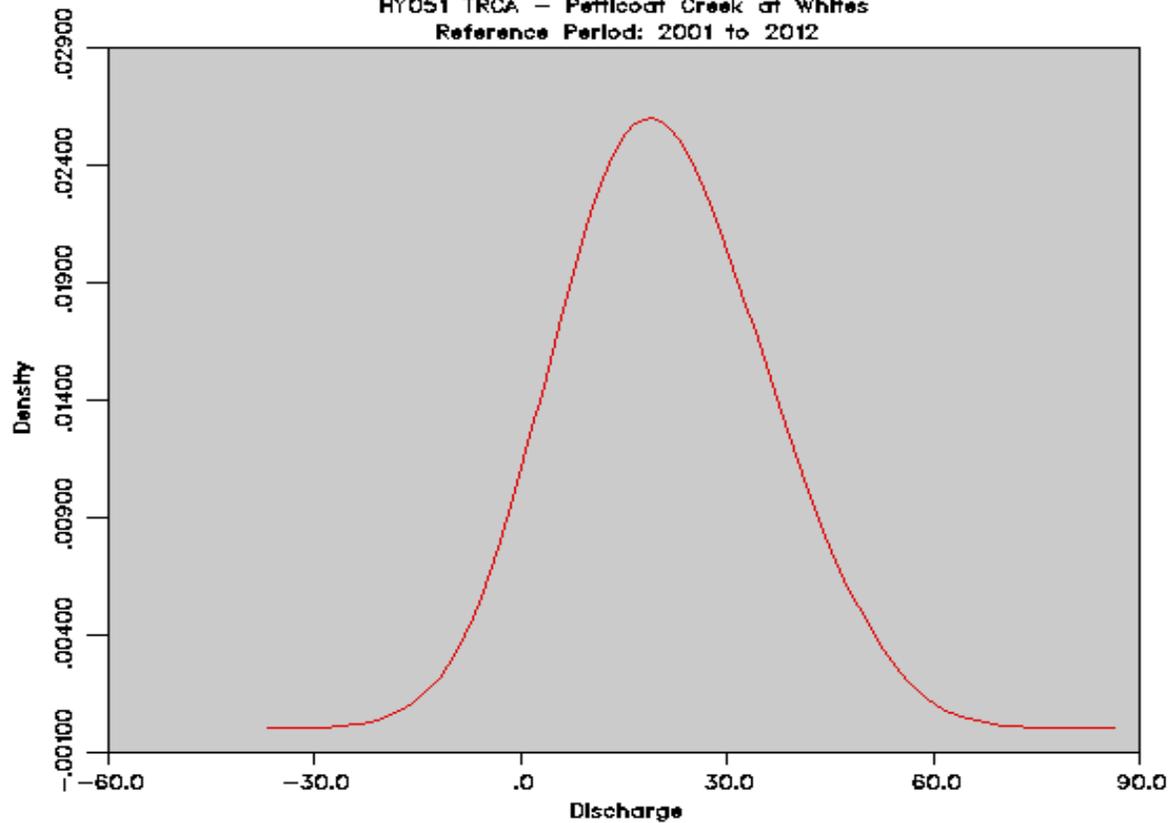
RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	-
1.050	.952	-
1.250	.800	7.84
2.000	.500	20.3
5.000	.200	33.7
10.000	.100	40.9
20.000	.050	46.6
50.000	.020	52.9
100.000	.010	56.8
200.000	.005	60.4
500.000	.002	64.5

Press <RETURN> to continue , <CTRL> P to obtain hard copy_

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3

Probability Density Function

HY051 TRCA - Petticoat Creek at Whites
Reference Period: 2001 to 2012



N CLIMATE
CHANGE
RESULTS

IDF for: TORONTO CITY ID:6158355

Station Info

IDF historical data 

IDF under climate change 

Station name: **TORONTO CITY**

ID: **6158355**

Latitude: **43.67**

Longitude: **-79.40**

Starting year: **1940**

Ending year: **2017**

Number of years (with data): **67**

IDF for: TORONTO CITY ID:6158355

Station Info

IDF historical data 

IDF under climate change 

GEV

Gumbel

Tables

Plots

Interpolation Equations

Total precipitation amounts are presented in mm and precipitation intensity rates are presented in mm/h for different return periods (T) presented in years

Total PPT (mm) Intensity rates (mm/h)

T (years)	2	5	10	20	25	50	100
5 min	8.65	11.88	14.41	17.18	18.13	21.34	24.94
10 min	12.28	16.23	19.22	22.39	23.46	27.00	30.87
15 min	14.63	19.92	24.08	28.65	30.22	35.53	41.51
30 min	18.98	26.44	32.03	37.94	39.93	46.47	53.58
1 h	23.73	32.78	39.12	45.49	47.57	54.16	60.99
2 h	27.61	37.94	45.54	53.46	56.10	64.69	73.91
6 h	33.62	45.16	54.21	64.13	67.56	79.06	92.03
12 h	40.22	53.09	62.78	73.05	76.53	87.94	100.40
24 h	45.63	59.35	69.21	79.29	82.63	93.32	104.60

IDF for: TORONTO CITY ID:6158355

Station Info

IDF historical data [?](#)

IDF under climate change [?](#)

GEV

Gumbel

Tables

Plots

Interpolation Equations

Total precipitation amounts are presented in mm and precipitation intensity rates are presented in mm/h for different return periods (T) presented in years

Total PPT (mm) Intensity rates (mm/h)

T (years)	2	5	10	20	25	50	100
5 min	9.01	12.42	14.68	16.84	17.53	19.65	21.75
10 min	12.62	16.70	19.40	21.98	22.81	25.34	27.85
15 min	15.23	20.82	24.52	28.06	29.19	32.65	36.10
30 min	19.61	27.17	32.18	36.98	38.50	43.20	47.85
1 h	24.10	33.08	39.03	44.73	46.54	52.11	57.65
2 h	28.25	39.21	46.46	53.42	55.63	62.43	69.18
6 h	34.87	47.32	55.56	63.47	65.97	73.70	81.37
12 h	41.34	54.45	63.14	71.47	74.11	82.25	90.33
24 h	46.42	60.08	69.13	77.80	80.56	89.03	97.45

IDF for: TORONTO CITY ID:6158355

Station Info

IDF historical data ?

IDF under climate change ?

Climate Model Selection

Scenario RCP 2.6 ?

Scenario RCP 4.5 ?

Scenario RCP 8.5 ?

Comparison Graphs ?

Tables

Plots

Interpolation Equations

Box Plot - Uncertainty ?

Total precipitation amounts presented in mm and precipitation intensity rates presented in mm/h for different return periods (T) presented in years

Total PPT (mm) Intensity rates (mm/h)

T (years)	2	5	10	20	25	50	100
5 min	9.50	13.14	15.90	18.91	19.83	23.29	27.10
10 min	13.48	17.97	21.18	24.51	25.61	29.60	33.89
15 min	16.07	22.04	26.58	31.56	33.07	38.78	45.10
30 min	20.84	29.25	35.28	41.50	43.58	50.92	58.57
1 h	26.03	36.26	43.10	49.69	52.18	59.84	67.51
2 h	30.31	41.98	50.14	58.38	61.34	71.11	81.26
6 h	36.93	49.96	59.84	70.64	73.89	86.29	99.95
12 h	44.15	58.79	69.19	79.95	83.55	96.47	110.33
24 h	50.07	65.74	76.25	86.55	90.53	102.95	116.23

IDF for: TORONTO CITY ID:6158355

Station Info

IDF historical data ?

IDF under climate change ?

Climate Model Selection

Scenario RCP 2.6 ?

Scenario RCP 4.5 ?

Scenario RCP 8.5 ?

Comparison Graphs ?

Tables

Plots

Interpolation Equations

Box Plot - Uncertainty ?

Total precipitation amounts presented in mm and precipitation intensity rates presented in mm/h for different return periods (T) presented in years

Total PPT (mm) Intensity rates (mm/h)

T (years)	2	5	10	20	25	50	100
5 min	10.01	13.84	16.72	19.77	20.81	24.23	27.85
10 min	14.21	18.93	22.36	25.89	27.06	30.82	34.57
15 min	16.94	23.22	27.95	32.98	34.70	40.32	46.31
30 min	21.97	30.79	37.21	43.75	45.97	53.12	60.26
1 h	27.46	38.16	45.47	52.67	55.03	62.41	69.34
2 h	31.96	44.20	52.94	61.76	64.71	74.13	83.24
6 h	38.93	52.65	62.97	73.92	77.64	89.76	102.62
12 h	46.54	61.92	73.06	84.49	88.29	100.43	112.49
24 h	52.79	69.22	80.56	91.96	95.64	107.10	118.11

APPENDIX

O

CORRESPONDENCE

TRCA Comments.

Email from Wilfred Ho (TRCA) to Albert Zhuge (WSP) dated February 21, 2020

[WSP responses in Blue \(May 1, 2020\)](#)

[TRCA reply in Green and Red \(May 5, 2020\)](#)

[WSP confirms in Orange \(May 19, 2020\)](#)

- 1) Should catchment 160 be further divided along the CN rail line?
 - WSP – Agree. Catchment 160 was divided along CN Rail line. New Catchment (175) was created at south of CN Rail line. OK
- 2) Catchments with concentrated development should be divided into rural and urbanized components in order to better estimate the time of concentration on the contiguous rural/natural areas:
 - a. 147 and 153 have clear divides and the aggregate hydrologic response (e.g. AddHYD) of separate NashHYD and StandHYD commands may be a better representation than using catchment-averaged parameters.
 - WSP – Agree. Urban areas were separated into new catchment for catchment 147 (New Catchment 176 created at south side) and 153 (New Catchment 177 created at south side) OK
 - b. 127, 151, and 165 have pockets of development; is the concentration significant enough to further discretize these catchments?
 - WSP- Catchment 127 pockets of development – 40ha, Catchment 127 was separated at CON RD 3 (into 127 and 178). The pockets of developments will be model as STANDHYD by Catchment 178. OK
 - WSP – Catchment 151 pockets of development – 5ha. Catchments 176 and 154 boundaries were revised to include pockets of development. OK
 - WSP – Catchment 165 pockets of development – 24ha, Catchment 165 was separated base on the development boundaries. New Catchment 179 was created for the pockets of development. OK
 - c. 173 and 174 have a significant amount of valleylands; should these be separated from the developed areas?
 - WSP – Agree. Catchments 173 and 174 were separated into two catchments, and the valleylands were separated from the development areas. New Catchments 180 and 181 were created for the developed areas. OK (note that 180 and 181 may need to be routed through channel)
Confirmed.
- 3) Does Strouds Lane form an urban drainage divide for catchment 155?
 - WSP – Agree. Catchment 155 was separated at Strouds Lane. New catchment 182 was created at the south side. OK (note that 155 may need to be routed through channel)
Confirmed.
- 4) Watershed boundary is generally okay. Some minor observations:
 - a. Rougemount Rd. between catchments 163 and 164. DEM shows that Rougemount rises toward Pine Ridge Rd.; was this area excluded because it has no clear outlet?

- WSP – Area of Rougemount Rd was excluded because both the major and minor system show that it drains away from Petticoat Creek. OK
 - For Catchments 163 and 164, only the minor system drains to Petticoat Creek base on the storm sewer pipes/maps. Does this need a flow split? Yes. DuHYD will be used.
- b. Based on DEM, catchment 160 appears to receive drainage around STMH-48-0040 (West Lane, west of Valley Rouge Cres.), such as the rear lots north of West Lane.
- Catchment 160 boundary was revised to include the drainage around STMH-48-0040 OK

Notes for later discussion:

- 1) The minor system in a number of the catchments appears to drain away from Petticoat Creek watershed:
 - a. Catchment 168
 - WSP – Yes, the minor system of Catchment 168 drains away from Petticoat Creek. Does this need a flow split? Yes. DuHYD will be used.
 - b. Southwest of Twyn Rivers Dr. and Woodview Dr. on catchment 160 appears to drain into Little Rouge.
 - WSP – Base on the windshield survey, the major system of southwest of Twyn River Dr and Woodview Dr drains to Petticoat Creek. The minor system drains to Little Rouge base on storm sewer network. A new catchment 183 was created to simulate the major/minor split at Catchment 160. OK
- 2) Catchment 167 has a long and narrow area that corresponds to Rosebank Rd.; routing may affect peak timing, perhaps split catchment and/or set up a route pipe and route channel to simulate the routing.
 - WSP – Agree. Catchment 167 was separated at Charnwood Crt. A new catchment 184 was created. OK (may need routing element) Confirmed.
- 3) Routing behind structures.
 - It is recognized that the undersized culverts or bridges along the watercourses would create storages upstream of such undersized culverts and consequently impact the watershed hydrology. To properly incorporate such storage upstream of undersized culverts in the model, the flood storage volumes in the channel resulted from the available hydraulic model (to be provided by TRCA, e.g., HEC-RAS) will be compared with those resulted from the model scenario that all river crossings are removed. If there is a significant change of the flood storage occur at a crossing, the flood storage at such crossing needs to be applied in the hydrological model. We will discuss with TRCA to discuss the approach and confirm how the storage-discharge rating curve should be determined. For example, the storage value can be obtained from HEC-Ras model, while the discharge value can be determined by culvert flow capacities (e.g., at culvert obvert or road deck, etc.) or based on the calculations (e.g., Culvert Master program). Noted

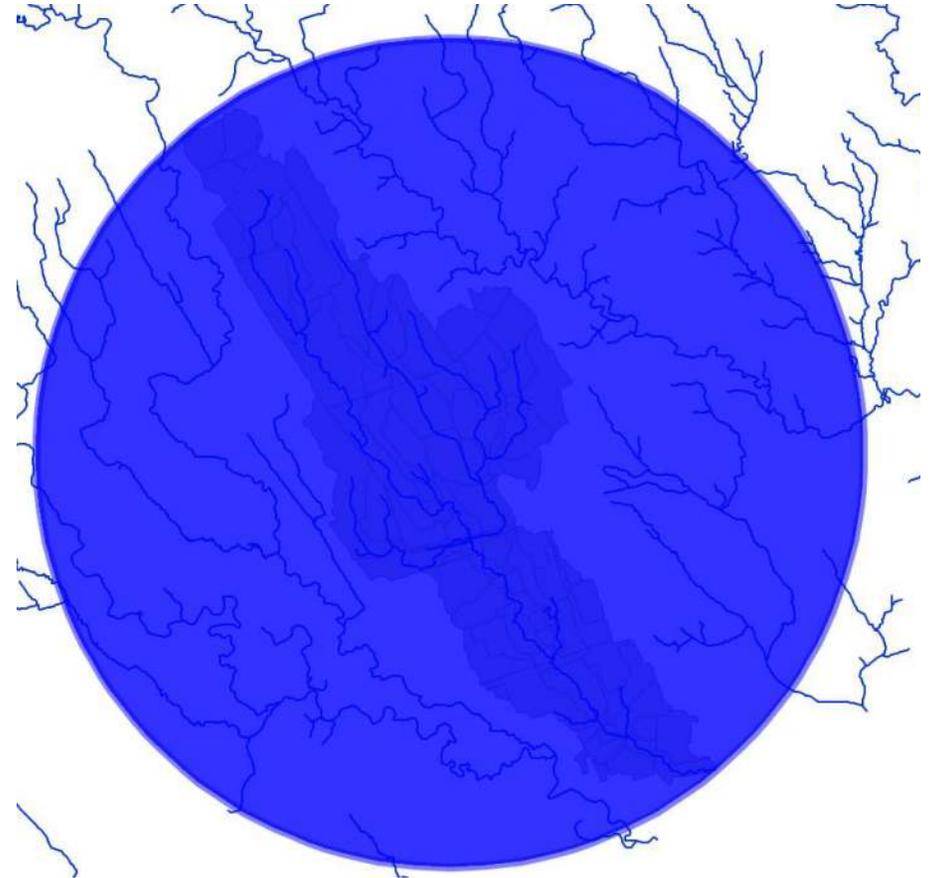
Zhuge, Albert

From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Thursday, October 08, 2020 4:08 PM
To: Zhuge, Albert
Cc: Chui, Jenny
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Thanks for your work to date, Albert and Jenny.

One thing to note in the report would be the change in areal reduction factors, especially toward the lake where the reduction factor was previously 94.8 (based on a drainage length of 14.14km) and is now 95.4 (based on a drainage length of 12.3km).

After taking a few measurements in GIS, I am confident that you have applied the correct equivalent circular area for the current work:



I think the clearest way to support the change in reduction factor is simply to include a sample image with length and area measurements alongside a table of reduction factors used for each node in the Appendix.

Stay well,

Wilfred Ho, B.E.S.
Project Manager, Capital Projects
Development and Engineering Services

T: [\(416\) 661-6600](tel:4166616600) ext. 5738
E: wilfred.ho@trca.ca
A: [101 Exchange Avenue, Vaughan, ON, L4K 5R6](https://www.trca.ca/101-Exchange-Avenue-Vaughan-ON-L4K-5R6) | [trca.ca](https://www.trca.ca)



From: Zhuge, Albert <Albert.Zhuge@wsp.com>
Sent: Thursday, October 8, 2020 2:22 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good afternoon, Wilfred.

As we promised, we have completed the hydrological simulation based on the final model. The simulation was performed for the selected design storms (12 hr SCS), Regional event (Hazel) and Climate Change Scenarios.

Please see the attached for the models and results in details.

We are currently preparing the draft final report. Once ready, it will be provided to you for review and comments.

Thanks, Wilfred. 😊

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Friday, September 25, 2020 3:04 PM
To: Zhuge, Albert <Albert.Zhuge@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Thanks for the summary, Albert.

Have a great weekend, folks.

Wilfred Ho, B.E.S.
Project Manager, Capital Projects
Development and Engineering Services

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From: Zhuge, Albert <Albert.Zhuge@wsp.com>
Sent: Friday, September 25, 2020 2:59 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events
Importance: High

Hi Wilfred,

Thank you so much for your time to discuss the study with me. It is very helpful.

Based on our discussion, I summarize the following items.

- 1) It is confirm that 12-hr SCS Type II will be used for Petticoat Ck watershed.
- 2) There will be no future development conditions for the study watershed.
- 3) We will prepare and submit the final design flows (2- 100- year and regional) and the flows based on climate change data (based on UWO IDF CC Tool v4 - <https://www.idf-cc-uwo.ca/>) to TRCA by Oct. 9.
- 4) The draft report will be completed and submitted to TRCA for review and comment by Oct 31.

Please feel free to let me know if you have any questions or concerns.

Thanks again, Wilfred. 😊

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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From: Zhuge, Albert
Sent: Tuesday, September 22, 2020 2:34 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good afternoon Wilfred,

We have completed the flood frequency analysis based on the 12 years records (2001 – 2012) at HY041. We also updated the SO 30% and 70% AES based on the distribution provided by Upper Thames River CA. Please see the attached for more information.

As shown below, the flows calculated by our frequency analysis are more close to those from 12-hr SCS (e.g., the most conservative peak flows for Main Branch at Hwy 401).

I think we can have a quick phone conversation to discuss the details and get an agreement on the selection of the design storms for the study watershed.

I am available on Wed (23rd) 9:30 AM, Thur (24th) 2:00PM, Friday (25th) 9:30 AM and 2:00 PM. Please let me know your availability. Thanks, Wilfred.

Source / Return Period		2-year	5-year	10-year	25-year	50-year
Design Storms	12-hr SCS Type II (MTO)	18.5	27.5	33.9	41.7	47.3
	24-hr SCS Type II (MTO)	18.1	26.4	32.2	39.6	44.8
	12-hr AES (30%)	12.6	21.2	27.4	35.7	42.7
	24-hr SCS Type II (MNRF)	11.9	19.7	25.3	33.0	39.3
Flood Frequency Analysis	Provided by TRCA (Sep 14, 2020)	10.5	19.7	25.7	33.4	39.7
	WSP: Generalized Extreme Value (GEV)	19.0	29.2	36.1	42.8	51.6
	WSP: Three-Parameter Lognormal (3PL / HILO)	19.1	29.2	36.3	43.3	52.7
	WSP: Log Pearson Type III (LPIII)	19.9	29.0	34.6	39.6	45.8
	WSP: Wakeby	18.8	29.6	36.9	43.5	51.3
	WSP: Nonparametric Method	20.3	33.7	40.9	46.6	52.8

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From: Zhuge, Albert
Sent: Thursday, September 17, 2020 10:20 AM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Thanks, Wilfred.

I will update the flow comparison table and provide it to you for our further discussion.

Thanks. 😊

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Wednesday, September 16, 2020 5:17 PM
To: Zhuge, Albert <Albert.Zhuce@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Thanks Albert and Jenny, for following up.

Agreed on comments 1, 4 and 5.

For comment 3, please find the 2001-2012 data here: [☐_2001-2012 Data](#)

Regarding comment 2:

Note that we typically perform the analysis on summer peaks; I believe the general rule for predicting a return period value is no more than double the period of record.

The AES Type II caused a lot of discussion when during the Don hydrology update. Ultimately, the project team found that it was applicable as a 1-hour storm, but did not find verified 12-hour AES distributions other than the 10%, 30%, 50%, 70%, 90% exceedance distributions. As such, the Don and Highland updates did not test a Type II 12-hr AES.

With the flow data provided, I think we can reach a reasonable compromise between conservative peak flows and gauged flood frequency.

It can be a complicated issue. Please let me know if you'd like to touch base for further discussion.

Stay well,

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From: Zhuge, Albert <Albert.Zhuge@wsp.com>
Sent: Wednesday, September 16, 2020 2:12 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hi Wilfred,

Your email is very informative. Please see below for our responses.

- 1) Thank you for the reference manual prepared by Upper Thames River CA. We will update the MNR's SO 30% and 70% 12-hr AES distributions, rerun the model and present the results.
- 2) You are absolutely correct, Wilfred. SCS (namely, Soil Conservation Service, if I remember correctly) type storm was developed in the US. Type II is used for most portion of US including the Greater Lakes area. Therefore, we also test SCS distribution in Southern Ontario. We understand that 12 Hr AES storm has been applied for both the nearby Rouge River watershed and the Petticoat Ck in the previous study. Furthermore, as you indicated, MNRF Technical Guidelines express a general inclination toward applying AES storms in Ontario. Therefore, we agree with you that, to keep it consistent, 12 Hr AES shall be used for Petticoat Ck. I prefer to use the 12-hr AES distribution based expanding a Type II AES 1-hr. This is because, first of all, type II AES has only been verified for 1-hour durations; secondly, it results in higher flows than those by MNR's 12hr AES (SO 30% or 70%).
- 3) Due to the limited years of record, based on my opinion, we should not rely on the gauged data. The 19 years of record is sufficient to predict flows with return period of 1 in 10 years. However, less frequent flows (e.g., 25-, 50, 100- years) resulted would include more uncertainties. As such, we believe, the flows calculated by the frequency analysis based on the 19 years of record should only be used for reference purposes. By the way, could you please provide me with the annual peak flows for these 19 years? We can also perform frequency analysis and include the results in the report.
- 4) We will add 3-, 4-, and 12-hour Chicago distributions to the test.
- 5) DuHYDs are used to simulate the major/minor system split. During the significant design storm events (e.g., 25- to 100-year), the minor system still takes the runoff until its capacity exceeds. Therefore, I would recommend keep all DuHYDs for 2- to 100-year design storms. However, for the Regional event, by considering the wet AMC, we can remove DuHYD and assume the minor system is full.

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For the future conditions, you have advised that the OP has been built. Therefore, there would be no future conditions model developed for the study. However, we do notice that the previous 2005 study includes a future (ultimate) condition, where there are 50% imperviousness for all rural catchment beyond OP. Is the similar ultimate condition required for the current study? Please confirm.

Thanks, Wilfred.



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Senior Project Manager
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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Monday, September 14, 2020 5:54 PM
To: Zhuge, Albert <Albert.Zhuge@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good afternoon, Albert and Jenny.

Thank you for preparing the information.

Please note that at outset of the project, the OP in the watershed was considered built. As of the previous (2005) study, the Future OP north of Finch (south of the rail line) only had a small portion of land designated for low- to medium-density residential use, which looks to be built judging from the ortho photos used for imperviousness measurement.

I've had a look through the design storms, did some testing and had some observations:

- 1) 12-hr AES, 30%: It looks like the hourly percentages were scaled down so that the rainfall total would match the IDF analysis, since the hourly percentages given by the MNRF Technical Guidelines total greater than 100%. TRCA encountered this issue when completing the Don and Highland hydrology updates and found that Upper Thames River CA published a correction to the distribution in their design storm guidance ([Guidance](#)). For documentation purposes, please update the 30% and 70% 12-hr AES distributions and the results.
- 2) Design storm selection: Previous study chose the most conservative peak flows upstream at the confluence point at Hwy 401 and Rosebank; this was considered to represent the characteristics of the majority of the watershed. WSP's recommendation of the 12-hr SCS, type II (MTO) is consistent with the previous approach, however the new peak flows are 17-49% higher at the gauge location than the previous study. This is most likely due to the change in distribution from a 12-hr AES (based expanding a Type II AES 1-hr distribution); in fact, the 100-year peak flows are very similar when applying this storm to the current update. TRCA has no issues moving away from the previous distribution, since the Type II AES has only been verified for 1-hour durations. However, the SCS distributions were not tested in the previous study, probably because the MNRF Technical Guidelines

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(section 1.3c) express a general inclination toward applying AES storms in Ontario. I'm familiar with the literature on how the SCS distributions were developed for rural areas in the U.S., but is there supporting documentation for applying the SCS Type II in this area? Please also see comment 3 (below) and let me know.

- 3) Please see the table below for comparisons of select design storms (including corrected 30% 12-hr AES) at the modelled gauge location with flood frequency (2001-2019 data for HY051). I believe that a minimum 50-year period of record is required in order to predict the 100-year flood in a gauged watershed, and HY051 has about 19 years of record (sufficient for perhaps a 25-year flood). Is this the rationale for not using a flood frequency analysis for selecting the design storms?

Source	2-year	5-year	10-year	25-year	50-year	100-year	Notes
Flood frequency	10.48	19.65	25.722	33.394	39.085	44.734	Based on summer maxima at HY051
12-hr SCS Type II (MTO)	18.536	27.521	33.938	41.744	47.252	53.533	Most conservative peak flows for M. of watershed characteristics)
24-hr SCS Type II (MTO)	18.124	26.354	32.224	39.581	44.825	50.153	
12-hr AES (30%)	12.582	21.241	27.363	35.736	42.658	49.651	
24-hr SCS Type II (MTRF)	11.944	19.692	25.306	33.003	39.256	45.661	Closest match to flood frequency at

- 4) For completeness, TRCA typically requests the inclusion of the 3-, 4-, and 12-hour Chicago distributions among the tested design storms; please include these storms for the Petticoat as well. Based on some testing on my end, it is unlikely that this will alter the choice of design storm, but it will bring the current study in-line with what was documented for more recent hydrology updates.
- 5) The previous hydrology model contained one major/minor system split (DuHYD) that was maintained even for the Regional storm simulation. The current update has 10 splits; would it be reasonable to disconnect the minor system for significant events (e.g. 25-year to Regional)?

Thanks again for your work to date, and please let me know of anything further.

Stay well,

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From: Zhuge, Albert <Albert.Zhuce@wsp.com>
Sent: Thursday, September 3, 2020 12:28 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events
Importance: High

Good morning Wilfred.

In order to determine the synthetic design storm which can provide the most effective runoff responses on the subject watershed, we evaluated a total of 12 storm distributions:

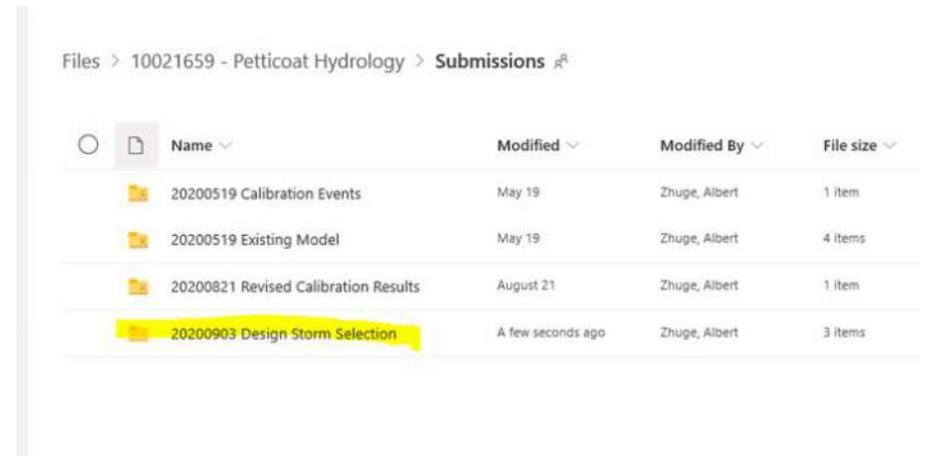
01. AES 1hr _ based on Southern Ontario 1 hr AES Type II
02. AES 6hr _ based on Southern Ontario 1 hr AES Type II
03. AES 12hr _ based on Southern Ontario 1 hr AES Type II
04. AES 24hr _ based on Southern Ontario 1 hr AES Type II
05. 30% Southern Ontario 12hr AES
06. 70% Southern Ontario 12hr AES
07. SCS 6hr - Based on MNR 24hr SCS Storm Type II
08. SCS 12hr - Based on MNR 24hr SCS Storm Type II
09. SCS 24hr - Based on MNR 24hr SCS Storm Type II
10. SCS 6hr _ MTO SCS Type II
11. SCS 12hr _ MTO SCS Type II
12. SCS 24hr _ MTO SCS Type II

Based on the evaluation results, we would like to recommend 12 hour SCS Type II Distribution based on MTO Design Chart 1.05 (#11) for Petticoat Creek watershed.

All supporting calculations, spreadsheets, documentations are uploaded to OneDrive for your review.

In the meantime, could you please provide us with the future landuse? We can start to work on the future conditions model.

Thanks, Wilfred. 😊



Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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From: Zhuge, Albert
Sent: Tuesday, August 25, 2020 3:17 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Yes. It looks like the extrapolated peak of 12 cms and the duration (time) are very promising. 😊 I think it would match 2.00 very well.

Anyway, please see the attached two simulated flow output for 2.00 and 2.01 for your use.

Thanks, Wilfred. 😊

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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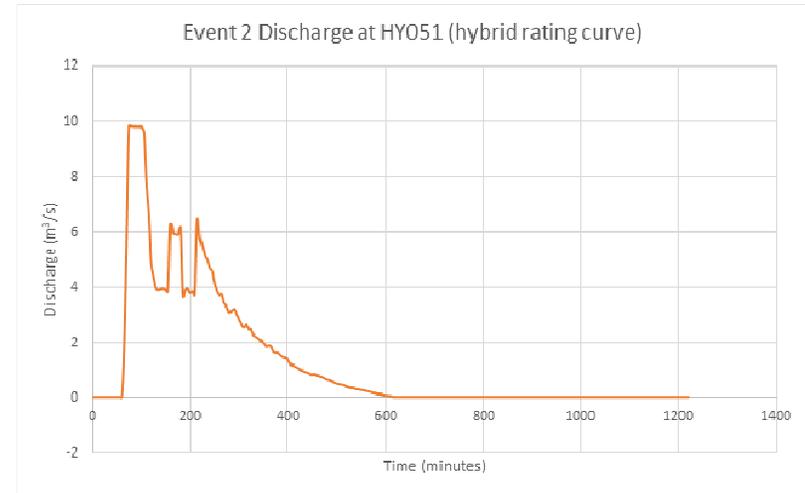
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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Tuesday, August 25, 2020 2:56 PM
To: Zhuge, Albert <Albert.Zhuge@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

No problem, Albert.

We eventually extended the rating curve in 2015, but the lower portion was not consistent with the 2014 rating curve. Anyway, based on a "hybrid" rating curve, the may have peak exceeded 10m³/s (extrapolated to about 12m³/s):



Obviously, we can't take this result as absolute, but it looks like simulation 2.00 fits pretty well.

Please proceed with the design storms, but may I ask for the simulated hydrographs at the gauge for simulations 2.00 and 2.01? I ran the models on my end but there was a computational error.

Thanks again,

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From: Zhuge, Albert <Albert.Zhuge@wsp.com>
Sent: Tuesday, August 25, 2020 2:34 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hi Wilfred,
Thanks for the quick response and the information you provided.

For Event 2, I am surprised, but happy, to see that the water level graph is visually in agreement with our simulated hydrograph. I added the water level graph to the comparison chart and try to further look at the difference (please see the attached figures). It seems, if we only compare the shape of both, they match very well. But if we plot both on the same time scale, it seems the increases of the level came faster and went down faster than the simulated. But anyway, as you suggested, since the event exceeded the limits of the rating curve, we should not rely on the observed data in this case.

For Event 7, it was expected that this event was a rain-on-snow event. Thank you for the confirmation.

We are now moving to the next task. As per your suggestion, we will proceed with the IDF at Toronto-City gauge. The attached is the latest IDF data obtained from ECCC. It is dated March 27, 2020, and based on 67 years data from 1940 – 2017. We will use this to generate the design storms. It won't take us long to complete this task. We will keep you updated.

Thanks, Wilfred.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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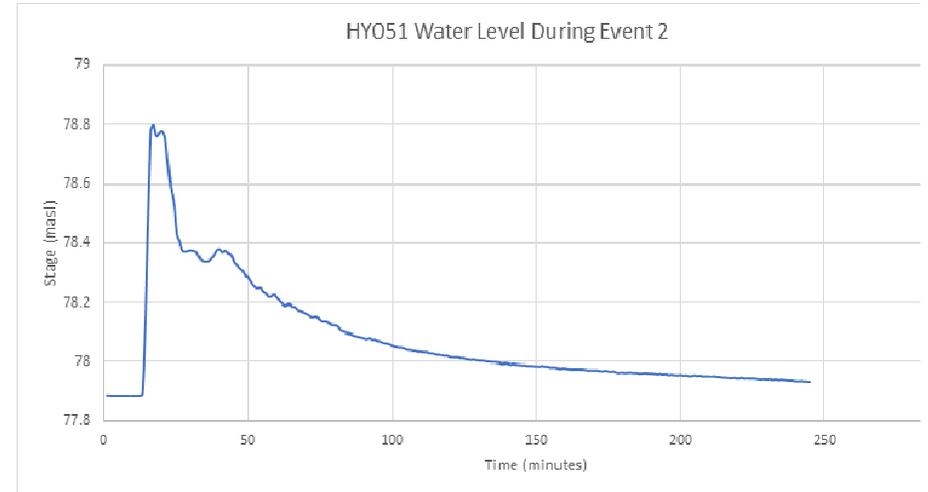
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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Monday, August 24, 2020 4:19 PM
To: Zhuge, Albert <Albert.Zhuce@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good afternoon, Albert and Jenny.

I've reviewed your latest materials and offer two observations:

- 1) Event 2. The highest point (6.82 m³/s) on the rating curve was exceeded twice during this event. I extracted the water level readings and created a chart (below). Based on visual inspection, the response timing and shape of the graph is much more in line with the simulation:



Unfortunately, we can't reliably calculate flows above a stage of 78.36 masl, but I would say that the simulation is reasonably close in terms of shape and timing.

- 2) Event 7. I checked TRCA's snow course records and flood forecasts for the Event 7. A jurisdiction-wide average of 8.5mm snow accumulation was estimated based on temperature and precipitation. Note that snow course samples were estimated to be depleted by the time of Event 7. Therefore it is plausible that this was a rain-on-snow event, which would have generated more runoff volume than the rainfall alone.

The other calibrations are very reasonable and I have no further issues therein; please share your thoughts on items 1 and 2, then let's proceed to the design storms. I looked at the IDF information for the Greenwood, Ellesmere, Buttonville, Toronto City, and Pearson; the differences in return period volumes is minor, so let's go with Toronto-City gauge since it has the longer period of record.

Stay well,

Wilfred Ho, B.E.S.
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From: Zhuge, Albert <Albert.Zhuce@wsp.com>
Sent: Friday, August 21, 2020 3:31 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hi Wilfred,

The file was uploaded to OneDrive for your review.

Thanks. 😊

The screenshot shows the OneDrive interface for a folder named '10021659 - Petticoat Hydrology > Submissions'. The folder contains three sub-folders: '20200519 Calibration Events' (modified May 19), '20200519 Existing Model' (modified May 19), and '20200821 Revised Calibration Results' (modified 'A few seconds ago'). The third folder is circled in red. The interface includes navigation options like '+ New', 'Upload', 'Share', 'Copy link', 'Sync', and 'Download'.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
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From: Zhuge, Albert
Sent: Friday, August 21, 2020 3:27 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events
Importance: High

Good afternoon Wilfred,

Thank you so your time to discuss with us regarding the model calibration.

As per our meeting, I checked the precipitation data used in the VO model. I was surprised to find out that some of the hyetographs in the calibration scenarios were wrong. I further discovered that the reason for the messed up precipitation input was due to the error of "Resource Library" in the VO6 model. We have to input only 1 observed hyetograph file to the Resources Library and save it one by one. If we input multiple hyetographs without saving the library, the data may get collapsed and messed up.

Anyway, we have fixed the issues and the calibration/validation has now been revised. As expected, the outcomes of the calibration/validation remain unchanged: no adjustments of the parameters would be required. Similarly, we recommend the calibration results to be used for reference purposes only. This is due to many limitations of the calibration inputs. We will document all the details of calibration/validation process, including all the limitations and our recommendations in the report.

Wilfred, please review our revised calibration results (you will receive an email from OneDrive to access the saved files), and let us know what you think. Once confirmed, we can start to work on the design storms. We will develop design storms based on different distributions, including 1-, 6-, 12- and 24-hour AES or SCS. These distributions will be prepared in spreadsheets with the links to the data sources for reference purposes. Based on the location of the watersheds, we have options to select the IDF rain gauges: 1) Greenwood – 19 years of data; 2) Ellesmere – 25 years of data; 3) Buttonville – 20 years of data; 4) Toronto City – 67 years of data and 5) Pearson – 64 years of data. The closest location is Greenwood; while the longest data is at Toronto City. We recommend to use the data from Toronto City. We can discuss to confirm.

Thank, Wilfred.

Have a great weekend.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Monday, August 10, 2020 8:02 AM
To: Zhuge, Albert <Albert.Zhuce@wsp.com>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good morning, Albert.

Let's touch base Friday morning.

Wilfred Ho, B.E.S.

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From: Zhuge, Albert <Albert.Zhuce@wsp.com>

Sent: Sunday, August 9, 2020 11:17 PM

To: Wilfred Ho <Wilfred.Ho@trca.ca>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hi Wilfred,

I am available Thursday afternoon and Friday morning.
Please let me know your availability. I will send the meeting invitation to you.

Thanks.

Albert Zhuge, M.Sc, P.Eng, PMP

Senior Project Manager
Water Resources



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From: Wilfred Ho <Wilfred.Ho@trca.ca>

Sent: Friday, August 07, 2020 4:11 PM

To: Zhuge, Albert <Albert.Zhuce@wsp.com>

Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

17

No problem, Albert.

Enjoy your vacation.

Wilfred Ho, B.E.S.

Project Manager, Capital Projects
Development and Engineering Services

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From: Zhuge, Albert <Albert.Zhuce@wsp.com>

Sent: Friday, August 7, 2020 4:10 PM

To: Wilfred Ho <Wilfred.Ho@trca.ca>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: Re: Petticoat Hydrology Update - Existing Model and Calibration Events

Good afternoon Wilfred.

I am on vacation these days and will be back to work around mid next week. We should be able to discuss upon my return. I will check my schedule and confirm with you tonight.

Thanks Wilfred.

Albert Zhuge, M.Sc, P.Eng, PMP

Senior Project Manager

Water Resources

WSP Canada Group Limited

Mobile: 416-816-6916

Sent from my iPhone

On Aug 7, 2020, at 3:27 PM, Wilfred Ho <Wilfred.Ho@trca.ca> wrote:

Hello Albert,

I hope you are well.

I've gone through the materials you provided ; would you be free next week for a teleconference?

18

Thank you and have a nice weekend,

Wilfred Ho, B.E.S.

Project Manager, Capital Projects
Development and Engineering Services

T: (416) 661-6600 ext. 5738

E: wilfred.ho@trca.ca

A: [101 Exchange Avenue, Vaughan, ON, L4K 5R6](#) | [trca.ca](#)

<image002.png>

From: Zhuge, Albert <Albert.Zhuge@wsp.com>

Sent: Tuesday, July 21, 2020 6:32 PM

To: Wilfred Ho <Wilfred.Ho@trca.ca>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Importance: High

Good afternoon Wilfred.

Sorry for a little bit delay. The calibration took longer than we expected due to the complexity of the multiple stations distribution and the uncertainty (e.g., data gap) of the observed data.

Please see the attached for the complete set of the calibration/validation results. Based on the results, no adjustments of the parameters would be required. As we expected, there are many limitations of the calibration process. I list some of them as follows,

- 1) Some observed events were found to have data gaps which results in missing peak flows. Therefore, estimated possible peak flows were considered during the calibration process.
- 2) Some events have multiple peaks which creates difficulties to determine the direct rainfall-runoff transformation. Therefore, the agreement of the time to peak value becomes challenge for these events.
- 3) Some observed events at the identified rain gauge were found to have inconsistent rainfall-runoff response (shifted timing). Therefore, in order to calibrate and match the time to peak, the data at the rainfall stations with the most representative rainfall-runoff responses was applied for the watershed.
- 4) Some early Winter and early Spring events may include runoff due to snow melt.
- 5) All the selected events are insignificant (less than 2-year flows which were estimated to be in the range from 13 cms to 18 cms based on various design storms).
- 6) There is only 7 years of record (Nov 2012 to Jan 2020) available at the streamflow gauges (HY051). Therefore, single station frequency analysis is not available/feasible at the gauge.

In conclusion, although the calibration results generally meet the targets as identified in PaWUG (2002), by considering the identified limitations, we recommend the calibration results to be used for reference purposes only. We will document all the details of calibration/validation process, including all the limitations in the report. Flows determined by previous studies or other methods (e.g., index methods) will be compared with those determined by the current model and referenced in the report.

Furthermore, we strongly recommend that when the additional rainfall and stream flows data become available in the future, the calibration and validation process should be updated.

Please review the attached information and let's discuss the details at your convenience.

Thank you so much, Wilfred.

We look forward to hearing from you.

Albert Zhuge, M.Sc, P.Eng, PMP

Senior Project Manager
Water Resources

<image003.png>

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Mobile: 1 416-816-6916

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Thornhill, Ontario, L3T 0A1 Canada

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From: Wilfred Ho <Wilfred.Ho@trca.ca>

Sent: Tuesday, June 23, 2020 10:48 AM

To: Zhuge, Albert <Albert.Zhuge@wsp.com>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Thank you for your efforts, Albert and Jenny.

Please continue and let me know if you need anything.

Stay well,

Wilfred Ho, B.E.S.

Project Manager, Capital Projects
Development and Engineering Services

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E: wilfred.ho@trca.ca

A: [101 Exchange Avenue, Vaughan, ON, L4K 5R6](#) | [trca.ca](#)

<image004.png>

From: Zhuge, Albert <Albert.Zhuge@wsp.com>

Sent: Tuesday, June 23, 2020 10:45 AM

To: Wilfred Ho <Wilfred.Ho@trca.ca>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good morning Wilfred.

Thank you so much for the quick response.

We will finalize the base model as per your recommendation (adjustment of the imperviousness for Catchments # 179, 171, 165, and 162). Once this is done, we will proceed with the calibration.

For the timeline, we do our best to have the tasks completed promptly and properly. The summer vacation season is coming, I will take one or two weeks off in July, and another one or two weeks in August. I have been constantly working (from home) since March. Need a little bit time to relax ... 😊

Anyway, we will start the calibration this week and we should have the calibration results produced around mid-July. Hope this timeline works for you.

Thanks, Wilfred. Please let us know if you have any questions or concerns.

Have a great day.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources

<image003.png>

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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Thursday, June 18, 2020 5:11 PM
To: Zhuge, Albert <Albert.Zhuce@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hello Albert and Jenny,

Thank you for providing the updated information; it was laid out very clearly and I was able to review the materials quickly.

Please note that water is considered an impervious surface; this does not affect the proposed NASHYDs and STANDHYDs, this is just for your reference.

The image classification generally worked well. From the image below, you can see that some paved areas were classified as pervious (i.e. some of the Hwy 401 lanes) and some of the pervious areas were classified as impervious. I recommend that the imperviousness of catchments 179, 171, 165, and 162 be manually adjusted to include Hwy 401, after which please proceed to calibration; let's use the events with the most complete data for calibration.

<image005.jpg>

If modelled runoff volume is too high during calibration, it can reasonably be assumed that the pervious areas classified as impervious had a cumulative effect on runoff production. I think minor calibration of imperviousness would be acceptable in this case.

Thanks again for your work to date.

As always, stay well and please let me know if you need anything.

Wilfred Ho, B.E.S.
Project Manager, Capital Projects
Development and Engineering Services

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<image006.png>

From: Zhuge, Albert <Albert.Zhuce@wsp.com>
Sent: Thursday, June 18, 2020 10:48 AM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events
Importance: High

Good morning Wilfred.

Please see our further responses (in red) to your comments below.

The attached file includes the parameter spreadsheets and the completed existing (base) model.

Due to the size of the updated impervious analysis and image classification analysis (approx. 10 GB), we have saved them at OneDrive. A separate email will be sent to you to access them.

Thanks, Wilfred. Please let us know whether we can start the calibration process.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources

<image003.png>

Direct: 1 289-982-4534 ***NEW DIRECT LINE***
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From: Wilfred Ho
Sent: Wednesday, May 27, 2020 9:52 AM
To: Zhuge, Albert <Albert.Zhuce@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good morning Albert and Jenny,

Thank you for the quick response.

I should clarify two of my comments:

Were the building footprints used for identifying rooftops? This would remove any potential ambiguity from the image classification.

- The building footprints base on the airphoto image "Pickering_15cm_2015.tif"
Clarification: TRCA provided shapefiles for building footprints in Pickering, Markham, and Toronto. We typically use this information to "burn-in" rooftops in order to avoid potential errors in the image classification (i.e. buildings that are outside the spectral distance of your training samples, such as shaded and atypical coloured rooftops).

- The rooftop areas were revised in the Impervious analysis base on the Building footprint shp file provided. The following tables show the updated TIMP and XIMP. The changes are minor.
- The updated impervious analysis saved in map package. The link to access the data will be provided in a separate email.

TIMP and XIMP before

Landuse	Percent Impervious (TIMP)	Directly Connected (XIMP)
Low Density Residential	9%	4%
Medium Density Residential	65%	26%
Commerical/Employment/Downtown	85%	50%
Road	92%	92%
Railway	100%	100%

TIMP and XIMP after rooftop revised

Landuse	Percent Impervious (TIMP)	Directly Connected (XIMP)
Low Density Residential	9%	4%
Medium Density Residential	64%	26%
Commerical/Employment/Downtown	85%	51%
Road	92%	92%
Railway	100%	100%

This is not a major issue, but how was the image classification affected by parked cars and building shadows? Please see STANDHYDs 171, 179 and 180 as examples.

- During the identifying the rooftop areas, the building shadows was excluded as much as possible and count these areas as parking lots/other impervious surface. (See the impervious site #7, 8 and 9)

Clarification: The training samples were well-chosen. The classification algorithm may have trouble distinguishing between shaded areas and dark vegetation when the spectral ranges in the land cover categories are applied to the watershed, since they are on a similar spectrum in the RGB bands. Here is a comparison from another project I worked on, green lines are vegetation samples and red lines are paved surface samples; the wider bands are the spectral distances as allowable deviations from the sample pixels:

<image007.jpg>

As you can see, there is some overlap.

Would it be possible to provide a geotif (or equivalent) of the resultant image classification (i.e. impervious areas rendered as red and pervious areas rendered as green)? Something like this:

<image008.jpg>

- The Pickering_15cm_2015.tif was classified base on Impervious (Road, Driveway and Rooftop), Pervious (farm land and forest) and water (natural pond and SWM Pond) using image classification function in GIS (See below print screen)
- The image classification analysis saved in map package. The link to access the data will be provided in a separate email.

<image009.png>

Thanks for you work to date.

Please stay well,

Wilfred Ho, B.E.S.
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<image010.png>

From: Zhuge, Albert <Albert.Zhuce@wsp.com>
Sent: Tuesday, May 26, 2020 2:22 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hi Wilfred,
Please see our response to your questions in green.

We will update the Tp values for the identified NASHYDs. Please confirm once it is completed, the model can be used for the calibration process.

Thanks.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources

<image003.png>

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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Friday, May 22, 2020 4:44 PM
To: Zhuge, Albert <Albert.Zhuge@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hello Albert and Jenny,

I have reviewed the initial catchment parameters along with your worksheet. The work is generally very solid with a few observations:

The following NASHYDs have Tp set to 0.2 hours rather than the values proposed in the worksheet:

1461
147
1481
149
151
153
1541
155
156
1581
1591
1611
1651
1661
1691
1701
1711
173
174
1751
1761
1781
1811

Please confirm the initial Tp values for these NASHYDs.

- The Tp values for these NASHYDs will update

For the image classification, the training samples for low- and medium density residential have an “other impervious surface” category; are these patio areas and side yards?

- Yes, the “other impervious surface” are patio areas, swimming pool at the backyard and side yards areas.

Were the building footprints used for identifying rooftops? This would remove any potential ambiguity from the image classification.

- The building footprints base on the airphoto image “Pickering_15cm_2015.tif”

This is not a major issue, but how was the image classification affected by parked cars and building shadows? Please see STANDHYDs 171, 179 and 180 as examples.

- During the identifying the rooftop areas, the building shadows was excluded as much as possible and count these areas as parking lots/other impervious surface. (See the impervious site #7, 8 and 9)

Have a great weekend and enjoy the weather,

Wilfred Ho, B.E.S.
Project Manager, Capital Projects
Development and Engineering Services

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<image011.png>

From: Zhuge, Albert <Albert.Zhuge@wsp.com>
Sent: Wednesday, May 20, 2020 11:11 AM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good morning, Wilfred!

Thanks for the email.
I downloaded and reviewed the video of the Radar for 20180416.

I agree with you that this event can also be used for the calibration/validation.

However, since all these 8 events are relatively small (e.g., 2~5 years), we really don't know what the calibration results will look like. I think maybe we should start the calibration process first. Let's see what we will get and then decide what events for calibration and what for validation.

Please let me know what you think.

Thanks, Wilfred.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources

<image003.png>

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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Wednesday, May 20, 2020 9:37 AM
To: Zhuge, Albert <Albert.Zhuge@wsp.com>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good morning, Albert and Jenny.

Thank you for the first cut of the model; I shall review it and supporting information promptly.

In the meantime, I have uploaded a video of the RADAR coverage for 20180416; unfortunately, I found no options for including a timeline in the output, so I calculated the frames per second to give you roughly 1 second of video time being 1 hour of actual time. I can also provide the PCSWMM RADAR acquisition project (RAP) that I used, but it's about 25 GB; the most efficient way to view it is probably just to teleconference and share screens.

I have also included a spreadsheet comparing each of the RADAR products to measured data; the RADAR consistently underpredicted, but the hyetograph peak timings are not bad and it demonstrates watershed-wide coverage of the event.

Based on the completeness of rainfall and stream flow data, perhaps these events would be best for calibration:

- 20150616
- 20150628
- 20151028
- 20181127

Due to possible missing hydrograph peaks or rainfall record, perhaps these events would be best for validation:

- 20140921
- 20141017
- 20150623
- 20180416

Please let me know of any further concerns or issues.

Stay well,

Wilfred Ho, B.E.S.

Project Manager, Capital Projects
Development and Engineering Services

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<image004.png>

From: Zhuge, Albert <Albert.Zhuge@wsp.com>

Sent: Tuesday, May 19, 2020 5:09 PM

To: Wilfred Ho <Wilfred.Ho@trca.ca>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

27

Subject: Petticoat Hydrology Update - Existing Model and Calibration Events

Importance: High

Hi Wilfred,

Thanks for your email.

Based on your comments on the catchments, we have completed the existing model. I saved all the detailed modelling files (including the parameter spreadsheets, PDF figures, GIS data and the VO model files) to the Project OneDrive.

When you review the existing model, please note the following,

- The % impervious values for different land uses were determined based on the calculated actual impervious areas for a total of 14 sample locations by using Airphotos. (See ImpAnalysis.mpk)
- The CN numbers were determined by different soil types, e.g., Urban lawn, meadows, culminative and woods, based on Technical Guidelines for Flood Hazard Mapping, March 2017.
- Route Channel was coded based on both existing Petticoat Hec-RAS model and contour line. For urban areas, Route Channels along the major flow path were also included in the model. It was determined based on the road cross-sections (See RouteChannel_CatchmentSlope.mpk). We assume 10m road width, manning's n of 0.015 for main channel (road), and 0.15 for beyond (boulevard, lawn, etc.).
- Peak flows generated from the 5-yr 4-hr Chicago design storm were used for the DuHYD commands to simulate minor and major system divides.

Please provide us with your comments on the existing model before we start the calibration.

For the calibration events, thank you for your time to provide us with the additional data. Yes, we now have a total of 7 selected events. The details of these events are also saved at OneDrive for your review. I didn't include the April 16, 2018 event. However, if the Radar data can demonstrate that the precipitation coverage during the period was steady (no fast movement) and generally covers the entire watershed area, we can then use the available HY009 and HY102 for the calibration. Therefore, a total of 8 events can be used. Could you please send us the radar map (video?) of this event for our reference?

Thanks, Wilfred.

Albert Zhuge, M.Sc, P.Eng, PMP

Senior Project Manager
Water Resources

<image003.png>

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From: Wilfred Ho <Wilfred.Ho@trca.ca>

Sent: Tuesday, May 19, 2020 1:50 PM

To: Zhuge, Albert <Albert.Zhuge@wsp.com>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: Petticoat - Rainfall and stream data follow-up

28

Hello Albert and Jenny,

I hope you are doing well.

As a follow-up to the rainfall and stream flow data delivery two weeks ago, have you decided on a method to distribute the rainfall events? All candidate events have three points of coverage with the exception of April 16, 2018, which is missing both HY043 and HY044; I extracted RADAR coverage for that event and found it to have good coverage of the watershed, but I'd like to hear your thoughts.

Thank you for your time and I look forward to hearing from you,

Wilfred Ho, B.E.S.

Project Manager, Capital Projects
Development and Engineering Services

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<image012.png>

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-LAEmlHhHsdJzBNTWw4Hps7pbkI

Zhuge, Albert

From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Thursday, June 18, 2020 5:11 PM
To: Zhuge, Albert
Cc: Chui, Jenny
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hello Albert and Jenny,

Thank you for providing the updated information; it was laid out very clearly and I was able to review the materials quickly.

Please note that water is considered an impervious surface; this does not affect the proposed NASHYDs and STANDHYDs, this is just for your reference.

The image classification generally worked well. From the image below, you can see that some paved areas were classified as pervious (i.e. some of the Hwy 401 lanes) and some of the pervious areas were classified as impervious. I recommend that the imperviousness of catchments 179, 171, 165, and 162 be manually adjusted to include Hwy 401, after which please proceed to calibration; let's use the events with the most complete data for calibration.



If modelled runoff volume is too high during calibration, it can reasonably be assumed that the pervious areas classified as impervious had a cumulative effect on runoff production. I think minor calibration of imperviousness would be acceptable in this case.

Thanks again for your work to date.

As always, stay well and please let me know if you need anything.

Wilfred Ho, B.E.S.
Project Manager, Capital Projects
Development and Engineering Services

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From: Zhuge, Albert <Albert.Zhuce@wsp.com>
Sent: Thursday, June 18, 2020 10:48 AM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events
Importance: High

Good morning Wilfred.

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Thanks, Wilfred. Please let us know whether we can start the calibration process.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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From: Wilfred Ho
Sent: Wednesday, May 27, 2020 9:52 AM
To: Zhuge, Albert <Albert.Zhuce@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good morning Albert and Jenny,

Thank you for the quick response.

I should clarify two of my comments:

Were the building footprints used for identifying rooftops? This would remove any potential ambiguity from the image classification.

- The building footprints base on the airphoto image "Pickering_15cm_2015.tif"

Clarification: TRCA provided shapefiles for building footprints in Pickering, Markham, and Toronto. We typically use this information to "burn-in" rooftops in order to avoid potential errors in the image classification (i.e. buildings that are outside the spectral distance of your training samples, such as shaded and atypical coloured rooftops).

- The rooftop areas were revised in the Impervious analysis base on the Building footprint shp file provided. The following tables show the updated TIMP and XIMP. The changes are minor.
- The updated impervious analysis saved in map package. The link to access the data will be provided in a separate email.

TIMP and XIMP before

Landuse	Percent Impervious (TIMP)	Directly Connected (XIMP)
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Medium Density Residential	65%	26%
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Railway	100%	100%

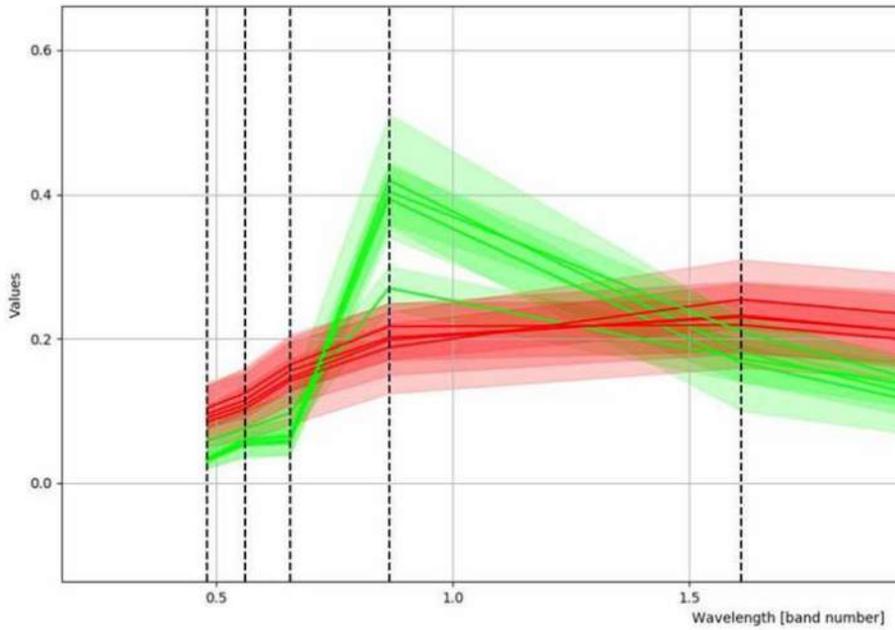
TIMP and XIMP after rooftop revised

Landuse	Percent Impervious (TIMP)	Directly Connected (XIMP)
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Medium Density Residential	64%	26%
Commerical/Employment/Downtown	85%	51%
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Railway	100%	100%

This is not a major issue, but how was the image classification affected by parked cars and building shadows? Please see STANDHYDs 171, 179 and 180 as examples.

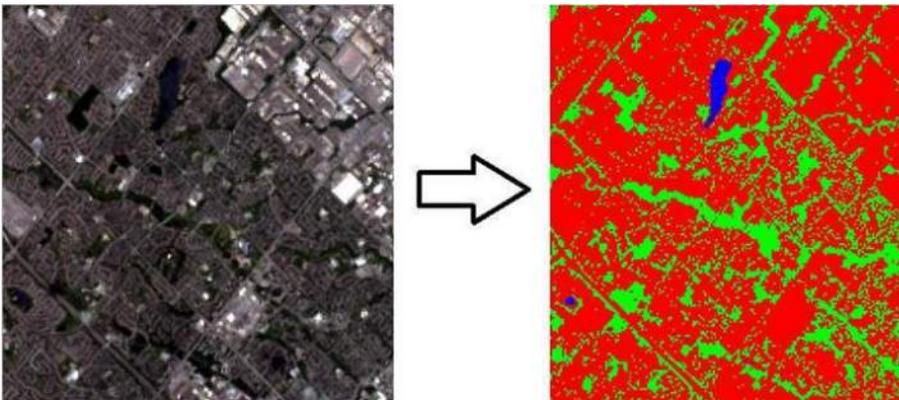
- During the identifying the rooftop areas, the building shadows was excluded as much as possible and count these areas as parking lots/other impervious surface. (See the impervious site #7, 8 and 9)

Clarification: The training samples were well-chosen. The classification algorithm may have trouble distinguishing between shaded areas and dark vegetation when the spectral ranges in the land cover categories are applied to the watershed, since they are on a similar spectrum in the RGB bands. Here is a comparison from another project I worked on, green lines are vegetation samples and red lines are paved surface samples; the wider bands are the spectral distances as allowable deviations from the sample pixels:

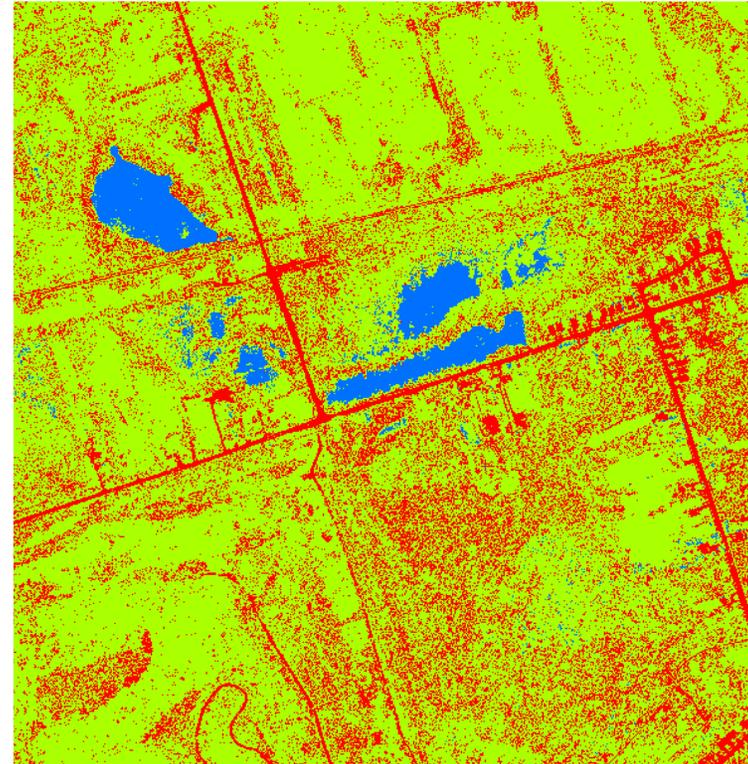


As you can see, there is some overlap.

Would it be possible to provide a geotif (or equivalent) of the resultant image classification (i.e. impervious areas rendered as red and pervious areas rendered as green)? Something like this:



- The Pickering_15cm_2015.tif was classified base on Impervious (Road, Driveway and Rooftop), Pervious (farm land and forest) and water (natural pond and SWM Pond) using image classification function in GIS (See below print screen)
- The image classification analysis saved in map package. The link to access the data will be provided in a separate email.



Thanks for you work to date.

Please stay well,

Wilfred Ho, B.E.S.
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Development and Engineering Services

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From: Zhuge, Albert <Albert.Zhuce@wsp.com>
Sent: Tuesday, May 26, 2020 2:22 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hi Wilfred,
Please see our response to your questions in green.

We will update the Tp values for the identified NASHYDs. Please confirm once it is completed, the model can be used for the calibration process.

Thanks.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Friday, May 22, 2020 4:44 PM
To: Zhuge, Albert <Albert.Zhuce@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Hello Albert and Jenny,

I have reviewed the initial catchment parameters along with your worksheet. The work is generally very solid with a few observations:

The following NASHYDs have Tp set to 0.2 hours rather than the values proposed in the worksheet:

1461

147
1481
149
151
153
1541
155
156
1581
1591
1611
1651
1661
1691
1701
1711
173
174
1751
1761
1781
1811

Please confirm the initial Tp values for these NASHYDs.

- The Tp values for these NASHYDs will update

For the image classification, the training samples for low- and medium density residential have an "other impervious surface" category; are these patio areas and side yards?

- Yes, the "other impervious surface" are patio areas, swimming pool at the backyard and side yards areas.

Were the building footprints used for identifying rooftops? This would remove any potential ambiguity from the image classification.

- The building footprints base on the airphoto image "Pickering_15cm_2015.tif"

This is not a major issue, but how was the image classification affected by parked cars and building shadows? Please see STANDHYDs 171, 179 and 180 as examples.

- During the identifying the rooftop areas, the building shadows was excluded as much as possible and count these areas as parking lots/other impervious surface. (See the impervious site #7, 8 and 9)

Have a great weekend and enjoy the weather,

Wilfred Ho, B.E.S.
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From: Zhuge, Albert <Albert.Zhuge@wsp.com>
Sent: Wednesday, May 20, 2020 11:11 AM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good morning, Wilfred!

Thanks for the email.
I downloaded and reviewed the video of the Radar for 20180416.

I agree with you that this event can also be used for the calibration/validation.

However, since all these 8 events are relatively small (e.g., 2~5 years), we really don't know what the calibration results will look like. I think maybe we should start the calibration process first. Let's see what we will get and then decide what events for calibration and what for validation.

Please let me know what you think.

Thanks, Wilfred.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Wednesday, May 20, 2020 9:37 AM
To: Zhuge, Albert <Albert.Zhuge@wsp.com>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Petticoat Hydrology Update - Existing Model and Calibration Events

Good morning, Albert and Jenny.

Thank you for the first cut of the model; I shall review it and supporting information promptly.

In the meantime, I have uploaded a video of the RADAR coverage for 20180416; unfortunately, I found no options for including a timeline in the output, so I calculated the frames per second to give you roughly 1 second of video time being

1 hour of actual time. I can also provide the PCSWMM RADAR acquisition project (RAP) that I used, but it's about 25 GB; the most efficient way to view it is probably just to teleconference and share screens.

I have also included a spreadsheet comparing each of the RADAR products to measured data; the RADAR consistently underpredicted, but the hyetograph peak timings are not bad and it demonstrates watershed-wide coverage of the event.

Based on the completeness of rainfall and stream flow data, perhaps these events would be best for calibration:

- 20150616
- 20150628
- 20151028
- 20181127

Due to possible missing hydrograph peaks or rainfall record, perhaps these events would be best for validation:

- 20140921
- 20141017
- 20150623
- 20180416

Please let me know of any further concerns or issues.

Stay well,

Wilfred Ho, B.E.S.
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From: Zhuge, Albert <Albert.Zhuge@wsp.com>
Sent: Tuesday, May 19, 2020 5:09 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: Petticoat Hydrology Update - Existing Model and Calibration Events
Importance: High

Hi Wilfred,

Thanks for your email.

Based on your comments on the catchments, we have completed the existing model. I saved all the detailed modelling files (including the parameter spreadsheets, PDF figures, GIS data and the VO model files) to the Project OneDrive.

Zhuge, Albert

From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Wednesday, February 12, 2020 4:03 PM
To: Zhuge, Albert
Cc: Chui, Jenny
Subject: RE: Windshield Survey Results - Petticoat Hydrology

Thanks for clarifying, Albert.

Please excuse the number of questions I've been asking; TRCA has typically limited the use of the DuHyd, but we have no issues with the approach as long as there is sufficient information.

In the few cases where the DuHyd was used, our documentation has not been clear on how the inlet capacity parameter for the command was determined. I suspect that one of two approaches were taken in the past. Where we had catchbasin inlet data, we probably counted the number of catchbasin inlets within the subcatchment and multiplied by a literature value for capacity, say 0.06m³/s. The other approach that comes to mind is to simulate a 5-year storm (Chicago distribution?) using the uncalibrated model and using those flows as the inlet capacity values (i.e. assume unlimited inlet capacity). Please feel free to correct any misunderstanding I may have.

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From: Zhuge, Albert <Albert.Zhuge@wsp.com>
Sent: Wednesday, February 12, 2020 11:33 AM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: RE: Windshield Survey Results - Petticoat Hydrology

Hey Wilfred!

You are absolutely correct.

The approaches between the sewer design and hydrological modelling are different.

We are building the watershed-based hydrological model that the dual drainage system must be properly reflected for those urban areas. It is recognized that the modelling platform (Visual OTTHYMO) has limitations to model the urban infrastructures by comparing with other urban drainage models (e.g., PCSWMM, InfoWorks, etc.). This is probably the reason that for Rouge River and Don River where the majorities of the watersheds are urbanized, PCSWMM model was selected by the Authority for the purposes of watershed hydrological modelling.

Based on our experience, the DuHYD based on the major/minor split in VO is the most effective and efficient way to model the dual drainage urban system. We have successfully applied such methods for other watersheds within CVC's areas of jurisdiction, where the VO model platform was used.

Hope it provides with some clarifications.

Thanks, Wilfred.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Wednesday, February 12, 2020 10:47 AM
To: Zhuge, Albert <Albert.Zhuge@wsp.com>
Subject: RE: Windshield Survey Results - Petticoat Hydrology

Good morning, Albert.

I hope things are well, I'm just following up on the two items you brought to my attention last week.

Please see my responses in **red**, below.

Thanks for your work to date.

Wilfred Ho, B.E.S.
Project Manager, Capital Projects
Development and Engineering Services

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From: Zhuge, Albert <Albert.Zhuge@wsp.com>
Sent: Wednesday, February 5, 2020 10:09 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>

Cc: Chui, Jenny <Jenny.Chui@wsp.com>

Subject: RE: Windshield Survey Results - Petticoat Hydrology

Hi Wilfred.

Thank you so much for the quick response.
Please see my response below.

Thanks.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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From: Wilfred Ho <Wilfred.Ho@trca.ca>

Sent: Tuesday, February 04, 2020 4:37 PM

To: Zhuge, Albert <Albert.Zhuce@wsp.com>

Subject: RE: Windshield Survey Results - Petticoat Hydrology

Hello Albert,

Thanks for the summary report for the windshield survey.

- 1) I may require a little more clarification. Do you require confirmation on the absolute inlet capacity values for proposed DuHyd commands or are you proposing to calculate the 5-year flows for use in proposed DuHyd commands?

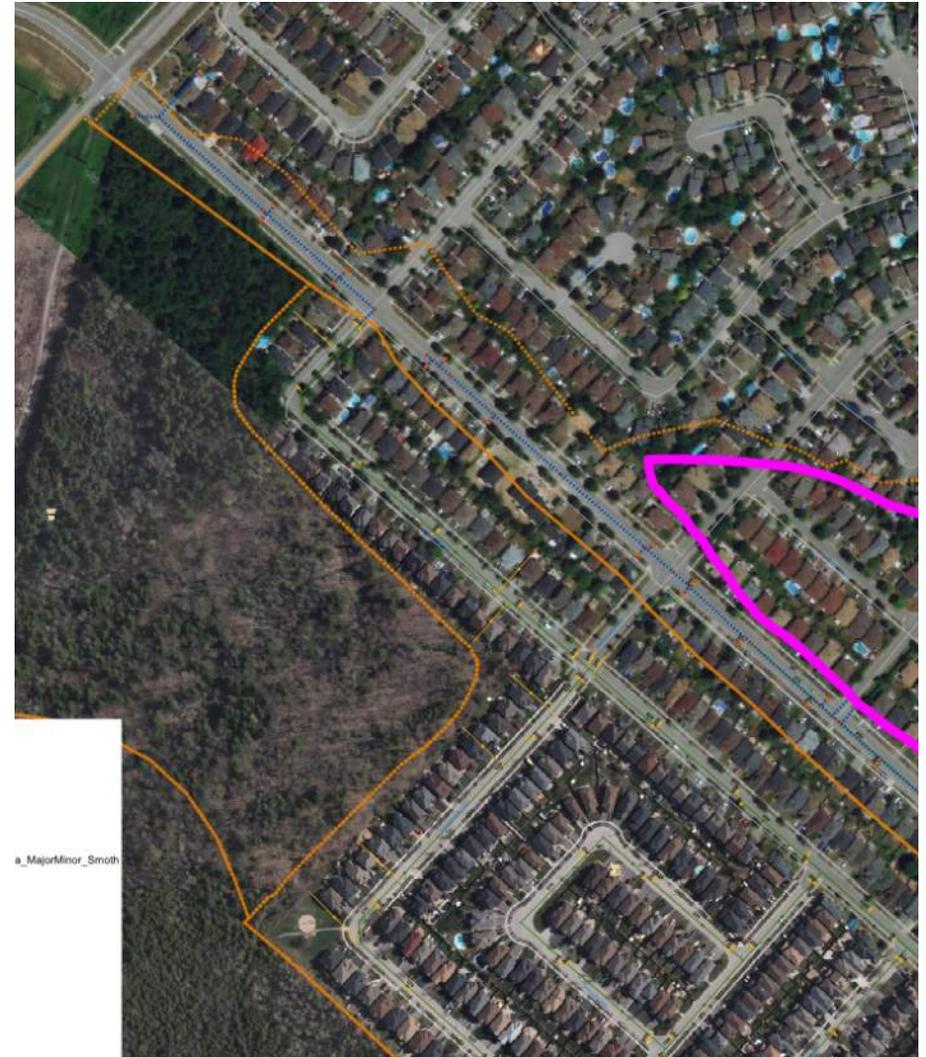
No. I don't need the detailed inlet capacity for the purpose of watershed hydrology. DuHYD will only be used to reflect the minor/major separation within the urban boundary. Once the design flow (e.g., 5-year) is confirmed, such flows will be used in the DuHYD command in VO5 model.

I have no issues with defining DuHyd commands based on a 5-year major/minor split, but it is my understanding that the City's 1 in 5-year design standard is based on the Rational Method and the local IDF data for areas less than 40ha; what is the proposed method to complete this analysis?

- 2) I've reached out to a contact at City of Pickering; hopefully we can provide clarification on the Rosebank Rd. stormsewer shortly.

Thanks Wilfred, we have received the STM along Rosebank Rd. However, what we requested is the STM within the residential areas (assumed Petticoat Creek drainage catchment). Please see Jenny's email attached and illustration below. Could you please help? Thanks.

The City provided the latest inventory of their sewershed. After reviewing the data for the requested area, I uploaded the information to OneDrive folder "Pickering_All". Please let me know if further information is needed.



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From: Zhuge, Albert <Albert.Zhuce@wsp.com>
Sent: Monday, February 3, 2020 5:20 PM
To: Wilfred Ho <Wilfred.Ho@trca.ca>
Cc: Chui, Jenny <Jenny.Chui@wsp.com>
Subject: Windshield Survey Results - Petticoat Hydrology

Hi Wilfred,

We have successfully completed the scheduled windshield survey to confirm some questionable drainage boundaries of the subject study area.
Please see the attached for the windshield survey results.

We have two questions.

- 1) Design storm for minor system. Based on the City of Pickering design guideline (July 2019), it states "the minor system conveys urban drainage from relatively "minor" storms having a return period of 5 years". Could you please confirm 5-year flows can be defined in the DuHYD to model the minor flows for the Petticoat Creek.
- 2) For the area near Rosebank between Finch and Strouds (Area #7 in the windshield survey report), we found the STM at this location. However the sewer information you previously provided to us doesn't cover this location (please attached figure). Could you please take a look and try to find the additional information for us?

Thanks.

Albert Zhuge, M.Sc, P.Eng, PMP
Senior Project Manager
Water Resources



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TRCA Comments on WSP Report (dated Oct 31, 2020) received on Nov 18, 2020.

WSP Responses - Dec 3, 2020.

Page	Comments	Response
3	VO6	Noted. Report was revised.
3	Recommend using the proper names for each ministry, the names in the report are dated	Noted. Report was revised.
7	Please include a brief description of the use of orthoimagery.	Noted. Report was revised.
8	Provide equations and methodology (e.g. $C > 0.47$)	Noted. Report was revised.
10	This is the first time we are using this approach in VO2 modelling. Historically rout channel commands have been reserved for large valley corridors where attenuation is possible, given that major system flow routs are designed to convey flow away from developed areas should we be accounting for it through channel routing? What are the benefits of this approach, and please clarify how much attenuation is occurring within overland flow paths?	We have been applied route channel to reflect wave travel times and reduction in peak flows for major system for urban areas (STANDHYD) for other watershed in Southern Ontario. Based on our experience, and confirmed by the calibration results for the subject study, this approach generally results in better hydrograph comparison for urbanized areas. Note that, generally, VO model generates higher flows than those observed. For NASHYD, Tp and N can be used for calibration; however, for STANDHYD, the applicable parameters are limited. By incorporating the Route Channel for major system, it gives the model some accessibility and flexibility for the calibration. The calibration results also confirm a generally better hydrograph comparison.
10	storage elements	Noted. Report was revised.
13	Different sets of rainfall gauges were used for the spatial distribution exercise. Please provide a brief description (either here in the report or in Appendix H) of each set (e.g. data quality, availability, etc.)	Appendix H was updated.
15	Abbreviation of terms	Noted.
16	This should be Time to Peak opposed to Time of Concentration.	Noted. Report was revised.
18	Please clarify. Summary tables in Appendix I indicate percentage increases/decreases to CN.	CN is not a calibration parameter. Since OTTHYMO is a single event simulation model, there is no other way of establishing antecedent conditions. The appropriate value of CN needs to be given to ensure that the modelled runoff volume would be close to that observed for each events. The initial conditions are prescribed (AMC II or AMC III) for design event simulations, and there is no need to establish a predictive relationship for antecedent conditions.
18	Including backfilled data?	No. The volume comparison was based on the observed data (with possible gaps). The gaps were filled for the purpose of peak flow comparison, since it substantially impacts the actual observed peak flows.
21	We need to further quantify the calibration results in terms of the previous update, the key question being, have we improved calibration results over the previous model, if so how and why?	Compare the current calibration with the those previously completed in 2006 study is not included in the RFP. It would be our pleasure to prepare a CO and revise the SOW to include the task. Please advise.
21	I recommend we include a recommendations section, and highlight gauge requirements, and locations.	The discussion of gauge requirements is not included in the RFP.
23	Please clarify if this has been applied to all events or just the Regional (Hurricane Hazel) event?	In the subject study, ARFs only apply to Regional event.
24	...not considered appropriate...	Noted. Report was revised.
24	Based on table 6.1 the next highest peak flow estimate is the 6h SCS storm, please revise the text as required. Perhaps reword to read something like "The next highest set of peak flows..."	Yes, the comparison was based on average of unit flow at all flow nodes (last column of Table 6.1). Report was revised to read as "The next highest set of peak flows..."
24	I recommend we note that due to the limitations of the calibration and validation process it is best practice to be conservative when defining peak flow estimates for floodplain mapping purposes. Typically we would assess design storm distribution estimates based on flood frequency analysis.	Noted. Report was revised.
24	Please provide a table comparing the previous hydrology update peak flow estimates for the 2, 25, 50 and 100 year events against the new estimates.	Appendix K was revised to include the flow comparison.
25	Please provide a comparison table for Regional storm peak flow estimates between this model and the previous model.	Appendix K was revised to include the flow comparison.
26	TRCA has considered summer and annual flow maxima for frequency analysis. Please include a brief summary of why annual maxima is more appropriate for Petticoat (e.g. impact of snow pack in rural areas)	Noted. Report was revised.
26	For clarification, the gauge has two periods of record, 2001-2012 and 2012-present; based on the data included in Appendix M, it looks like the frequency analysis was completed using the 2001-2012 period of record.	The frequency analysis was completed using the 2001-2012 period of record. The data was provided by TRCA. Report was revised to indicate that the frequency analysis was performed based on the peak annual floods (2001-2012) provided by TRCA.
27	Confirm which period of record was used.	Noted. Report was revised.
31	Confirm period of record used.	Noted. Report was revised.
31	You made some good observations about snow pack and gauged flow in conversation; would there be value in future model updates to consider rain-on-snow events more explicitly? If so, can you outline the processes that would be used?	Report was revised to include rain-on-snow consideration for future study.
31	Allocation of hydrometric resources is crucial to TRCA operations. Please provide recommendations (if any) for the gauge network in the Petticoat watershed. Was the rain gauge network sufficiently dense for this study? If not, are there locations that would have been optimal for a) capturing lag time to runoff and b) data processing for models (e.g. DRMT in VO)? Similarly, was the single streamflow gauge sufficient for this study? Petticoat has a distinct rural/urban divide, and it may be difficult to directly calibrate rural catchment parameters. Are there stream locations that would have been optimal for subwatershed calibration?	Noted. Report was revised to include recommendation on hydrometric resources and data collection for the purpose of watershed calibration.

Zhuge, Albert

From: Wilfred Ho <Wilfred.Ho@trca.ca>
Sent: Thursday, December 03, 2020 4:23 PM
To: Zhuge, Albert
Subject: Petticoat Hydrology

Good afternoon Albert,

I hope you are staying busy and keeping well.

NASHYD 173 has a surface slope of 338.31%, which appears to be the result of a typo in the calculation sheet ('Channel_Petticoat', upstream elevation value). This results in a shorter Tp for the catchment.

It is a small catchment that is very far downstream and affects flows at the last three ADDHYDs; after testing a longer Tp value, the difference on flows at downstream ADDHYDs is negligible.

To keep things simple, I could rerun the models and provide you with updated values for the report tables.

Please let me know how you would like to proceed.

Take care,

Wilfred Ho, B.E.S.
Project Manager, Capital Projects
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Zhuge, Albert

From: Chui, Jenny
Sent: Friday, December 04, 2020 4:34 PM
To: Zhuge, Albert
Subject: US elevation for Catchment 173

Hi Albert,

I check the parameter spreadsheet again. The number 1729.35 is stand for the Hec-RAS cross-section number that TRCA send to us. Therefore, the U.S elevation should be 86.2m (channel invert of the XS). The % of slope for catchment 173 should be 0.9%.

Please let me know if you have any questions. 😊

Thank you,
Jenny

Jenny Chui, M.Sc.
Water Resource Modeller
Infrastrucutre



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