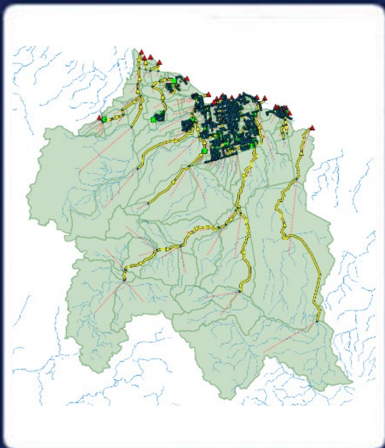
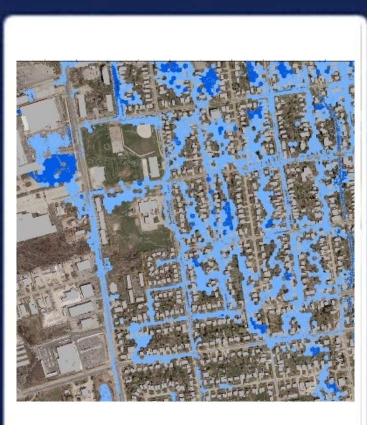


Collingwood Stormwater Management Master Model

Prepared for:
The Town of Collingwood

January 18 2022



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1 Introduction

In the South Georgian Bay region, heavy winter snowfalls, frequent snowmelt plus rainfall events, combined with increasing population have made flood mitigation for all urban communities a high priority. The unpredictable nature of these weather patterns represents a tremendous risk to municipalities, homeowners, insurance companies, wastewater system infrastructure and other stakeholders. To assess the capabilities of the existing stormwater infrastructure in the Town of Collingwood (Town), Greenland International Consulting Ltd. (Greenland) was retained by the Town to complete an existing conditions Master Stormwater Management (SWM) model consisting of the existing storm sewer drainage system and multiple watercourses that traverse the Town limits.

Presently, the Town does not have a comprehensive SWM model. Most existing models have limitations, such as using old hydrology models, missing recently constructed subdivisions, or only include a portion of the total watercourses within the Town, and therefore are in need of an update. The existing conditions SWM model developed in this assignment will ultimately assist the Town with forecast modelling, reviewing the impact of development proposals, completing asset management, assessing future capital improvement projects and could form the basis of a stormwater infrastructure improvement Class Environmental Assessment Master Plan project.

In consultation with the Town of Collingwood, the selection of the SWM model tool to be incorporated into this assignment had to include the flexibility to incorporating hydrologic, as well as hydraulic models for five (5) riverine systems and two (2) identified urban areas within the Blue Mountains Watersheds, all with outlets located within the Collingwood municipal boundary. The various watersheds are listed below (in no particular order):

- Pretty River
- Black Ash Creek
- Silver Creek
- Batteaux Creek
- Townline Creek
- Urban Town Centre, and
- Resort Drainage Areas.

See Maps in **Figure 3-1**, **Figure 3-2** and **Figure 3-3** for watercourse locations.

This report provides basis for the fundamental hydrologic and hydraulic modelling inputs to simulate the existing conditions of the stormwater infrastructure and open channel flows within the Town. The model and subsequent analysis presented herein will update flood damage zones within the Town. This Report assists the Town in comprehensive planning and approvals of future development in the municipality and the hydraulic model will also inform any discussion on future stormwater drainage improvements (e.g. future Class EA Master Plan) and funding delivery methods for future Capital Asset Management Plans.

1.1 Communication and Consultation

During the preparation of the report, Greenland had monthly meetings with the Town staff to review the status of field work, model preparation, and data gaps. Interim documents were prepared that identified the monitoring program, model basis report, and the independent review and update of the Pretty River hydraulic analysis which have been included with this document. The methodology being proposed to prepare the analyses described in this document were reviewed with the NVCA staff in August 2019. All meetings and correspondence are included in **Appendix 1**.

2 Project Deliverables

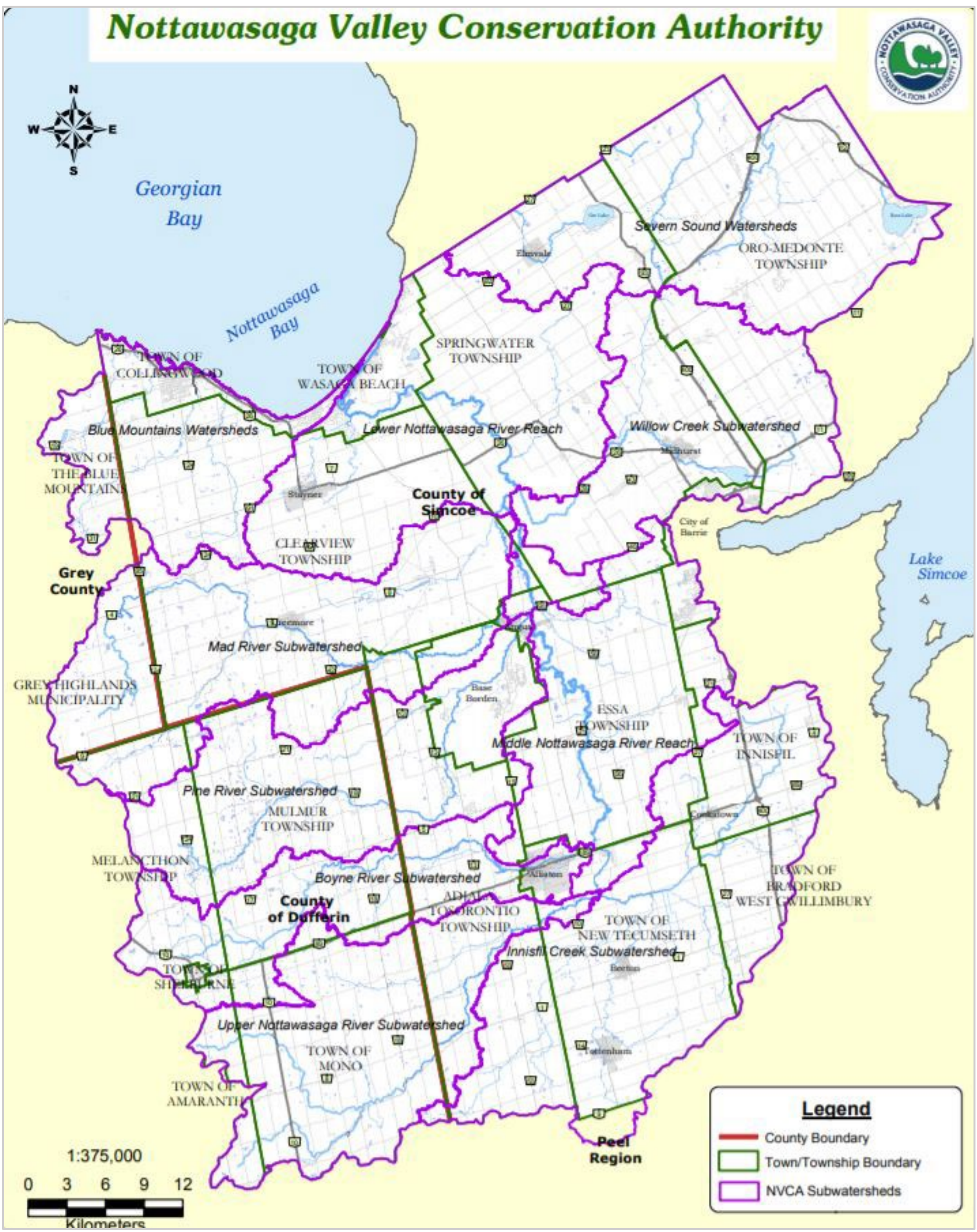
In accordance with the project mandate, the following deliverables are provided by Greenland:

1. The Pretty River Hydraulic Assessment Report is included as **Appendix 2-I** within this report. The updated report in **Appendix 2-I**, incorporates comments from the Nottawasaga Valley Conservation Authority (NVCA) on the Report submitted to the Town in September 2019 to aid discussion regarding pending development approval for the Pretty River Estates Phase II.
2. The Model Basis Report is included as **Appendix 2-II**. This interim technical report details the development of the hydrologic and hydraulic models, and was presented to the Town and NVCA in August 2019 to receive input on the developed models before proceeding with model runs.
3. The Updated Asset Inventory which includes the Town's storm sewer database was updated with additional invert elevation data and the sewer attributes confirmed. This updated information was used to create minor storm sewer system model for the Town.
4. Updated Hydrologic and Hydraulic models of the Town's existing storm drainage and watercourse systems.
5. Assessment of the potential watercourse spills that may occur in various locations in the Town.

6. A report outlining model development and presenting updated flood line mapping, including the identification of potential flood damage centres.

3 Background

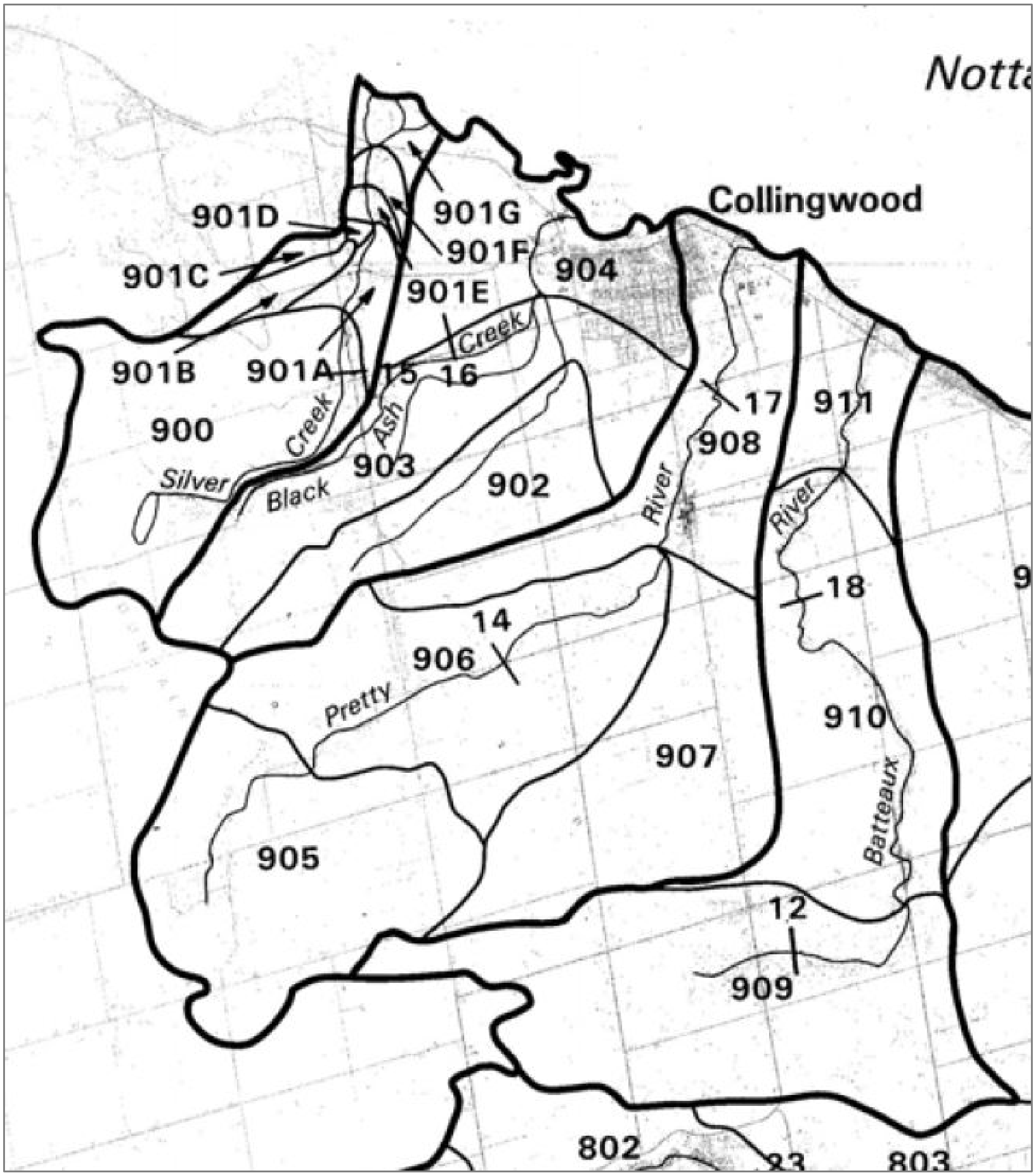
Located between the base of Blue Mountain and Georgian Bay, Collingwood is a major component of the Blue Mountains Watersheds drainage area, which have multiple outlets within the Town limits. **Figure 3-1** depicts the subwatershed boundary defined by the NVCA.



As outlined in **Section 1.0**, the existing model study focused on the major catchments and receiving watercourses traversing through, and outletting within, the Town boundaries. The Blue Mountains Watersheds consist of multiple rivers and creeks which outlet directly to Georgian Bay.

Although all of the catchments identified as part of this study outlet within the Town limits, five (5) of the six (6) catchments have headwaters outside the municipal boundary. For the watercourses originating outside Town limits, previous approved studies were utilized to establish the flow conditions at the location where the watercourse enters the Town of Collingwood jurisdiction.

The Watershed Hydrology Study for the Nottawasaga, Pretty and Batteaux Rivers, Black Ash, Silver and Sturgeon Creeks was prepared by MacLaren Plansearch Inc. (1988) [1]. This is the most up to date and accepted hydrology which captures the Blue Mountains Watersheds as a whole. This study is the basis for most of current floodplain mapping in the NVCA jurisdictional limits. Watershed boundaries as presented in the report are depicted in **Figure 3-2**.



There are a number of updated watershed studies for some of the local watersheds that have been completed since MacLaren's work. The most up to date approved model for each watershed was used to form the basis for the modelling for this assignment. A summary of the most recent hydrology study for each watershed, and the peak flow values (where applicable) in the Town from each report are presented in **Table 3-1**.

Table 3-1 Summary of Available Hydrology Studies

Watershed	Most Recent Hydrology Study	Peak Flow Rate at Outlet
Pretty River	Pretty River Hydrology Update. CC Tatham and Associates Ltd., 2018 [2]	180.04 m^3/s
Black Ash Creek	Black Ash Creek Subwatershed Plan. Nottawasaga Valley Conservation Authority, 2000 [3]	35.0 m^3/s
Silver Creek	Watershed Hydrology Study for Nottawasaga, Pretty and Batteaux Rivers Black Ash, Silver and Sturgeon Creeks. MacLaren Plansearch Inc., 1988 [1]	105.1 m^3/s
Batteaux Creek	Watershed Hydrology Study for Nottawasaga, Pretty and Batteaux Rivers Black Ash, Silver and Sturgeon Creeks. MacLaren Plansearch Inc., 1988 [1]	169.8 m^3/s
Urban Town Centre	Watershed Hydrology Study for Nottawasaga, Pretty and Batteaux Rivers Black Ash, Silver and Sturgeon Creeks. MacLaren Plansearch Inc., 1988 [1]	n/a
Resort Drainage Areas	Regional Stormwater Management Update & Master SWM Study. C.F. Crozier & Associates Inc., 2007 [4]	n/a

Figure 3-3 provides the Collingwood Study Area updated watershed boundary. It provides a summary of the main watersheds for the key outlets to Georgian Bay for the Town Subwatersheds. The figure is based on the data collected and modelling carried out as described in the subsequent section of this report. The individual catchment boundaries for the minor streams are based on nomenclature from the drainage reports for these areas.

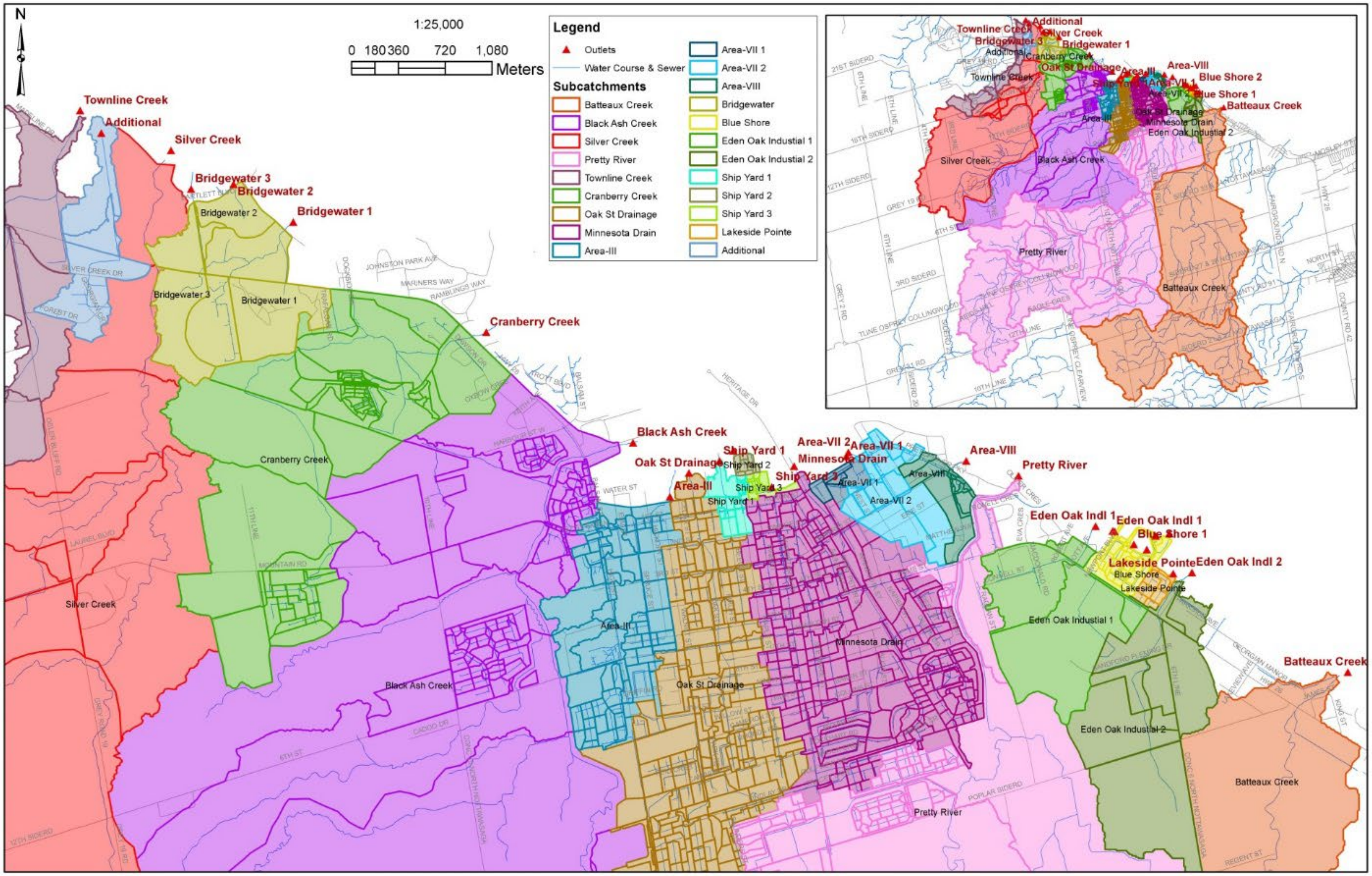


Figure 3-3 Study Watersheds

3.1 Existing Data

In order to update the available hydrologic models for the Collingwood Study Area, Greenland, in consultation with the Town, undertook an extensive background review to update the areas within the Town where development has occurred since the publishing of the original hydrologic studies. In addition to existing development, attention was given to approved developments and those currently under construction. Background data included any information the Town has access to, including, but not limited to: Stormwater Management (SWM) reports, site plans, Master Servicing Studies, Record Drawings, existing models, and SWM pond Environmental Compliance Approvals (ECAs). The background information was reviewed and all available information has been summarized in a spreadsheet provided in **Appendix 3**.

The Town also provided Greenland with their asset inventory of stormwater infrastructure to create the minor system model. The inventory included:

- SWM ponds
- Storm sewers
- Manholes
- Catch basins
- Oil Grit Separators
- Headwalls; and,
- Outlets & Outfalls.

3.2 Data Update

After the initial analysis of background data, including the review of various reports available for the Study Area, the existing data and models were updated with data collected from the field in 2018 to 2020, including:

- Topographic Field Survey (including sewer manholes and inverts);
- Storm Sewer Flow Monitoring;
- Airborne LiDAR, and
- Meteorological Data.

Methods of data acquisition and their results are detailed in **Appendix 4.**

3.3 Climate Change Consideration

As part of the evaluation of the hydraulic performance of watercourses and drainage infrastructure, it is important to have regard for the impact of changing climate conditions. The challenge of determining how best to represent these climate changes has typically been met by adjusting the design storm distributions being used to size drainage infrastructure or assess flooding impacts from storm events. For example, the City of Ottawa has adopted a 20% multiplier on all design storm intensities as a stress test for the infrastructure design. The City of Barrie has adjusted its design storm intensities by 15%. **Figure 3-4** shows an example of the potential annual precipitation projections regionally that are estimated by climate models supported by the Province.

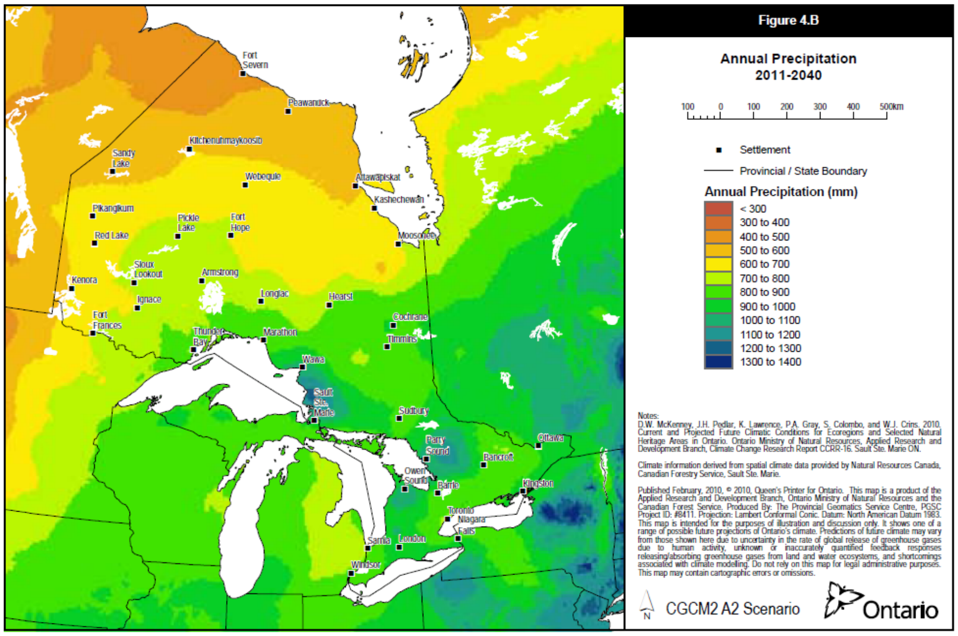


Figure 4. *Annual precipitation projections using version 2 of the Canadian Global Climate Model (CGCM2) with the A2 scenario across Ontario ecoregions for four time periods: (a) 1971-2000, (b) 2011-2040, (c) 2041-2070, and (d) 2071-2100*

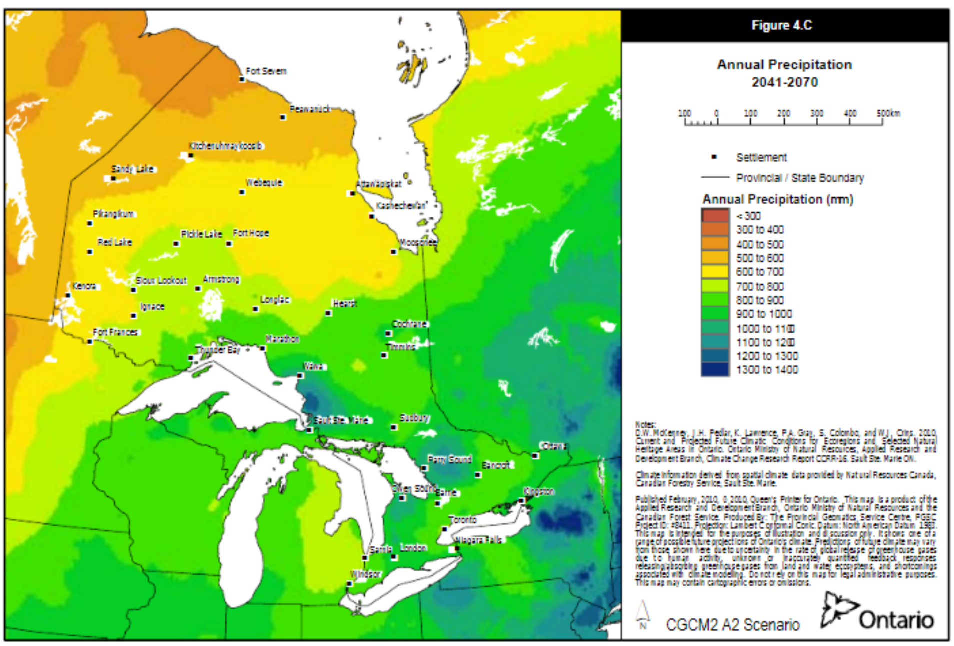


Figure 3-4 Example of Annual Precipitation Projections Global Climate Model

The selection of design storms to be used for the new drainage models for the Town in this Study were taken from the Ministry of Transportation (MTO) IDF tool or rainfall intensity, duration, frequency tool. The MTO has developed a portal to produce IDF curves for any geographic position based on merging climate information from local Environment Canada and National Oceanic and Atmospheric Administration (NOAA) stations. The historic data for each station has been introduced into one (1) of four (4) statistical distributions (Gumbel distributions) traditionally used to evaluate rainfall data. Then, the historic information was reviewed to establish the trend of the change in conditions over recent decades and extends this trend with composite curves projecting rainfall conditions to 2060 in developing these IDF curves. This provides the MTO IDF tool with inherent climate change resiliency, as opposed to needing to apply a multiplying factor to current design storms as done in Barrie or Ottawa examples provided herein.

The MTO IDF tool was applied to two (2) separate conditions in this Study. These conditions include storm events that impact riverine systems and the storm events that impact localized drainage infrastructure.

In addition to assessing the impacts of the MTO IDF tool generated rainfall events, and the climate change resiliency built in to the tool, an investigation was completed that had regard for the unique climate conditions found in the Collingwood /Blue Mountain region as it relates to the local snow melt conditions. This investigation builds upon information that was presented by Greenland to the MEA Stormwater Group in 2014. The two (2) main climatic functions were investigated to determine which condition would produce the greatest impact. These conditions included:

- Extended warm periods on snowpack introducing earlier snow melt conditions (present April conditions migrating into March); and,
- Additional rainfall in summer frontal storms (with several climate models investigated and data adjusted to local weather station information similar to the MTO method).

The purpose of the exercise was to determine whether the unique conditions of a heavy snow pack with spring melt conditions would create a greater impact than the projected frontal rainfall systems identified in the climate models. Prior to implementing the MTO IDF curves, the Town was interested to establish that these curves represented the worst-case conditions for infrastructure design and riverine conditions. Specifically, it was important to confirm that the frontal rainstorm event clearly creates the greatest impact on local municipal drainage systems and when the rain-on-snow event has the potential of creating a greater impact on riverine systems based on the size of the drainage area.

Using historical climatic data Greenland has developed a snowmelt model capable of determining the statistical return periods of potential snowmelt events. **Figure 3-5** shows an example of the comparison of a rain-on-snow snow melt event (SPROS2) with the traditional rainfall distribution for a 25-year event. The summer climate change event is an adjustment of rainfall to account for a frontal storm system similar to the MTO IDF method.

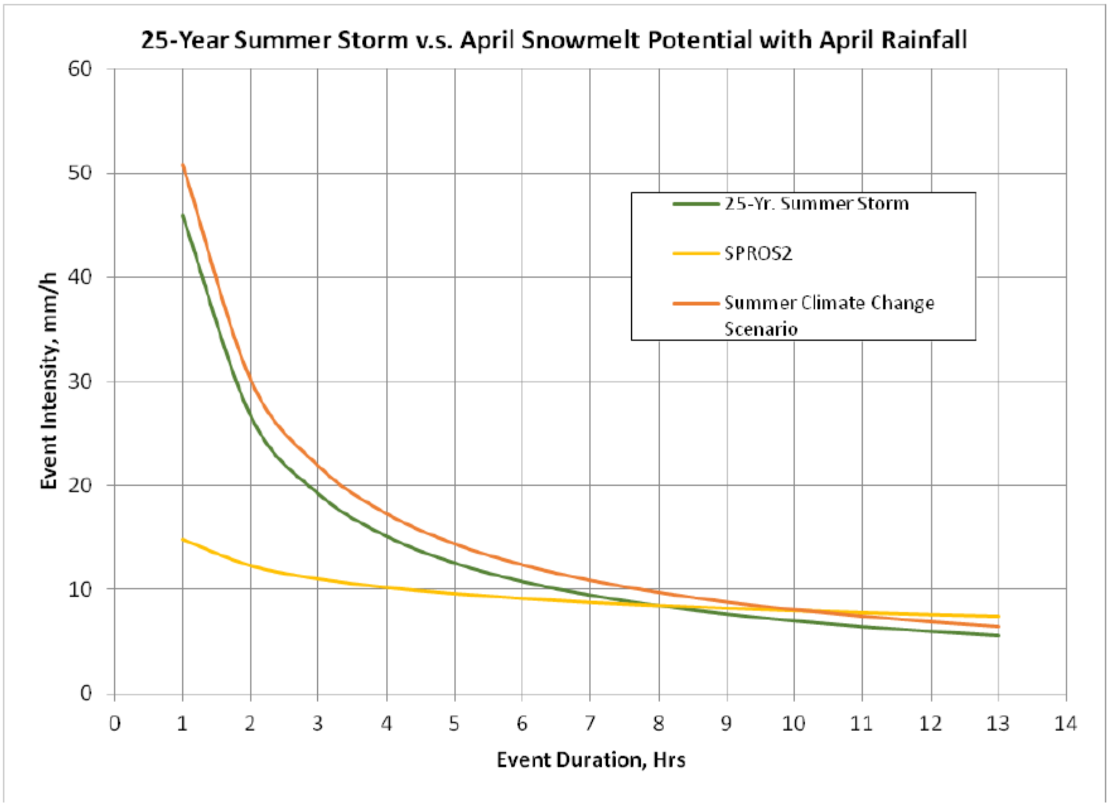


Figure 3-5 Comparison of Rain-On-Snow Event with Summer Rainfall Event

The snow melt event does not become the critical distribution for short response times that are typical within local subdivisions in urban boundaries. In the Collingwood area, the 25-year flood event could be impacted by snow melt only on a river system that has greater than a 12-hour response and if there is an available snow pack with at least 90 mm of snow water equivalent. In other words, the snow melt event becomes the significant event only with warm temperatures that extend through the night and a full snow pack still available to produce runoff.

However, the snow melt event is not the controlling event once the 25-year event is exceeded. Once the 100-year frontal rain storm event occurs, this climate adjusted (MTO IDF) rainfall event becomes the controlling event for both riverine and municipal drainage infrastructure. **Figure 3-6** shows the comparison at the 100-year event where the summer frontal rainfall condition is the worst-case condition.

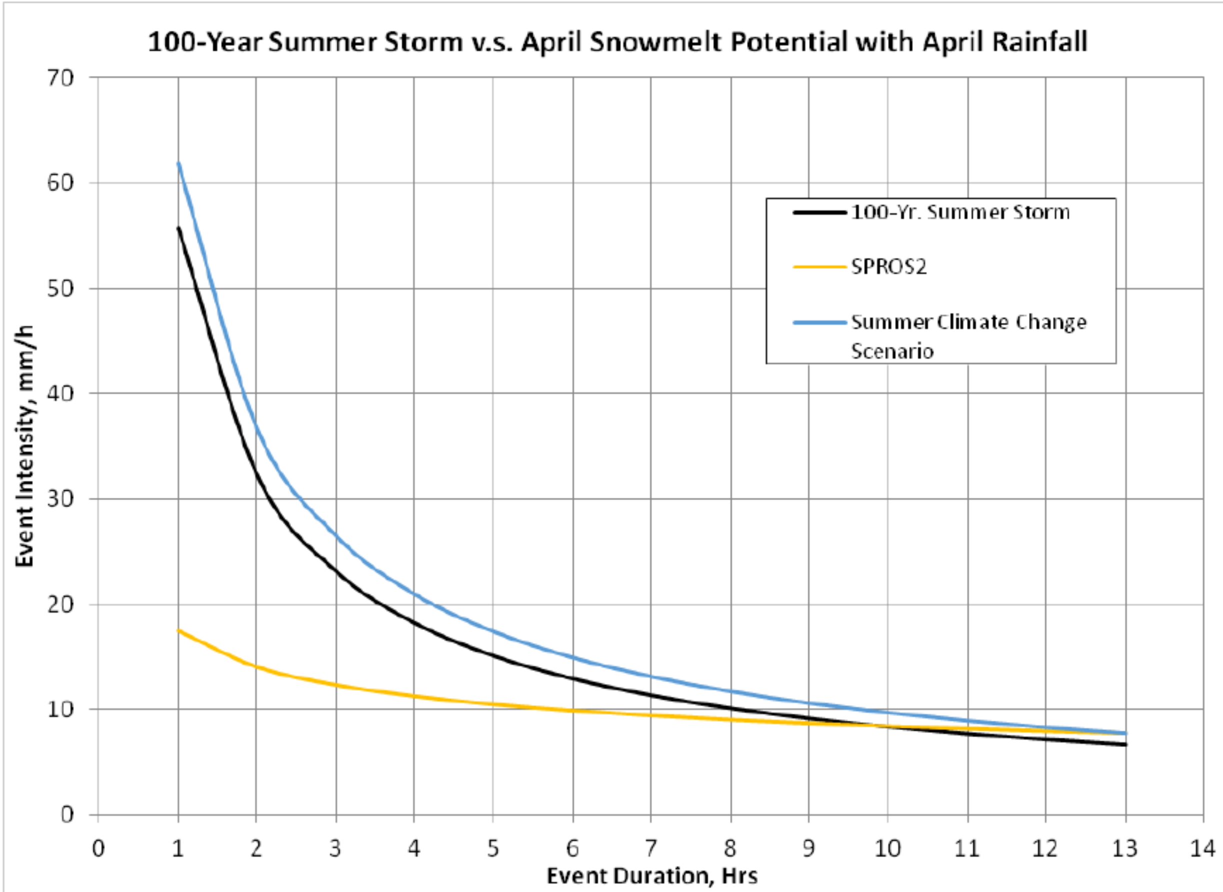


Figure 3-6 Comparison of Rain-On-Snow Event with Summer Event (100 Year)

With the more severe events (i.e., 100-year event), the greater impact on the riverine system flooding and urban infrastructure are still controlled by the frontal rain events. Therefore, climate change considerations will use the summer frontal rain events to analyze local drainage infrastructure and the Regional storm (Timmins storm event) to analyze flooding events in the river systems.

Since this Study is intended to assess existing riverine flooding and existing municipal infrastructure capacity conditions, the Town considers the use of the MTO IDF curves as a reasonable approach to the potential increase in rainfall events/intensity due to its inherent climate change resiliency when compared to the Town the Standard IDF curves (which are based on historic Environment Canada monitoring station data only, with no climate change projection).

The Town may consider adjustments to the MTO IDF curves as a “stress test” with the Phase 2 work program, when the Town will review solutions to existing Town flooding or drainage issues and future development scenarios. The MTO IDF curves can be compared with the rainfall volumes being estimated with other climate models as new information becomes available. For example, the Ontario Climate

Change Data Portal (OCCDP) provides a means of accessing model data from several Global Climate Models (GCMs) dynamically downscaled and summarized spatially. Analysis of the RCP8.5 scenarios using OCCDP provides some general estimates of future change in precipitation patterns. For example, the periods 1986-2005 (baseline) and 2070-2099 (future horizon) were compared for Collingwood. Based on this review, the five (5) models predict an increase in average annual precipitation of 10% in the 2070-2099 time period for Collingwood relative to the baseline condition.

3.4 Model Development

In order to study the hydrology of the Collingwood Study Area watersheds, the hydraulic performance of the watercourses and the existing storm sewer network within the Urban Town Centre, mathematical modelling software was assessed. Among the various available modelling tools, PCSWMM (Personal Computer – Storm Water Management Model) by Computational Hydraulics International (CHI), was selected to carry out the required hydrologic, storm drainage system and hydraulic modelling. PCSWMM is an advanced software for stormwater, wastewater, watershed and water distribution systems. It is a computer program that computes dynamic rainfall-runoff for single event and long-term (continuous or period-of-record) runoff quantity and quality from developed urban and undeveloped or rural areas.

PCSWMM accounts for various hydrologic processes that produce runoff from urban areas. PCSWMM also contains flexible hydraulic modelling capabilities to route runoff and external inflows through the drainage system network of surfaces, pipes, channels, storage/treatment units and diversion structures. Specifically, the software also enables the user to import HEC-RAS cross sections to simulate irregular conduits that can represent the watercourses. This enabled the hydraulic model section construction to be used from earlier studies where the information could be tied into digital terrain information.

PCSWMM has a very user-friendly interface and is a widely accepted modelling tool within the storm drainage and water resources engineering community. Greenland also has a network licence version of the software package. Therefore, PCSWMM was selected as the modelling tool to update the existing hydrology for the watersheds and construct the master storm water management model for the Town of Collingwood.

The overall strategy adopted to construct the existing conditions master hydrology model for the Town included the following general steps:

- Prepare rural catchments in PCSWMM for the main watercourses using similar areas to the original watershed models (adjusted based on updated digital terrain information);

- Prepare routing features with irregular conduits that simulated the original configurations;
- Test rural watershed PCSWMM models with previous hydrology models to produce a similar response to original watershed models and adjust where required;
- Update hydraulic models for each watershed to HEC-RAS models with cross sections reproduced in similar geographic locations from earlier studies but determined or supplemented using the new digital terrain information developed from collected LiDAR data;
- Prepare a storm sewer infrastructure PCSWMM model based on the Town sewer network information for pipe and manholes augmented by field survey to fill data gaps (e.g. sewer invert elevations);
- Update drainage infrastructure (ditches and culverts) linked to the sewer network;
- Introduce the storm water management facilities (constructed) to the infrastructure model and confirm the facilities operational response;
- Import the hydraulic model information for Oak Street Canal and Minnesota Drain as irregular conduits linked to culvert crossings and connect to sewer infrastructure 1D model;
- Add overland road sections described by conduits linked to the manhole nodes;
- Complete the calibration and verification of the models with monitored data;
- Adjust the infrastructure model to connect with a mesh created by the digital elevation model to produce a 2D model;
- Link the 2D mesh with the conduits for the Oak Street Canal and Minnesota Drain; and,
- Plot the flow spread within the mesh for various storm events (Identify flood damage areas).

The downstream boundary condition for all models was the 2019 high lake level at the time of model development (177.30m).

The following Report sections detail various aspects of the background hydrologic and hydraulic analyses (**Section 4 and 5**) and the detailed model construction for the drainage system within the Town of Collingwood (**Section 6**).

4 Hydrologic Analysis

In any flood inundation/mapping study, it is imperative to first establish the flow values corresponding to various design scenarios. This is carried out through the hydrology study, employing hydrologic models as the requisite tool. For each of the study watersheds, first a review of the existing studies and models was carried out and then the new hydrology model was updated with the pertinent information. The following section outlines the methods used to prepare the Town-wide hydrology model.

4.1 Design Storm Selection

To simulate the governing flow scenarios, different design storms were selected in accordance with the standard guidelines applied through the Ministry of Natural Resources and Forestry (MNRF), local conservation authorities, and the Town guidelines. At the outset of this project, Greenland proposed to model the following storm return periods: 2-year, 5-year, 10-year, 25-year, 50-year and 100-year. The 24-hour SCS type II distribution was used to generate the precipitation distribution for these design storms. The 4-hour Chicago distribution was also reviewed to meet the NVCA guidelines. Since there is a significant rural drainage area in each of the study watersheds, the 24-hour SCS type II distribution storm produced more conservative results. Typically, the 4-hour Chicago distribution provides the more conservative response in urban catchments, while 24-hour SCS type II distribution produces the more conservative response in rural catchments. The referenced storm distributions are derived from the MTO Drainage Manual (1997) [5].

In accordance with the Town's design standards, intensity-duration-frequency (IDF) data should be obtained from Environment Canada's station at Collingwood. The Town requested that for the purpose of this study that the IDF curves from the MTO's online IDF Curve Look-Up tool [6] be used instead. On comparing the data from the two (2) IDF curves, the total rainfall depth was found to be higher in the IDF data derived from MTO, as shown in **Figure 4-1**.The MTO information is based on the climate models previously discussed in **Section 3.3**. The new precipitation values are higher ranging from 11 to 22% for different return periods compared to those from the Environment Canada data.

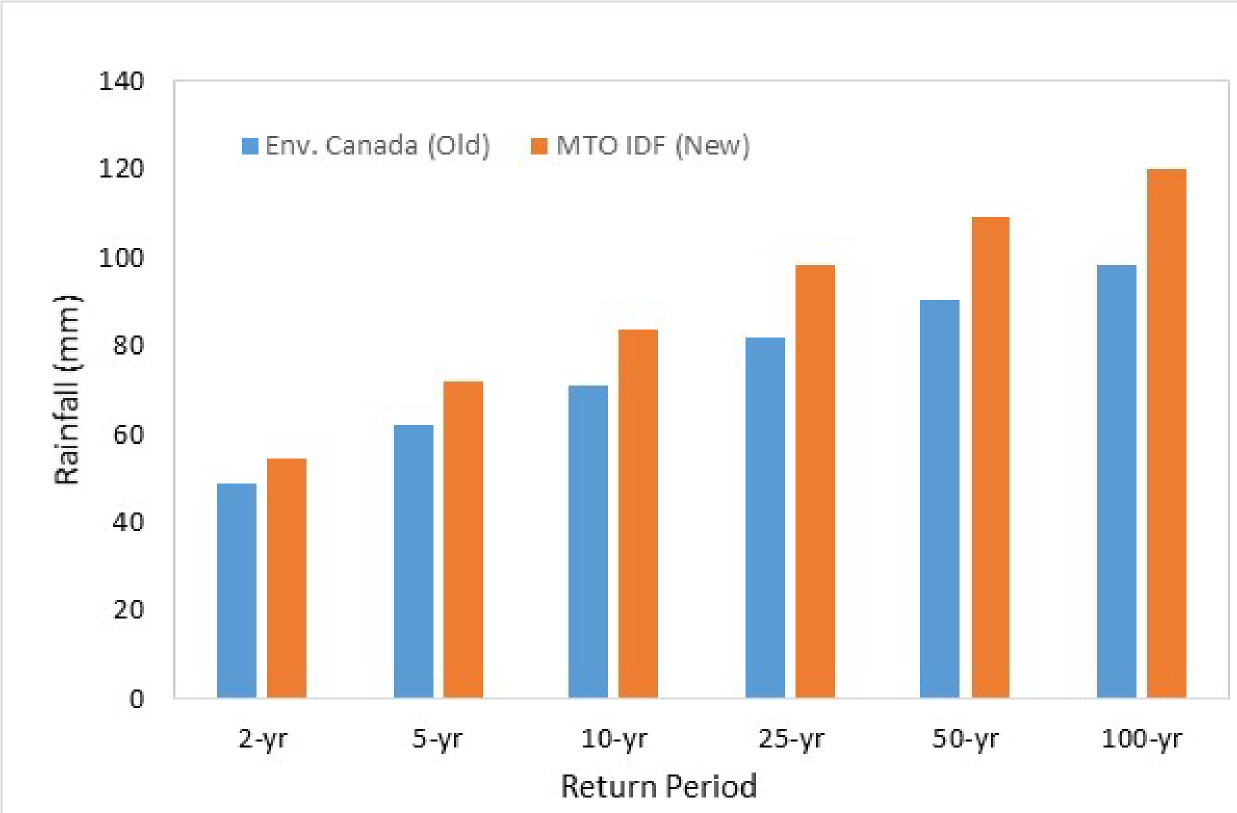


Figure 4-1 Comparison of Environment Canada & MTO IDF Curves

This change in rainfall volume implies that events that were once considered a 10-year event are now nearly a 5-year event, or in other words, the probability of an event occurring any given year has risen from 10% to nearly 20%. Therefore, the likelihood of large storm events occurring more often is increasing. The MTO curves are generated by taking into account recent precipitation data and climate models. Therefore, it is prudent to adopt the MTO curves, considering the impact that changing climate conditions is causing on local patterns of precipitation. Using this storm data in designing the drainage system would have regard for climate resiliency when investigating the storm water infrastructure current capacity.

4.2 Regional Storm

The technical guidelines published by the Ministry of Natural Resources [7] provides several flood hazard zones in Ontario. The present study area, under NVCA jurisdiction, falls into the Zone-3 flood hazard. Therefore, in accordance with these guidelines, a flood produced by the Timmins storm or 1 in 100-year flood, whichever is greater, should be considered as the flood hazard standard. The Timmins storm is equivalent to 193 mm of rainfall distributed over a duration of 12 hours. The storm distribution is presented in **Figure 4-2**.

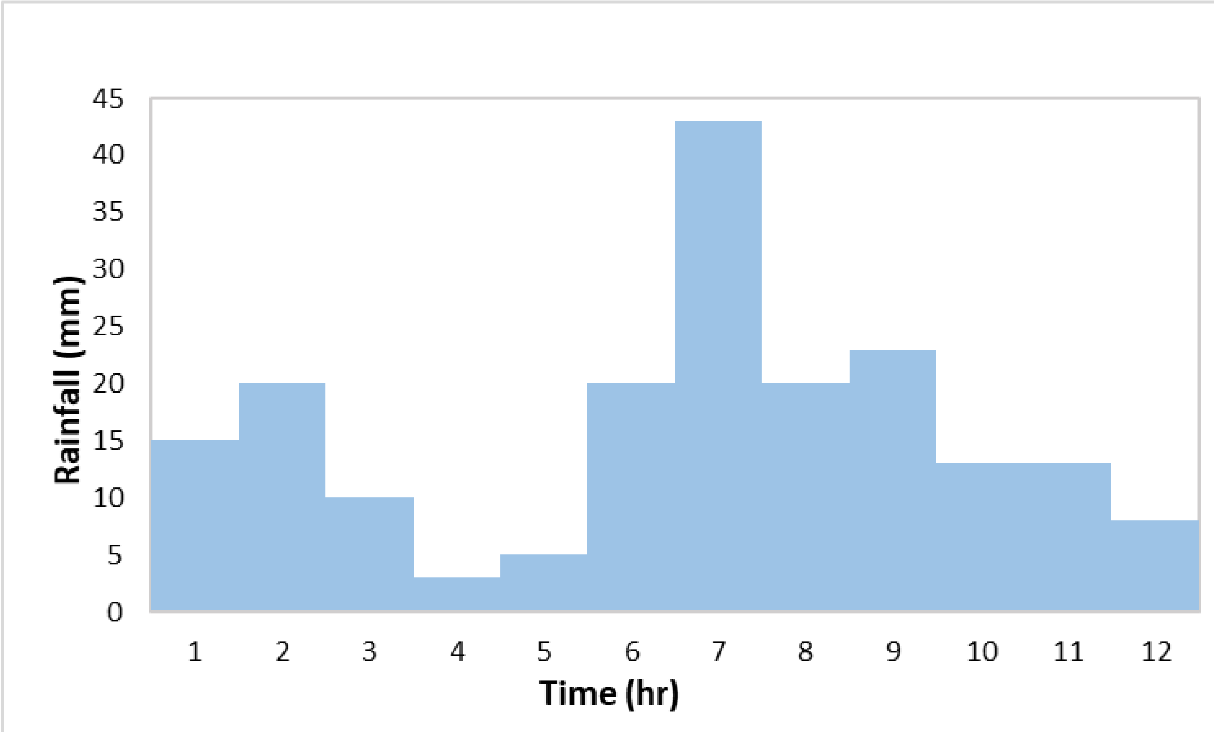


Figure 4-2 Timmins Storm Distribution

For a regional storm, an areal reduction factor must be applied to account for watershed areas greater than 25 km^2. The reduction factors, as provided in the guidelines, are computed based on the equivalent area of watersheds. The reduction factors for Batteaux Creek, Pretty River, Black Ash Creek and Silver Creek are computed as 84%, 84%, 90% and 90%, respectively.

4.3 Pretty River Watershed

4.3.1 Existing Model

The Pretty River watershed is the largest of the five (5) riverine watersheds being studied in this assignment (traverse and/or outlet in the Town) with a catchment area of 67.7 Km^2. The existing flow conditions for the Pretty River catchment were developed using the Pretty River Hydrology Update [8], completed by C.C. Tatham and Associates Ltd. (Tatham) in 2018. The purpose of the Tatham 2018 study was to create a comprehensive hydrologic model that predicts Regulatory Flow generated by the Timmins Storm. The hydrologic models in the report were developed in Visual OTTHYMO version 5.0 (VO5).

A PCSWMM model was created by Greenland that imported the catchment areas and SCS-related parameters based on the VO5 model used by Tatham. Adjustments to the PCSWMM model were made to match the previous VO5 results. **Table A5-1** (**Appendix 5**) demonstrates that the PCSWMM model has a flow output of 180.08 cubic meters per second (m^3/s) at the outlet to Georgian Bay, closely matching that of the aforementioned VO5 model of 180.04 m^3/s. The adjustments are documented in **Appendix 5**.

4.3.2 Updated Model

Using the PCSWMM model that was matched to the Tatham 2018 VO5 model output, the PCSWMM model was then adjusted to integrate updated catchment boundaries delineated from the Town-wide DEM, created as part of this study. The length to width ratios of the updated catchments, however, remain similar to those generated when matching the existing VO5 model. The updated catchment area is slightly smaller (67.2 Km^2) which compares with the 67.7 Km^2 in the earlier Tatham 2018 study. The delineated catchment boundaries in PCSWMM are shown in **Figure 4-3**. The computed peak flow in the new PCSWMM model (with drainage catchment area updated) for the Timmins storm was found to be 179.79 m^3/s at the outlet into Georgian Bay. The results from the updated model are also summarized in **Table A5-2 of Appendix 5.**

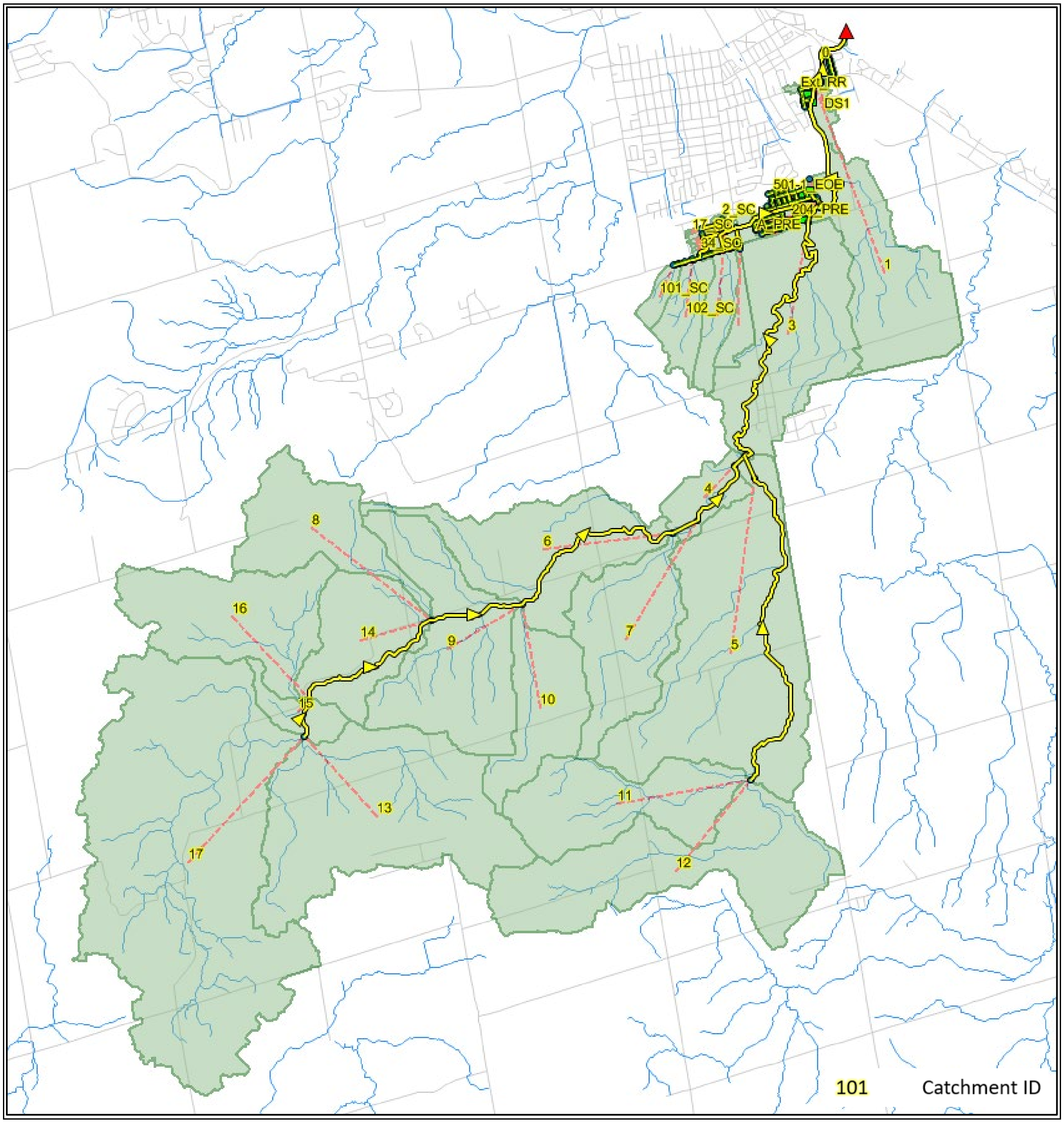


Figure 4-3 Pretty River Watershed in PCSWMM

4.4 Black Ash Creek Watershed

4.4.1 Existing Model

The reference study for the existing conditions for the Black Ash Creek watershed is entitled Black Ash Creek Subwatershed Plan (2000) [3], prepared by the Nottawasaga Valley Conservation Authority (NVCA), with technical support from Greenland. It includes the following aspects:

- Stormwater management;
- Hydrologic study; and,
- Hydraulic study.

The Integrated Science and Watershed Management System (ISWMS), a decision-support system developed by Greenland, was utilized to develop hydrologic models for the 2000 study. A Visual OTTHYMO model was also developed to verify the results of the ISWMS model.

A new PCSWMM model was created for this assignment based on the catchment areas and SCS-related parameters in the 2000 approved VO2 model. The PCSWMM model results were validated by comparing with the model results from the original approved VO2 model. The irregular conduits in the PCSWMM model used the channel configuration dimensions from the ROUTE CHANNEL features in the VO2 model. The catchment width and length parameters in the PCSWMM model were adjusted in order to match flow values from the existing study as shown in **Table A5-3** (**Appendix 5**).

4.4.2 Updated Model

The new PCSWMM model was then updated by adjusting the Black Ash Creek watershed boundary to match the revised neighbouring Pretty River watershed boundary derived from the new digital terrain information (Town-wide DEM). The length to width ratio of the updated catchments remains the same as the earlier PCSWMM model developed from the original VO2 model. Since the completion of the previous study, there have been four (4) major developments constructed within the watershed namely, Georgian Meadows, Summit View, Balmoral, and Mair Mills subdivisions. These four (4) developments have been included to update the local catchments in the model, as shown in **Figure 4-4**. The overall watershed area is found to be 32.6 Km^2.

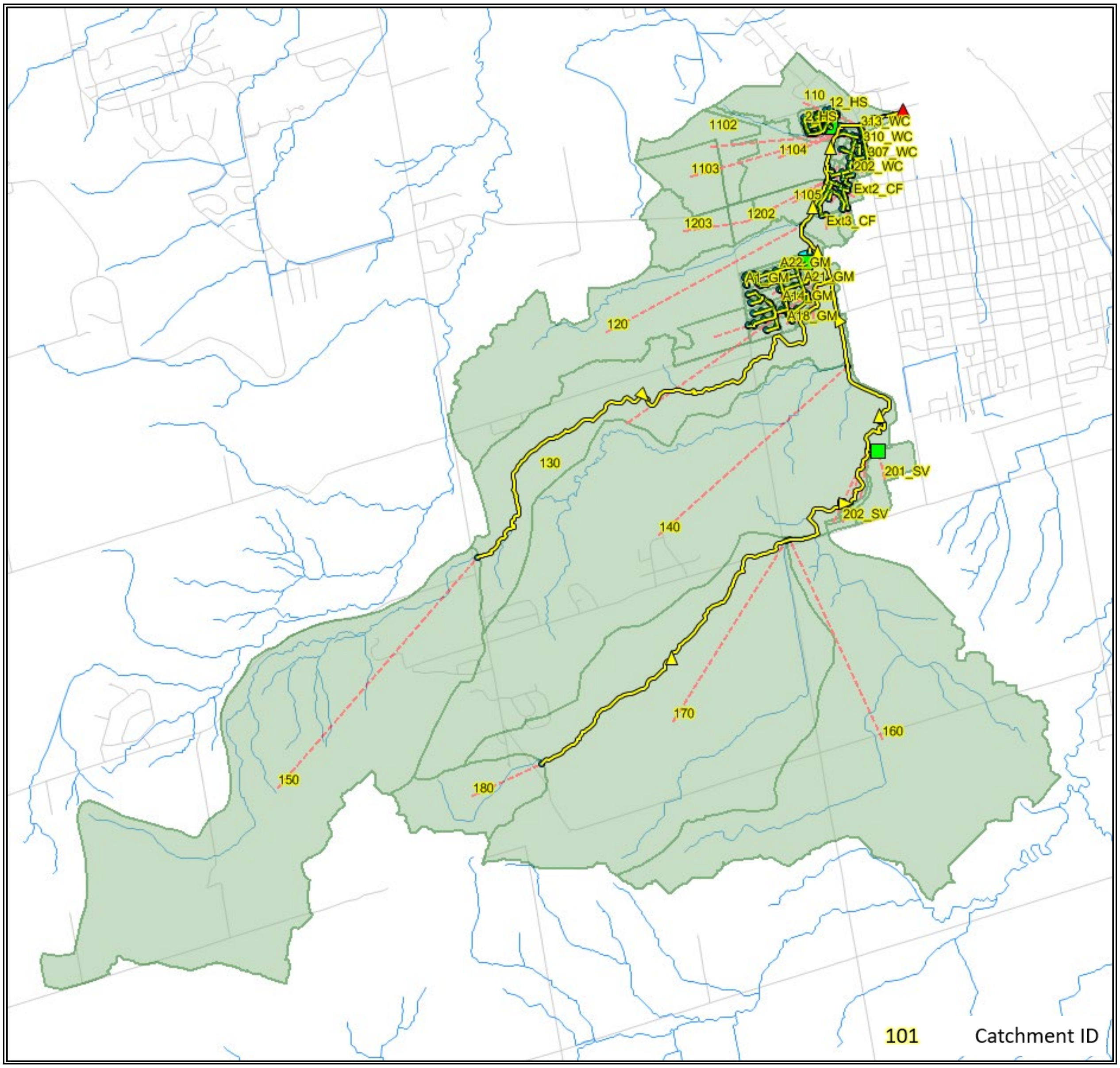


Figure 4-4 Black Ash Creek Watershed

Flows, catchment areas, and SWM facility rating curve information from the SWM Reports for each of the four (4) new developments were used to update the appropriate parameters in the PCSWMM model. This information is summarized in **Appendix 5** (flows, catchment areas) and **Appendix 6** (SWM facility rating curves). The PCSWMM model was run for a 100-year return period storm with the four-hour Chicago distribution to match the distribution which was used in the original model. The model generated a 100-year peak flow of 28.6 m^3/s, compared to 29.7 m^3/s in the VO2 model from the 2000 study. Once this comparison was completed, then other distributions were tested. The simulation results are also presented in **Table A5-4, Appendix 5**.

The Timmins storm flow for Black Ash Creek is 129.3 m^3/s

4.5 Silver Creek Watershed

4.5.1 Existing Model

The existing model for the Silver Creek Watershed was prepared by MacLaren Plansearch Inc. in 1988 [1] (MacLaren Study). This study established Regulatory Flow values for watercourses within the NVCA and is the basis for the original floodplain mapping for the riverine systems within the Collingwood Study Area watershed. In MacLaren Study, QUALHYMO was utilized to simulate the watershed hydrology. The catchment boundaries, including the Silver Creek watershed, were generated from either 1 to 50,000 National Topographic survey maps, or 1 to 10.000 Ontario Base Maps (1984). These local catchments in the MacLaren study for the Blue Mountain watersheds (which includes the Collingwood watersheds) were previously shown in **Figure 3-2**.

To re-create the Silver Creek watershed model, a PCSWMM model was developed for the watershed utilizing parameters representative of information found in the MacLaren Study (depicted in **Figure A5-2** / **Appendix 5**). In order to develop a PCSWMM model, a methodology was determined to establish equivalent parameters as used in the QUALHYMO model. **Equation 1** was used to determine CN values from S_{MAX}, S_{MIN}, SK, API.

$$\boldsymbol{S^* = S_{min}(S_{max} - S_{min})e^{-(S_k * API)}} \qquad \textbf{\textit{Equation 1}}$$

$$\boldsymbol{S^* = \frac{25400}{CN} - 254}$$

where:

- S^* = Loss Parameter
- S_{min} = Minimum Storage Capacity
- S_{max} = Maximum Storage Capacity
- S_k = Slope of Storage Capacity between S_{min} and S_{max}
- API = Antecedent Precipitation Index (S_{min} – S_{max})/2
- CN = Curve Number (corresponding to AMC-I condition)

The existing conditions model catchment boundaries were created based on the catchments identified from the MacLaren Study and updated to reflect current conditions. The flows were matched to the QUALHYMO model by adjusting the catchment flow length and slope in the PCSWMM model. QUALHYMO parameters and the computed CN values are shown in **Table A5-5** (**Appendix 5**). The rainfall input in the

QUALHYMO model and PCSWMM model were matched using the Timmins storm areally reduced to 94% with the results shown in **Table A5-6** (**Appendix 5**).

4.5.2 Updated Model

In order to update the hydrology in the Silver Creek watershed, the catchment and flows derived in Windfall Master Stormwater Management Report (2012) [8] were utilized. **Figure A5-3** (**Appendix 5**) identifies the Windfall original catchment boundaries. The VO2 model developed for this 2012 study was re-evaluated for the Price's Subdivision by Greenland in 2018 [9]. The hydrologic model encapsulates the largest land use changes in the Silver Creek watershed, since the completion of the MacLaren Study [1], namely, the Windfall Subdivision and the Orchard at Blue Mountain Resorts Ltd. The PCSWMM model created by Greenland for this study was matched to the results of the VO2 model from the 2012 Tatham study for the 100-year return period storm (24-hour SCS II rainfall distribution). The results are shown in **Table A5-7** (**Appendix 5**).

The watershed boundary was adjusted to match the neighbouring watershed boundaries of the Black Ash Creek Watershed and Camperdown Catchment - delineated as part of ongoing floodplain mapping completed by Greenland for the Grey Sauble Conservation Authority (GSCA). **Figure 4-5** displays the updated catchment for Silver Creek.

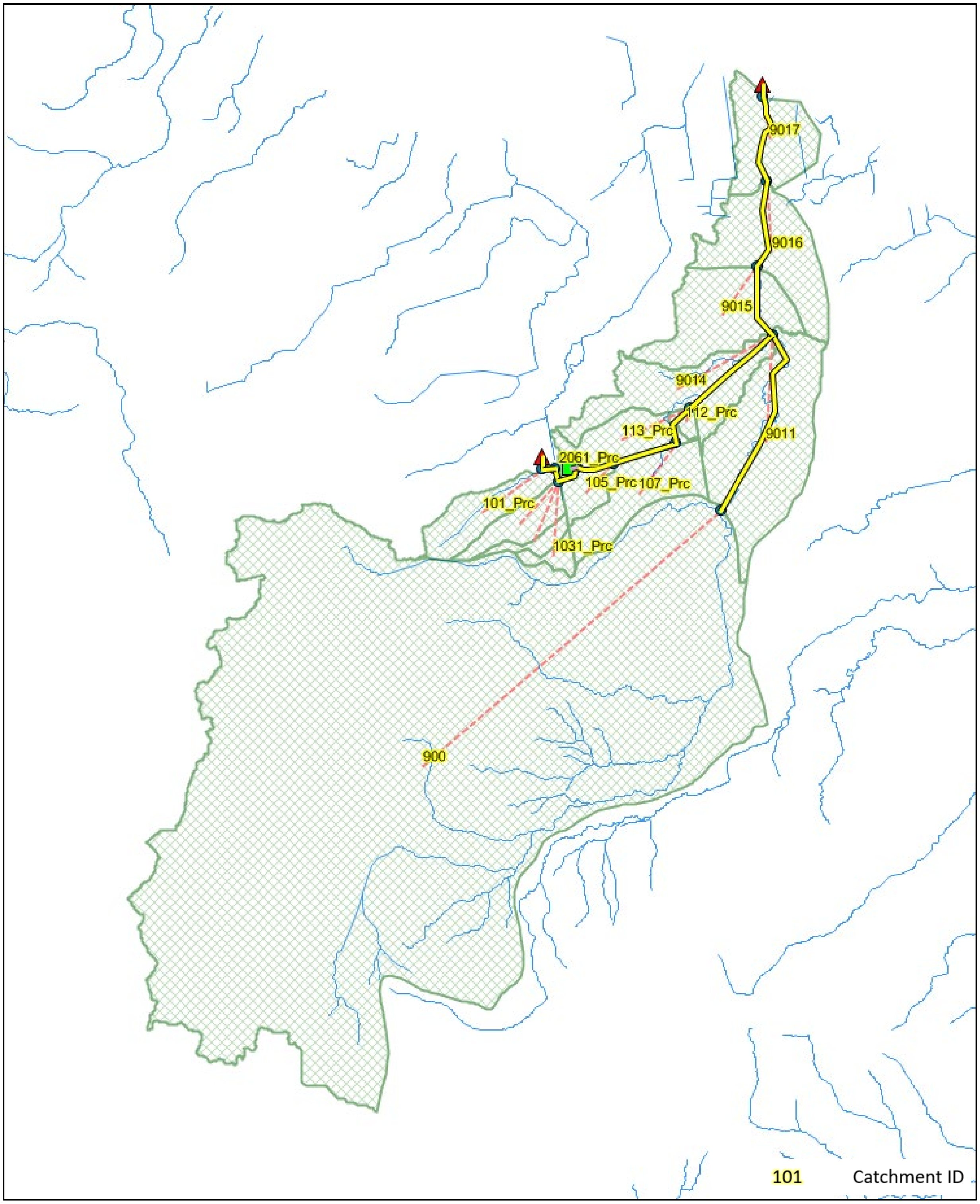


Figure 4-5 Silver Creek Watershed in PCSWMM

The length to width ratio in the updated project model remains unchanged from the MacLaren Study. With the adjusted parameters, the PCSWMM model was run for the Timmins Storm (areally reduced to

90%). The peak flow was determined as 93.49 m^3/s. The Timmins Storm (areally reduced to 94%) peak flow is 110.3 m^3/s for the original MacLaren Study. The detailed results are presented in **Table A5-8** (**Appendix 5**).

4.6 Townline Creek

4.6.1 Existing Model

The existing hydrology for Townline Creek was available from the 1993 Craigleith Camperdown Subwatershed Study by Gore and Storrie completed for the Town of the Blue Mountains. Townline Creek was labelled as Watercourse 1 in that study. The original modelling was completed using Qualhymo. This hydrology had been recently updated by Greenland in a study prepared for the Grey Sauble Conservation Authority (GSCA) in concert with the Town and Grey County completed under the National Disaster Mitigation Program (NDMP). The hydrology was updated using the HEC-HMS model platform. This hydrology was introduced into PCSWMM following the same methods employed for the other watersheds.

4.6.2 Updated Model

The Townline Creek watershed boundary was adjusted in PCSWMM to conform to the updates to the Silver Creek watershed boundary, as the drainage catchment delineation was modified to reflect the updated digital terrain model. Although the drainage areas changed slightly, the length to width ratios in the updated catchments remain the same as determined for the original HEC-HMS model. There were no significant developments that needed to be introduced to the watershed model to update the hydrology. **Figure 4-6** shows the updated Townline Creek watershed. The updated model was run for the Timmins storm and the peak flow was computed as 17.14 m^3/s which is about 7% lower than the Timmins Storm peak flow of 18.42 m^3/s from the original Camperdown Study. Further comparisons of the results are presented in **Table A5-13** (**Appendix 5**).

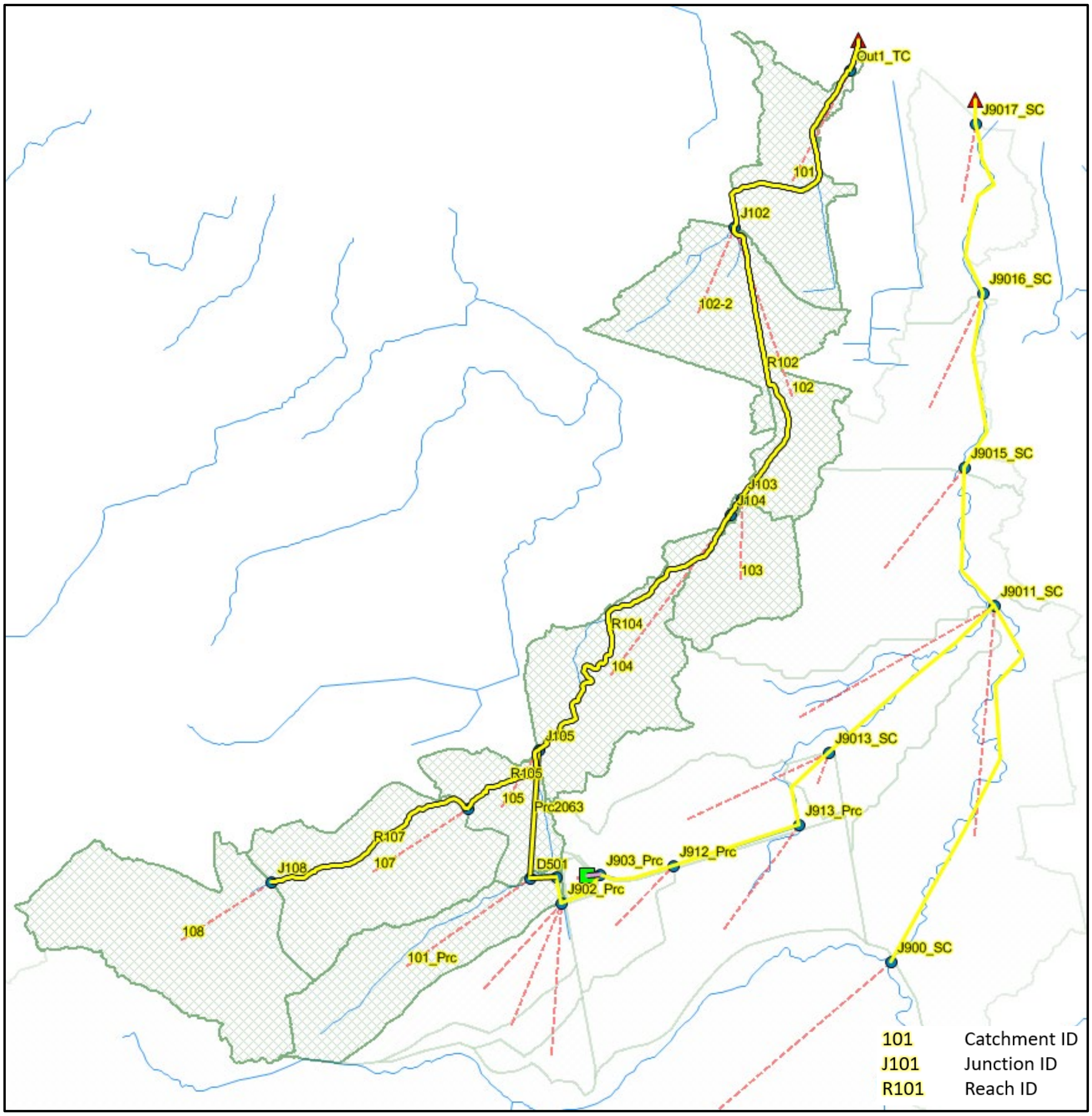


Figure 4-6 Townline Creek

4.7 Batteaux Creek Watershed

4.7.1 Existing Model

The existing hydrology of the Batteaux Creek Watershed is based on the MacLaren study [1]. The existing conditions catchment area details from the MacLaren Study (**Figure 3-2**) were imported into PCSWMM and used as the basis to create the individual catchment boundaries (**Figure A5-4**, **Appendix 5**). The QUALHYMO model parameters were converted to equivalent PCSWMM parameters, based on the methodology described in **Section 4.5.1**. The parameters are shown in **Table A5-9** (**Appendix 5**). The PCSWMM model and parameters were adjusted to match flows with the original QUALHYMO using the Timmins (areally reduced to 87%) storm (178.837 m^3/sec) and the model comparison results are shown in **Table A5-10** (**Appendix 5**).

4.7.2 Updated Model

The Batteaux Creek watershed boundary was adjusted in PCSWMM to conform to the updates to the Pretty River watershed boundary from **Section 4.3.2**, as the delineation changed to reflect the changes determined from the updated digital terrain model (Town-wide DEM). Although the drainage areas change slightly, the length to width ratios in the updated catchments remain the same as determined for the PCSWMM model described in **Section 4.7.1**. There were no significant developments that needed to be introduced to the watershed model to update the hydrology. **Figure 4-7** shows the updated Batteaux Creek watershed. The updated model was run for the Timmins (areally reduced to 84%) storm and the peak flow was computed as 160.31 m^3/s which is about 10% lower than the original model (areally reduced to 87%) results (178.837 m^3/sec). Further comparisons of the results are presented in **Table A5-11** (**Appendix 5**).

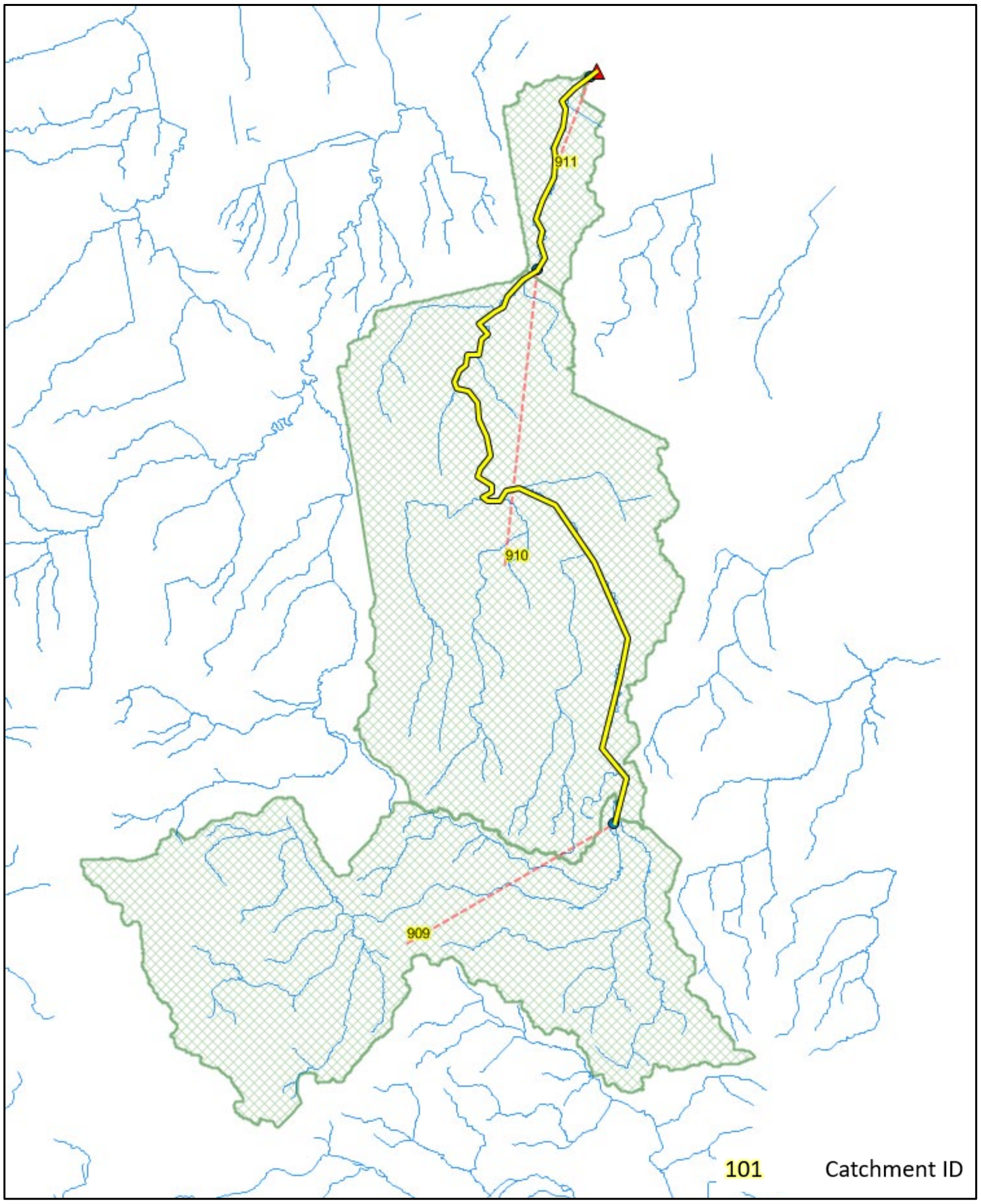


Figure 4-7 Batteaux Creek Watershed in PCSWMM

4.8 Urban Town Centre

4.8.1 Existing Model

The Urban Town Centre hydrology was also included in the earlier MacLaren study [1]. Most of the Town was included in the delineation of the Black Ash Creek watershed, with the eastern portion of Collingwood included in the Pretty River watershed. Since the MacLaren study has been completed, the watershed boundaries and hydrology have been updated for both the Pretty River watershed and Black Ash Creek watershed. The Town Centre is no longer included within either of the watersheds. Therefore, the Urban

Town Centre does not have any up-to-date hydrology to base the PCSWMM model on, as the flows from the MacLaren report are not relevant for the urban area. The Qualhymo software used in the MacLaren study did not have an urban catchment routine.

4.8.2 Updated Model

The primary drainage for the Town Centre is through the storm sewer and ditch drain networks. The completely new PCSWMM model for the existing Urban Town Centre has been developed as a minor-major system model which is further detailed in **Section 6**.

4.9 Resort Drainage Areas

The hydrologic model for the Resort Drainage Areas has been created based on catchment drainage areas previously defined in post development drainage plans for several constructed and planned developments (see **Appendix 3**). The SWM report prepared by C.F. Crozier and Associates for Tanglewood at Cranberry Trail (2007) [4] provides the most comprehensive hydrology for the Resort Drainage Areas, and therefore provided considerable background for the new PCSWMM hydrologic model created by Greenland for this watershed. **Figure 4-8** shows the Tanglewood catchments and the Cranberry Creek watershed.

Figure 4-8 Tanglewood Catchments and Cranberry Creek Watershed

A particular focus of the analysis was to quantify the spill from the Silver Creek watershed as it flows through the Resort Drainage Areas and establish the extent and nature of its subsequent impacts on not only Cranberry Creek but the other minor watercourses as well. **Figure 4-9** shows the other minor drainage catchments that have been included in the Resort Areas analysis. These include three (3) small drainage courses named Bridgewater 1, 2, and 3. There is also an unnamed small drainage course between Silver Creek and Townline Creek that has been labelled Additional.

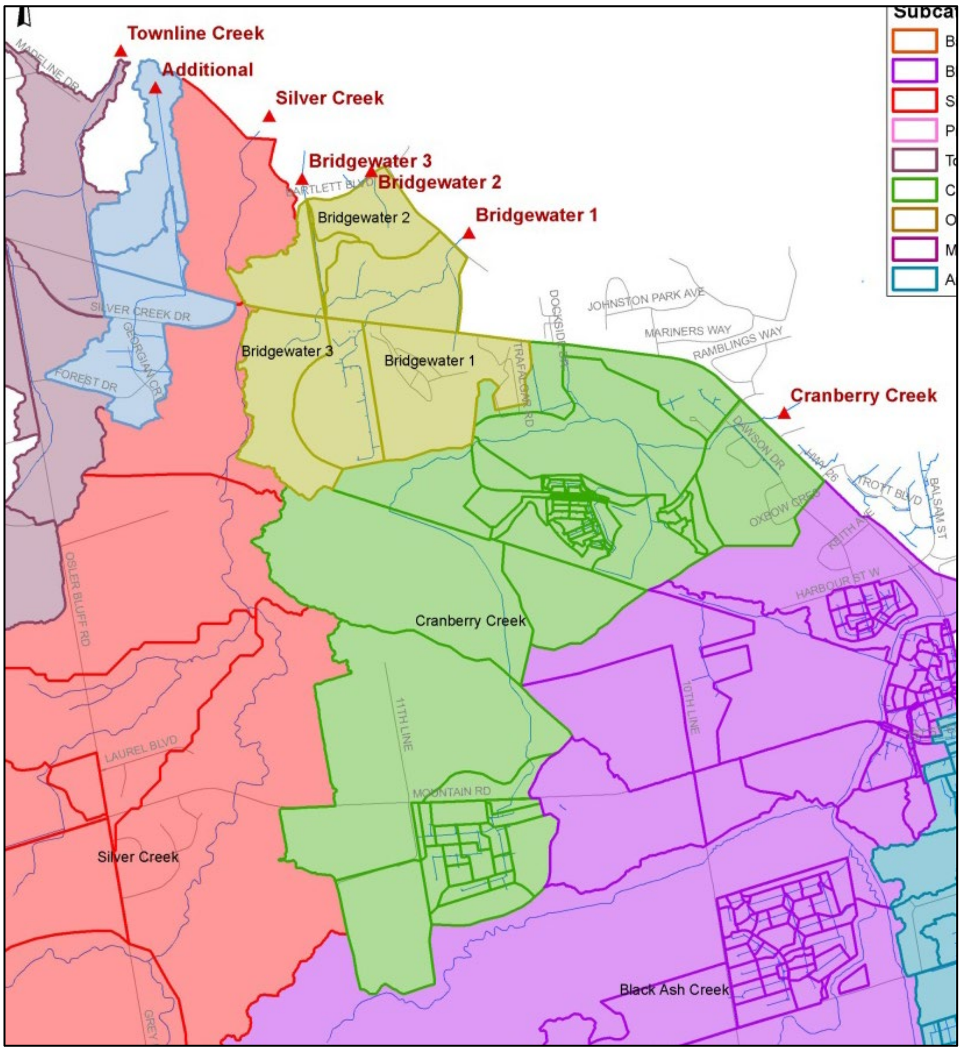


Figure 4-9 Resort Areas and Minor Watersheds

There are numerous spill locations on Silver Creek and Townline Creek that interact with both Cranberry Creek and these minor drainage courses. Since the flows from the spills are significantly greater than the actual flows generated in these catchments, they are documented in **Section 7.1.2**, which discusses the results of the model simulations for Silver and Townline creeks.

4.10 Combined PCSWMM Model

The PCSWMM models completed for the four (4) major watersheds in the Collingwood area, namely Pretty River, Batteaux Creek, Black Ash Creek and Silver Creek, were combined into a single PCSWWM model. The model was run for the 100-year 24-hr SCS storm and the Timmins storm event (adjusted for each sub-watershed). A summary of results for the four (4) riverine watersheds is presented in **Table 4-1**.

Table 4-1 Summary of Study Watersheds

Watershed	Catchment Area (Km^2)	Peak Flow (m^3/s)		Reduction factor for Timmins storm
		100-yr 24hr SCS	Timmins Storm	
Pretty River	67.5	85.88	179.79	0.84
Black Ash Creek	30.7	108.24	129.29	0.90
Silver Creek	26.2	53.98	93.49	0.90
Batteaux Creek	52.2	92.32	160.31	0.84

The watersheds in the preceding table were linked with the Urban Town Centre, Townline Creek and the Resort Drainage Areas to create a composite PCSWMM model as shown in **Figure 4-10**.

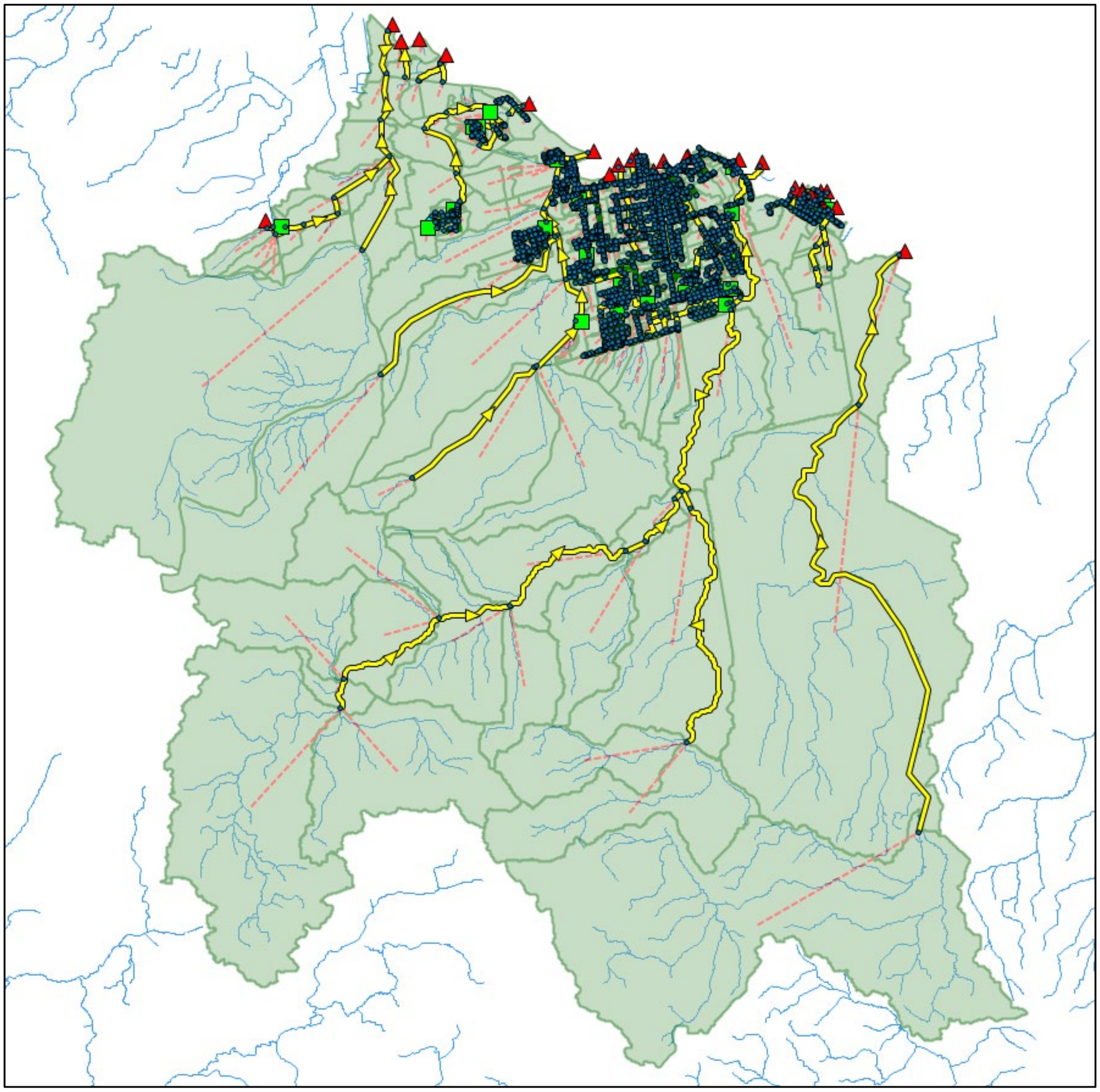


Figure 4-10 Combined Watershed in PCSWMM

5 Hydraulic Model Development

Riverine interaction is included in the PCSWMM model and could be used for hydraulic (floodplain) simulation. However, the HEC-RAS software is better equipped for riverine and flood plain mapping, and is more widely accepted, which allows the model to be easily utilized by future users. Therefore, the hydrologic results from the PCSWMM major and minor conveyance models were coded into HEC-RAS model to develop the riverine models and develop detailed hydraulics of the water flow and spill routes. Hydraulic models for various river reaches are described in the subsequent sections.

5.1 Pretty River

The Pretty River hydraulic model development and results are presented as a standalone separate document in this report as **Appendix 2-I**. A separate report has been prepared for the Pretty River watershed, as the Town has acknowledged that the updated flood flows for the Pretty River could bring about potential changes to the Town's Official Plan, namely the Pretty River Two Zone Special Policy Area. The purpose of the Pretty River standalone report is to provide all technical details required to update the Pretty River hydraulics, based on the recently accepted hydrology. The updates to the Pretty River hydraulics may in turn require changes to the required flood protection and delineation of the Pretty River spill zones.

5.2 Black Ash Creek

The current Black Ash Creek hydraulic study is based on the Black Ash Creek Subwatershed Plan prepared by Greenland and the NVCA (2000) [3]. Since the release of this Subwatershed Plan report, the Black Ash Creek flood control works were completed using the design prepared by Ainley Consulting Engineers. This included the channelization and horizontal realignment of approximately 3.9 kilometers of the Black Ash Creek. In the Subwatershed Plan the proposed design of the flood control works was included as a future "Ultimate" condition of the creek, including a hydraulic model for the proposed works. This "Ultimate" condition hydraulic model was utilized as the basis for the updated hydraulic model of the Black Ash Creek for this assignment.

The existing model was not georeferenced. In order to update the model with the elevations from the latest available DEM, georeferencing was first completed. This task was carried out using the cross-sections on the upstream and downstream sides of the bridge crossings at various locations along the primary channel and tributaries.

The existing hydraulic model included the trapezoidal channel section for the Black Ash Creek; however, it did not contain any of the overbank areas. In order to include potential spills and flooded areas, the model had to be updated using the LiDAR data collected as part of this study. The channel sections were cut from the existing hydraulic model created by Greenland for the Subwatershed Plan. It was decided not to extract them from the DEM due to the steep slopes of the banks of Black Ash Creek, as the DEM could not be fully relied upon for the accuracy of elevations in the steep slope sections (LiDAR limitation). Instead, the channel modification tool in HEC-RAS was used to modify the existing sections with the overbanks from the DEM. The layout of the existing hydraulic model is presented in **Figure 5-1**.

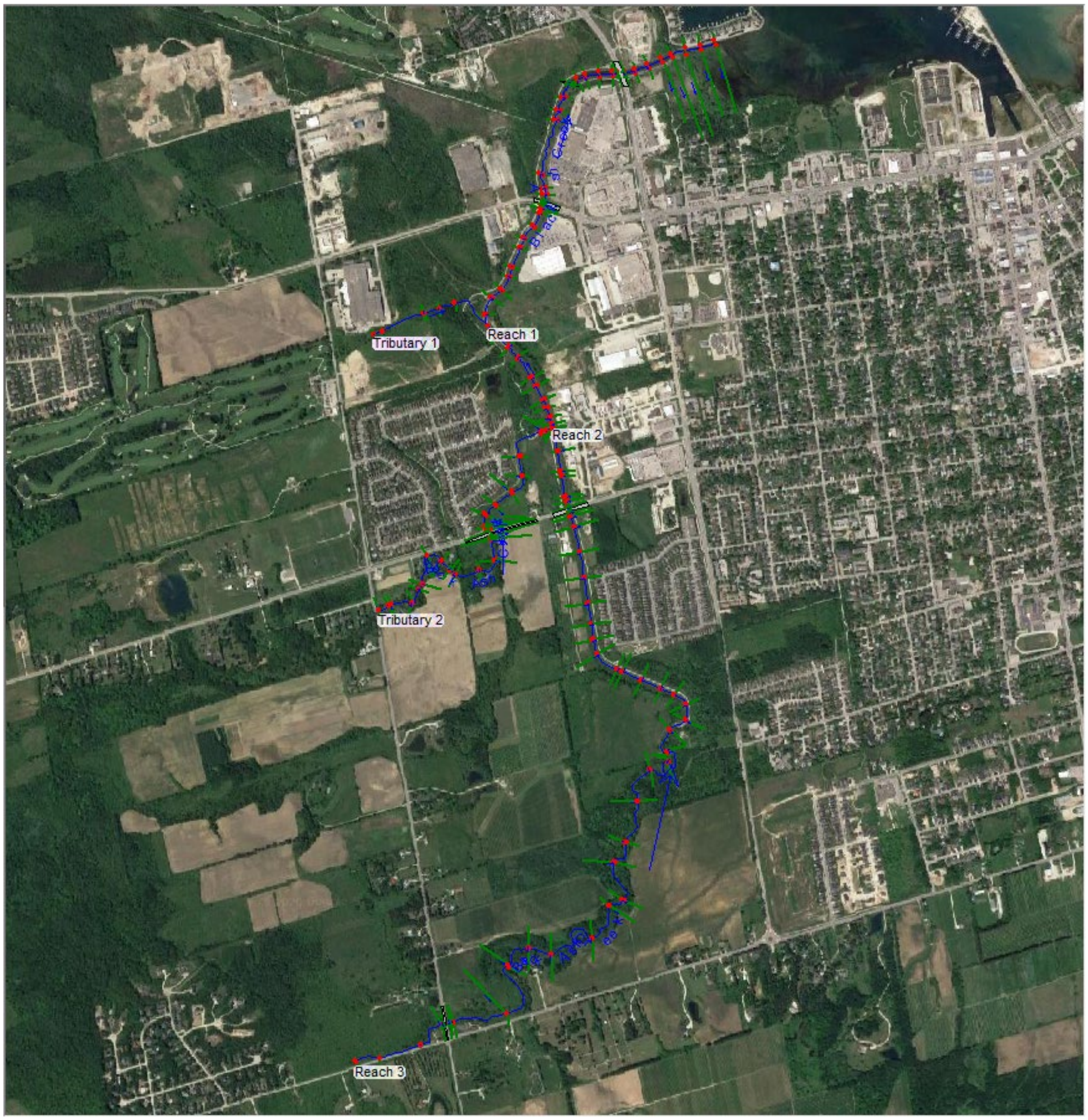


Figure 5-1 Black Ash Creek HEC-RAS Model Layout

The modified sections were similar to the terrain from the DEM for much of the creek through the Town, however, in the downstream reach of the creek, particularly north of the Mountain Road Bridge **(see Figure 5-2)**, there were some significant differences in the invert elevation of the channel. This was determined to be due to the increased water depth in the creek, which LiDAR is not capable of penetrating. Additionally, in the original model created by Greenland the channel was modelled with bank heights of 10m. This affected the width of the top of channel as it was modelled 70m wide in many locations, which does not match with the existing geometry of the Black Ash Creek. When modifying the channel overbanks, the top of channel was lowered to match the elevation from the DEM, correspondingly reducing the top width of the channel.

The HEC-RAS model was simulated for the flows corresponding to storm events of various return periods for the SCS Type II distribution storm and the Timmins storm. Emphasis was given to the results of 100-year and Timmins storm events.

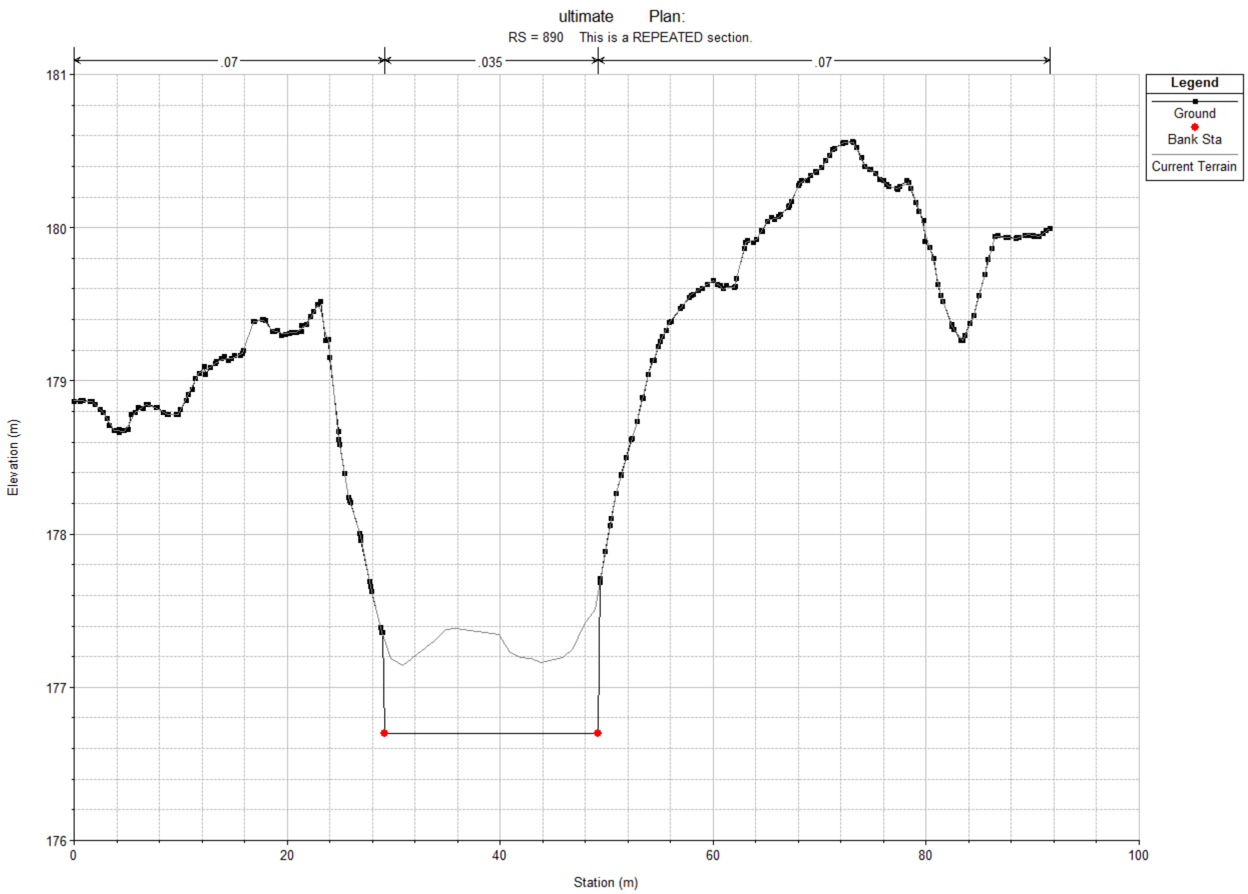


Figure 5-2 Black Ash Creek HEC-RAS Model Invert Comparison, c.s. 890

5.3 Silver Creek

At the outset of the study, there was no existing hydraulic model for Silver Creek. A HEC-RAS model was created from the modified DEM (detailed below) in ArcMap using the HEC-GeoRAS toolkit. The river and flow path were created using watercourse data obtained from Ontario Open Data. Prior to creating cross-sections, to confirm to accuracy of LiDAR data in the creek channel, the LiDAR point file data was obtained from the GSCA and compared to the Town-wide DEM elevations. A separate DEM was created for a 50-metre radius surrounding the creek using the point file data, then merged with the Town-wide DEM to create a highly accurate terrain of the Silver Creek (modified DEM). Cross-sections were then created, cutting the geometry using the modified DEM to determine the floodplain of the creek. The data was then imported into HEC-RAS, where bank stations, channel, and over bank roughness coefficients were assigned. As there was no existing field hydraulic information for the creek, field survey data was collected for two (2) of the bridge crossings within the Town of Collingwood: the Georgian Trail crossing and Highway 26. The data was then incorporated into the HEC-RAS model. The final HEC-RAS model schematic is depicted in **Figure 5-3**.

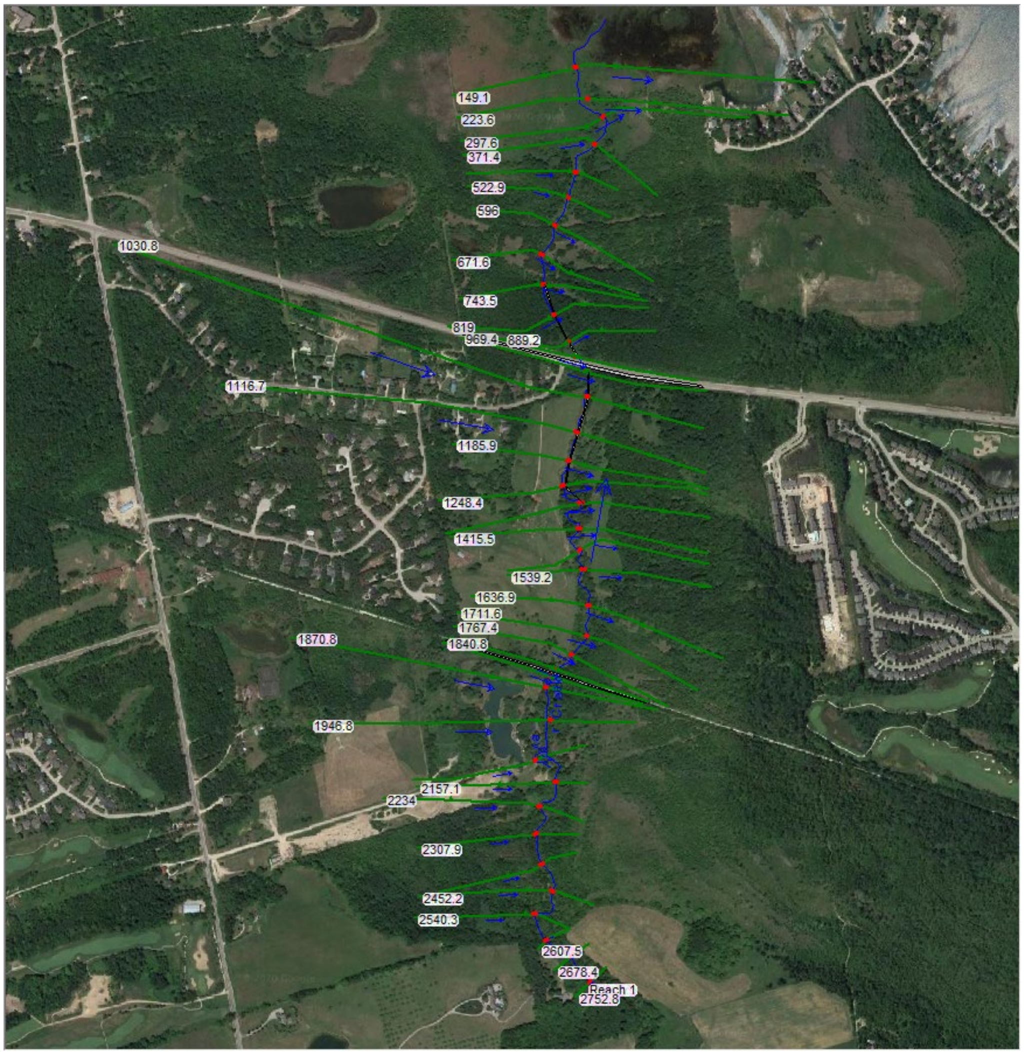


Figure 5-3 Silver Creek HEC-RAS Model Layout

5.4 Townline Creek

The Townline Creek hydraulic model is based on the HEC-RAS model created for Watercourse 1 in the recent NDMP work prepared by Greenland for the GSCA and the Town of the Blue Mountains. It had to be adjusted for use within the Town of Collingwood. Since the Town has all its infrastructure tied to the older CGVD28 geodetic datum, the LiDAR data for Collingwood and Camperdown has a 0.37 m difference. The surveyed culvert elevation in the original HEC-RAS model matched the Camperdown LiDAR which is

0.37 m lower. Therefore, the culvert elevations were increased by 0.37 m. The cross sections were recut based on the Collingwood LiDAR data. A modified DEM was also created for Townline Creek using the LiDAR point file data, as described in **Section 5.3**. **Figure 5-4** shows the hydraulic model layout for Townline Creek.

Figure 5-4 Townline Creek HEC-RAS Model Layout

5.5 Batteaux River

Similar to Silver Creek, there was no existing hydraulic model and data available for the Batteaux River. Only a small portion of the Batteaux River flows through the Town, approximately 1.5 km in length. The hydraulic model development was completed in a similar manner to the Silver Creek model, where the river, flow path, and cross-sections were derived using HEC-GeoRAS, then imported into HEC-RAS (see

Figure 5-5). A modified DEM was also created for Batteaux Creek using the LiDAR point file data. There are two (2) bridge structures crossing the river within the Town: Highway 26 and Beachwood Road. The Highway 26 Bypass was developed within the last 10 years, and as-built drawings were used for the bridge crossing of the highway. The data incorporated in the model included field surveyed data for the crossing at the Beachwood Road structure.

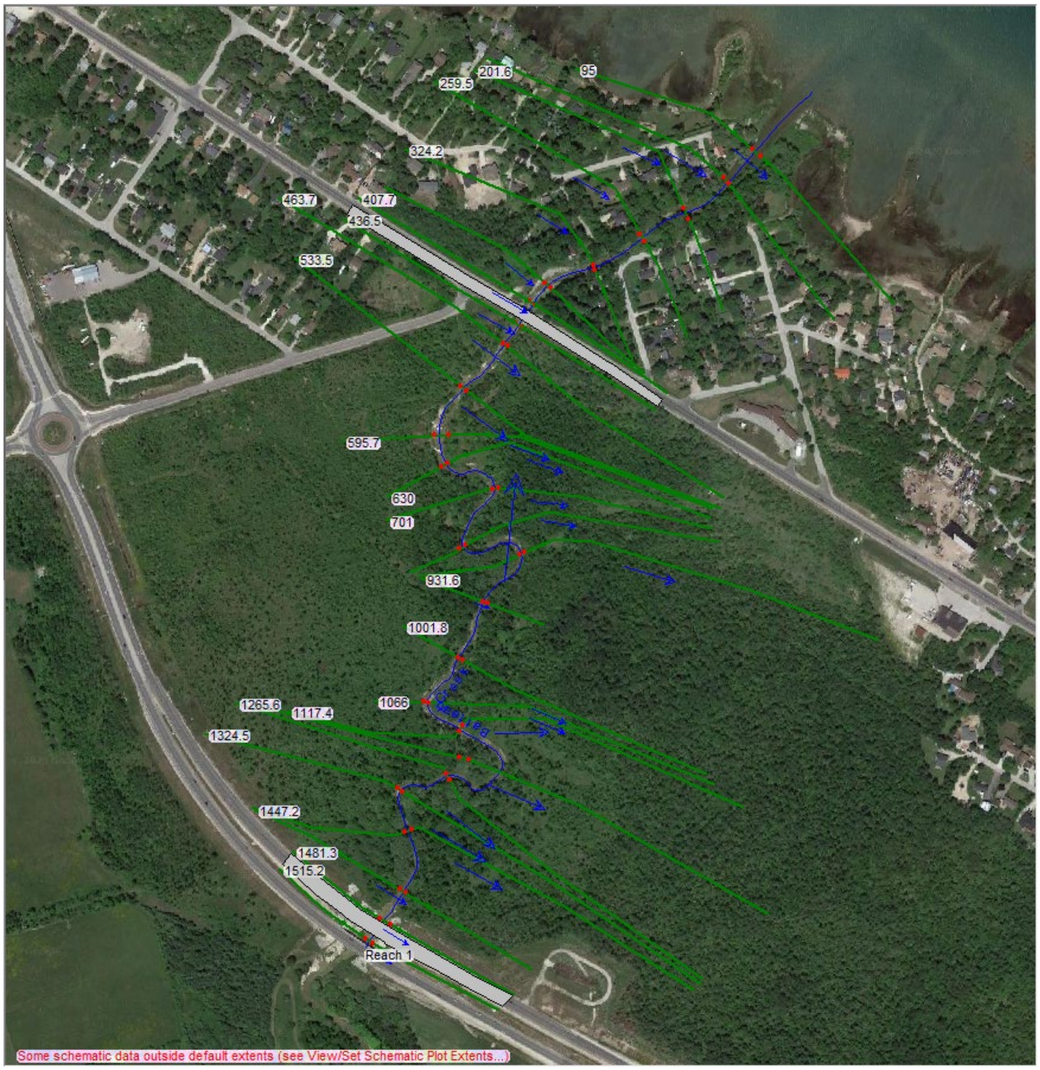


Figure 5-5 Batteaux River HEC-RAS Model Layout

6 Major-Minor System Model Development

The urban drainage system consists of storm sewers, gutters, overland flow and catch basins. The surface runoff must be first collected by surface inlets i.e., the catch basins and then directed to the storm sewer system. Storm sewer system is termed as the *'minor'* system, while the overland flow is called the *'major'* system. The overall flow system is considerably complex. In order to accurately simulate the system, these two (2) systems are modeled dynamically, using a linked approach known as dual drainage modelling. Dual drainage modelling considers the interaction between the two (2) systems that allows for an improved assessment of the deficiencies in both systems.

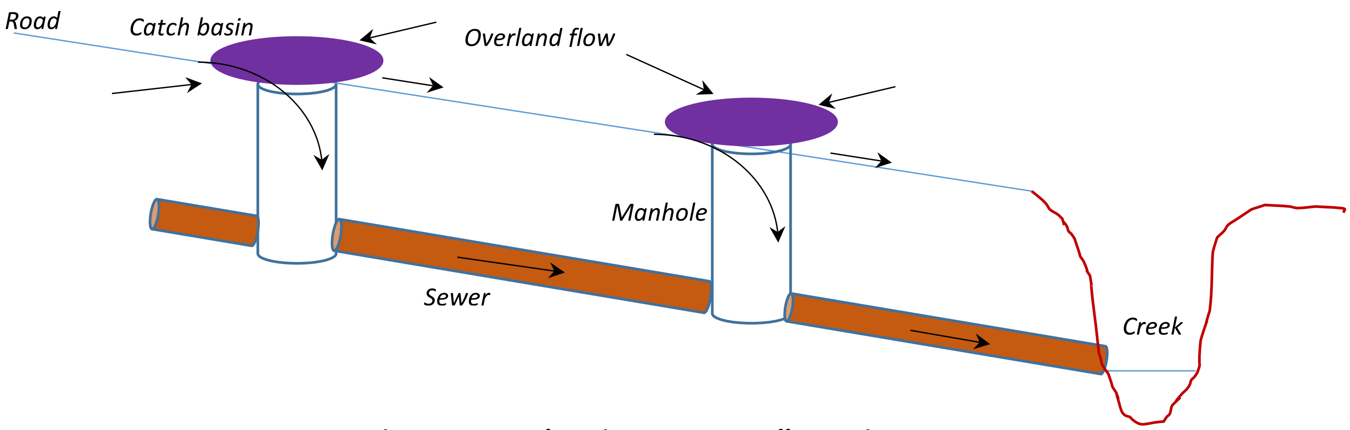


Figure 6-1 Dual Drainage System Illustration

Two (2) PCSWMM models were developed during this stage of the process to represent the drainage infrastructure and its anticipated performance:

- 1D PCSWMM – This model represents the basic municipal infrastructure that describes the dual drainage system (storm sewer and overland flow through roads etc.), illustrated in **Figure 6-1**. The flows only proceed in one direction.
- 2D PCSWMM – This model links the 1D infrastructure with a mesh representing the terrain. The model can simulate flow in two directions thereby having regard for areas that could be impacted by riverine flows entering the municipal sewer and ditch infrastructure (and vice versa).

6.1 Minor System Development

To create the minor system model, the primary data was imported from the storm sewer database provided by the Town, which contain mapping of every manhole, catch basin and storm sewer in the Town limits. To create the PCSWMM model, attributes in the imported shapefiles must contain:

- **Manhole:** Name (ID), Invert Elevation and Depth;
- **Sewer:** Name (ID), Inlet Node (Upstream Manhole), Outlet Node (Downstream Manhole), Inlet Elevation (Upstream invert), Outlet Elevation (Downstream invert), Shape (CIRCULAR,

RECT_CLOSED, ARCH, HORIZ_ELLIPSE, VERT_ELLIPSE, etc.), Geom1 (depth, or diameter), Geom2 (width);

- **Catch basin:** Catch basin Type - single catch basin (CB), double catch basin (DCB), triple catch basin (TCB), ditch inlet catch basin (DICB), catch basin manhole (CBMH), rear lot catch basin (RLCB).

Catch basins which serve as a primary junction for the storm sewer network (connector on the trunk sewer), were added to the manhole layer. Rating curves were developed based on the type of catch basin. Each node in the model has the rating curve adjusted to represent the number of inlets within each created catchment. The shapefiles for the various data layers for pipes and manholes provided by the Town were updated using survey data collected as part of this study, detailed in **Appendix 4**. The total number of minor system items adopted in the PCSWMM model are summarized in **Table 6-1**.

Table 6-1 Summary of Minor System Items

Item	Total
Manholes	1620
Sewers	1588
Catch basins	3460

6.2 Major System Development

The major system conduits were created by the "Dual Drainage Creator" in PCSWMM. This simulates all street flow as parallel to the minor system. For areas where there were no storm sewer networks, the major system was created manually. Prior to use of the dual drainage creator tool, the road transacts had to be created using the DEM to estimate the right of way (20m or 26m ROW). All road transacts were assumed to have a maximum depth in the ROW (curb height and boulevard) of 0.3 meters and a cross-slope of 0.005 meters/meter.

Figure 6-2 shows a typical ROW coded into PCSWMM to represent the overland flow channel feature.

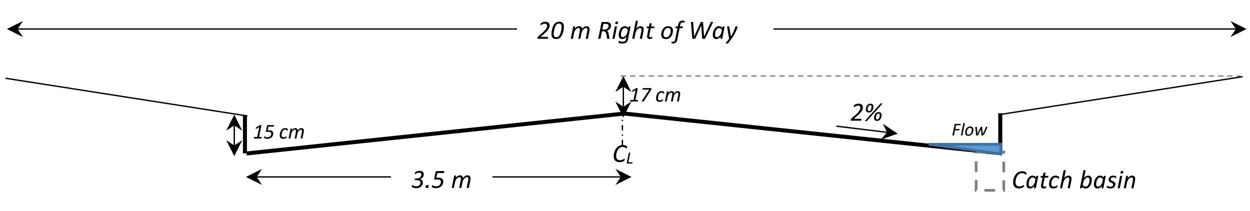


Figure 6-2 Typical Road Section

For the dynamic wave routing method, the Outlet (Major to Minor) has to be selected in the software. This routing method will simulate the major system outletting to the minor system during modelled events, and can take into account: channel storage, pressurized flow, backwater, surcharging, reverse flow and surface ponding conditions required to simulate conditions. This routing method will enable the user to evaluate the performance of the Town's major and minor systems under various design storms and what-if scenarios such as, lake levels, ice jams and snow melt.

6.2.1 Catchment Delineation

To import catchments into PCSWMM, they were first delineated in ArcGIS augmented with the proposed drainage plans from stormwater management (SWM) Reports, detailed in **Appendix 6**. For areas where SWM reports were not available, primarily older sections of the Town, historical catchment mapping, such as the one completed by Ainley in 1972, was used as a starting point to rediscretize the catchments. Then, the catchments were updated using the Town-wide DEM created from the collected LiDAR data. The urban catchments are then set at an approximate scale of one block by one block. The outlet of the catchments was set using "SET Outlet" in the Tools Menu in PCSWMM. The outlet should be set at the Major Node, a necessary modification from automatic settings. The rating curve of the outlets (major to minor) were calculated based on the catch basins in the contributing catchment. To complete this, the catch basin shapefile was clipped inside each catchment then the contributing catch basins within each catchment were compiled in a spreadsheet. The composite rating curve was derived in the spreadsheet based on the number of catch basins and imported into the PCSWMM model for each node.

6.2.2 Stormwater Management Ponds

Since the last comprehensive hydrologic model representing the Town infrastructure, multiple subdivisions and associated SWM ponds have been constructed within the Town to provide stormwater protection to each subdivision. As each pond has its own drainage area, they must be added to the model to account for the storage they provide. A summary of the ponds added to the hydrologic model is included in **Appendix 7**.

To add SWM ponds to the model, its storage rating curve and outlet structure are required. The rating curve is set as depth-area relationship. Therefore, the pond area (or volume)-elevation data is needed either from the SWM report or CAD file. The Stage-Storage-Discharge curves for some of the ponds have been compiled in **Appendix 7**. For ponds without an available SWM report or CAD file, the area and depth were estimated from the Town-wide DEM.

6.3 Model Calibration

To calibrate the major-minor system model (1D PCSWMM), flow monitoring was originally undertaken at five (5) locations for six (6) months in 2019. Water level and velocity measurements were taken at every five-minute interval at each of these locations. Flow was then computed using the observed variables. The PCSWMM 1D model was also simulated for the same time period and the flows generated from the model were compared with the observed flow. Due to a lack of large events during the 2019 monitoring period, a second monitoring program was initiated during 2020 that resulted in several large storms being captured.

A detailed report on model calibration efforts to-date was prepared separately and is presented in **Appendix 8.** A brief summary of the report is as follows:

- There were no major rainfall events in 2019 (>30 mm volume) observed during the monitoring period, therefore the resulting recorded flows are very low with the maximum recorded flow being ~ 0.6 m^3/s;
- Eight (8) rainfall events exceeded 20 mm in volume in 2020 with four (4) events exceeding 30 mm and one event in June representing a 10-year event at 62.2 mm;
- The timing of the peak flows was accurately simulated but the modelled peak flow magnitudes during rainfall events were larger than recorded for many events. It was more pronounced in the urban catchments that contained hybrid drainage infrastructure (partial curb with road side ditches);
- There is significant evidence from the monitored data that the runoff volumes in areas where there were ditch systems flows are getting captured in the groundwater table;
- Seven (7) model parameters affecting the peak flow that were calibrated in 2019 were adjusted further in 2020;
- The peak flows in the calibrated model are significantly reduced from those recorded in the original model simulation with default parameters; and,
- Since the PCSWMM model is to be used to simulate flood events where the soil moisture condition is to reflect AMCII conditions, there was no attempt to adjust parameters outside of normal ranges just to more accurately simulate flows during the extremely dry conditions present during the period that the flow monitors were installed.

Refer to **Appendix 8** for detailed calibration analysis and results.

6.4 2D PCSWMM Model Development

Once the 1D PCSWMM model had been calibrated, a 2D model was developed in PCSWMM using the calibrated parameters. A 1-D unsteady flood simulation is created for the stormwater drainage system, while a 2-D mesh is created for surface flows. The 2D PCSWMM model assists in delineating surface flows and identifying flood damage centers within the urban center of the Town during storm events. A 1-D/2-D model provides a better understanding of the performance of stormwater infrastructure during extreme events and also allows for a more accurate insight into the overland path of storm flows, the associated flooding and surface ponding.

6.4.1 Model Setup

The sewer system and catchments in the 2D PCSWMM model are the same as in the 1D model. The major to minor connections still use the rating-curves for the catch basins. As 2D meshes are introduced into the model, the major road conveyance systems previously created in the 1D model are removed from the 2D model. The 2-D layers include a 2-D mesh for the overland flow area, an obstruction layer, surface roughness, and slope. Since each of the subcatchments were created from the 1-D model, the roughness layer and slope layer had already been incorporated into the model. A building footprint shapefile was provided by the Town as an obstruction layer. As the layer was slightly out of date missing some of the newest developments, it was updated manually in ArcMap, then imported into PCSWMM.

6.4.2 Mesh Size Selection

Considering the balance between the required model accuracy and a reasonable computational time, two (2) different mesh sizes were used in the 2D PCSWMM model. The areas around the road (20 m on either side of the sewer lines) are simulated using a 3 m resolution mesh, while a coarser mesh of 15 m being used for all other areas. This provides a high level of model accuracy for the area surrounding stormwater infrastructure as a primary area of focus for potential flooding, while maintaining the balance between accuracy and computational feasibility for the model run. A typical meshing arrangement is presented in **Figure 6-3**.

Figure 6-3 PCSWMM 2D Model Mesh Size

6.4.3 Study Area Zone Selection

The PCSWMM 2D model is specifically applied to the Collingwood Town urban area. Due to the finer mesh size required to accurately represent surface flows, the total number of nodes in the 2D PCSWMM model exceeded 100,000. Exceeding this number of nodes causes a significant increase in model computation time (30+ hours). Therefore, to develop a model that is represented by an appropriate number of nodes and a reasonable simulation time, the study area was divided into four (4) zones. Each of these four (4) zones were modelled separately. The four (4) zones represented in the 2D model simulation are:

- Oak Street drainage area;
- Minnesota Street drainage area;
- Area-III (West area); and
- Area-VII (East area).

Figure 6-4 shows the four (4) zones being represented. The model for each of these zones were simulated separately and the results were later compiled into a single map in ArcGIS. The model runs were made, most of the time, simultaneously, thus saving considerable computational time.

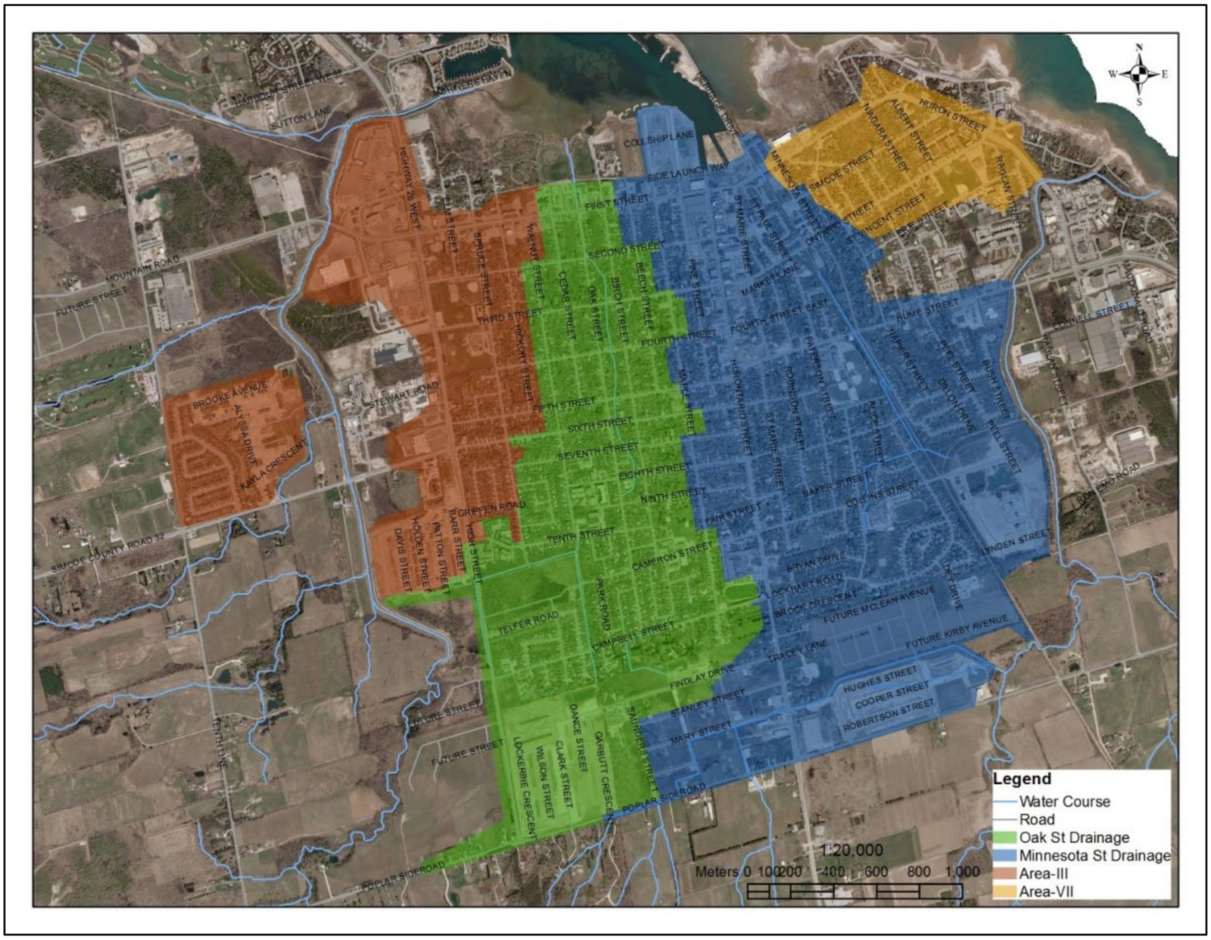


Figure 6-4 2D PCSWMM Model Zones

6.4.4 LiDAR Data Modification

The sewer outlets discharging into the various streams are directly connected to the Nodes in the 2D PCSWMM model. The elevations of most of these outlets from the Town-wide LiDAR derived DEM, were found to be higher than the actual outlet elevation based on the sewer data, resulting in perched outlets in the model. Also, some elevations points on the stream layer were also found to be higher than both upstream and downstream elevations. This phenomenon was likely affected by the local vegetation. Therefore, the LiDAR DEM was required to be modified at stream locations. The 2D nodes and mesh elevations were updated based on maintaining a continuous gradient linked by the structures (upstream to downstream elevations). **Figure 6-5** presents an example of a mesh elevation modification at one of the locations.

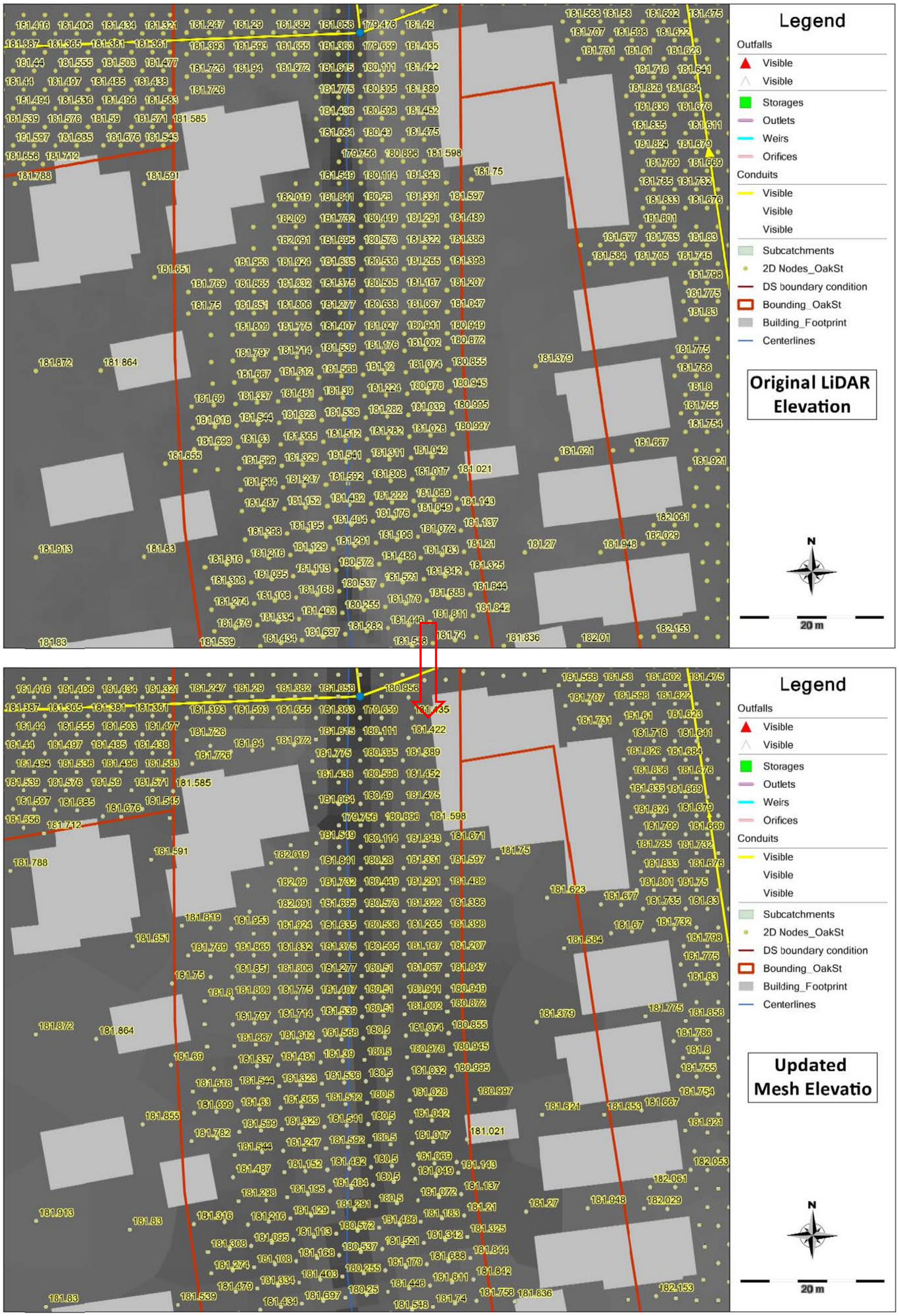


Figure 6-5 LiDAR Data Modification

7 Model Results

The results of the model analyses completed in both the HEC-RAS and PCSWMM models are presented in this section of the Report. The models have been provided to the Town as a separate deliverable. Detailed mapping of the results for the hydraulic, PCSWMM 1D and PCSWMM 2D models is presented in **Appendices 9-11**, respectively.

7.1 HEC-RAS Model Results

7.1.1 Pretty River

The model results for the Pretty River watershed are presented in the standalone report included as **Appendix 2**.

7.1.2 Black Ash Creek

As the Black Ash Creek drainage system has been designed as a flood control system, no spills were expected during any of the tested design storms up to and including the Timmins storm. This was confirmed upon running the final hydraulic model. A reduced rendering of the full-scale flood mapping that has been prepared from the HEC-RAS simulation is presented in **Figure 7-1**.

Figure 7-1 Black Ask Creek Flood Mapping

Potential minor flooding was determined at two (2) of the cross sections, 206, and 211.5, along a Black Ash Creek Tributary. The HEC-RAS modeled cross-sections (c.s.) at each of these locations are presented in **Figure 7-2**, and **Figure 7-3**, respectively.

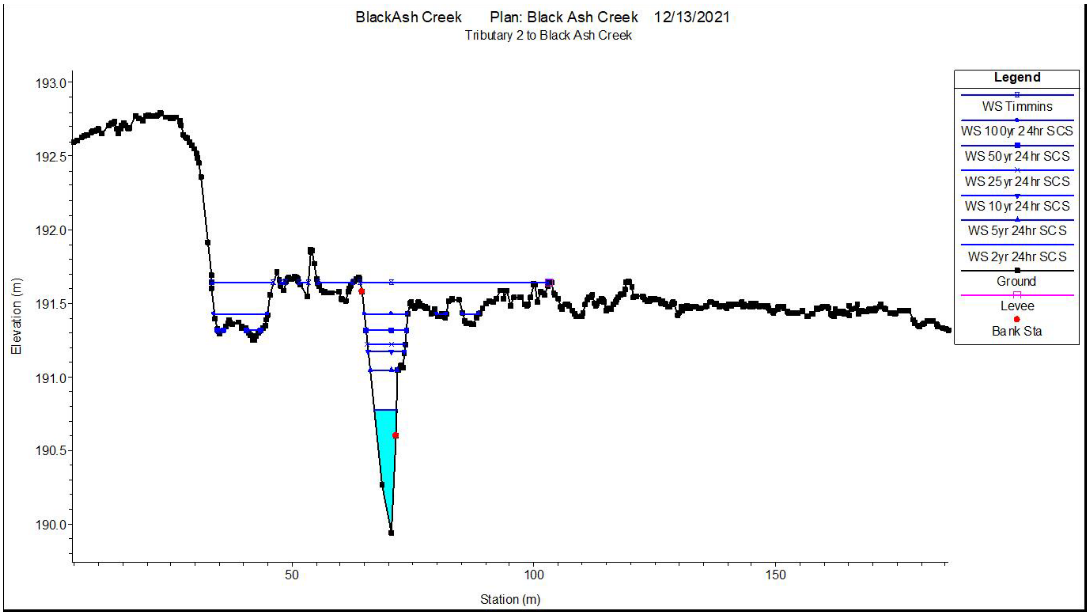


Figure 7-2 HEC-RAS Section 206

At cross-section 206 the Black Ash Creek Tributary flows through a very narrow main channel section and minor overtopping was observed on the right bank. At cross-section 211.5, overtopping was observed on the right and left banks, as the Tributary flows through a very narrow main channel section. The spill from the right bank of cross-section 211.5 is conveyed east by a swale along Sixth Street to Black Ash Creek. The resulting flow from the spill overtops the right bank of the swale (cross-section 1000), as shown in **Figure 7-4**.

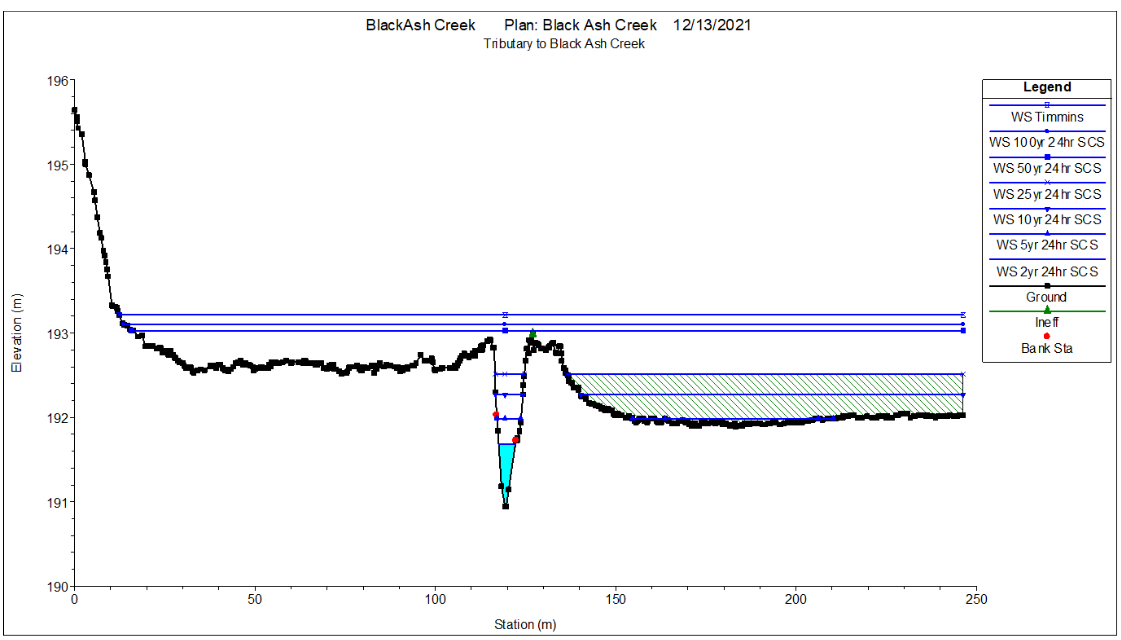


Figure 7-3 HEC-RAS Section 211.5

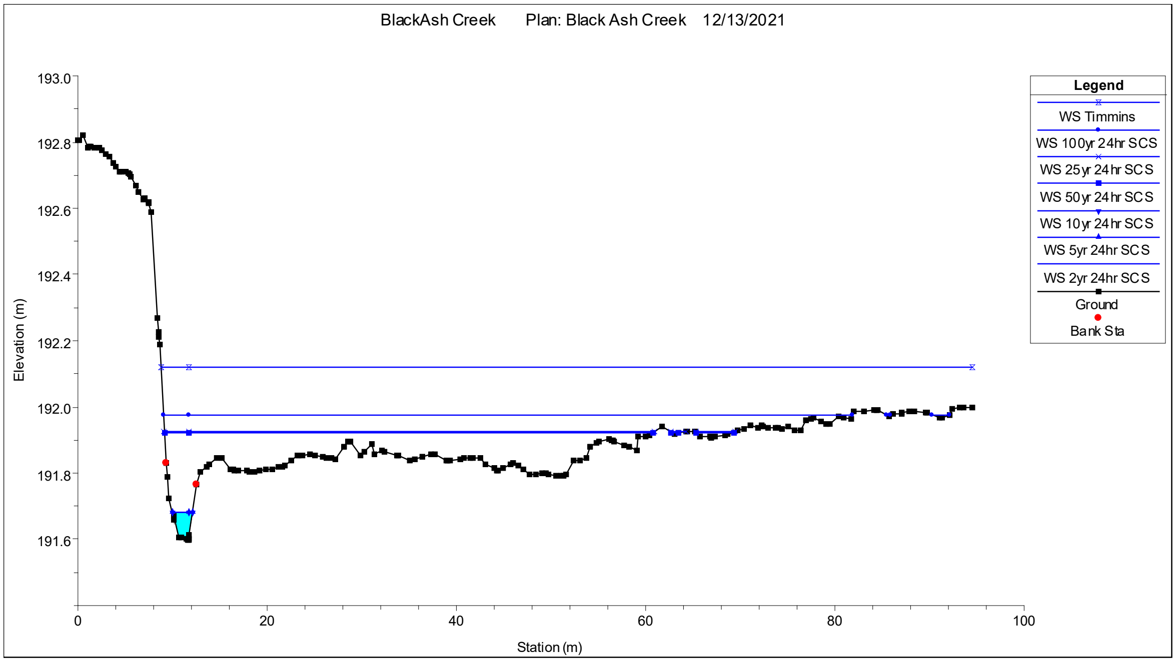


Figure 7-4 HEC-RAS Section 1000

The cross-section 211.5 is located just upstream of the Black Ask Creek Tributary 2 crossing at Sixth Street while cross-section 206 is located approximately 140m downstream of the Tributary 2 Sixth Street crossing.

7.1.3 Silver Creek and Townline Creek

HEC-RAS simulations were carried out for both Silver Creek and Townline Creek for different design storms. A reduced rendering of the full-scale flood mapping for the 1 in 100-year return period and the Timmins storm floods is presented in **Figure 7-5**.

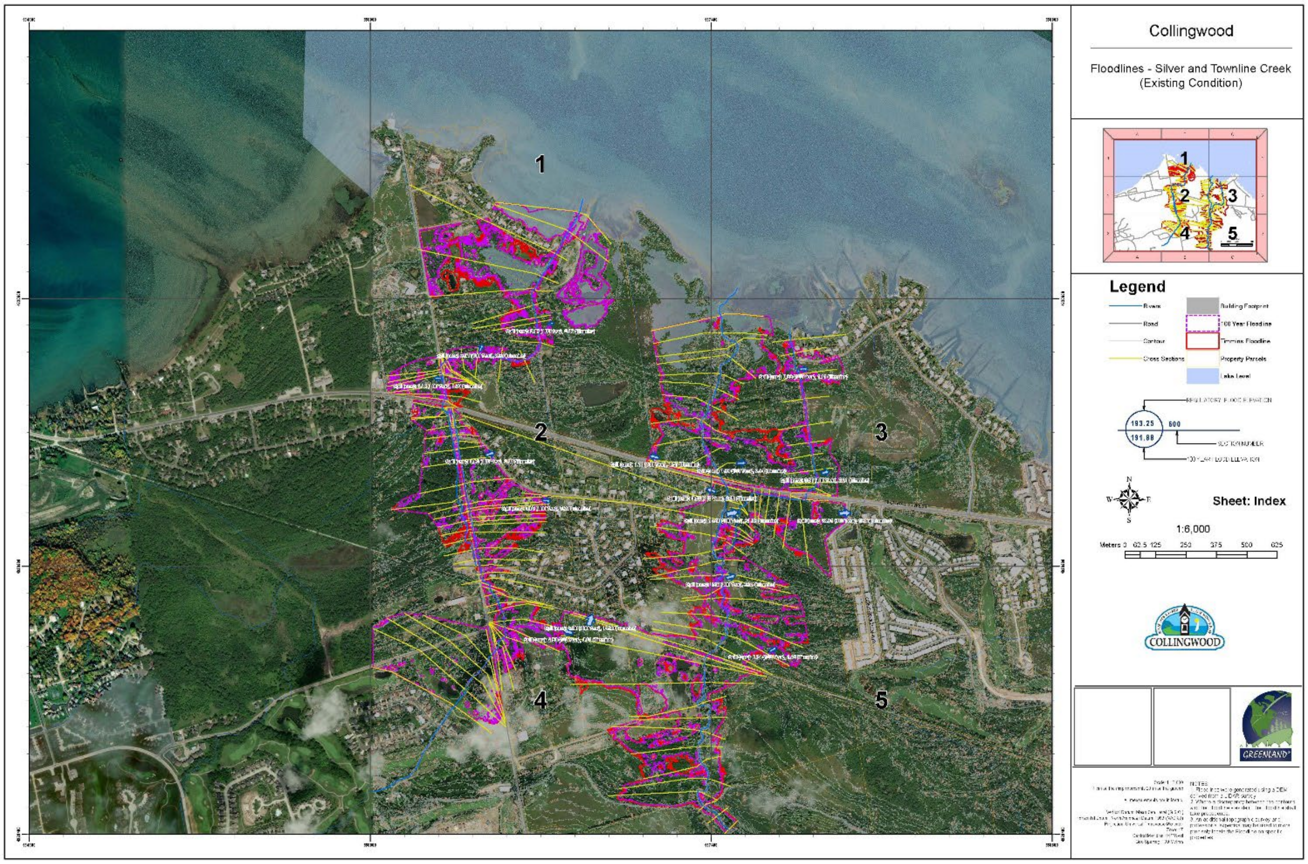


Figure 7-5 Silver Creek and Townline Creek Flood Mapping

There are eight (8) significant spills on Silver Creek and five (5) potential spills on Townline Creek. There are two (2) additional spills that are indirectly caused in the minor creeks in the Resort Areas as a result of the Silver Creek spills. The extent of the spill flows has been determined by introducing lateral weirs into the hydraulic models to match the ground surface in the locations where the spills can potentially occur. A summary of these spills is presented in **Table 7-1.**

Table 7-1 Silver Creek and Townline Creek Spills

Lateral Structure	Spill (m^3/s) 1-100 year	Timmins
Silver Cr		
1936	2.50	3.81
1840.8	6.90	14.80
1730	0.74	1.43
1655	0.48	2.58
1268.5	15.4	21.06
1102	3.58	9.28
826	1.51	1.18
930	1.38	2.44
Townline Cr		
1740	0.03	0.23
1630	0.63	3.91
1208	1.18	1.26
1066	2.61	3.30
669	0.17	0.65

There are two (2) main areas that are impacted by spills from both creeks. These areas include Silver Creek Drive and the ditch between Silver Creek Drive and Highway 26. Another area is the south side of the Georgian Trail in the vicinity of Craigleith Court. The spill areas are discussed in the following subsections.

7.1.3.1 Silver Creek

There is a potential of eight (8) spill locations on Silver Creek. The significant spill locations are upstream of the Georgian Trail and both upstream and downstream of Highway 26, as shown in **Figure 7-6.**

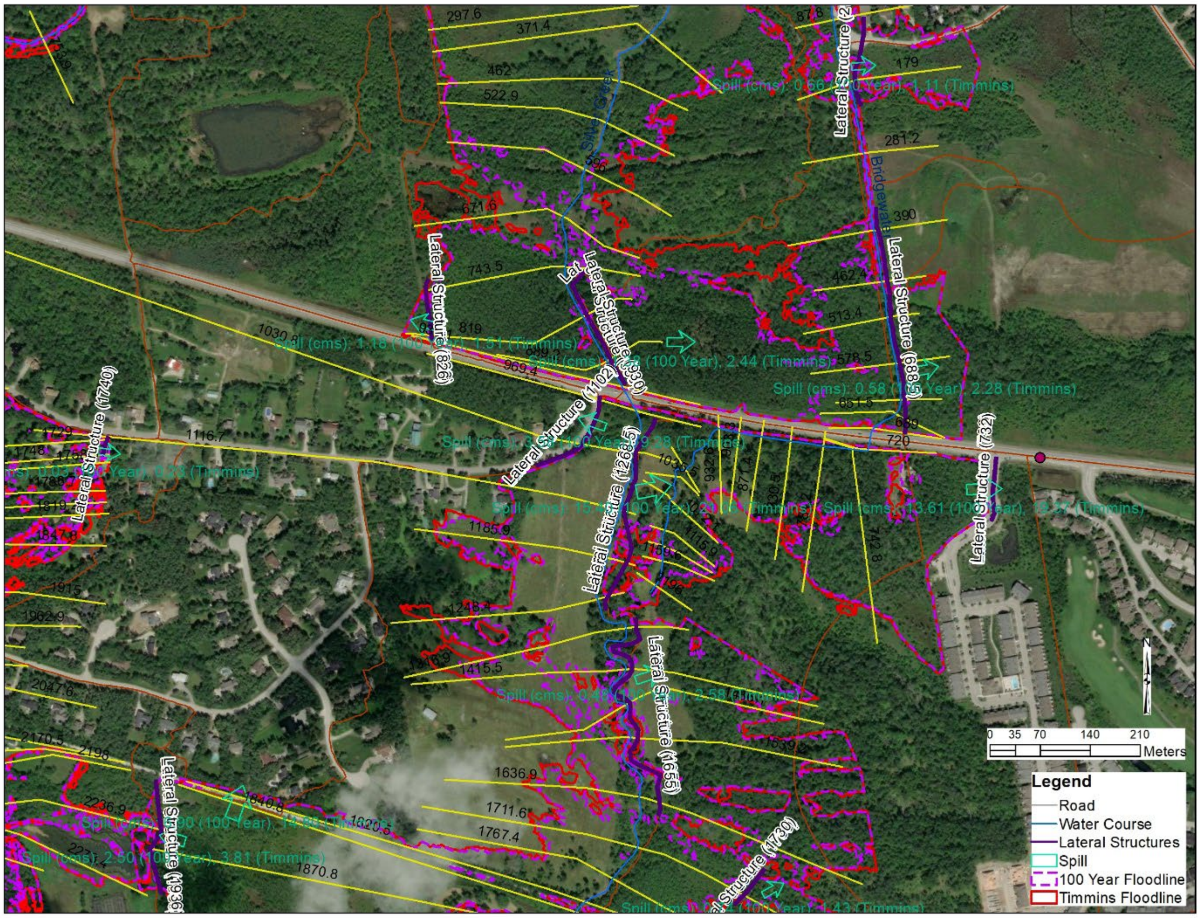


Figure 7-6 Silver Creek Spill Locations

Immediately upstream of the Georgian Trail, the flows spill to the west along the base of the trail and eventually will build up until the spill occurs over the trail. **Figure 7-7** shows the spill at the Georgian Trail for an area spanning 600 m west of Silver Creek. The spill will continue to the west once exceeding the elevation of 187.0 m. The spill will also cross over the trail starting at 187.04 m. The lateral weir structure 1936 that was introduced indicated that significant spill flows would pass through this location. The spill flow was split by including a portion of the trail. These flows will spill over the trail and through Craigleith Crt or back towards Silver Creek.

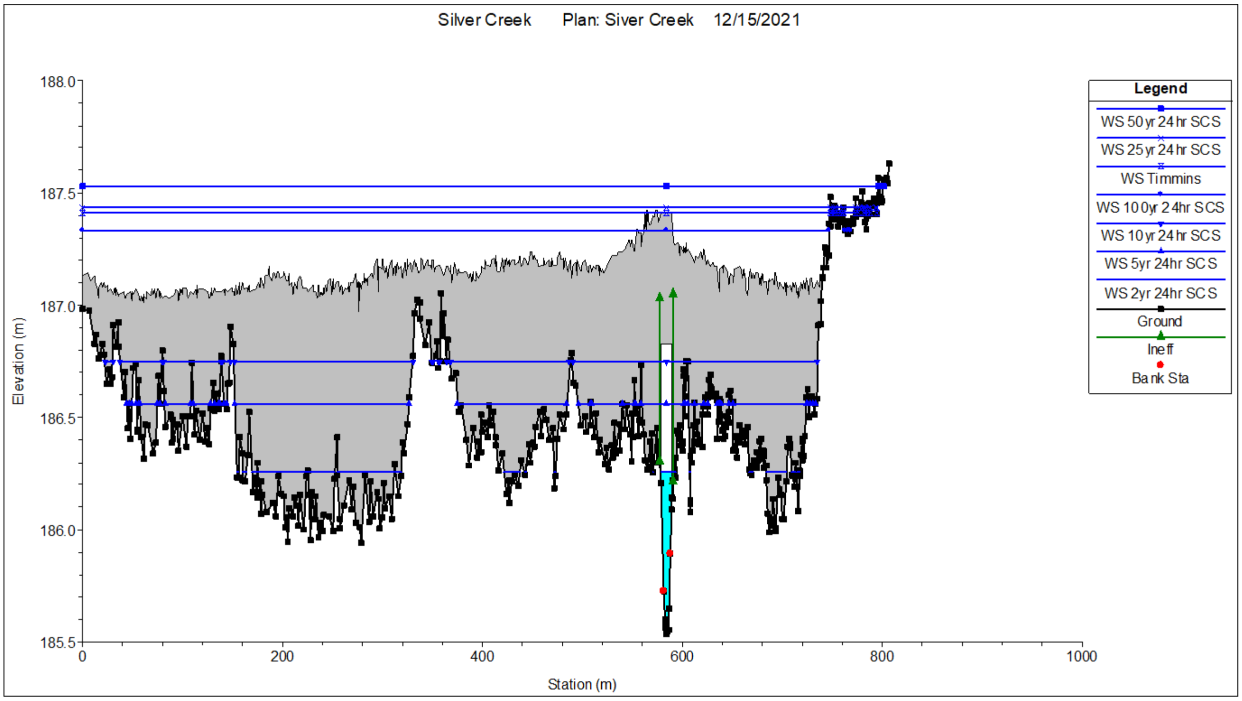


Figure 7-7 HEC-RAS Section 1833

Between cross-section 1767.4 and cross-section 1636.9, there is a small spill to the east. The lateral weir 1730 represents this spill. The modelled profile for this cross-section 1767.4 is shown in **Figure 7-7.**

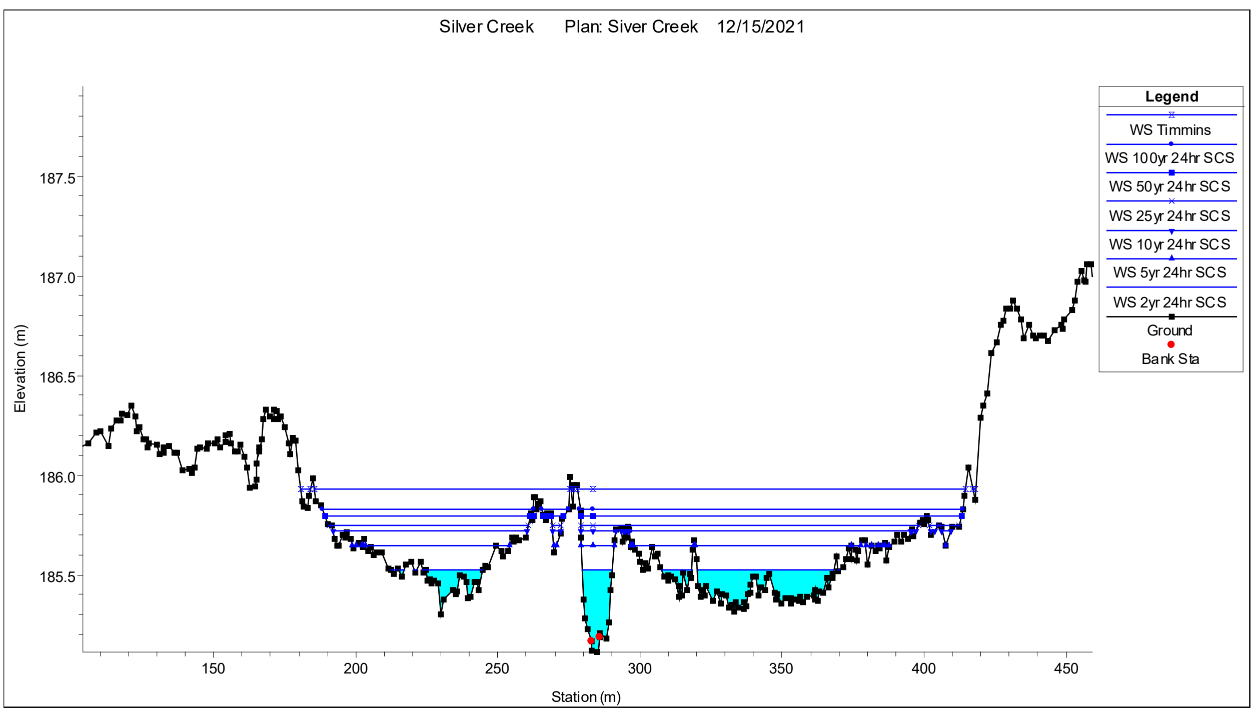


Figure 7-8 HEC-RAS Section 1767.4

A second small spill to the east will occur between cross-section 1415.5 and 1316.9, represented by the lateral weir labelled 1655. The modelled profile for this cross-section 1415.5 is shown in **Figure 7-9.**

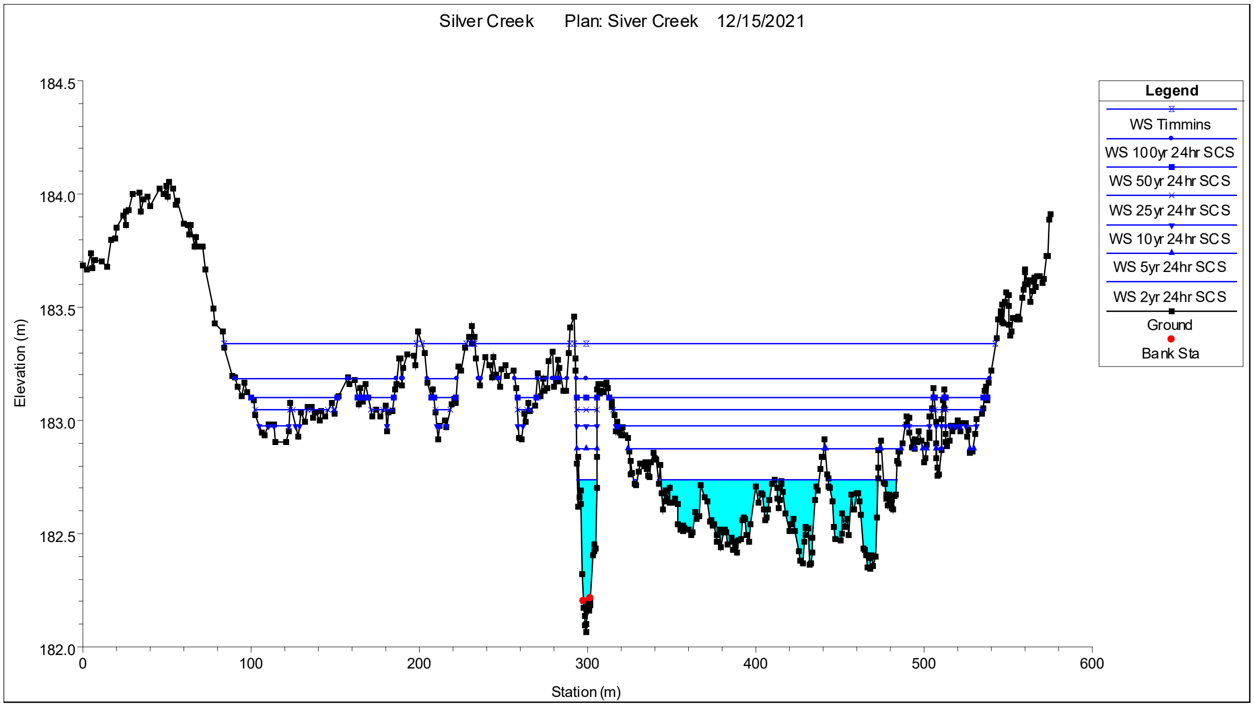


Figure 7-9 HEC-RAS Section 1415.5

Between cross-section 1316.9 and cross-section 969.4, the flows from Silver Creek will spill to the east into the Cranberry Creek watershed. The lateral weir labelled 1268.5 represents this spill. The modelled profile for this cross-section 1316.9 is shown in **Figure 7-10.**

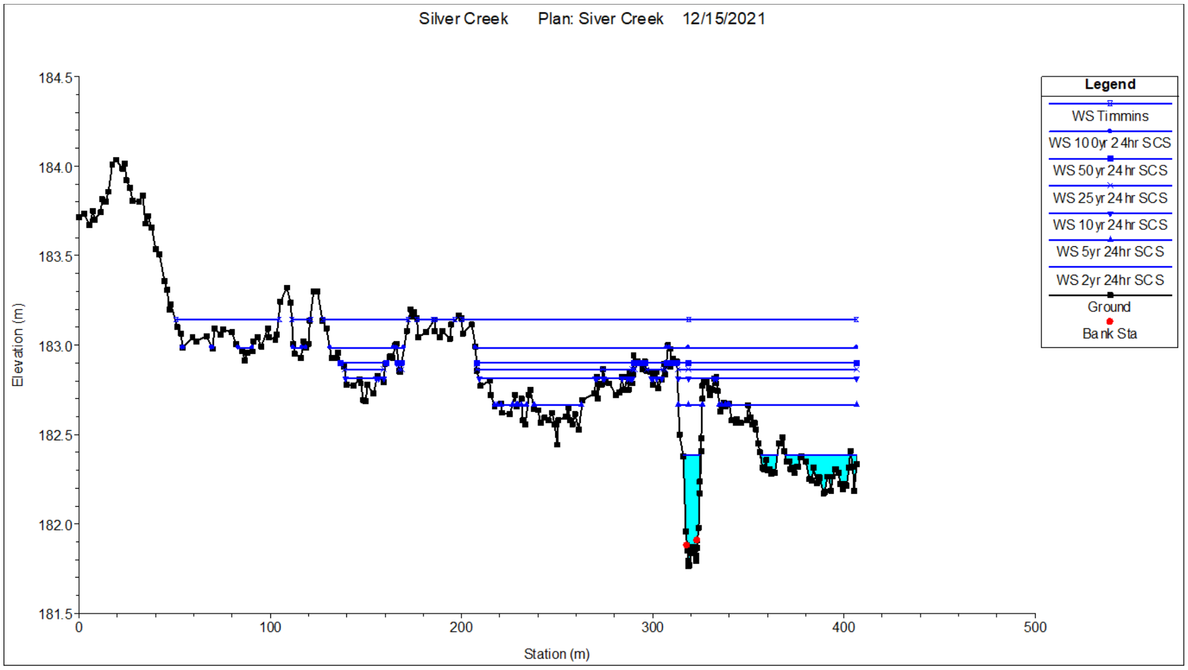


Figure 7-10 HEC-RAS Section 1316.9

Cross-section 949 is located immediately upstream of the Highway 26 crossing on Silver Creek. Here there are spills to both the east and west. **Figure 7-11** shows cross-section 949. Flows would spill to the east first (lateral weir 1268.5) and eventually overtop Silver Creek Drive to the west (lateral weir 1102). The spill to the east has been modelled with cross sections to track the path of the spill flow under Silver Glen Boulevard (lateral weir 732) and following this spill in Cranberry Creek to the outlet at Georgian Bay. This is discussed further in **Section 7.1.4**.

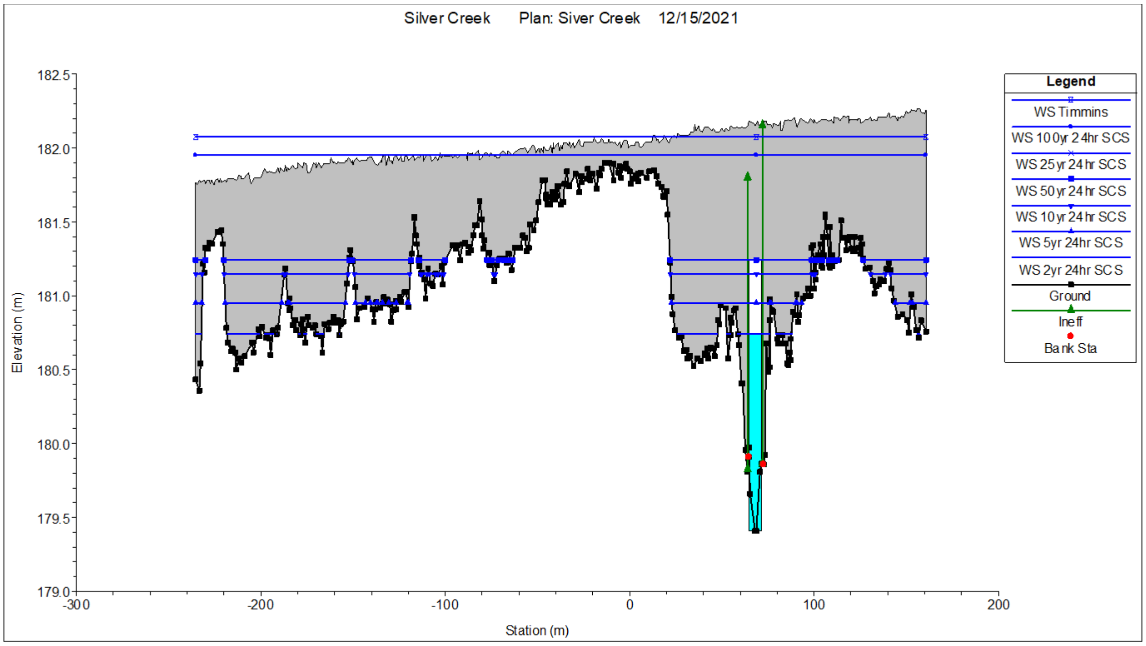


Figure 7-11 HEC-RAS Section 949

The last two (2) spills are on the downstream side of Highway 26. Lateral structure 930 and 826 represent the spills to the east and west respectively. **Figure 7-12** shows cross-section 889.2 which gives a representation of the potential spill in either direction. The spill to the east will go to Cranberry Creek. The spill to the west goes to a very small unnamed watercourse. This unnamed watercourse drains a portion of the spill between Silver Creek Drive and Highway 26 as well.

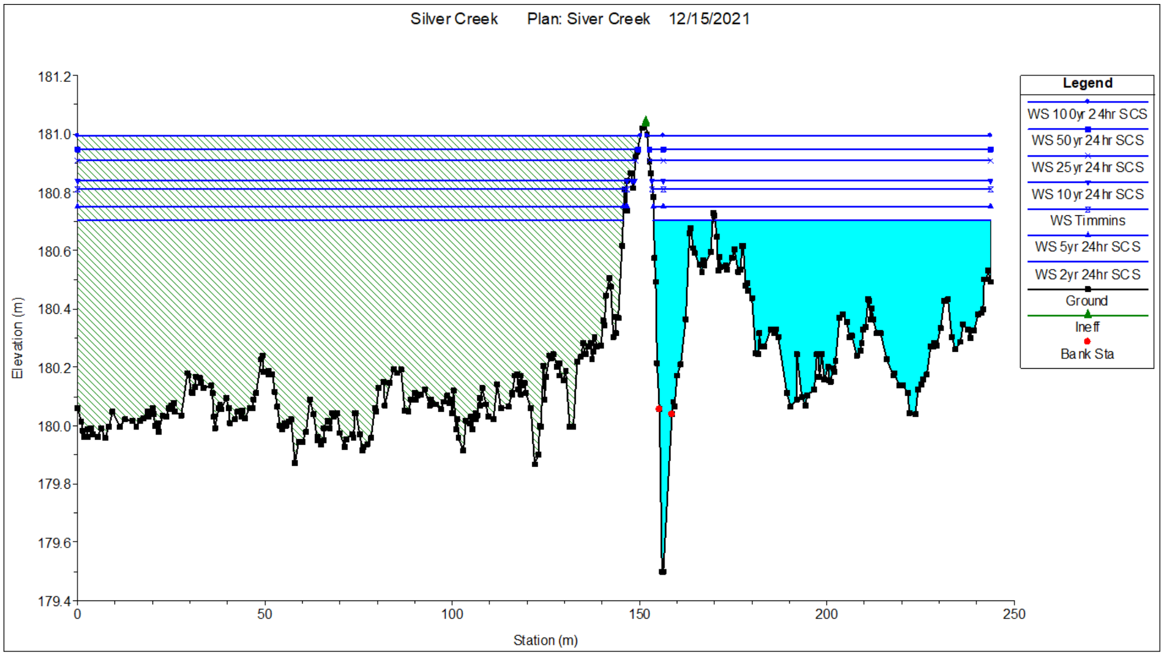


Figure 7-12 HEC-RAS Section 889.2

7.1.3.2 Townline Creek

There are five (5) main spill areas on Townline Creek. **Figure 7-13** shows the locations of these spills. Two (2) are minor in nature. The other three (3) include a spill across Silver Creek Drive through the existing development to the ditch system along the south side of Highway 26 and two (2) spills between Highway 26 and the Georgian Bay.

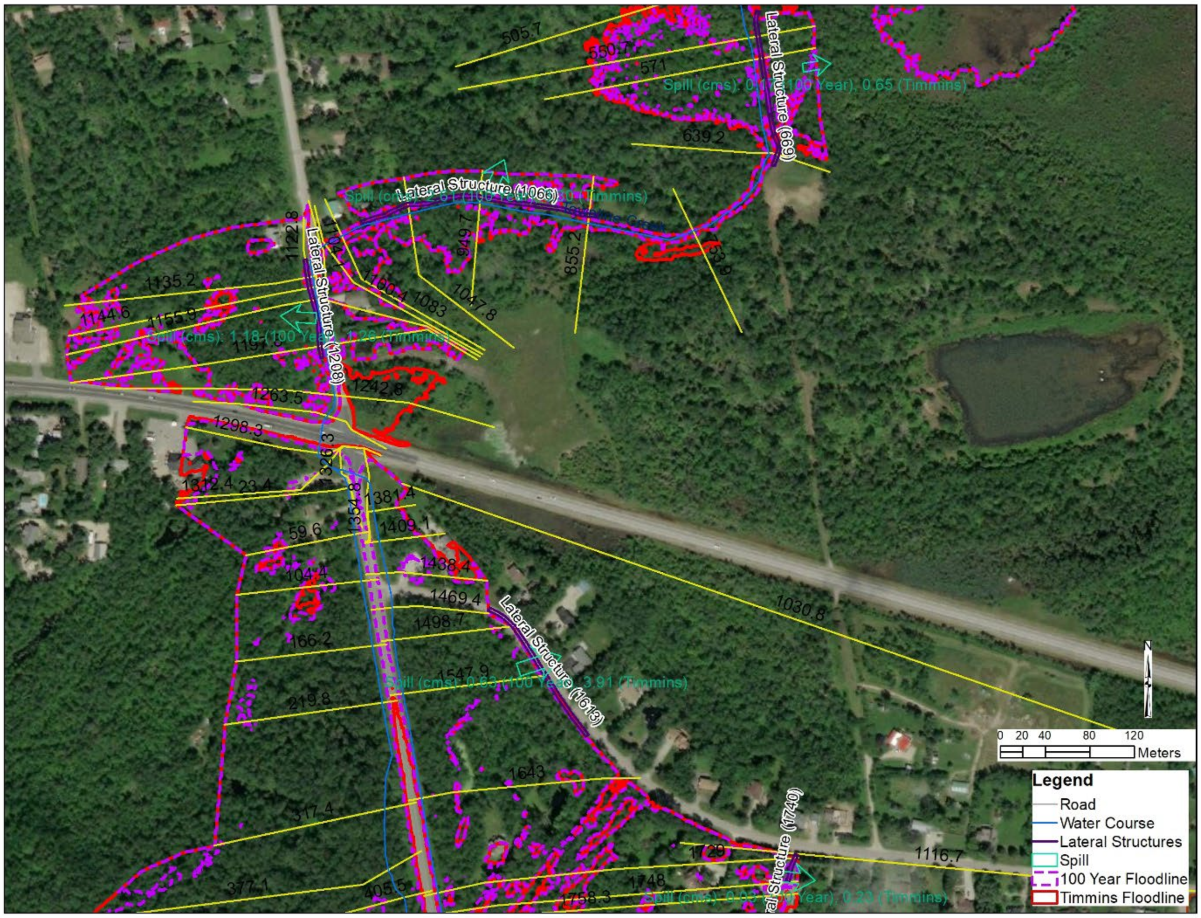


Figure 7-13 Spill Locations Townline Creek

Lateral structure 1613 describes a portion of Silver Creek Drive between cross-section 1647 and cross-section 1469.4. This spill interacts with the spill from Silver Creek described previously in **Figure 7-11**. **Figure 7-14** shows cross-section 1547.9 which forms part of the lateral structure. This cross section shows the east ditch along Grey Road 21 forming Townline Creek and is bounded by Silver Creek Drive to the east. The flood flows overtopping Silver Creek Drive can be 0.2 m deep. The other two (2) spills are downstream of Highway 26.

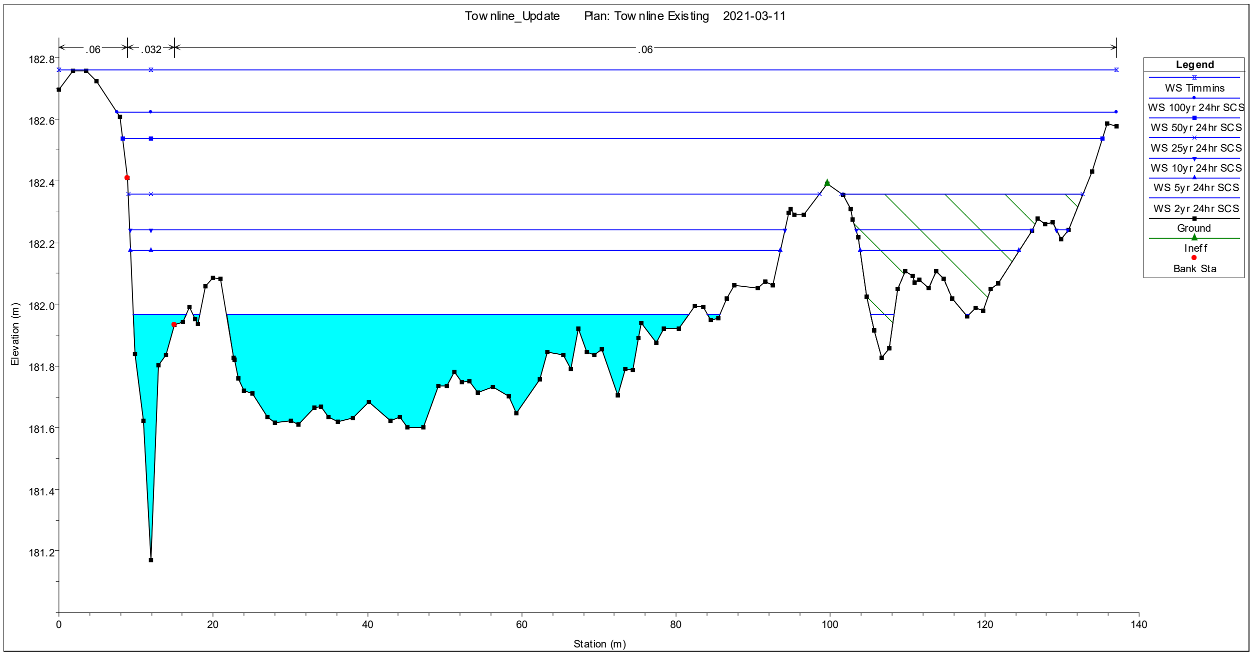


Figure 7-14 HEC-RAS Section 1547.9 Townline Creek

Downstream of Highway 26, Townline Creek is on the west side of Grey Road 21 (Long Point Road). There is a spill to the west that is described by lateral structure 1208 which includes cross-section 1197.8 to cross-section 1122.8. Long Point Road is described at approximately station 230 to 240 in **Figure 7-15** which represents cross-section 1155.9.

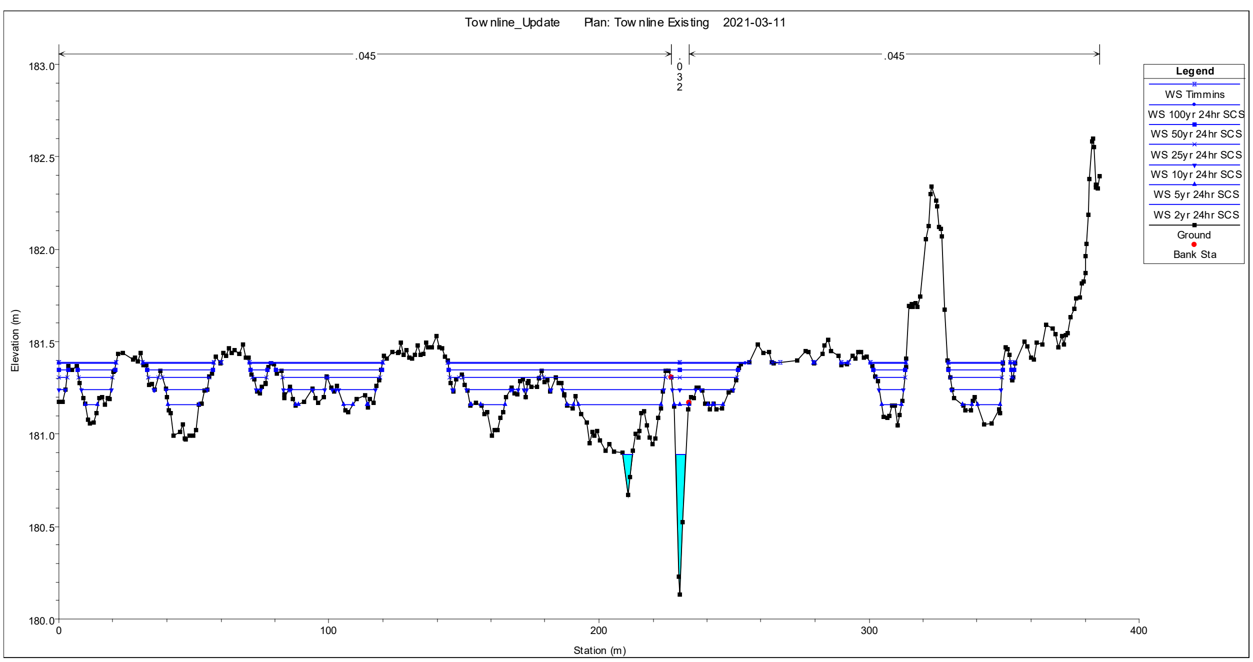


Figure 7-15 HEC-RAS Section 1155.9

The last major spill on Townline Creek is described by lateral structure 1073 representing cross-section 1083 to cross-section 855.2. **Figure 7-16** shows cross-section 949.7 where the spill is directed to the Georgian Bay.

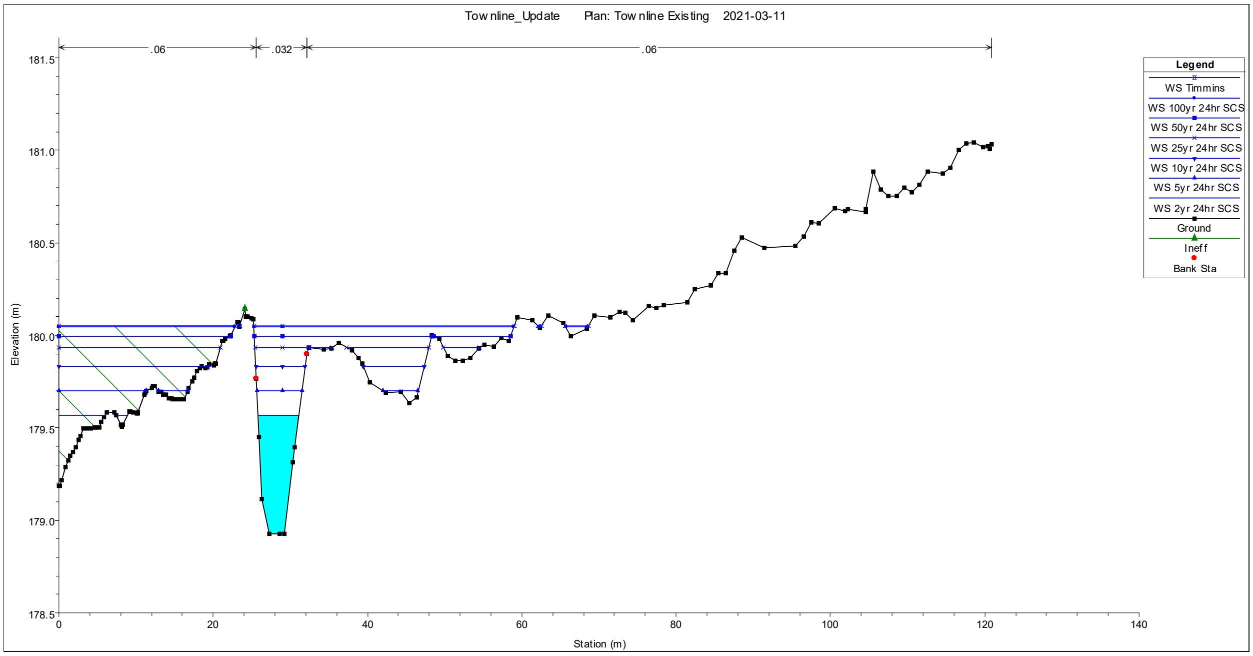


Figure 7-16 HEC-RAS Section 949.7

7.1.4 Resort Areas Spills

The small watercourses that pass through the resort areas are impacted by spills from both Townline Creek and Silver Creek. **Figure 7-17** shows the spill locations and the overall amount of flow that passes to the various small watercourses. These small watercourses have small drainage areas. The predominant flow during severe events will be as a result of the spills from Silver Creek. The major spill from Silver Creek (represented by lateral weir 1268.5) splits between flowing to an unnamed watercourse under Highway 26 and flowing underneath Silver Glen Boulevard to the east, where it will eventually flow under Highway 26 to outlet at Georgian Bay. The flow under Silver Glen Boulevard has been observed to overtop Cranberry Trail West into the adjacent golf course during large rain events.

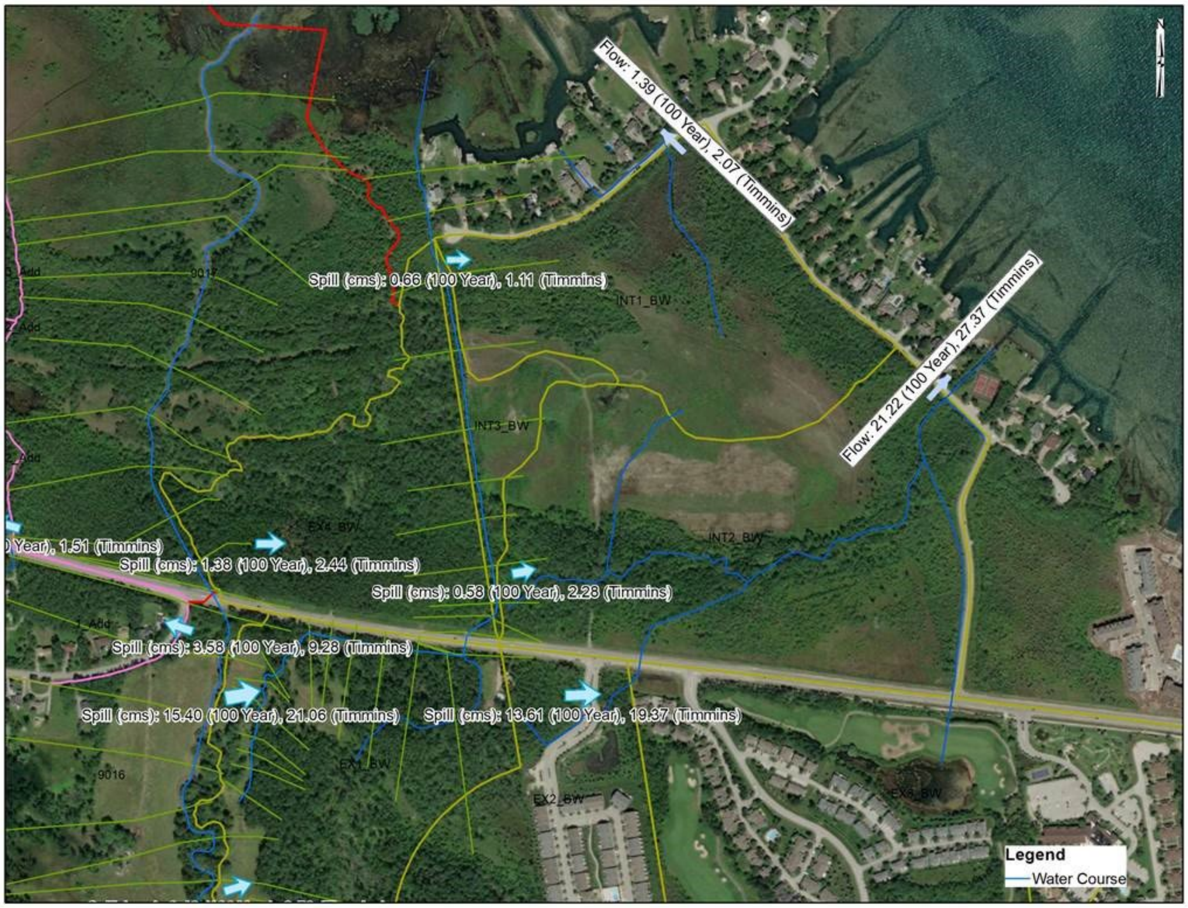


Figure 7-17 Spill Locations in Resort Areas

7.1.5 Batteaux River

Large spills were anticipated for the Batteaux River downstream of Highway 26. One of the primary goals for this hydraulic model was to determine potential points with safe access for residents in the case of a flood event. It was anticipated that some roads would be inundated during the severe storm events. **Figure 7-18** presents a reduced rendering of the flood mapping for the Batteaux River.

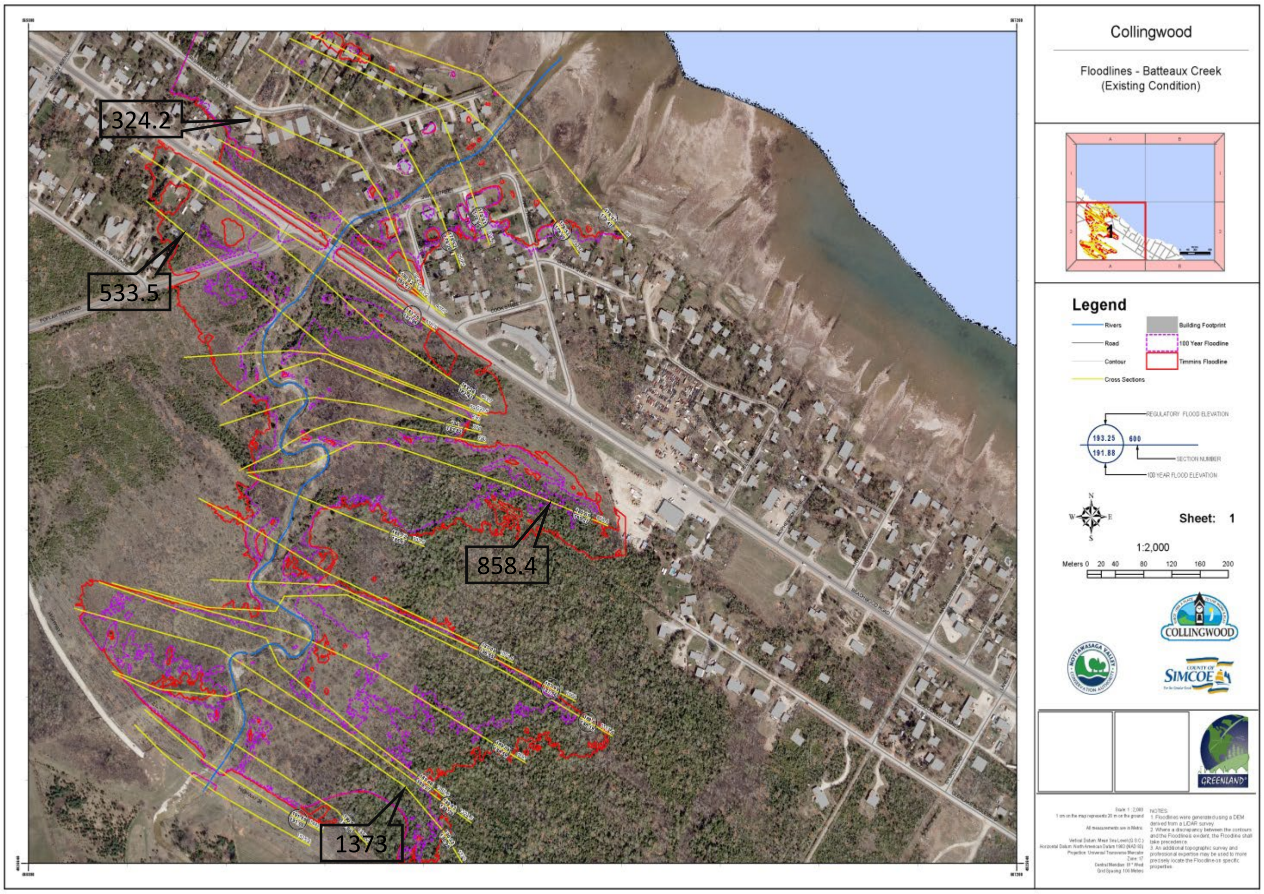


Figure 7-18 Batteaux Creek Flood Mapping

Based on the flood mapping exercise, four (4) key flooding areas are identified**.** These are at cross sections 1373, 858.4, 533.5 and 324.2 in the HEC-RAS model. Cross-section 1373 is located 118m downstream of the Highway 26 Batteaux Creek crossing, cross-section 858.4 is located between the Highway 26 and Beachwood Road crossings, approximately 430m upstream of the Beachwood Road crossing and cross-section 533.5 is also located between the two (2) bridge crossings, approximately 104m upstream of the Beachwood Road crossing.

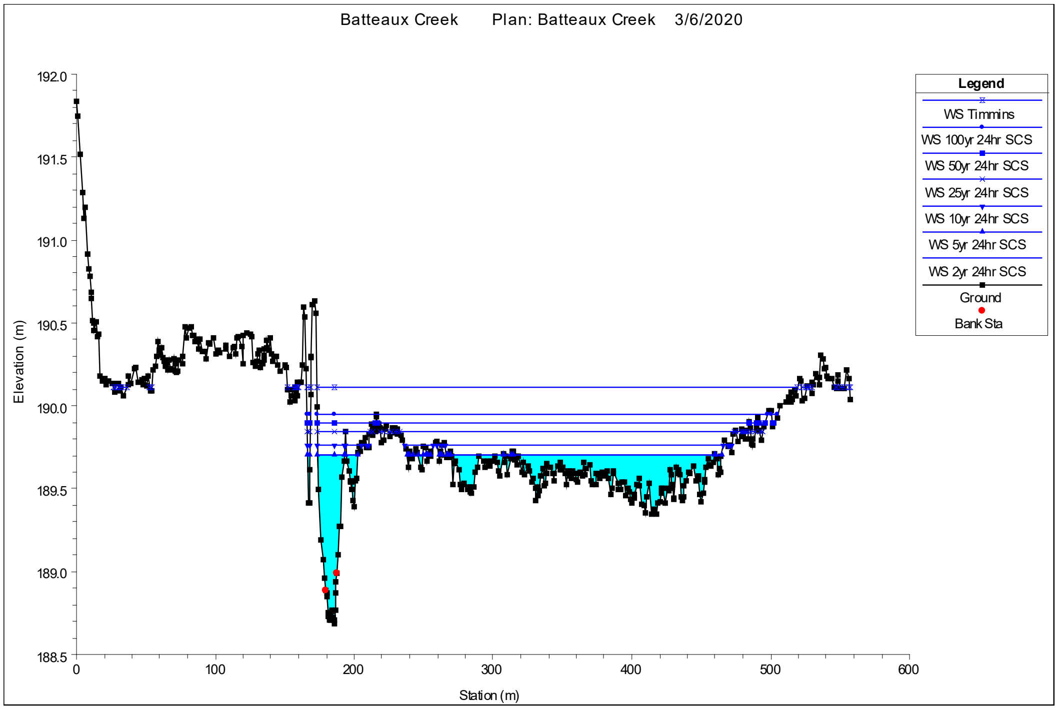


Figure 7-19 HEC-RAS Section 1373

The spill area described at cross-section 1373 in **Figure 7-19** shows that this area is flood prone for up to 300 metres to the east of the creek.

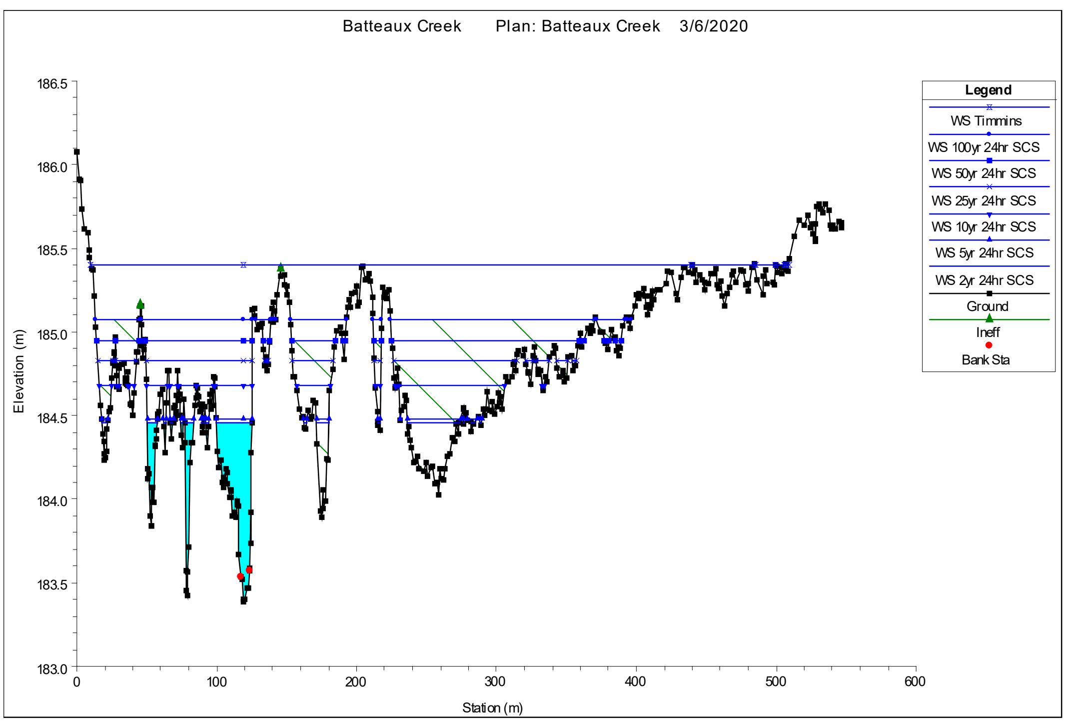


Figure 7-20 HEC-RAS Section 858.4

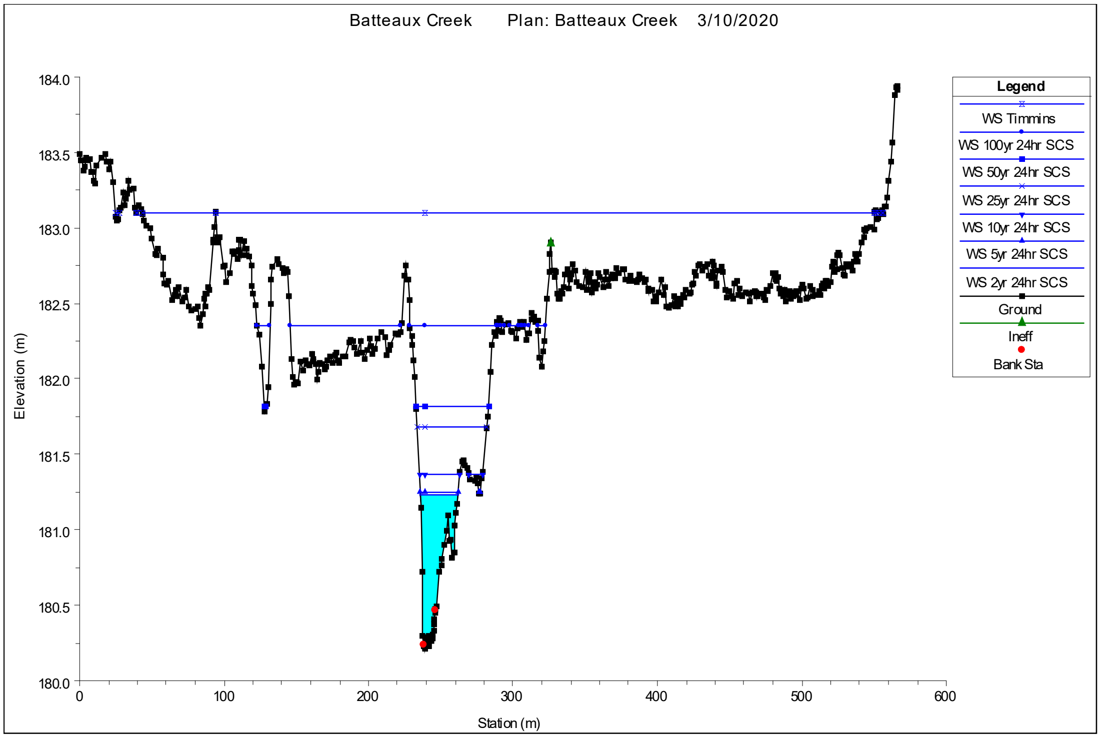


Figure 7-21 HEC-RAS Section 533.5

Flooding in all three (3) of these locations do not directly impact inhabited areas. The critical flood area represented at cross-section 324.2 is located approximately 93m downstream of the Batteaux Creek crossing on Beachwood Road, and just upstream of a pedestrian crossing of the creek. This area would be a focus for flood protection measures from the expected flood damages.

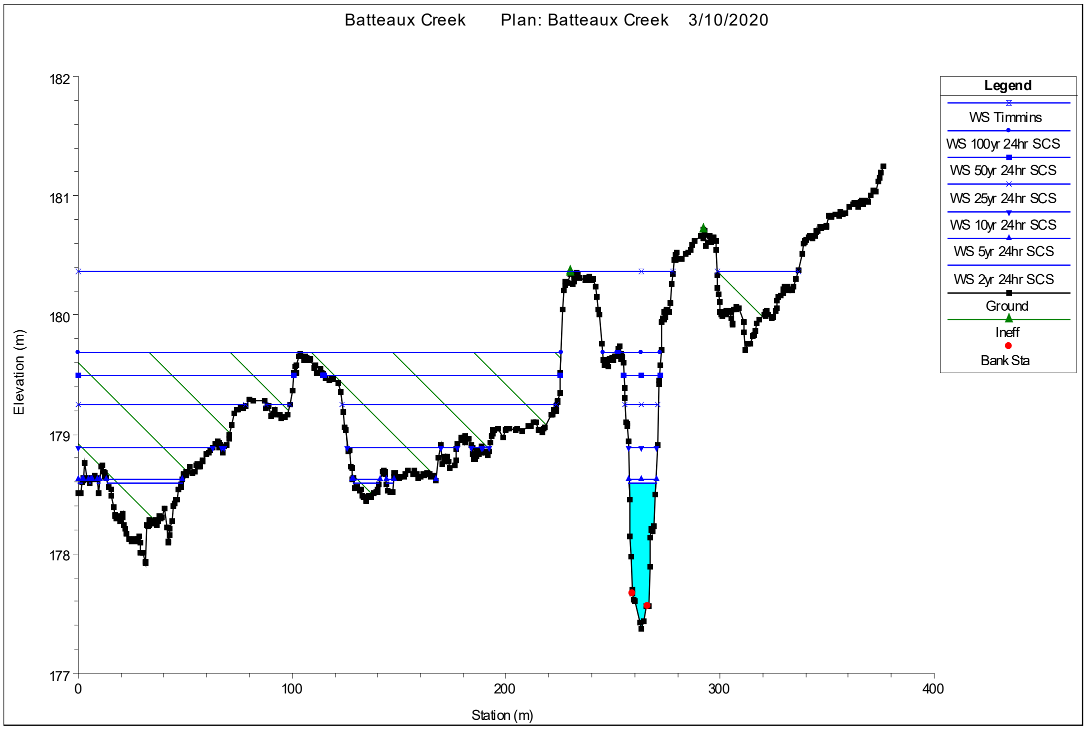


Figure 7-22 HEC-RAS Section 324.2

7.2 PC-SWMM 1D Model Results – Urban Town Centre

First, the PC-SWMM 1D model was simulated for a series of 24-hr design storms. The model was simulated for a minimum period of 48 hours for each of the return period scenarios. The key results of interest from these simulations were the node surcharge and node flooding. Flooding occurs when the water depth at a node exceeds the maximum available depth, and the excess flow is either lost from the system or can pond atop the node and re-enter the drainage system. **Figure 7-23** presents a typical schematic of node surcharging and flooding conditions as considered in PCSWMM.

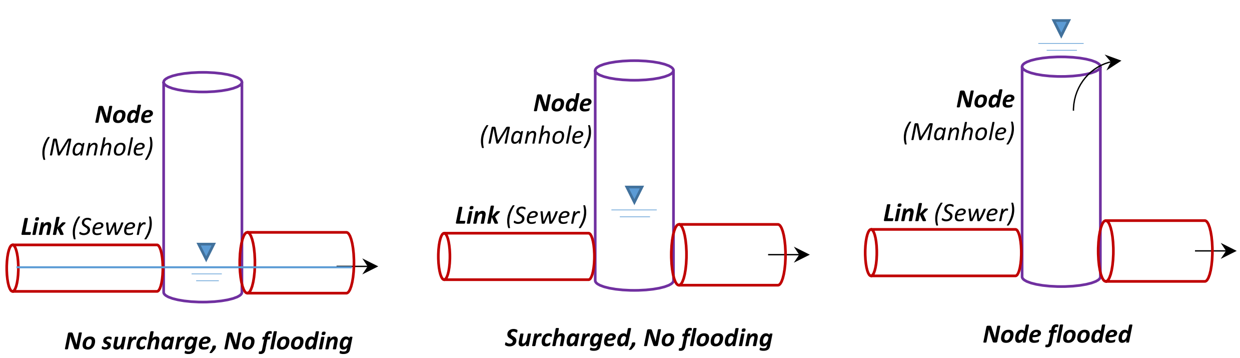


Figure 7-23 Node Surcharging and Flooding

Figure 7-24 shows the change in the percentage of nodes surcharged during each of the simulations. As expected, the number of nodes surcharged increases with the increasing return period. Out of all the surcharged nodes, some of the nodes may be flooded, which are analyzed separately.

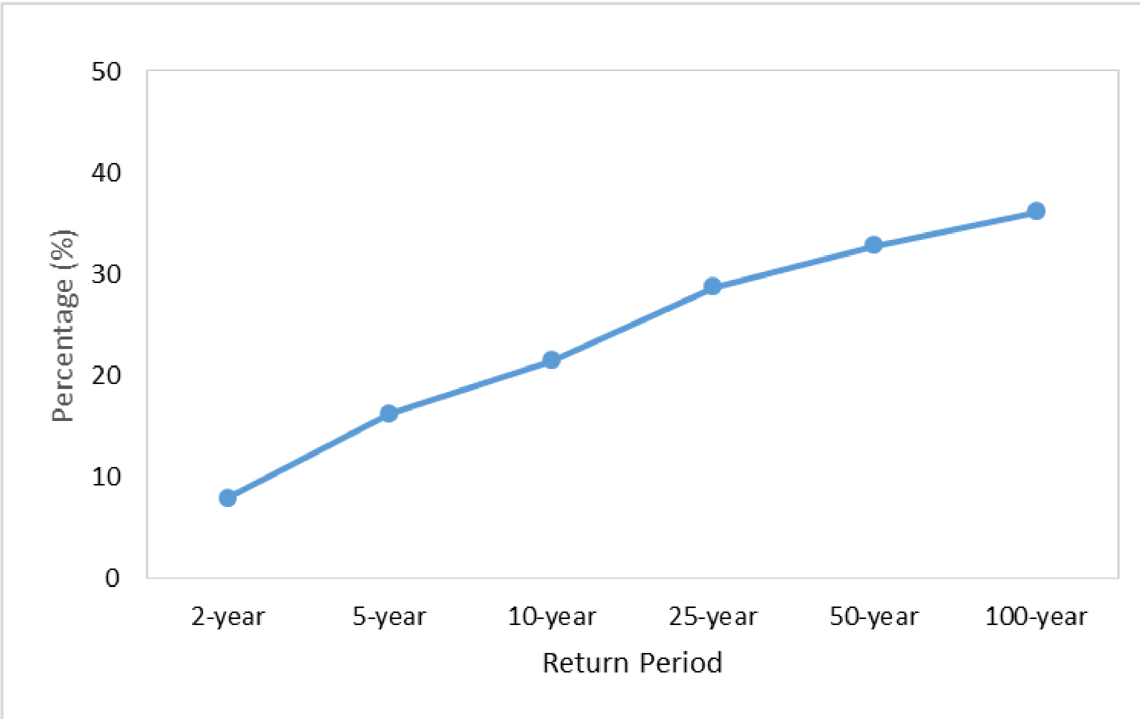


Figure 7-24 Percentage of Nodes Surcharged, Urban Town Centre

Nodes that experience surcharging give an indication of the performance of the basic drainage infrastructure. Nodes that experience flooding at the surface provide an indication of the resiliency of the drainage system for both the residents and emergency response. The PCSWMM simulation results were analyzed for different depths of flooding for each return period. The flood maps indicating the nodes flooding in the study area are presented in **Appendix 10**.

Figure 7-25 presents the overall summary of node flooding in the entire study area. The summary presents the percentage of total nodes that experience potential flooding and the nodes having ponding depths greater than 5cm, 15cm and 25cm.

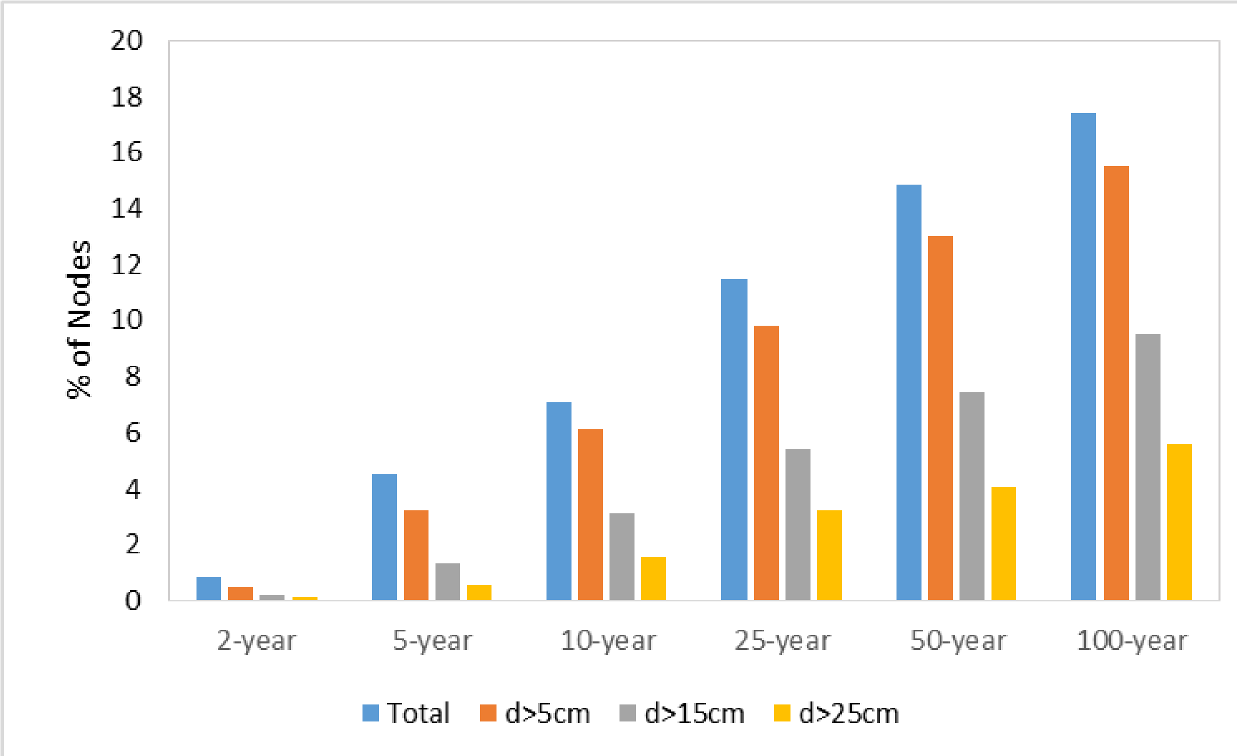


Figure 7-25 Percentage of Nodes Experiencing Flooding, Urban Town Centre

For a 2-year return period storm about 3% of nodes are flooded with the majority of the flooding under 5 cm in depth. The total number of nodes experiencing flooding increases to 24% for a 100-year storm. For a 1 in 100-year storm, although 24% of nodes are flooded, only 7% of nodes have a flood depth greater than 25cm, which is critical for movement of emergency vehicle. Similar interpretation can be made for other return periods.

For the entire urban town study area, the median depth and 90 percentile depth of flooding is presented in **Figure 7-26** for various return periods. For a 2-year return period storm, the median depth (among all the nodes) is 0.1 cm while that for 100-year storm is 13 cm. Also, 90% of nodes have water depth less than 15cm and 38cm for 2-year and 100-year return periods, respectively. This implies that for the extreme storm event, say 100-year return period, only 10% of the nodes will have a ponding greater than 38cm. For the 10% of nodes with greater than 38 cm of flooding during the 100-year return period storm, this ponding exceeds the available depth within the municipal right-of-way and would result in flow spread elsewhere (e.g. to residential lots). This supports the preparation of the 2D PCSWMM model to simulate the surface flow conditions during these extreme events.

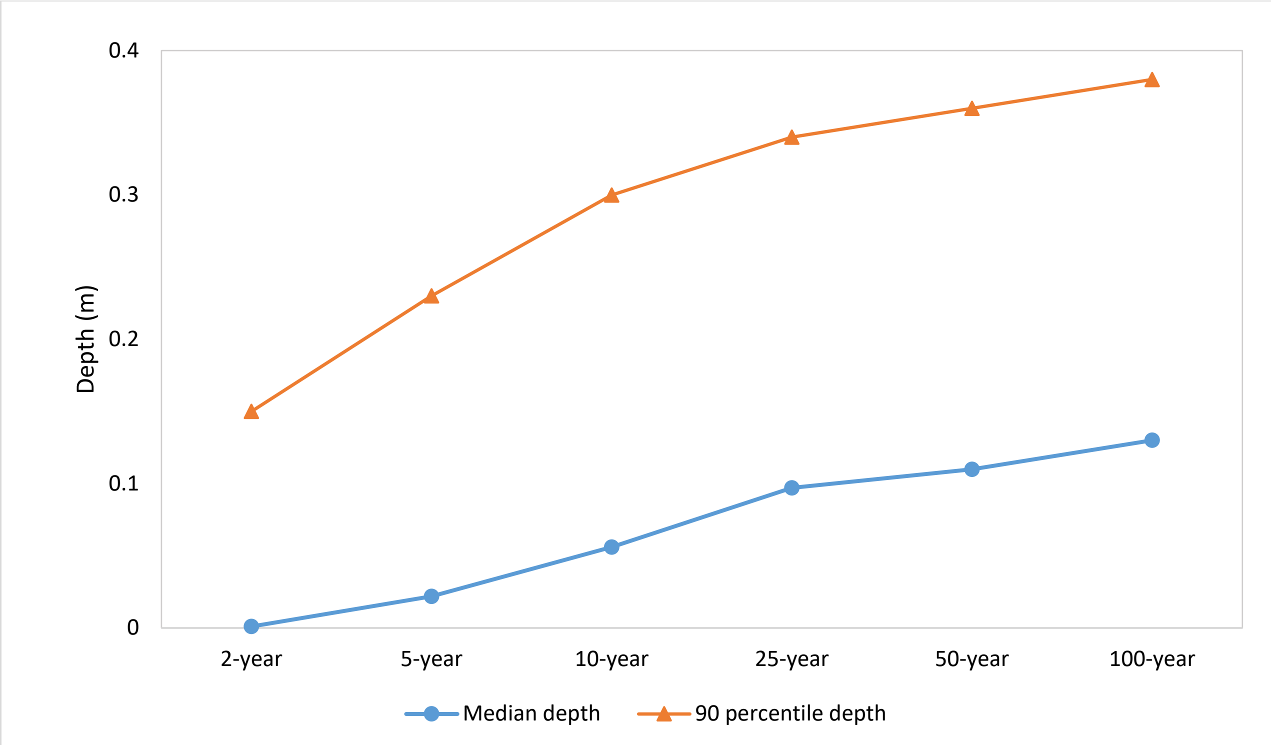


Figure 7-26 Node Flooding Depth, Urban Town Centre

7.3 PCSWMM 2D Model

Subsequent to the analysis of 1D PCSWMM model results, the 2D PCSWMM model simulation results were analyzed primarily for overland flooding in the urban town centre area. In order to present the extent of the flood spread overland, it was decided to display the areas with flooding separately based on the threshold depth of 25cm. This is depth criteria is used by the County of Simcoe Emergency Services for the safe movement of ambulances. The areas with depths greater than 25cm were highlighted and areas with less than 25 cm were also shown separately.

The 2D PCSWMM model results are presented for each of 13 zones in the town. Typical flood inundation mapping corresponding to 100-year return period storm, for Zone-4, is presented in **Figure 7-27**. The 2D PCSWMM model simulation results for the entire Town of Collingwood and for all zones for the same storm event are included in **Appendix 11**.

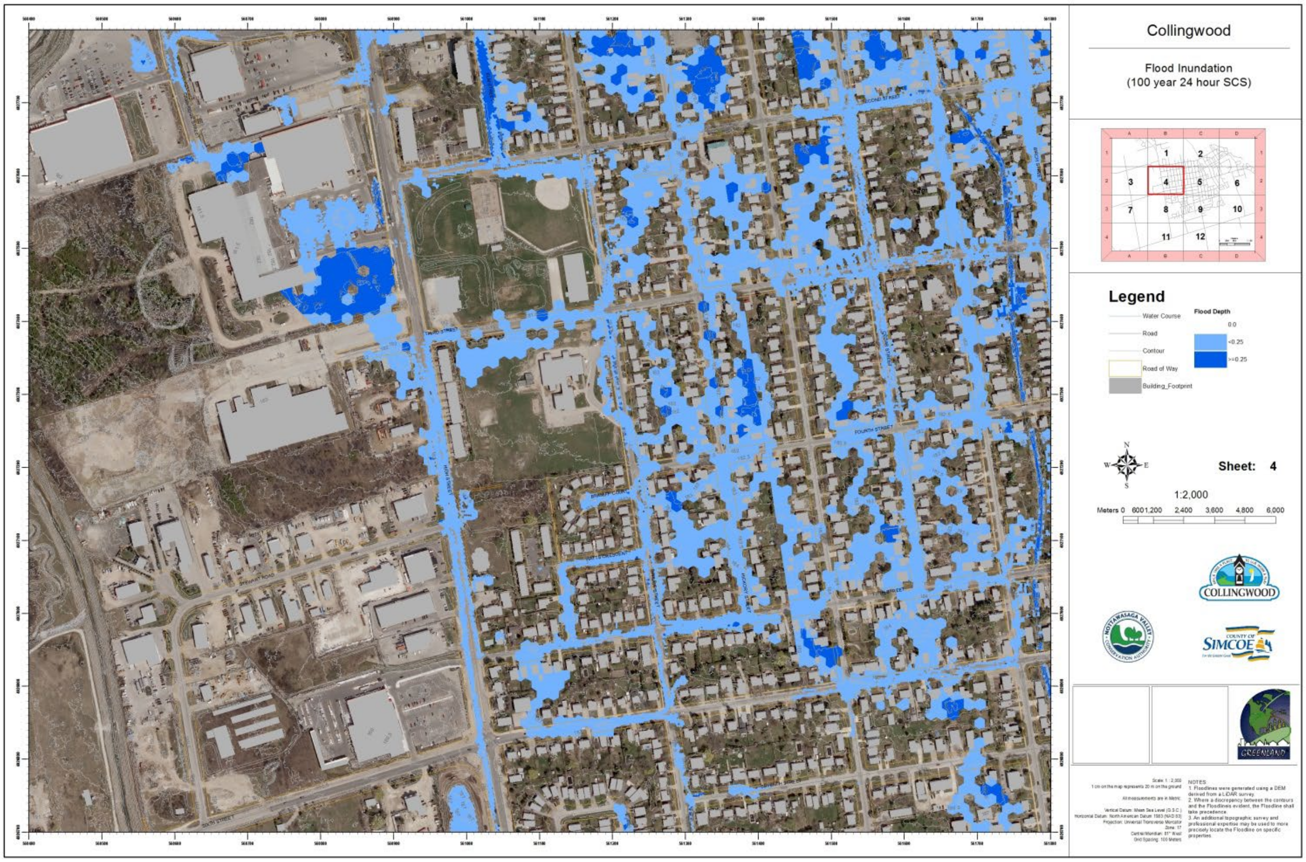


Figure 7-27 Flood Mapping for Zone-4

Based on the results presented in **Appendix 11**, it is found that the older areas of the town are those primarily affected by flooding. Specifically, the areas between Birch Street and Spruce Street found in Zone-4, the area between Minnesota Street and Niagara Street in Zone-2, and the area between Robinson Street and Alice Street in Zone-5 are the most severely affected.

While there is significant flooding during the 100-year event, the majority of flooding is contained within the Town right-of-ways with the exception of the areas mentioned previously. Additionally, the vast majority of flood depths through the Town are less than 25cm, thereby presenting a reduced safety concern for pedestrians and resulting in few limitations to vehicular access in the event of a 100-year storm.

8. Conclusions and Recommendations

The following conclusions and recommendations can be made concerning the development of the Collingwood SWM Master Model:

- Two (2) models were created for the Town including a 1D and 2D PCSWMM model. The PCSWMM 1D model includes all river systems and the urban town area. The external watersheds for each of the main rivers were created based on the previous studies. The sewer network system was obtained from the Town and updated based on the new LiDAR data. Field survey was completed to confirm the elevations and structure information. Missing sewer and manhole information was also inputted based on the as built data and SWM reports. The PCSWMM 2D model focused on the urban town area and was constructed based on the 1D minor system and the major overland system was replaced by a 2D mesh (that allowed the overland flow to interact with the riverine systems in the Town) generated from the LiDAR data.
- The sewer system represented in the 1D model does not take into account any losses due to infiltration into the groundwater table. The 2D model represents the flow spread once the sewer is surcharged.
- The model was calibrated using flow data collected at five (5) monitoring locations. It was determined with the larger events during dry periods in mid-summer that the flow monitors indicated that considerable flows were being lost in the older neighbourhoods through ditch systems directly connected to the water table.
- The older neighbourhoods that do not have curb and gutter drainage systems have a much slower response than modelled. The 2D model represents these areas more effectively.
- The spill areas from the main river systems have been identified and flood maps for all areas have been provided. The Town should adopt the new flood information in its update of the Official Plan.

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