Niagara Peninsula Conservation Authority

Welland River Floodplain Mapping Update

Final Report

November 5, 2018

Confidential

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Project No. 15M-00704-01:
Date: November 2018

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November 5, 2018

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Niagara Peninsula Conservation Authority
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Attention: Tareq Al-Zabet, Ph.D., P.Geo., CRSP, Director, Watershed Management

Dear Mr. Al-Zabet:

Subject: Welland River Floodplain Mapping - Final Report

We are pleased to submit the Welland River Floodplain Mapping Update - Final Report. This report produces the final floodplain maps for the subject study area and are presented in **Appendix E**. The results and discussion of scenario and sensitivity analyses pertaining to the hydraulic performance of the Welland River under various impacts are included in the final report. The hydrology components for the study is documented in the *Final Phase I Hydrology Report* prepared by MMM Group Limited (WSP Acquisition) dated May 2017, as included in the **Appendix F**.

It was acknowledged that NPCA has reviewed and confirmed that the produced floodplain maps were prepared in accordance with the NPCA's mapping criteria.

We trust the submission of this document meets your requirements. Should you have any comments we look forward to your response.

Yours sincerely,

Steve van Haren, P.Eng.
Manager, Land Development

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1 Introduction

1.1 Background

The overarching objective of the final report is to summarize the findings of the hydrological analysis, present the hydraulic model used to evaluate the hydraulic conditions of the Welland River, and produce the updated Regulatory floodplain maps for the Welland River from the Binbrook Dam, south of Hamilton, to the Niagara River.

The hydraulic modelling and relevant flood hazard analyses were informed by the detailed hydrological modelling and report completed in May 2017 by MMM Group Limited (WSP acquisition), where a hydrological simulation of the synthetic 100-year flow event was developed using a calibrated Visual OTTHYMO hydrological model. The results from the hydrological model were used to provide corresponding hydrological input (i.e., hydrographs) to the hydraulic model for the purposes of updating the Regulatory floodplain for the Welland River. A *Final Phase I Hydrology Report* prepared by MMM Group Limited (WSP Acquisition) dated May 2017 is included in the **Appendix F**.

The modelling and analysis methodology used as part of this report was developed with the view of achieving the objectives specified in the Terms of Reference (TOR). Background information and historical reports provided by NPCA pertinent to the study were reviewed and incorporated as necessary. Furthermore, extensive discussions with NPCA have been facilitated at key milestones within the model development process to ensure that the modelling approach and the findings are in conformance with NPCA's expectations.

1.2 Description of the Study Area

The Welland River is approximately 135 kilometres in length, and drains a watershed area of approximately 990 square kilometres in size. The Welland River flows in an easterly direction from its headwaters in Ancaster to its historical physical outlet at the Niagara River. Historically, the natural flow of the Welland River discharged into the Niagara River; however, since the completion of the Sir Adam Beck Generating Station No. 1 in 1920 and the Queenston-Chippawa Power Canal in 1921, the river flows into the Power Canal. This results in a flow reversal between the confluence of the Welland River and the Power Canal and the mouth of the Welland River at the Niagara River. The grade of the headwater channel of the Welland River upstream of the Port Davidson weir generally ranges from ~ 0.5 – 1% and is approximately 0.1% in the lower section below Port Davidson (Gartner Lee Limited, 1987). The lower portion of the Welland River, from downstream of the weir at Port Davidson, has been modified for major infrastructure including the old (renamed the Welland Recreational Waterway) and New Welland Canals (which allow passage of major ship traffic). Ontario Power Generation (OPG) facilities along the Niagara River include the hydraulic structure known as the International Niagara Control Works (INCW) that extends approximately halfway across the Niagara River and uses 18 sluice gates for control of river flow. The lower reach of the Welland River (also referred to as Chippewa Creek) flows upstream into the Queenston-

Chippewa Power Canal. Since 1953, the INCW has been used to better control the diversion of the Niagara River, up the Welland River, and into the Power Canal.

The regulated diversion of water in the lower Welland River creates a pattern of regular diurnal fluctuations in water levels that can extend to approximately 60 km upstream of the diversion to Port Davidson. Many hydraulic structures, including dams, bridges, weirs, and two siphons that carry the river under the Welland Shipping Canal, have been built on the Welland River and the hydraulics of flow (e.g. backwater effects and flooding) are further complicated due to operations of the power generating stations on the Niagara River.

The Welland River Water Level Fluctuation Study (Phillips, 2004) noted that due to the downstream controls on water level, the Welland River has been changed from a typical inland watercourse to one that has characteristics similar to watercourses that are situated in tidal and coastal settings. A variety of factors cause a complex hydraulic performance along the Welland River main channel. These include the presence of numerous crossings and hydraulic structures (including the Old Siphon and the New Siphon), the operation of the hydroelectric generating facilities drawing water from the Niagara River, and the mild channel gradients in the lower portion of the Welland River. The Grass Island Pool is located approximately 1500 m upriver of the falls and is where the New York Power Authority (NYPA) and Ontario Power Generation (OPG) draw water from, for their respective hydro-generating stations. The regulation of water levels in the Grass Island Pool is governed by a directive issued by the International Niagara Board of Control (INBC) with approval of the International Joint Commission. The Board monitors the operation of the control structures; it requires that the long-term average water level of the Grass Island Pool remain within a prescribed tolerance range. Based on the March 1993 Directive (revised May 2003), water levels in the GIP should be maintained between 170.70 m to 171.61 m (IGLD 1985) with a maximum daily fluctuation of 0.46 m.

2 Development of the Hydraulic Model

2.1 Model Selection

Hydraulic conditions in the Welland River were numerically simulated using the MIKE 11 model (developed by the Danish Hydraulic Institute - DHI). MIKE 11 is a one-dimensional modeling software designed for the simulation of flows, water quality, and sediment transport in estuaries, rivers, irrigation systems, and channels. Due to its one-dimensional capabilities, hydraulic characteristics such as flow and velocity were defined through cross-sectional averages, where variations along the length of the Welland River were simulated. Accordingly, changes in flow through depth and/or river width are not provided as part of the simulation.

As part of previous studies, a combination of HEC-2 model (Philips, 1999), HEC-RAS model (Aquafor Beech, 2012), and MIKE 11 (Phillips, 2004) was used to assess the hydraulics of the Welland River. Specifically, HEC-2 and HEC-RAS for the upper reaches and MIKE 11 for the lower reaches.

MIKE 11 was selected to characterize and analyse hydraulic conditions for this study due to its recognized strengths (e.g. incorporating siphons and defining reverse flows), in addition to its ability to maximize the use of existing data, which ensures accuracy of the results and efficiency of the process. More specifically, MIKE 11 provides the following hydrodynamic engines and tools:

- 1D hydrodynamic engine for rivers and open channels, with fully dynamic solution to the complete nonlinear St. Venant equations for open channel flow
- Muskingum and Muskingum-Cunge routing method options for simplified channel routing
- Automatic adaptation to subcritical and supercritical flow
- A large suite of standard hydraulic structures, such as weirs, culverts, bridges, pumps, energy loss and tabulated structures
- Extremely flexible control module for movable gates, pumps, turbines, etc.

2.2 Model Development and Modelling Approach

The development of the MIKE 11 hydraulic model has incorporated the following components:

- Background Information
  - Previous studies and models
  - Existing datasets
- River Network

- Cross Sections and Bathymetry
- Channel Roughness and other Hydraulic Parameters
- Structures
- Siphons
- Boundary Conditions

2.2.1 Background Information

Previous Studies and Models

A significant amount of data exists for the study area, which has been collected over many decades and from many studies dating back to the 1920s when the Queenston-Chippewa Power Canal was constructed. Documented studies involving hydrology on the Welland River date back to 1965, and perhaps even earlier in the 1920s when the designs for the Old Welland Canal was undertaken. An extensive review of relevant studies was conducted to complete the present hydraulic study. The reviewed documents are summarized below:

- Welland River Study (Canada / Ontario Flood Damage Reduction Program), Dillon, 1985.
- Watershed Flood Damage Assessment Study (Canada / Ontario Flood Damage Reduction Program), Cuming Cockburn Ltd., 1988.
- Binbrook Dam, Dam Safety Review Report, Klohn Cripen, 2003.
- Binbrook Dam, Probable Maximum Flood – Dam Break Analysis and Inundation Mapping, Klohn Cripen, 2004.
- Welland River Water Level Fluctuation Study, Philips Engineering Limited, 2004.
- Central Welland River Floodplain Mapping Study, Aquafor Beech Limited, June 2012
- Floodline Mapping Study of the Main Branch of the Welland River Watershed: Hydrologic Characterization, Aquafor Beech, May 2012
- Binbrook Dam Operations and Maintenance Manual, NPCA, 2013

Three key models have been reviewed for the purpose of developing the overall MIKE 11 model. These models are:

1. HEC-2 model from Binbrook Dam to QEW, developed by Philips (1999);
2. HEC-RAS model from Woodburn Road to New Siphon, developed by Aquafor Beech (2012); and
3. MIKE 11 model from Old Siphon to the mouth of the Welland River, developed by Philips (2004)

Existing Datasets

A range of data sets pertaining to channel geometry, bathymetry, structures, and hydraulic parameters have been assembled to support the hydraulic analyses of the Welland River system. Some of the key data that have ultimately been used in the hydraulic modelling are:

- Water level and flow monitoring data from NPCA website, particularly used to calibrate water levels at Caistors Corners Gauge – West Lincoln (also referred to as Church Road gauge), and at Old Siphon West – Welland Riverbank Park (located at the upstream end of the Old Siphon)
- DTM information from NPCA: NPCA originally partnered with 2002 GTA Orthopotography and DTM project to acquire digital aerial imagery and elevation information that is capable for pre-engineering survey and design, the production of municipal planimetric mapping and detailed topographic mapping at a minimum scale of 1:2000 with a contour interval of no less than one meter (1.0 m). The 2002 DTM information was updated in 2012 through funding provided by Niagara Region and its Niagara Water Strategy program using the SWOOP 2010 imagery and associated stereo models observing the same accuracy support intentions. The NPCA 2012 DTM data was used to determine elevations in the overbank areas along the entire river extents.
- Existing bathymetry from previous hydraulic models.

2.2.2 River Network

The river network defines the length and spatial extent of the watercourse to be modeled, and the linkages between the various river channels. For this study, the overall river network has been developed graphically in the MIKE11 system using a combination of previous models bathymetry for the low flow channel (except for the channel between Port Davidson and the Old Siphon, where a bathymetric survey was completed in 2016), and floodplain elevations developed using the DTM data. Study limits of the numerical modeling domain include the Welland River from Binbrook Dam to the Niagara River (at Material Dock). The Chippawa Power Canal from the confluence with the Welland River to the location known as “Crossover” is not included in the model. Figures presenting model domain, structures, and MIKE 11 model setup are included in **Appendix A**

In order to develop an overall MIKE 11 model for the study area, geometric and physical characteristics were synthesized from the following reaches (**Figure 1**):

- **Reach 1:** Reach 1 extends from Binbrook Dam to the Port Davidson weir. River geometry and the low flow channel for Reach 1 was modeled using HEC-2 and HEC RAS (Aquafor Beech, 2012);
- **Reach 2:** Reach 2 extends from the Port Davidson Weir to the upstream end of the Old Siphon. The WSP bathymetric survey team obtained bathymetric survey data of the channel geometry in Reach 2. In July 2016, a bathymetric survey was carried out on a 50 km stretch of the Welland River, using a boat equipped with a Knudsen

single beam echosounder system and an RTK-GPS unit. The survey had a 10 cm accuracy, and used a local benchmark based on Ontario Geospatial Monument System. Following the bathymetric survey, the data was delivered to NPCA in the form of Ascii csv file and an AutoCAD DWG file of the survey. The data was later used to create cross sections between Port Davidson Weir and the Old Siphon. A surface was generated in Civil3D using the bathymetric survey points to define the low flow channel.

- **Reach 3:** Reach 3 extends from downstream of the Old Siphon to the Niagara River. River geometry and the low flow channel for Reach 3 was modeled using MIKE 11 as part of the Welland River Water Level Fluctuation Study (Philips, February 2004).

2.2.3 Cross Sections and Bathymetry

The computation of water surface profiles requires cross-sections at representative locations throughout a river reach. Depending on changes and transitions in channel plan or profile, cross-sections should fully define transitional elements of a river such as; the cross-sectional area increasing or decreasing, channel or overbank roughness changes, or marked breaks in bottom slope. When encountered by hydraulic structures and crossings, such as at bridges, dams or other manmade or natural restrictions, several cross-sections should be used in order to appropriately describe the change in hydraulic parameters.

Following the considerations above and based on our best modeling practices, we have reviewed the locations and representations of cross sections from previous models (specifically for Reach 1 and Reach 3 as shown in **Figure 1**). We have examined cross section intervals, low flow channel widths and depths, floodplain width and slopes. In general, the cross sections seem to agree with good modeling and channel geometry representation practices. Based on most recent DTM files (NPCA, 2012), the cross sections obtained from previous models were updated. In particular, the connectivity between low flow channel and associated floodplain was revised to reflect existing topography and higher resolution (refer to **Appendix B** for examples from the two reaches).

2.2.4 Structures

Based on a comprehensive background review followed by field investigations and survey work along the Welland River on October 5th and 6th, 2016, the study team confirmed a total of 38 structures, including one culvert, 35 bridges, and two siphons. A list of the structures is included in **Table 2-1**. Figures presenting model domain, structures, and MIKE 11 model setup are included in **Appendix A**. A full structure inventory, with detailed description and photo log is provided in **Appendix C**.

Table 2-1: Summary of Structures Data

Structure No.	Location	Type	Dimensions[1] [m]	Top of Deck elevation [m]
1	Harrison Road	Concrete Arch Culvert	9.4 x 5.2	195.78
2	Regional Road 56	Concrete Bridge – Flat Soffit	16.0	193.19
3	Trimble Road	Concrete Bridge – Arched Soffit	8.0	189.42
4	Hall Road	Concrete Bridge – Flat Soffit	14.0	188.40
5	Private Road	Concrete Bridge – Flat Soffit	9.2	186.37
6	Woodburn Road	Concrete Bridge – Arched Soffit	15.3	188.33
7	Sinclairville Road	Concrete Bridge – Flat Soffit	27.6	187.21
8	Westbrook Road	Concrete Bridge – Arched Soffit	12.8	186.35
9	Caistorville Road	Concrete Bridge – Arched Soffit	15.3	184.89
10	Abingdon Road	Concrete Bridge – Flat Soffit	18.9	183.58
11	N Chippawa Road	Concrete Bridge – Flat Soffit	18.8	182.99
12	Caistor Centre Road	Concrete Bridge – Flat Soffit	21.4	183.69
13	Smithville Road	Concrete Bridge – Arched Soffit	18.3	179.98
14	Church Road	Concrete Bridge – Flat Soffit	44.7	178.52
15	S Chippawa Road	Concrete Bridge – Flat Soffit	32.8	178.77
16	Caistor Gainsborough Townline Road	Concrete Bridge – Flat Soffit	48.6	177.33
17	Canborough Road	Concrete Bridge – Flat Soffit	45.6	177.79
18	Rail 04 (Abandoned TH&B)	Concrete Bridge – Flat Soffit	46.4	177.89
19	Wellandport Road	Concrete Bridge – Flat Soffit	50.7	177.21
20	Boyle Road	Concrete Bridge – Flat Soffit	52.8	177.61
21	Victoria Avenue	Concrete Bridge – Flat Soffit	50.5	177.78
22	Rail 03 (TH&B)	Concrete Bridge – Flat Soffit	137.0	177.27
23	O'Reilly's Road N	Concrete Bridge – Flat Soffit	38.5	176.18
24	Webber Road	Concrete Bridge – Flat Soffit	72.7	178.36
25	Prince Charles Drive	Concrete Bridge – Flat Soffit	70.9	177.85
26	Niagara Street	Concrete Bridge – Flat Soffit	57.4	175.99
27	Old Siphon	Siphon (Culvert), 6 circular barrels	6.7 (each)	n/a
28	Woodlawn Road	Concrete Bridge – Flat Soffit	211.1	180.27
29	Highway 406	Concrete Bridge – Flat Soffit	120.0	181.68
30	Rail 02 (CNR)	Concrete Bridge – Flat Soffit	115.0	179.50
31	New Siphon	Siphon (Culvert), 4 rectangular barrels	5.3 x 8.0 (each)	n/a
32	Rail 01 (CNR)	Concrete Bridge – Flat Soffit	91.4	179.86
33	Moyer Road	Concrete Bridge – Flat Soffit	240.1	177.99
34	Montrose Road	Concrete Bridge – Flat Soffit	68.0	177.42
35	QEW	Concrete Bridge – Flat Soffit	289.0	180.11
36	Rail 05 (Michigan Central Railway)	Concrete Bridge – Flat Soffit	70.0	176.60
37	Stanley Avenue	Concrete Bridge – Flat Soffit	146.7	178.41
38	Portage Road	Concrete Bridge – Trapezoidal Soffit	97.0	175.86

Source: [1] Culvert dimensions = span x rise. Bridge dimensions = span. Siphon dimensions = diameter or span x rise

2.2.5Siphons

Two inverted siphons have been built to convey the flow of Welland River beneath the Old and New Welland Ship Canals. According to the Floodline Mapping Study of the Main Branch of the Welland River (John Perdikaris, May 2012), both structures flow full under pressure and create backwater pools during floods in a manner similar to dams. In addition to backwater pools, sedimentation and blocking of the siphons add more complexity to forecasting flooding scenarios along the Welland River.

- **Old Siphon**: Constructed during the period between 1925 and 1930, the inverted siphon culvert under the Old Welland Canal is located in the City of Welland, north of Main Street. It consists of six 6.7 m diameter tubes in parallel beneath the canal, connected at each depth to six vertical shafts which rise to the river bed. The siphon headwall on each side of the canal is 5.5 m thick. The total available cross-sectional area of the siphon tubes is about 207 m^2. Following an exploratory investigation of silting conditions of the Old Siphon in 2010 (ASI, 2010), it was determined that the Old Siphon was operating at approximately 67% capacity (100% being no sediment accumulation). This is based on the respective remaining capacity for all six siphon tubes. Thus, the blockage for Old Siphon is approximately 33%.
- **New Siphon**: Constructed in 1973, the New Siphon is located near Port Robinson. It conveys the Welland River under the new ship canal, east of the Welland River. The New Siphon consists of four 5.3 x 8 m rectangular barrels in parallel. The total available cross-sectional area, assuming no blockages, is approximately 169 m^2.

The Welland River Flood Damage Reduction Study (Dillon Engineering, 1985) compared the theoretical rating curves between the Old Siphon and the New Siphon, and found that the New Siphon is more efficient than the Old Siphon, with approximately 75% excess capacity for a constant head differential.

For model input, data was extracted as follows:

- Theoretical head loss calculations suggest approximately 0.32 m head loss across the Old Siphon (Welland River Flood Damage Reduction Study, Dillon Engineering, 1985). In the Welland River Flood Damage Reduction Study, the Old Siphon was modelled as a bridge and head loss rating curve was used as an internal boundary condition. The head loss coefficients were selected on the basis of the physical characteristics of the siphon barrels. The validity of the proposed head loss calculations has been examined and subsequently approved for application in previous studies such as: The Floodline Mapping Study of the Main Branch of the Welland River (John Perdikaris, May 2012).
- Old Siphon characteristics (size, inverts, length, bend loss) were obtained from The Welland River Flood Damage Reduction Study (Dillon Engineering, 1985). Manning's n was back-calculated to achieve desired head loss of 0.32 m. Partial blockage, namely 33% of the Old Siphon due to sedimentation has been simulated in the model to represent baseline conditions.

- New Siphon characteristics (size, inverts, length, entrance and exit losses, Manning's n) were obtained from the ASI 2010 Internal Inspection of Welland River Siphons Report.

2.2.6 Channel Roughness

The channel roughness (Manning's n) values were assigned as appropriate based on review of aerial photography (**Appendix D**). After calibrating water levels and peak flows for Manning's n values between 0.02 and 0.035, the low flow channel portion was assigned a Manning's n of 0.025, which is agrees with literature and constitutes a typical value for major streams with no boulders or brush in the channel. The portion of the channel above the low flow channel (i.e., overbanks) was assigned a Manning's n of 0.05 to represent floodplains with mature field crops and/or light brush and trees, as is present along the Welland River (refer to **Appendix D**, which shows typical floodplain land cover along the Welland River, where a Manning's n of 0.05 was rendered suitable).

2.2.7Boundary Conditions

Water level Open Boundary conditions were applied at the upstream end of the Niagara River and the upstream end of the Power Canal. Constant water level were set at Grass Island Pool gauge (GIP), located at the upstream end of Niagara River and at Montrose Gauge, located at the junction of the Welland River and the Chippawa Power Canal. The average, minimum and maximum historical recorded water levels for these gauges was obtained from Welland River Water Level Fluctuation Study (Philips, Feb. 2004) and the International Niagara Board of Control 1993 Directive (revised May 2003):

- The maximum, average and minimum historical water level at Grass Island Pool gauge are 171.61 m, 171.16 m and 170.708 m, respectively
- The maximum, average and minimum historical water level at Montrose Gauge are 171.33 m, 170.91 m and 170.38 m, respectively

Inflow hydrographs were extracted from the Welland River Visual OTTHYMO hydrology model, and were applied to the Mike 11 model at the upstream end of the Welland River where the Binbrook Dam is located, and where tributaries enter the Welland River main branch. There are approximately16 tributaries that connect to the main branch of the Welland River, including West Wolf Creek, Buckhorn Creek, Elsie Creek, Wolf Creek, Moores Creek, Wilson Creek, Oswego Creek, Beaver Creek, Sucker Creek, Little Forks Creek, Forks Creek, Coyle Creek, Draper Creek, Thompson Creek, GrassyBrook Creek and Lyons Creek. The hydrographs from these tributaries was applied to the Mike 11 model as Point Source boundary conditions. Hydrographs from catchments directly connected to the main branch were applied to the Mike 11 model as a Distributed Source boundary condition.

2.3 Model Calibration

The overarching objective of model calibration is to reach a good agreement between measured and simulated results. In order to arrive to best "fit" between observed and simulated MIKE 11 results, the MIKE 11 model calibration procedure involved the following three tasks:

- Adjust the manning's n parameter within a range from 0.02 to 0.035;
- Compare the peak flow rate and runoff volume resulting from the MIKE 11 model with the hydrologic model results for Event 15; and
- Compare the water level with two NPCA water level monitoring stations: Caistors Corners Gauge and Old Siphon West.

The results of the calibration process are presented below, and summary tables are provided as part of **Appendix D**.

2.3.1 Manning's n Calibration

A range of Manning's n values (0.02 to 0.035) was applied to the MIKE 11 model to evaluate the sensitivity of water surface elevations to these values at different locations. These values agree with the values used in previous models, covering upstream and downstream reaches. Following several iterations, a manning's n of 0.02 was selected as it provided "best fit" at the examined two gauges **(Appendix D).**

Manning's n value of 0.05 was used for floodplains**.** This agrees with aerial photos taken along the Welland River **(Appendix D),** where ground cover ranges between Cultivated Areas (average Manning's n = 0.02 – 0.05) and Brush (average Manning's n = 0.05 – 0.10). The Manning's n values were extracted from Chow (1959).

2.3.2 Peak Flows and Runoff Volumes Calibration

After comparing the MIKE 11 peak flows and runoff volumes at Church Road gauge to peak flows and volumes from the hydrologic model hydrograph at the same location, it was found that the hydraulic model results are very close to the results provided by the hydrologic model. Specifically, there is less than 1% difference in peak flow magnitude, and only 2% difference in runoff volume magnitude (**Table 2-2** and Figure 2-1).

Table 2-2: Calibration Results – Runoff Volume and Peak Flow Rate

Event ID	Runoff Volume			Peak Flow Rates		
	Hydrology model results -10^6 m^3	MIKE 11 model results -10^6 m^3	Difference -%	Hydrology model results -m^3/s	MIKE 11 model results -m^3/s	Difference -%
15	25.4	24.9	-2%	94.9	95.3	0.3%

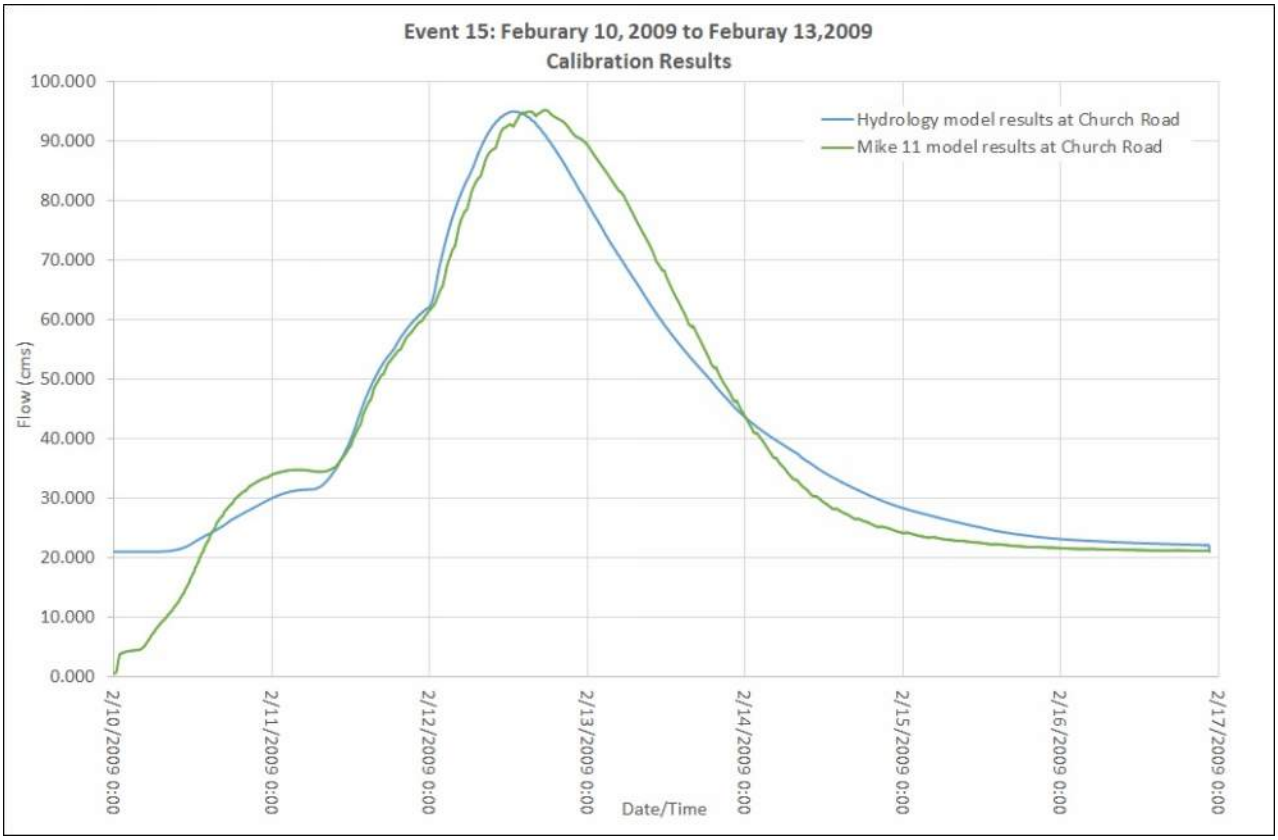

Figure 2-1: Hydrograph Comparison – Event ID 15 (Feb. 2009)

2.3.3 Water Level Calibration

The MIKE 11 simulated water levels were compared to observed water levels from NPCA monitoring stations at two locations:

1. Caistors Corners Gauge – West Lincoln (also referred to as Church Road gauge)
2. Old Siphon West – Welland Riverbank Park (located at the upstream end of the Old Siphon)

While the NPCA has other monitoring stations throughout the Welland River watershed, these two are the only ones with available water level data between February 10 and February 14, 2009, which is the time period of the Event 15 precipitation event (originally used to calibrate the hydrologic model).

- The GIP water level was adjusted (but maintained within GIP Directive of 170.70 and 171.61 m (IGLD 1985) to achieve reasonable match (within 10%) of recorded water level at old Siphon (Figure 2-2).
- The Power Canal water level under the Event 15 condition was also adjusted (but maintained within “Variation of Recorded Water Levels” at the Crossover Gauge (Figure 5 in Philips 2004 Fluctuation study) to achieve reasonable match (within approximately12%) of recorded water level at old Siphon (Figure 2-3).

Surface water level calibration results, shown in **Table 2-3** and **Figures 2-2** and **2-3** provide acceptable results considering the good agreement with observed water levels at the two monitoring stations (i.e. less than 2% for the Caistors Corners gauge and less than12% difference for the Old Siphon West gauge)

Table 2-3: Calibration Results – Water Level and Depth

NPCA water level monitoring stations	Maximum Water Level			Water Depth*		
	Observed (m)	Simulated (m)	Difference (m)	Observed (m)	Simulated (m)	Difference %
Caistors Corners Gauge	175.75	175.81	0.07	4.06	4.13	1.6%
Old Siphon West	173.12	173.86	0.74	6.32	7.06	11.6%

*Water Depth = maximum water level – minimum water level

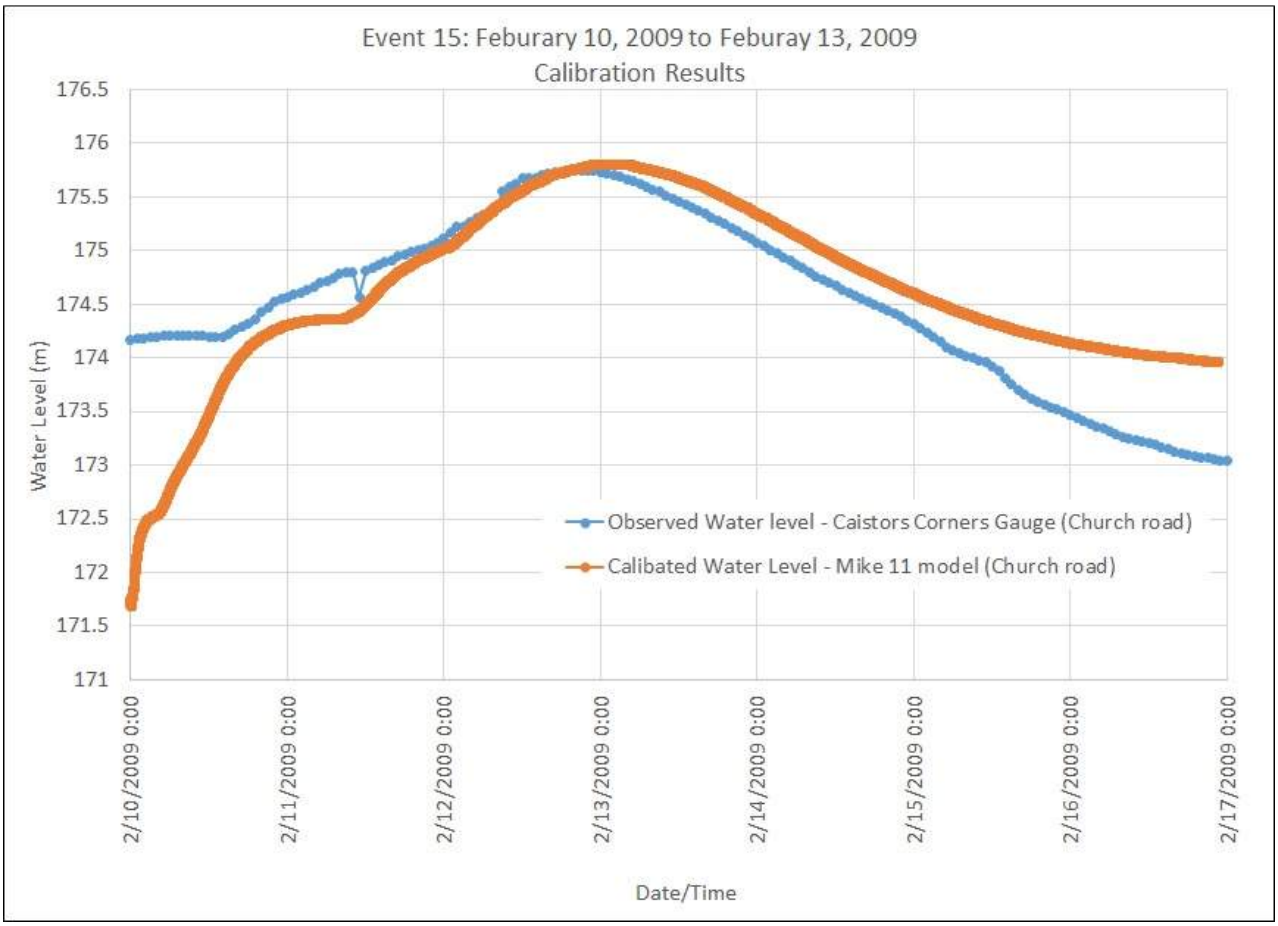

Figure 2-2: Water Level Comparison at Caistors Corners Gauge – Event ID 15 (Feb. 2009)

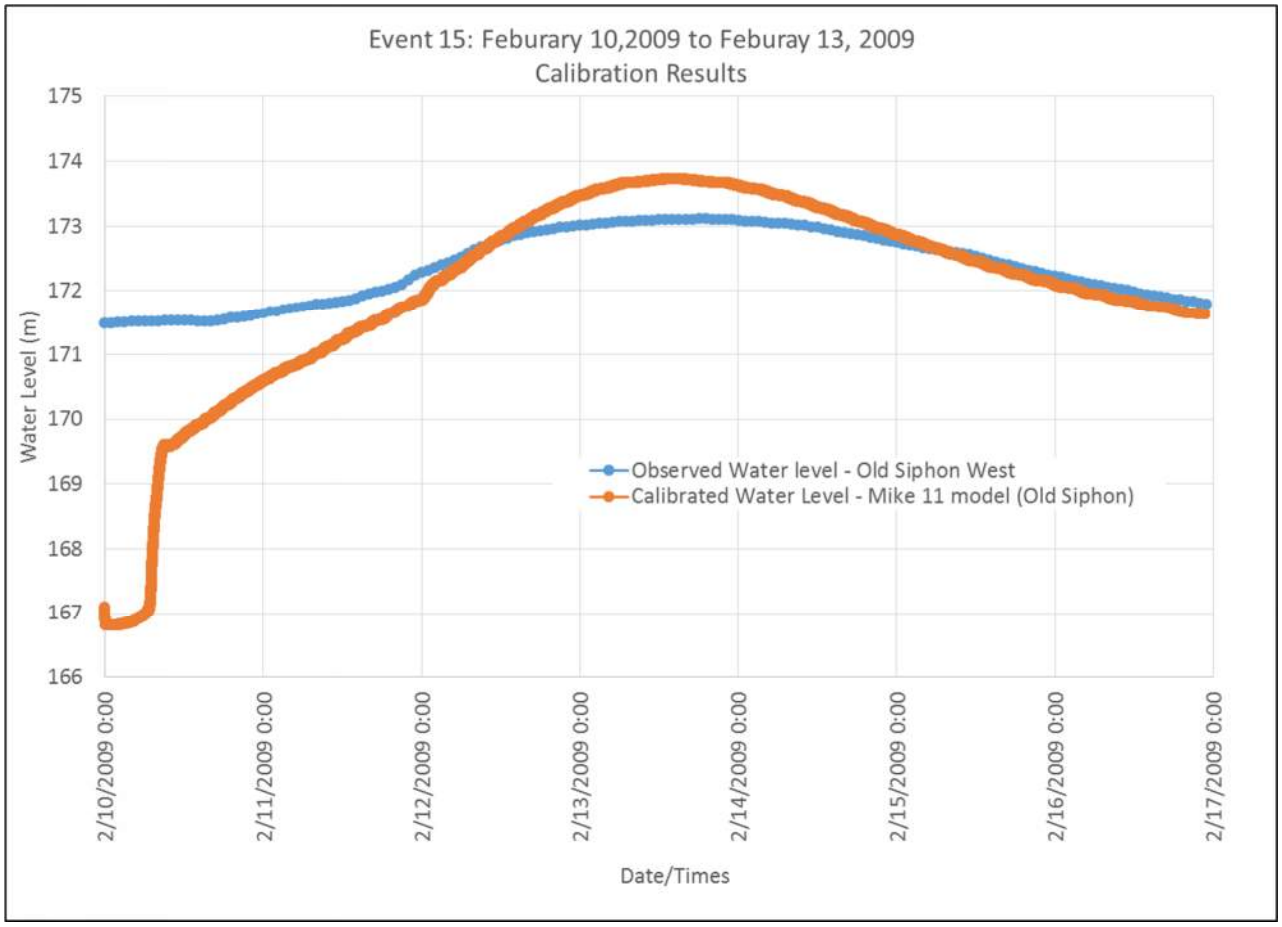

Figure 2-3: Water Level Comparison at Old Siphon West – Event ID 15 (Feb. 2009)

3 Model Results

3.1 Scenario Modelling and Sensitivity Analysis

The impact of the Niagara River Hydroelectric Development, in addition to impacts of various blockage scenarios at the Old Siphon, were modeled along the model domain of the Welland River, spanning approximately 135 km of the main channel. The Grass Island Pool (GIP) water levels were based on historical data and followed the International Niagara Board of Control 1993 Directive (revised May 2003). Water level variations of Montrose Gauge, located at the junction of the Welland River and the Chippawa Power Canal, were extracted from the Welland River Fluctuation Study (Figure 5, Phillips, 2004).

Backwater effects result from variations of water levels on the Niagara River at Grass Island Pool (GIP). These backwater effects have been observed and simulated to occur approximately 60 km up to Port Davidson (Baird, 2005). Under low flow conditions, water level fluctuations are in the order of 30 to 35 cm at Port Davidson during dry weather periods. Under high flow conditions, the upriver fluctuations become significantly reduced (Baird, 2005).

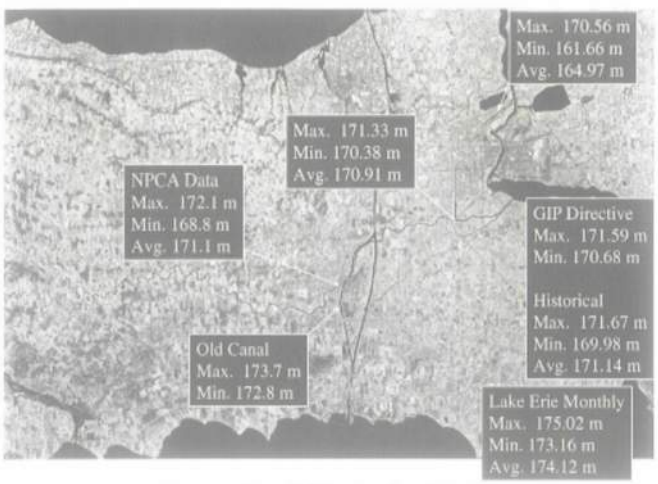

Figure 5 Variation of Recorded Water Levels at Selected Locations (in GSC)

Our hydrology report submitted in 2017 established a schematic (Welland River Floodplain Mapping Update - Hydrology Report, **Figure 2.5**) showing flow reversal from Niagara River to the Chippawa Power Canal. The outlet of the Welland River was set to be at the confluence of Chippawa Power Canal (approximately 6 km west of the Welland River and downstream of Montrose Gauge). Based on our review of the DWOPER flow schematic, the reversal flow was also simulated as part of the Welland River Study completed by Dillon in 1985 (Welland River Study – Dwoper Schematic, **Figure 5-2**). Both schematics are enclosed in **Appendix A**.

The boundary conditions (i.e., water elevations under various conditions) at the upstream end of flow reversal at Niagara River and at the downstream end at Chippawa Power Canal are discussed below to determine the flood elevations under scenarios of interest.

The sensitivity of the hydraulic model results was thoroughly examined by adjusting key model inputs and parameters (**Table 3-1**), and comparing water surface elevations and top widths

between a “Base Condition” and five other scenarios (conditions). The synthetic 100-year storm event was run under these conditions as follows:

1. **Scenario 1**: Base Condition – Using average historical water levels at Niagara River and the Montrose Gauge: 171.16 m and 170.91 m, respectively, and assuming 33% blockage at the Old Siphon
2. **Scenario 2**: 50% blockage – Average historical water levels (similar to Base Conditions), but with 50% blockage at the Old Siphon
3. **Scenario 3**: 75% blockage – Average historical water levels (similar to Base Conditions), but with 75% blockage at the Old Siphon
4. **Scenario 4**: High water level –Using maximum historical water levels at Niagara River and Montrose Gauge (171.61 m, 171.33 m), and assuming 33% blockage at the Old Siphon
5. **Scenario 5**: Low water level –Using minimum historical water levels at Niagara River and Montrose Gauge (170.70 m, 170.38 m), and assuming 33% blockage at the Old Siphon
6. **Scenario 6**: 0% blockage – Using average historical water levels at Niagara River and the Montrose Gauge: 171.16 m and 170.91 m, respectively, and assuming 0% blockage (i.e. Clean) at the Old Siphon

Table 3-1: Old Siphon Culvert Parameters under Different Blockage Conditions

	Blockage Condition			
	Clean	**33% (Base Condition)**	**50%**	**75%**
Culvert diameter (m) / opening area (m^2)	6.7 / 35.3	6.7 / 25.1	6.7 / 17.6	6.7 / 6.9
Upstream invert elevation (m)	154.4	156.611	157.75	159.43
Downstream invert elevation (m)	154.4	156.611	157.75	159.43
Depth blocked (m)	0	2.2	3.4	5.0

As presented in **Table 3-2** and **Table 3-3**, and as expected according to previous studies, water levels are more sensitive in the lower portion of the Welland River, specifically downstream of Church Road. Upstream of Church Road, zero or close to zero increases in water surface elevations and top widths are expected. According to **Table 3-2**, changes in water surface elevations, compared to Scenario 1: Base Conditions, are largest under Scenario 4: High Water Level scenario, with a maximum increase of approximately 0.477 m at Rail05MID downstream of QEW. Moreover, and in general, Scenario 4 has a larger impact than Scenario 5, in terms of Top Width, with a maximum increase of 28.8 m at Oreilys Rd.

With respect to the impact of the adjustment of the blockage at Old Siphon (**Table 3-3**), water levels are more sensitive at and upstream of the Old Siphon (up to Caistor Centre Rd), with a highest water level increase of 2.09 m (under Scenario 3: 75% blockage), followed by an increase of 2.05 m at Niagara St. and 2.02 m at Prince Charles Drive.

With respect to Top Width, and under Scenario 3: 75% blockage, the highest increase in Top Width is expected to happen at Boyle Road (approximately 294 m), followed by an increase of approximately 276 m at Victoria Avenue.

It should be noted that significant local changes in water surface elevations occur at areas where sudden changes in channel bed and/or hydraulic jump situations occur (Appendix A).

Table 3-2: Sensitivity Analysis – Surface Water Elevation and Flow Top Width for Scenario 1, 4 and 5

Structure	Cross-section	Scenario 1 – Base Condition	Scenario 4 – High Water level		Scenario 5 – Low Water level		Scenario 1 – Base Condition	Scenario 4 – High Water level		Scenario 5 – Low Water level	
		Elevation (m)	Elevation (m)	Change (m)	Elevation (m)	Change (m)	Top Width (m)	Top Width (m)	Change (m)	Top Width (m)	Change (m)
Harrison Road	234.6	191.71	191.71	*0.00*	191.71	*0.00*	8.47	8.47	*0.01*	8.48	*0.01*
Reg Rd 56	3021.8	190.17	190.17	*0.00*	190.17	*0.00*	16.30	16.30	*0.00*	16.30	*0.00*
Trimble Rd	6938.7	188.31	188.31	*0.00*	188.31	*0.00*	101.11	101.11	*0.00*	101.11	*0.00*
Hall Rd	12979.9	185.99	185.99	*0.00*	185.99	*0.00*	40.59	40.59	*0.00*	40.59	*0.00*
Private Road	13034.9	185.23	185.23	*0.00*	185.23	*0.00*	59.22	59.22	*0.00*	59.22	*0.00*
Woodburn Road	14077.6	184.84	184.84	*0.00*	184.84	*0.00*	17.08	17.08	*0.00*	17.08	*0.00*
Sinclairville Rd	19561.8	183.84	183.84	*0.00*	183.84	*0.00*	69.37	69.37	*0.00*	69.37	*0.00*
Westbrook Road	22690.3	183.32	183.32	*0.00*	183.32	*0.00*	16.58	16.58	*0.00*	16.58	*0.00*
Caistorville Road	28418.2	182.24	182.24	*0.00*	182.24	*0.00*	22.83	22.83	*0.00*	22.83	*0.00*
Abingdon Road	33038.9	180.52	180.52	*0.00*	180.52	*0.00*	23.20	23.20	*0.00*	23.20	*0.00*
Nchippawa Road	37100.9	178.67	178.67	*0.00*	178.67	*0.00*	20.30	20.30	*0.00*	20.30	*0.00*
Caistor Centre Rd	38209.6	177.81	177.82	*0.00*	177.81	*0.00*	18.38	18.38	*0.00*	18.38	*0.00*
Smithville Road	39200.6	177.19	177.20	*0.00*	177.19	*0.00*	23.25	23.25	*0.00*	23.25	*0.00*
Church Rd	43100.8	176.02	176.03	*0.01*	176.02	*0.00*	21.87	21.89	*0.02*	21.87	*0.00*
SChippawa Rd	50193.2	175.67	175.69	*0.02*	175.67	*0.00*	31.75	31.83	*0.08*	31.74	*-0.01*
CaistorGainsborough TL	52164	175.60	175.61	*0.02*	175.59	*0.00*	192.34	195.89	*3.55*	192.01	*-0.34*
Canborough Rd	55881.5	175.46	175.48	*0.02*	175.46	*0.00*	35.83	35.88	*0.05*	35.83	*0.00*
Rail 04	56463.7	175.40	175.43	*0.03*	175.40	*0.00*	41.32	41.44	*0.11*	41.31	*-0.01*
Wellandport Road	67153.3	175.21	175.25	*0.04*	175.21	*0.00*	58.37	58.53	*0.16*	58.37	*0.00*
Boyle Rd	77477.6	174.99	175.03	*0.05*	174.99	*0.00*	47.79	62.07	*14.28*	48.02	*0.23*
Victoria Ave	81847.4	174.87	174.93	*0.06*	174.82	*-0.06*	35.61	35.79	*0.18*	35.45	*-0.17*
Rail 03	84199	174.67	174.74	*0.07*	174.61	*-0.06*	127.37	129.05	*1.69*	125.73	*-1.64*
Oreillys Rd	88158.7	174.50	174.57	*0.07*	174.42	*-0.07*	205.85	234.65	*28.80*	192.60	*-13.26*
Webber Rd	93529.1	174.28	174.37	*0.10*	174.20	*-0.08*	281.71	285.19	*3.48*	278.86	*-2.85*
Prince Charles Dr	94962	174.11	174.21	*0.10*	174.03	*-0.08*	64.96	65.22	*0.27*	64.74	*-0.22*
Niagara St	95586.9	174.07	174.17	*0.10*	173.99	*-0.08*	54.06	65.88	*11.81*	53.62	*-0.45*
Old siphon	95909.6	174.00	174.10	*0.10*	173.92	*-0.07*	74.41	74.63	*0.22*	74.24	*-0.17*
Woodlawn Rd	98485.6	172.95	173.07	*0.12*	172.85	*-0.09*	70.39	71.32	*0.93*	69.65	*-0.74*
Hwy 406	100277.2	172.80	172.93	*0.13*	172.69	*-0.10*	69.90	70.96	*1.06*	69.08	*-0.82*
Rail 02	100434.7	172.77	172.91	*0.14*	172.66	*-0.11*	84.02	85.09	*1.07*	83.19	*-0.83*
New siphon	101450.4	172.65	172.79	*0.15*	172.73	*0.08*	45.65	45.75	*0.10*	45.71	*0.06*
Rail 01	102025.8	172.39	172.54	*0.15*	173.90	*1.51*	70.48	71.14	*0.66*	76.86	*6.38*
Moyer Rd	104918.1	172.10	172.29	*0.19*	171.94	*-0.16*	84.11	94.73	*10.62*	76.02	*-8.09*
Montrose Rd	110756.4	171.18	171.58	*0.40*	170.66	*-0.52*	50.07	52.66	*2.59*	35.95	*-14.12*
QEW	110858.9	171.18	171.65	*0.47*	170.71	*-0.47*	74.84	94.75	*19.91*	66.09	*-8.75*
Rail05 (Michigan Central Railway)	112.1	171.16	171.57	*0.41*	170.59	*-0.57*	66.63	69.34	*2.71*	51.14	*-15.49*
Rail05DS (Michigan Central Railway)	7438.6	171.22	171.70	*0.48*	170.60	*-0.61*	92.15	94.58	*2.43*	89.02	*-3.13*
Stanley Ave	4385.8	171.16	171.56	*0.41*	170.63	*-0.53*	105.74	107.27	*1.53*	103.73	*-2.01*
Portage Rd	1332.2	171.16	171.60	*0.44*	170.68	*-0.49*	93.78	96.14	*2.36*	90.85	*-2.93*
Grassy Island Pool		171.16	171.61	*0.45*	170.70	*-0.46*					

Table 3-3: Sensitivity Analysis – Surface Water Elevation and Flow Top Width for Scenario 1, 2, 3 and 6

Structure	Cross-section	Scenario 1 - Old Siphon 33% blockage (Base)	Scenario 2 – Old Siphon 50% blockage		Scenario 3 – Old Siphon 75% blockage		Scenario 6 –Old Siphon 0% blockage (Clean)		Scenario 1 - Old Siphon 33% blockage (Base)	Scenario 2 – Old Siphon 50% blockage		Scenario 3 –Old Siphon 75% blockage		Scenario 6 - Old Siphon 0% blockage (Clean)	
		Elevation (m)	Elevation (m)	Change (m)	Elevation (m)	Change (m)	Elevation (m)	Change (m)	Top Width (m)	Top Width (m)	Change (m)	Top Width (m)	Change (m)	Top Width (m)	Change (m)
Harrison Road	234.6	191.71	191.71	0.00	191.71	0.00	191.71	0.00	8.47	8.47	0.01	8.49	0.02	8.47	0.00
Reg Rd 56	3021.8	190.17	190.17	0.00	190.17	0.00	190.17	0.00	16.30	16.30	0.00	16.30	0.00	16.30	0.00
Trimble Rd	6938.7	188.31	188.31	0.00	188.31	0.00	188.31	0.00	101.11	101.11	0.00	101.11	0.00	101.11	0.00
Hall Rd	12979.9	185.99	185.99	0.00	185.99	0.00	185.99	0.00	40.59	40.59	0.00	40.59	0.00	40.59	0.00
Private Road	13034.9	185.23	185.23	0.00	185.23	0.00	185.23	0.00	59.22	59.22	0.00	59.22	0.00	59.22	0.00
Woodburn Road	14077.6	184.84	184.84	0.00	184.84	0.00	184.84	0.00	17.08	17.08	0.00	17.08	0.00	17.08	0.00
Sinclairville Rd	19561.8	183.84	183.84	0.00	183.84	0.00	183.84	0.00	69.37	69.37	0.00	69.37	0.00	69.37	0.00
Westbrook Road	22690.3	183.32	183.32	0.00	183.32	0.00	183.32	0.00	16.58	16.58	0.00	16.58	0.00	16.58	0.00
Caistorville Road	28418.2	182.24	182.24	0.00	182.24	0.00	182.24	0.00	22.83	22.83	0.00	22.83	0.00	22.83	0.00
Abingdon Road	33038.9	180.52	180.52	0.00	180.52	0.00	180.52	0.00	23.20	23.20	0.00	23.20	0.00	23.20	0.00
Nchippawa Road	37100.9	178.67	178.67	0.00	178.67	0.00	178.67	0.00	20.30	20.30	0.00	20.30	0.00	20.30	0.00
Caistor Centre Rd	38209.6	177.81	177.81	0.00	177.82	0.00	177.81	0.00	18.38	18.38	0.00	18.38	0.00	18.38	0.00
Smithville Road	39200.6	177.19	177.19	0.00	177.20	0.01	177.19	0.00	23.25	23.25	0.00	23.26	0.01	23.25	0.00
Church Rd	43100.8	176.02	176.05	0.03	176.48	0.46	176.01	0.00	21.87	21.91	0.03	106.09	84.21	21.87	-0.01
SChippawa Rd	50193.2	175.67	175.75	0.08	176.46	0.78	175.65	-0.03	31.75	32.13	0.38	36.34	4.59	31.63	-0.12
CaistorGainsborough TL	52164	175.60	175.69	0.09	176.44	0.85	175.57	-0.03	192.34	212.58	20.24	451.61	259.26	186.55	-5.79
Canborough Rd	55881.5	175.46	175.56	0.10	176.42	0.96	175.42	-0.04	35.83	36.16	0.33	168.87	133.04	35.69	-0.14
Rail 04	56463.7	175.40	175.50	0.10	176.35	0.95	175.34	-0.06	41.32	41.68	0.36	44.71	3.39	41.13	-0.19
Wellandport Road	67153.3	175.21	175.36	0.15	176.33	1.12	175.14	-0.07	58.37	59.42	1.05	275.00	216.63	58.07	-0.30
Boyle Rd	77477.6	174.99	175.21	0.23	176.31	1.32	174.89	-0.10	47.79	120.12	72.33	341.98	294.19	33.68	-14.11
Victoria Ave	81847.4	174.87	175.15	0.27	176.30	1.42	174.75	-0.12	35.61	36.42	0.81	311.52	275.91	35.25	-0.36
Rail 03	84199	174.67	175.02	0.35	176.28	1.61	174.49	-0.18	127.37	133.49	6.12	221.81	94.44	122.84	-4.52
Oreillys Rd	88158.7	174.50	174.91	0.41	176.25	1.75	174.28	-0.22	205.85	282.24	76.39	395.73	189.88	156.40	-49.45
Webber Rd	93529.1	174.28	174.78	0.50	176.18	1.90	174.00	-0.28	281.71	301.78	20.07	394.77	113.06	270.25	-11.46
Prince Charles Dr	94962	174.11	174.64	0.53	176.13	2.02	173.81	-0.30	64.96	66.36	1.41	82.24	17.29	64.16	-0.79
Niagara St	95586.9	174.07	174.62	0.55	176.12	2.05	173.76	-0.31	54.06	108.52	54.46	169.96	115.90	51.49	-2.57
Old siphon	95909.6	174.00	174.54	0.54	176.09	2.09	173.69	-0.31	74.41	75.58	1.17	79.07	4.66	73.70	-0.71
Woodlawn Rd	98485.6	172.95	172.71	-0.24	171.57	-1.38	173.06	0.11	70.39	68.52	-1.87	56.66	-13.73	71.25	0.86
Hwy 406	100277.2	172.80	172.56	-0.24	171.49	-1.31	172.91	0.11	69.90	68.05	-1.85	59.63	-10.27	70.74	0.84
Rail 02	100434.7	172.77	172.54	-0.23	171.47	-1.30	172.88	0.11	84.02	82.25	-1.77	67.43	-16.59	84.87	0.85
New siphon	101450.4	172.65	172.43	-0.22	171.41	-1.24	172.75	0.11	45.65	45.50	-0.15	44.83	-0.82	45.72	0.07
Rail 01	102025.8	172.39	172.21	-0.17	171.34	-1.04	172.47	0.08	70.48	69.71	-0.77	63.98	-6.50	70.85	0.37
Moyer Rd	104918.1	172.10	171.95	-0.15	171.27	-0.84	172.18	0.08	84.11	76.35	-7.76	68.54	-15.57	88.45	4.34
Montrose Rd	110756.4	171.18	171.16	-0.02	170.95	-0.23	171.23	0.06	50.07	49.95	-0.11	39.02	-11.04	50.43	0.37
QEW	110858.9	171.18	171.15	-0.03	171.02	-0.15	171.23	0.05	74.84	74.41	-0.43	72.26	-2.58	75.72	0.89
Rail05 (Michigan Central Railway)	112.1	171.16	171.14	-0.02	170.98	-0.18	171.21	0.04	66.63	66.51	-0.12	64.26	-2.37	66.92	0.29
Rail05DS (Michigan Central Railway)	7438.6	171.22	171.21	-0.01	171.08	-0.13	171.29	0.07	92.15	92.11	-0.04	91.46	-0.69	92.53	0.38
Stanley Ave	4385.8	171.16	171.16	0.00	171.16	0.00	171.16	0.00	105.74	105.74	0.00	105.74	0.00	105.74	0.00
Portage Rd	1332.2	171.16	171.16	0.00	171.16	0.00	171.16	0.00	93.78	93.78	0.00	93.78	0.00	93.78	0.00
Grassy Island Pool		171.16	171.16	0.00	171.16	0.00	171.16	0.00							

3.2 Model Results Compared to the Welland River Study (Dillon, 1985)

3.2.1 Overview of Key Features in MIKE 11 and DWOPER

In order to provide context to the MIKE 11 results, we have compared key features and characteristics between the MIKE 11 model and the hydraulic model used in the Welland River Study (Dillon, 1985).

Generally speaking, the Welland River Study (Dillon, 1985) was divided into two parts: delineation of the flood vulnerable areas and investigation of flood remedial measures. The Dynamic Wave Operational Model (DWOPER) was used to calculate the flood elevations for the 100-year storm event. The results of the Welland River Study showed that except for a small part of the City of Welland at Mill Street and Riverside Drive, the 100-year flood line affects mainly isolated buildings and agricultural land in rural areas. The DWOPER model used by Dillon (1985) is a dynamic routing model developed in the US. By the Hydrologic Research Laboratory of the National Weather Service (NWS), in conjunction with Flood Wave (FLDWAV). These models were primarily used in the seventies and eighties to simulate river hydraulics, flow diversions, and local head losses. Following the development of the HEC-2 and HEC RAS modeling platforms, the DWOPER and Flood Wave (FLDWAV) models have been gradually phased out by the NWS.

Table 3-4 provides a comparison between the approach and key modeling procedures applied by MIKE 11 (this study) and DWOPER (Dillon, 1985). These procedures include:

- Hydraulic models used
- Model Domain and Study Area
- Cross-section data source
- Bridge modeling approach
- Siphon modeling approach
- Input hydrographs and boundary conditions
- Flow schematic; and
- Sensitivity Analysis

Regarding the flow schematics of MIKE 11 and DWOPER, and as Table 3-4 indicates, flow reversal from Niagara River to Welland River was assumed under all flood events, including the 100-year event.

Table 3-4: Comparison of Key Features and Approaches between the MIKE 11 Model and the DWOPER Model used in Dillon (1985)

Procedure/Feature	Historical Floodline Mapping (1985)	MIKE 11 Model
Study Area	• Welland River from Niagara River to the Glanbrook/West Lincoln Township boundary. • The total modelled channel length is approximately 96km.	• Welland River from Niagara River to downstream of Binbrook dam. • The total modelled channel length is approximately 119km.
Computer Model Selection	• Hec-2 model from Glanbrook/West Lincoln boundary to South Chippawa Road. • DWOPER model from South Chippawa Road to Niagara River	• Mike 11 model for the entire study area
Cross-section data source	• Sections above normal water levels (floodplain) were taken from 1:2000 or 1:5000 topographic mapping (1 m contour interval photo-based maps, supplied by the Conservation Authority, were prepared by J.D Barnes in 1980). • Sections below normal water level (low flow channel) were taken by field survey measurement at bridge crossings. • Field survey could not be taken between Chippawa Power Canal and Niagara River due to high velocities. Sections were taken from "as built" drawings of the bridge crossing.	• Sections above normal water levels (floodplain) were developed using recent 1-m contour supporting DTM data (NPCA 2012.) • Sections below normal water level (low flow channel) were based on previous models' cross sections and bathymetry, except for the channel between Port Davidson and the Old Siphon, where a bathymetric survey was completed by WSP in 2016
Bridge modelling approach	• Bridges were coded as internal boundary conditions within DWOPER model. o Contracted flow coefficient = 0.8 o Orifice flow coefficient = 0.6 o Weir coefficient = 2.0	• Bridges were coded as bridges/culverts in Mike 11 model o Contraction Loss = 0.3 o Expansion Loss = 0.5 o Broad Crested Weir formulation was used.
Siphon modelling approach	• Each siphon was input as a table of head loss vs discharge. The curve labelled "ALL TUBES CLEAR" was used for the Old Siphon.	• Each siphon's characteristics (size, inverts, length) were input in the model. For Old Siphon, 33% of partial blockage due to sedimentation was simulated in the model to represent baseline conditions.
Input hydrograph / boundary conditions	• DWOPER upstream boundary condition: Inflow hydrograph at South Chippawa Road. • DWOPER downstream boundary condition: Surface water elevation at Niagara River = 171.7m • Chippawa Power Canal: o Negative lateral inflow hydrograph input to model withdrawal rate conveyed by Chippawa Power Canal. A constant withdrawal rate of 635 m3/s • 3 lateral inflow hydrograph drain to Welland River 1. Hydrograph from Oswego Creek 2. Hydrograph from Beaver, Parker, Sucker and Little Forks 3. Hydrograph from Drapers, Coler and overland runoff.	• Upstream boundary condition: Inflow hydrograph at Binbrook Dam. • Downstream boundary condition: Surface water elevation at Niagara River = 171.16m (average water level from Grass Island Pool gauge) • Chippawa Power Canal: o Surface water elevation = 170.91m (average water level from Montrose Gauge) • 16 lateral inflow hydrographs drain to Welland River 1. Hydrograph from West Wolf Creek 2. Hydrograph from Buckhorn Creek 3. Hydrograph from Elsie Creek 4. Hydrograph from Wolf Creek 5. Hydrograph from Moores Creek 6. Hydrograph from Wilson Creek 7. Hydrograph from Oswego Creek 8. Hydrograph from Beaver Creek 9. Hydrograph from Sucker Creek 10. Hydrograph from Little Forks Creek 11. Hydrograph from Forks Creek 12. Hydrograph from Coyle Creek 13. Hydrograph from Draper Creek 14. Hydrograph from Thompson Creek 15. Hydrograph from Grassy Brook 16. Hydrograph from Lyons Creek
Flow schematic	• Flow from South Chippawa Road to Chippawa Power Canal. • Flow from Niagara River to Chippawa Power Canal • Negative Lateral outflow at Chippawa Power Canal.	• Flow from Binbrook Dam to Chippawa Power Canal • Flow from Niagara River to Chippawa Power Canal. • 2.2 km of Chippawa Power Canal included in the model

Procedure/Feature	Historical Floodline Mapping (1985)	MIKE 11 Model
Sensitivity analysis of Niagara River Level results	• 3 scenarios for Sensitivity Analysis o High water condition at Niagara River, 172.1m o High water condition at Niagara River, 171.7m o Low water condition at Niagara River, 170.9m • Sensitivity analysis results show: o Lower Welland River, downstream of the New Siphon, is sensitive to the Niagara River levels o Upstream from the siphon, the variation of the water level is less than 15cm o The effect of Niagara River level are negligible upstream of Becketts Bridge (Victoria Ave)	• 6 scenarios for Sensitivity Analysis o Base condition (33% blockage on Old Siphon) o 50% blockage on Old Siphon o 75% blockage on Old Siphon o 0% blockage on Old Siphon o High water condition at Niagara River and Montrose Gauge. (171.61m & 171.33m) o Low water condition at Niagara River and Montrose Gauge. (170.70m & 170.38m) • Sensitivity analysis results show: o Water levels are more sensitive in the lower portion of Welland River, specifically downstream of Church Road. o Water levels are less or not sensitive upstream of Church Road, negligible increases in water surface elevation.

3.2.2Comparison of Peak Flows

The Welland River Study used peak flows generated by the HYMO hydrologic model parameters originally developed by Kilborn (Nov, 1981). Accordingly, peak flows, including the 100-year event, were generated by applying snowmelt (plus rain) over five-day period over the watershed.

On the other hand, inflows for Scenario 1 were extracted from the Welland River Visual OTTHYMO hydrology model. This hydrology model also includes the effects of snowmelt in the modelling by adding the calculated equivalent snow water contents to the recorded rainfall depths to complete the precipitation data for the rainfall-runoff calibration events.

Table 3-5 compares the 100-year peak flows between Base conditions (Scenario 1), High water level (Scenario 4) and the results of the Welland River Study (Dillon, 1985).

For Base condition (Scenario 1), the comparison shows an overall increase in peak flow rates compared to historical values, with the exception of slight decreases at Victoria Ave, Oreilys Road, and Old Siphon. (7%, 1% and 10%, respectively).

For High water level (Scenario 4), the comparison shows an overall increase in peak flow rates compared to historical values, with the exception of slight decreases at Victoria Ave, Oreilys Road and Old Siphon. (6%, 0.2% and 10%, respectively).

Table 3-5: Comparison of Peak Flows between Base Conditions (Scenario 1), High Water Level (Scenario 4) and the Historical Floodline Mapping (Dillon, 1985)

Locations	Historical NPCA Welland River Regulatory Riverine Floodline Mapping (1985)*	Scenario 1 - Old Siphon 33% blockage (Base)		Scenario 4 - Old Siphon 33% blockage (High Water Level)	
	100 Year Peak Flow (m3/s)	100 Year Peak Flow (m3/s)	*Change (%)*	100 Year Peak Flow (m3/s)	*Change (%)*
Wentworth/Binbrook Township Boundary (Westbrook Road)	60	65.1	*8%*	*65.1*	*8%*
Abingdon Road	75	94.6	*26%*	*94.6*	*26%*
Church Rd	100	114.6	*15%*	*114.5*	*15%*
Becketts Bridge / Victoria Ave	205	190.3	*-7%*	*193.0*	*-6%*
Oreillys Rd	245	243.0	*-1%*	*244.5*	*-0.2%*
Old siphon	275	246.8	*-10%*	*247.7*	*-10%*
Montrose Rd	275	280.2	*2%*	*308.2*	*12%*

*Peak flow computed in Welland River Flood Plain study by Kilborn Ltd (November 1981)

3.2.3 Comparison of Flood Elevations under the 100-Year Storm Event

The 100-year flood elevations were extracted from the Welland River Study using two sources of information:

1. The Welland River Study (Dillon, 1985), Table 5-8: Summary of Computed Welland River Water Levelas (m)
2. The NPCA Regulatory Floodlines, delivered by NPCA in shapefile format.

These results were compared to the 100-year flood elevations (Scenario 1 and 4) estimated by the MIKE 11 model, and presented in **Table 3-6.**

The results under the Base Conditions scenario (Scenario 1) show an overall decrease in water level values compared to historical values for all locations, except for the Harrison Road, Trimble Road, and Hall Road, where slight increases (between 0.01 and 0.05 m) are calculated. The most decrease in water surface elevations is predicted at Woodburn Road (reduced by 1.09 m).

The results under the High Water Level scenario (Scenario 4) show an overall decrease in water levels compared to the historical values for all locations, except for the Harrison Road, Trimble Road, Hall Rd, Webber Rd, Niagara St and Michigan Central Railway, where slight increases (between 0.01 to 0.1m) are calculated. Similarly, the most decrease in water surface elevations is calculated at the Woodburn Road location (reduced by 1.09 m).

Results also show that High Water Level scenario (Scenario 4) has less differences in flood elevations by comparing with the Base Condition (Scenario 1), especially at the downstream end of Welland River (between Portage Road and Montrose Road).

Table 3-6: Comparison of the 100-year flood levels between Base Conditions (Scenario 1), High Water Level (Scenario 4) and the Historical Floodline Mapping (Dillon, 1985)

Structure	Cross-section	Historical NPCA Welland River Regulatory Riverine Floodline Mapping (1985)	Scenario 1 – Old Siphon 33% blockage (Base)		Scenario 4 – Old Siphon 33% blockage (High Water Level)	
		Elevation (m)	Elevation (m)	Change (m)	Elevation (m)	Change (m)
Harrison Road	234.6	191.66	191.71	*0.05*	191.71	*0.05*
Reg Rd 56	3021.8	190.19	190.17	*-0.02*	190.17	*-0.02*
Trimble Rd	6938.7	188.30	188.31	*0.01*	188.31	*0.01*
Hall Rd	12979.9	185.96	185.99	*0.03*	185.99	*0.03*
Private Road	13034.9	185.96	185.23	*-0.73*	185.23	*-0.73*
Woodburn Road	14077.6	185.93	184.84	*-1.09*	184.84	*-1.09*
Sinclairville Rd	19561.8	184.30	183.84	*-0.46*	183.84	*-0.46*
Westbrook Road	22690.3	183.95	183.32	*-0.63*	183.32	*-0.63*
Caistorville Road	28418.2	182.48	182.24	*-0.24*	182.24	*-0.24*
Abingdon Road	33038.9	180.66	180.52	*-0.14*	180.52	*-0.14*
Nchippawa Road	37100.9	179.01	178.67	*-0.34*	178.67	*-0.34*
Caistor Centre Rd	38209.6	178.49	177.81	*-0.68*	177.82	*-0.67*
Smithville Road	39200.6	178.15	177.19	*-0.96*	177.20	*-0.95*
Church Rd	43100.8	176.27	176.02	*-0.25*	176.03	*-0.24*
SChippawa Rd	50193.2	175.85	175.67	*-0.18*	175.69	*-0.16*
CaistorGainsborough TL	52164	175.70	175.60	*-0.10*	175.61	*-0.09*
Canborough Rd	55881.5	175.50	175.46	*-0.04*	175.48	*-0.02*
Rail 04	56463.7	175.50	175.40	*-0.10*	175.43	*-0.07*
Wellandport Road	67153.3	175.39	175.21	*-0.18*	175.25	*-0.14*
Boyle Rd	77477.6	175.25	174.99	*-0.26*	175.03	*-0.22*
Victoria Ave	81847.4	175.03	174.87	*-0.16*	174.93	*-0.10*
Rail 03	84199	174.92	174.67	*-0.25*	174.74	*-0.18*
Oreillys Rd	88158.7	174.81	174.50	*-0.31*	174.57	*-0.24*
Webber Rd	93529.1	174.32	174.28	*-0.04*	174.37	*0.05*
Prince Charles Dr	94962	174.28	174.11	*-0.17*	174.21	*-0.07*
Niagara St	95586.9	174.14	174.07	*-0.07*	174.17	*0.03*
Old siphon	95909.6	174.01	174.00	*-0.01*	174.10	*0.09*
Woodlawn Rd	98485.6	173.50	172.95	*-0.55*	173.07	*-0.43*
Hwy 406	100277.2	173.31	172.80	*-0.51*	172.93	*-0.38*
Rail 02	100434.7	173.31	172.77	*-0.54*	172.91	*-0.40*
New siphon	101450.4	173.26	172.65	*-0.61*	172.79	*-0.47*
Rail 01	102025.8	173.14	172.39	*-0.75*	172.54	*-0.60*
Moyer Rd	104918.1	172.89	172.10	*-0.79*	172.29	*-0.60*
Montrose Rd	110756.4	171.90	171.18	*-0.72*	171.58	*-0.32*
QEW	110858.9	171.90	171.18	*-0.72*	171.65	*-0.25*
Rail05 (Michigan Central Railway)	112.1	171.90	171.16	*-0.74*	171.57	*-0.33*
Rail05DS (Michigan Central Railway)	7438.6	171.60	171.22	*-0.38*	171.70	*0.10*
Stanley Ave	4385.8	171.62	171.16	*-0.46*	171.56	*-0.06*
Portage Rd	1332.2	171.90	171.16	*-0.74*	171.60	*-0.30*
Grassy Island Pool		171.70	171.16	*-0.54*	171.61	*-0.09*

4 Floodplain Mapping

As previously described, this study adopts the Grassy Island Pool Average Water Level resulted from Scenario 1 as a comparator to illustrate the sensitivity of the Welland River flood elevations to various events. With respect to map the Regulatory Flood Hazard, the NPCA prefers to take the approach of utilizing the Grassy Island Pool Maximum Water Level. The Authority further notifies that the same methodology was undertaken in Dillon's 1985 Welland River Floodplain Mapping Study.

The floodplain maps for the Welland River are produced in accordance with NPCA's mapping requirements and are included in **Appendix E**.

5 Bibliography

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APPENDIX

A Figures

Figure 1
Welland River Hydraulic Model
Reaches Limits and Data Source

0 1 2 3 4 5
kilometres
1:90,000

Date: March 2018

Project No: 3815516

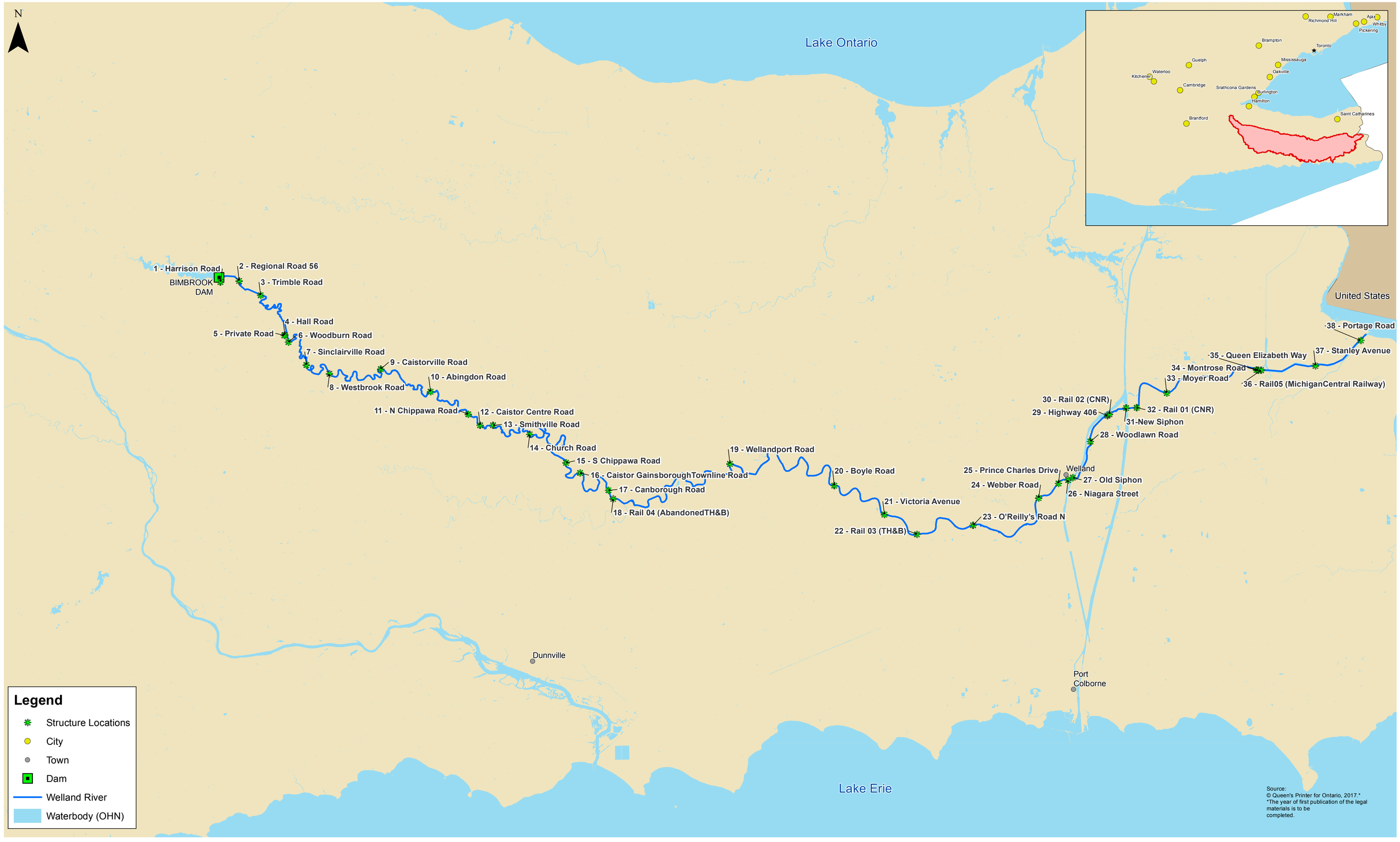


Figure 2
Welland River Hydraulic Model
Hydraulic Structure Locations

0 1 2 3 4 5
kilometres
1:90,000

Date: August 2017

Project No: 3815516

Old Siphon Location

Old Siphon – Upstream face

Figure 3: Old Siphon

New Siphon location

New Siphon – Downstream face

Figure 4: New Siphon Photos

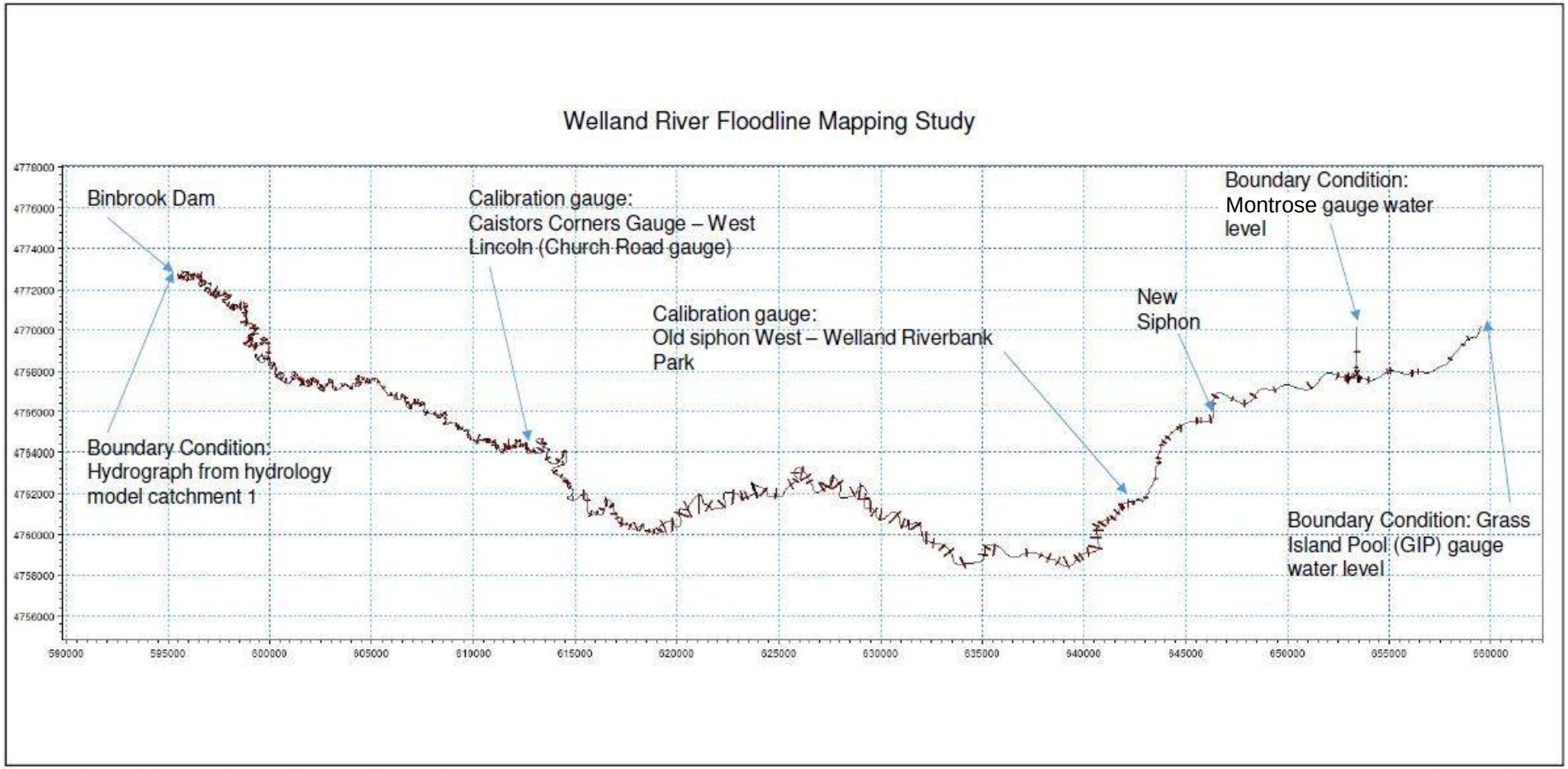


Figure 5 – Welland River Mike 11 Model Network

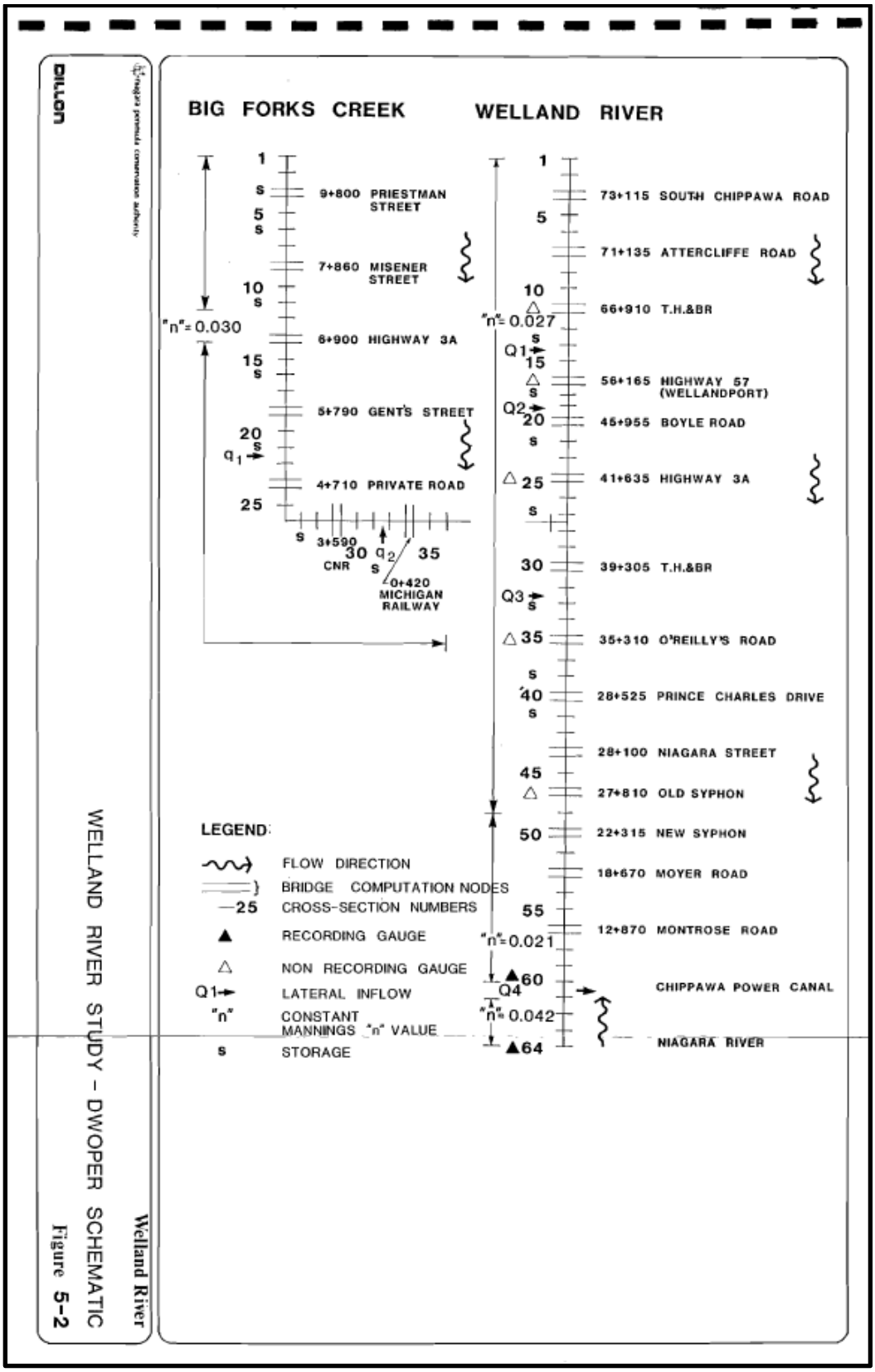


Figure 6 – Welland River Study – DWOPER Flow Schematic (Dillion 1985)

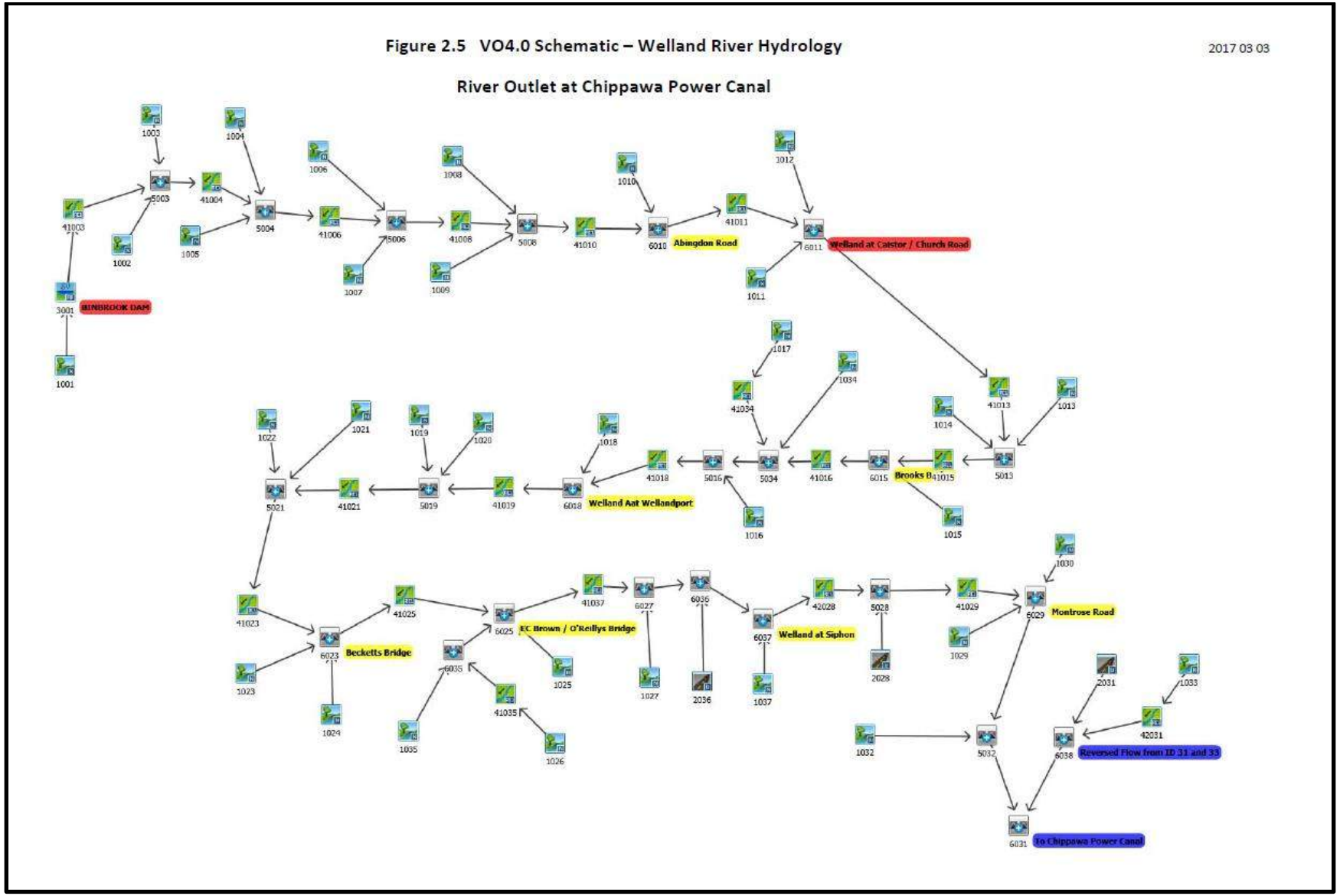


Figure 7 – Welland River Hydrology Study – Visual Otthymo 4.0 Flow Schematic (WSP 2017)

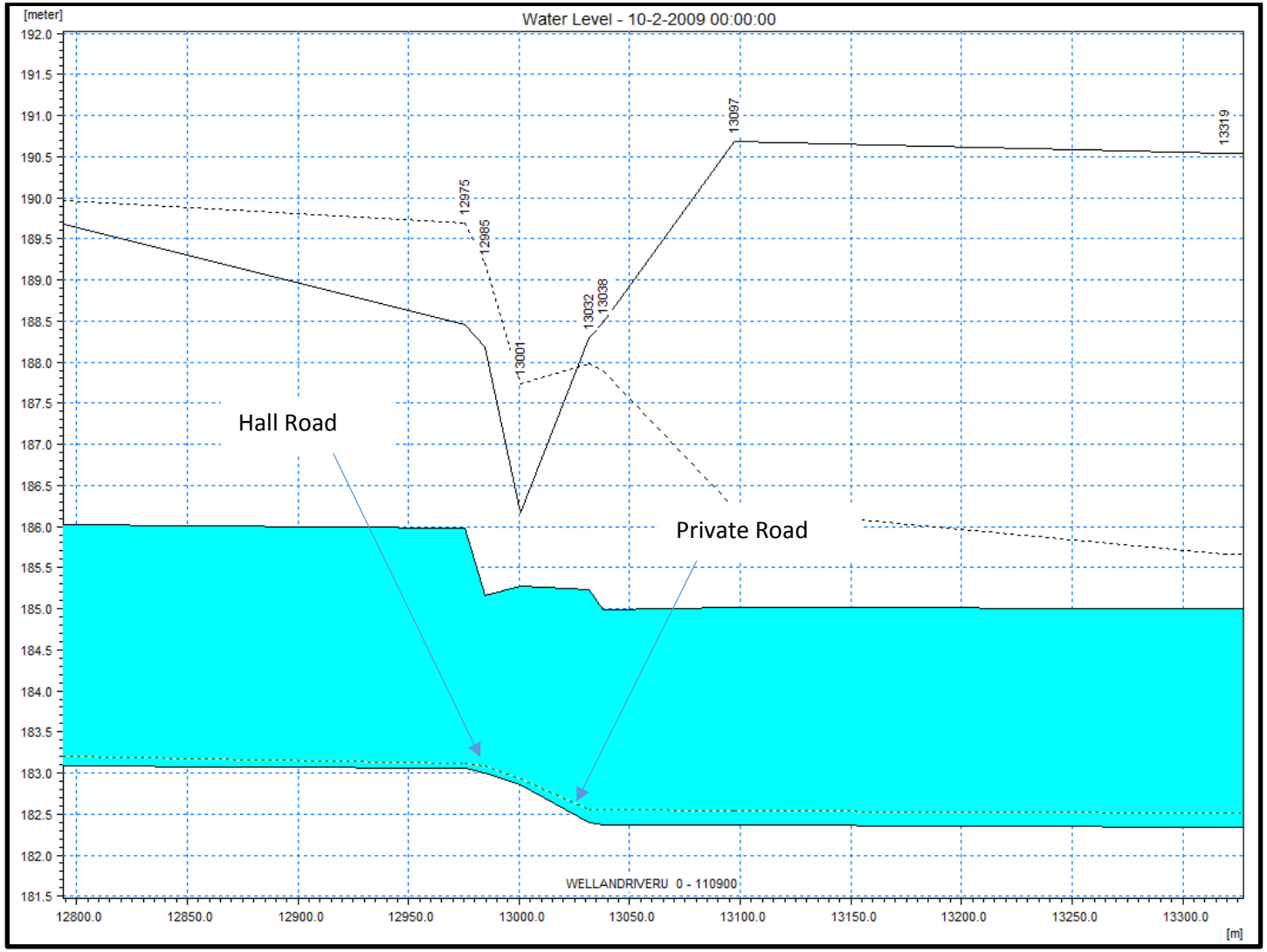


Figure 8 – Profile Plot of Mike 11 model at Hall Road and Private Road.

(The private road is only 55m downstream of Hall Road, but the floodplain elevation drop significantly due to the channel bed elevation dropped)

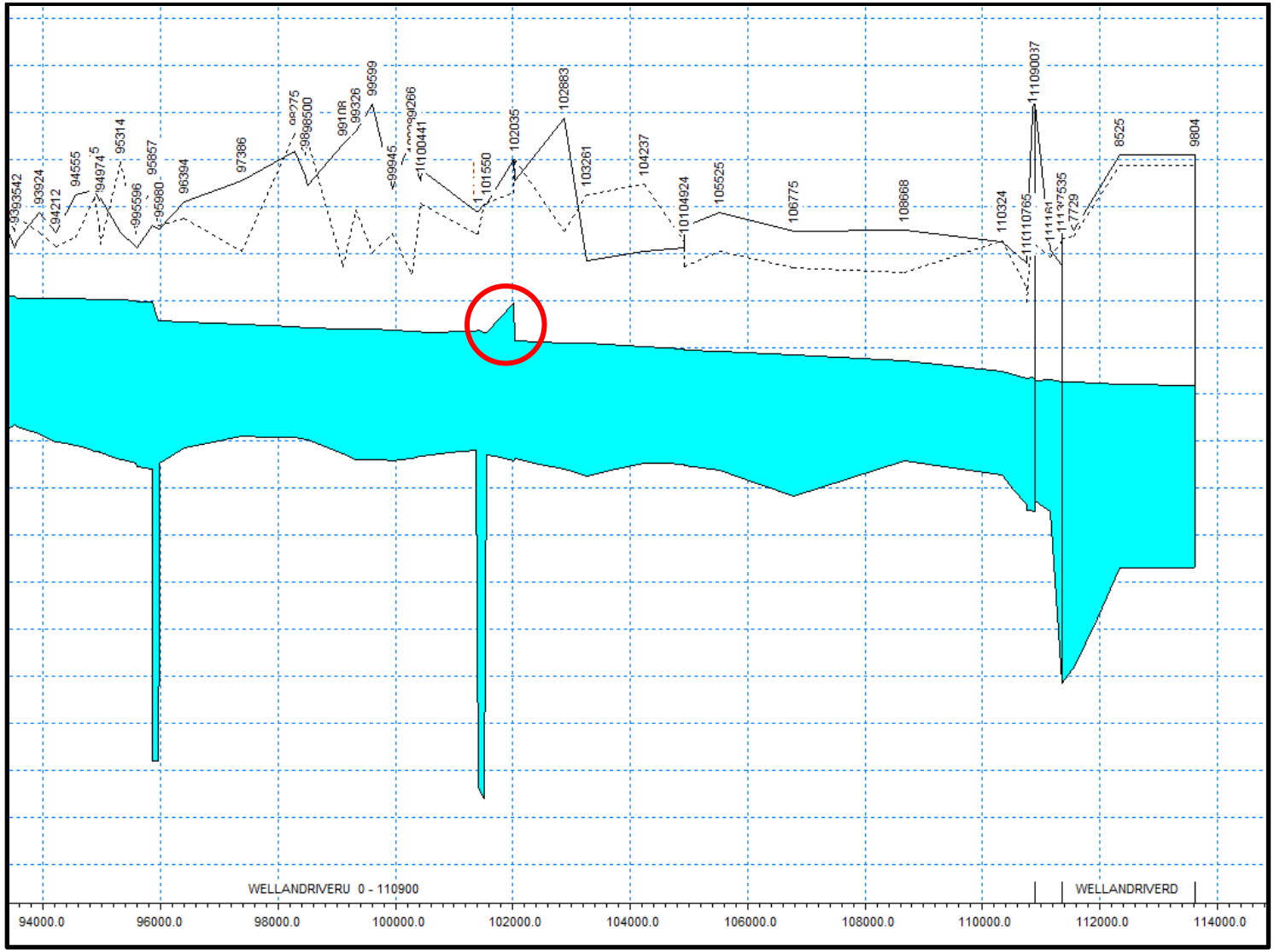


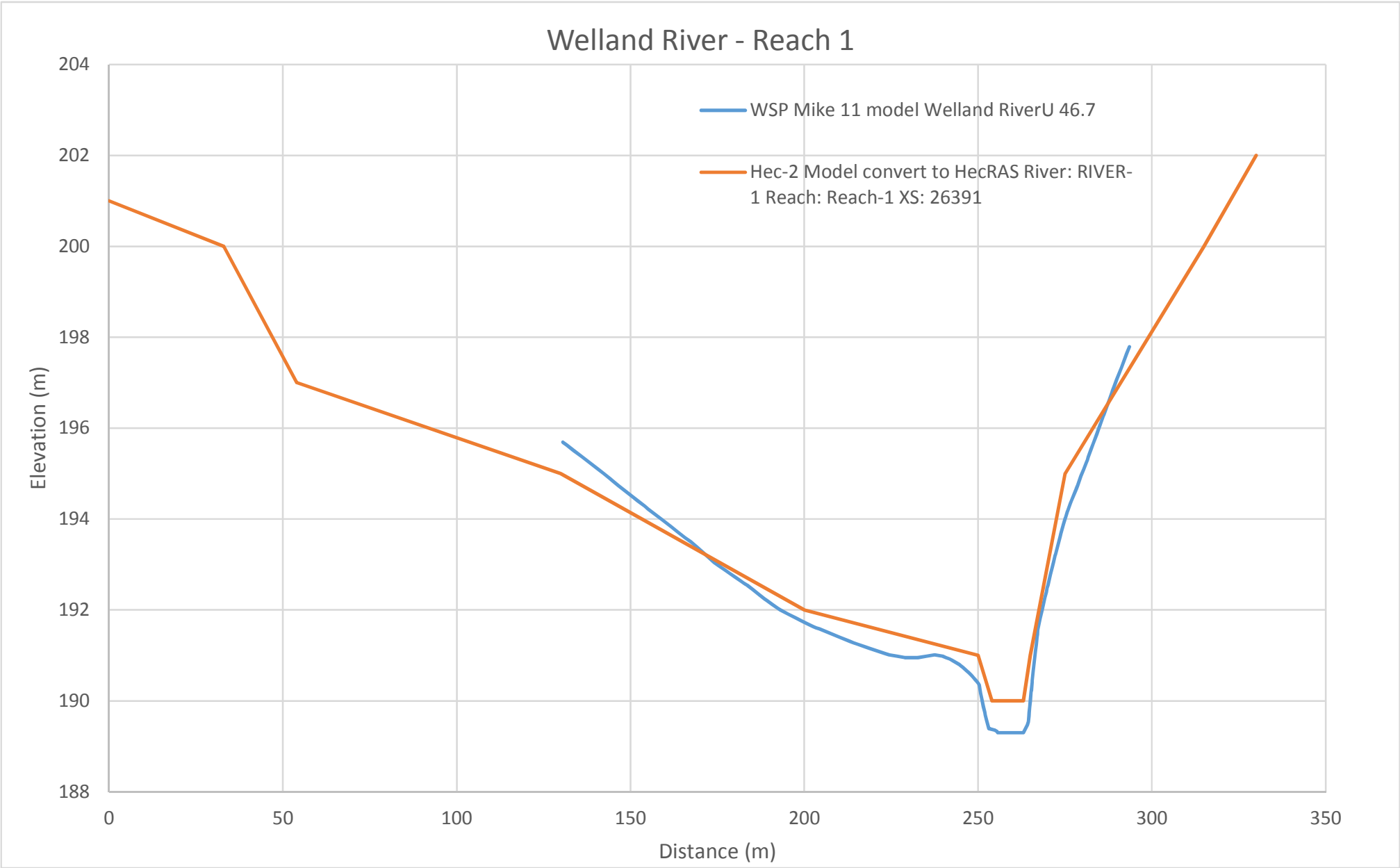
Figure 9 – Profile Plot of Mike 11 model at Rail 01 for Scenario 5.

For Scenario 5, the Rail 01 floodplain elevation is higher than New Siphon (which located at the upstream of Rail 01) due to the hydraulic jump. This hydraulic jump only occurs at Scenario 5. There are no hydraulic jump in other Scenarios.

APPENDIX

B

Cross Sections Comparison with Previous Studies


Welland River - Reach 1
WSP Mike 11 model Welland RiverU 46.7
Hec-2 Model convert to HecRAS River: RIVER-1 Reach: Reach-1 XS: 26391
Elevation (m)
Distance (m)
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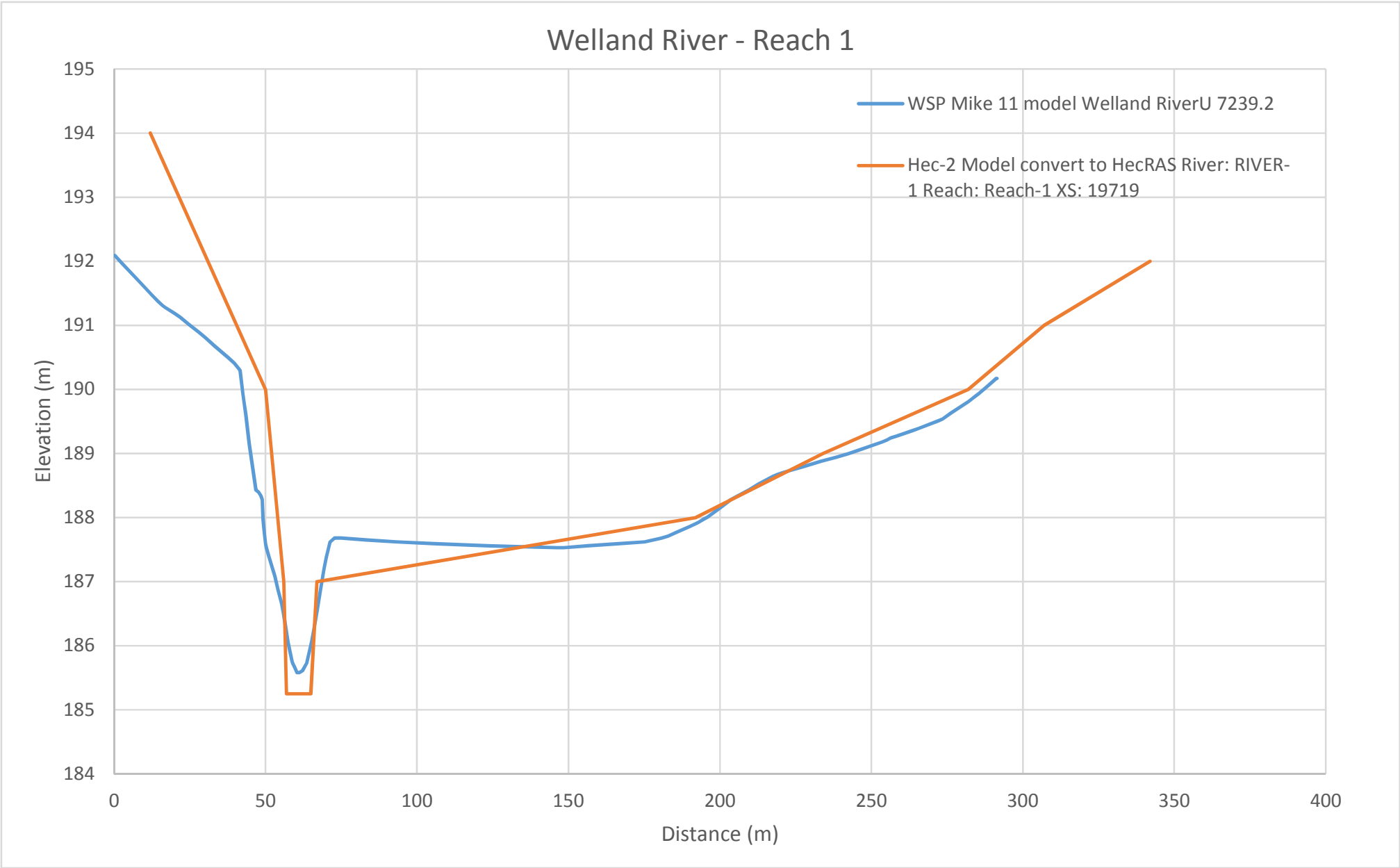
202
200
198
196
194
192
190
188
0
50
100
150
200
250
300
350


Welland River - Reach 1
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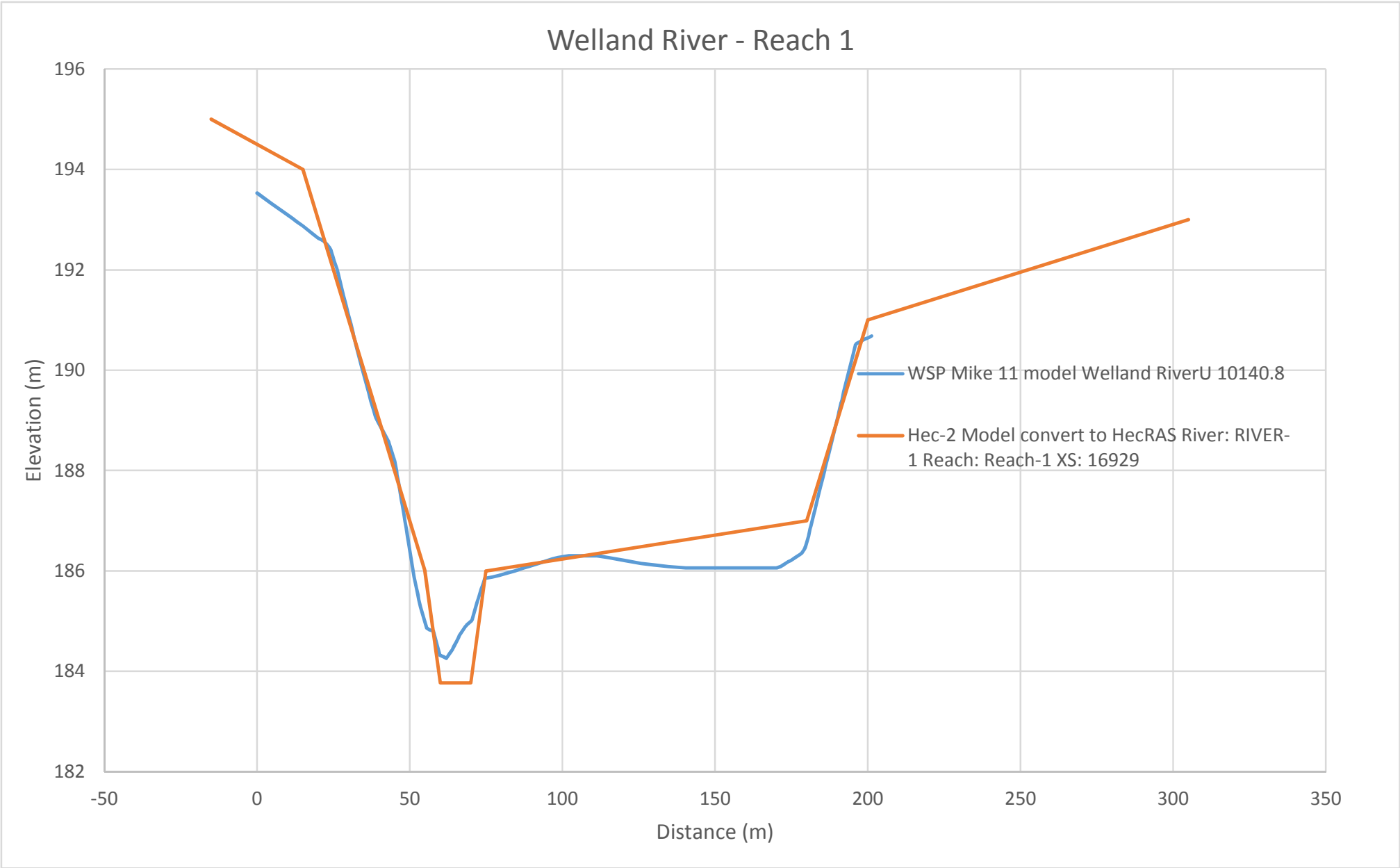
Hec-2 Model convert to HecRAS River: RIVER-1 Reach: Reach-1 XS: 19719
Elevation (m)
195
194
193
192
191
190
189
188
187
186
185
184
0
50
100
150
200
250
300
350
400
Distance (m)


Welland River - Reach 1
196
194
192
190
188
186
184
182
Elevation (m)
-50
0
50
100
150
200
250
300
350
Distance (m)
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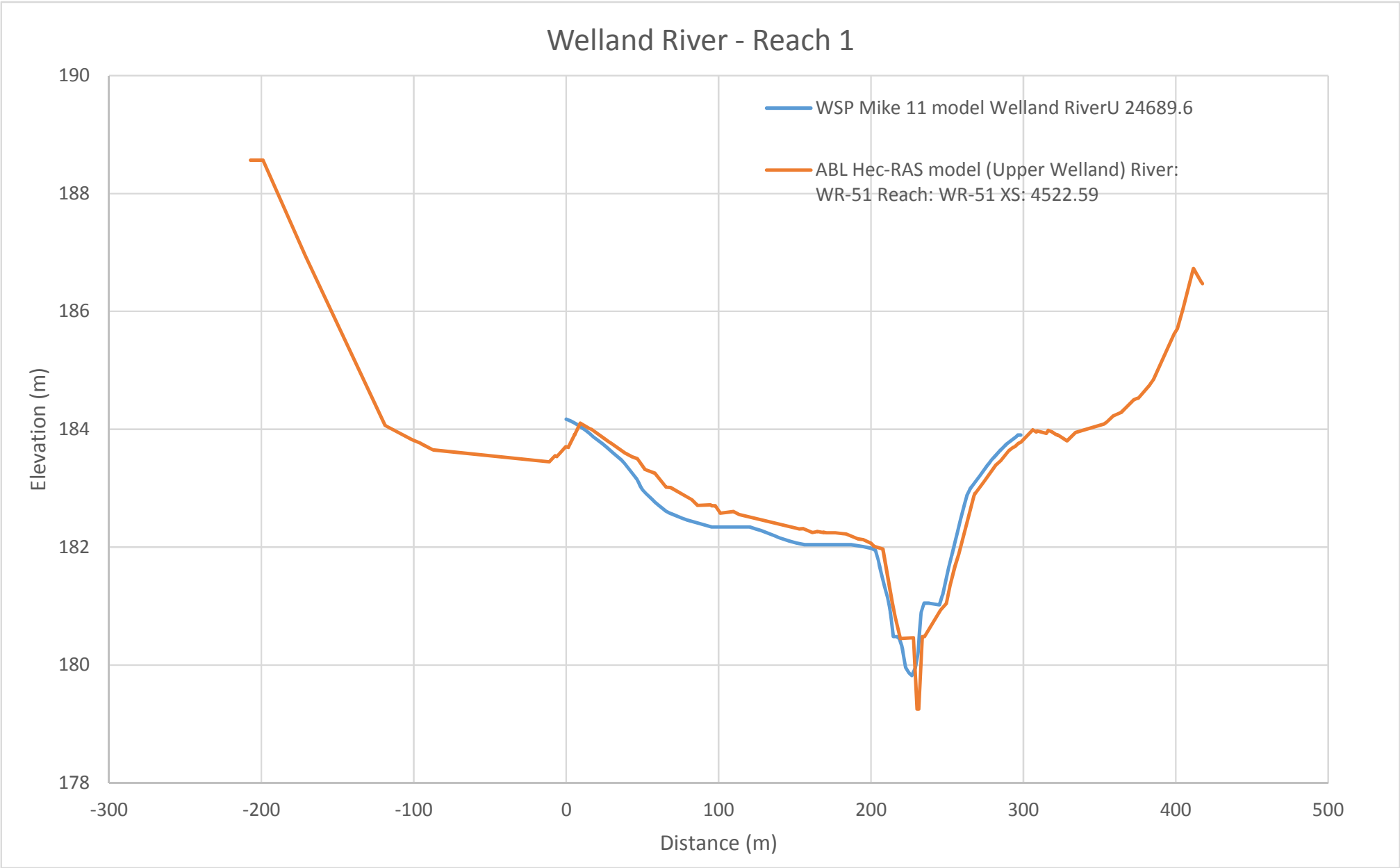
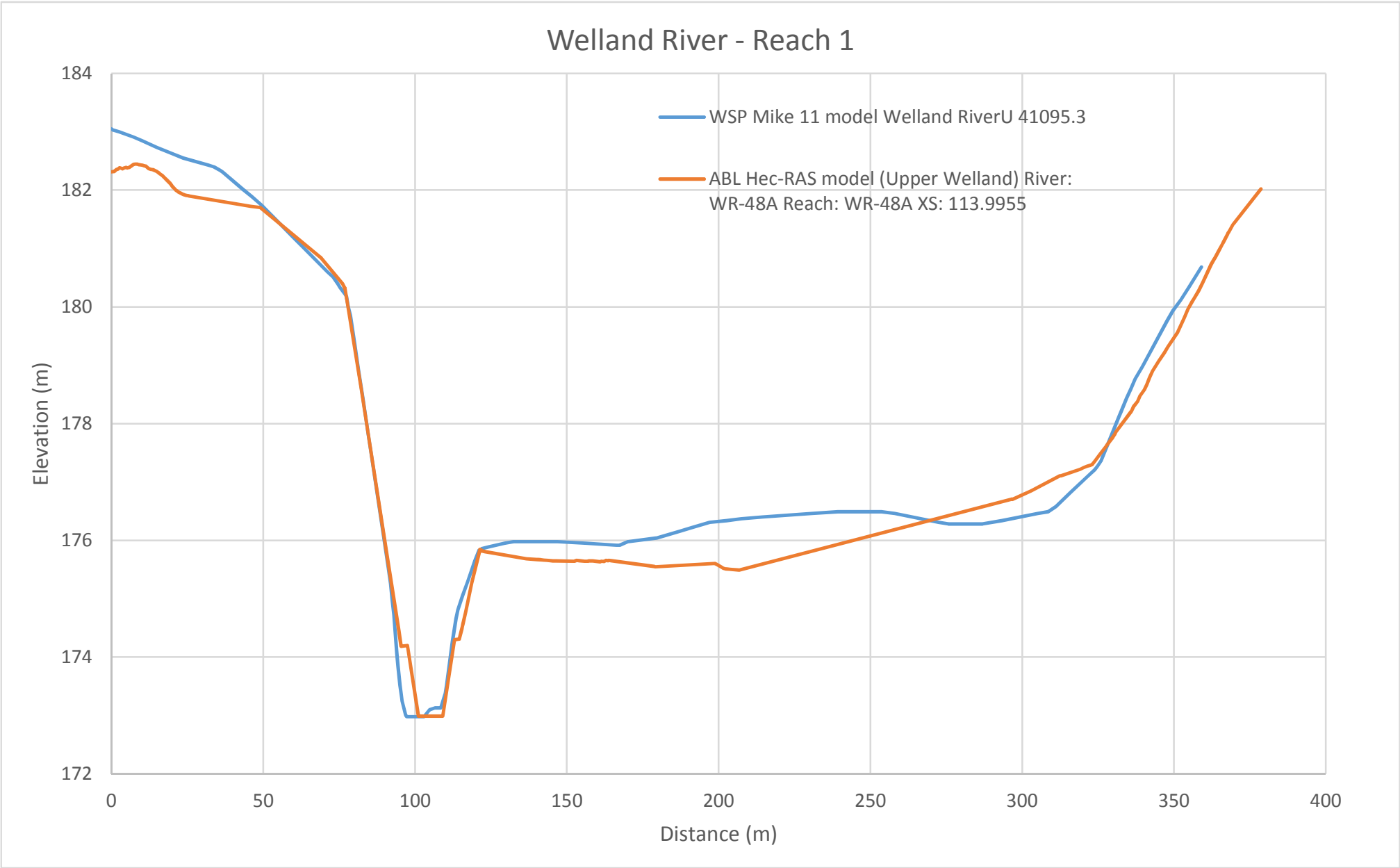

Welland River - Reach 1
WSP Mike 11 model Welland RiverU 24689.6
ABL Hec-RAS model (Upper Welland) River: WR-51 Reach: WR-51 XS: 4522.59
Elevation (m)
190
188
186
184
182
180
178
-300
-200
-100
0
100
200
300
400
500
Distance (m)


Welland River - Reach 1
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ABL Hec-RAS model (Upper Welland) River: WR-48A Reach: WR-48A XS: 113.9955
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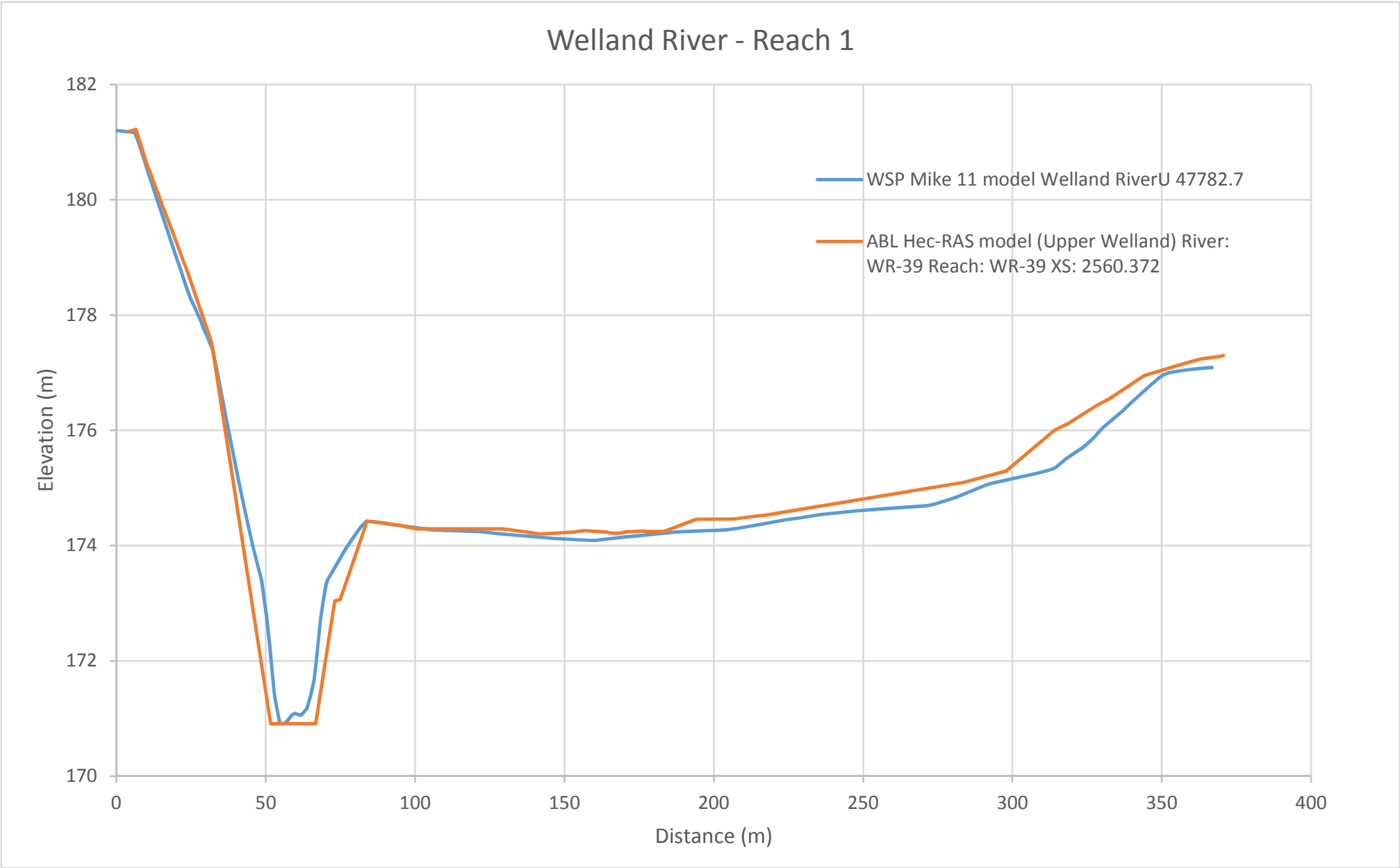
180
178
176
174
172
0
50
100
150
200
250
300
350
400
Distance (m)


Welland River - Reach 1
182
180
178
176
174
172
170
Elevation (m)
0
50
100
150
200
250
300
350
400
Distance (m)
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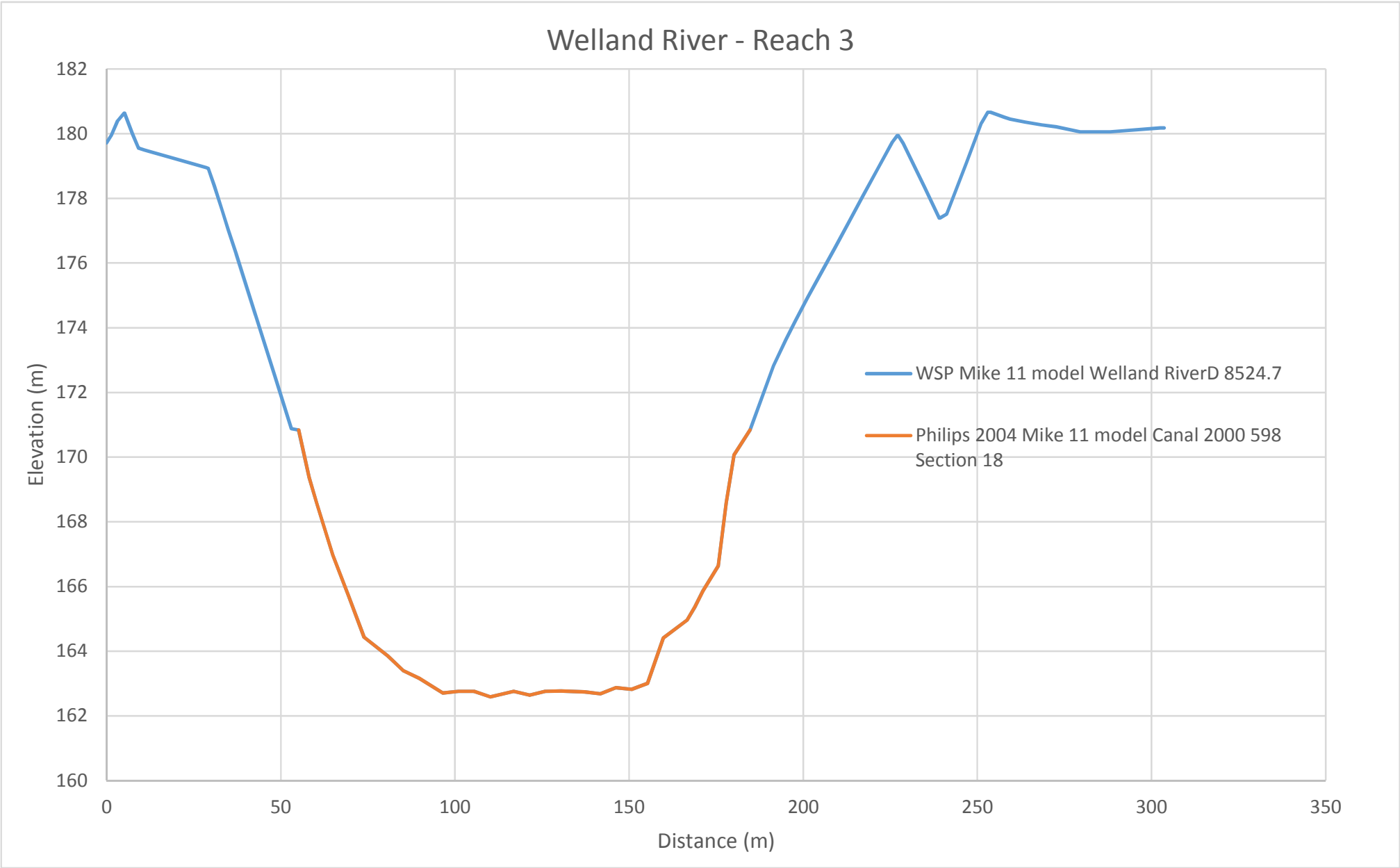
Welland River - Reach 3
Elevation (m)
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176
174
172
170
168
166
164
162
160
0
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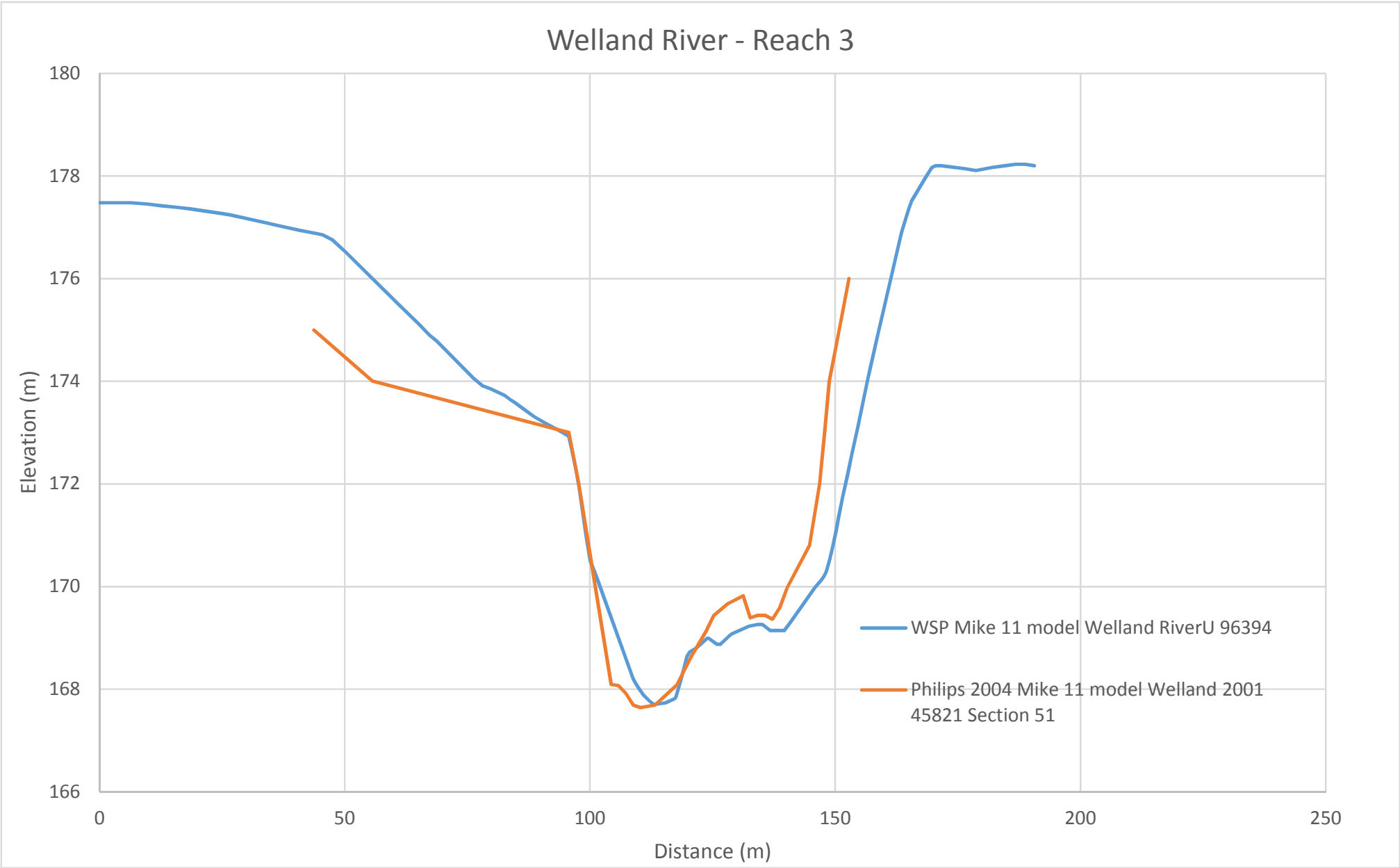
100
150
200
250
300
350
Distance (m)
WSP Mike 11 model Welland RiverD 8524.7
Philips 2004 Mike 11 model Canal 2000 598 Section 18


Welland River - Reach 3
180
178
176
174
172
170
168
166
Elevation (m)
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50
100
150
200
250
Distance (m)
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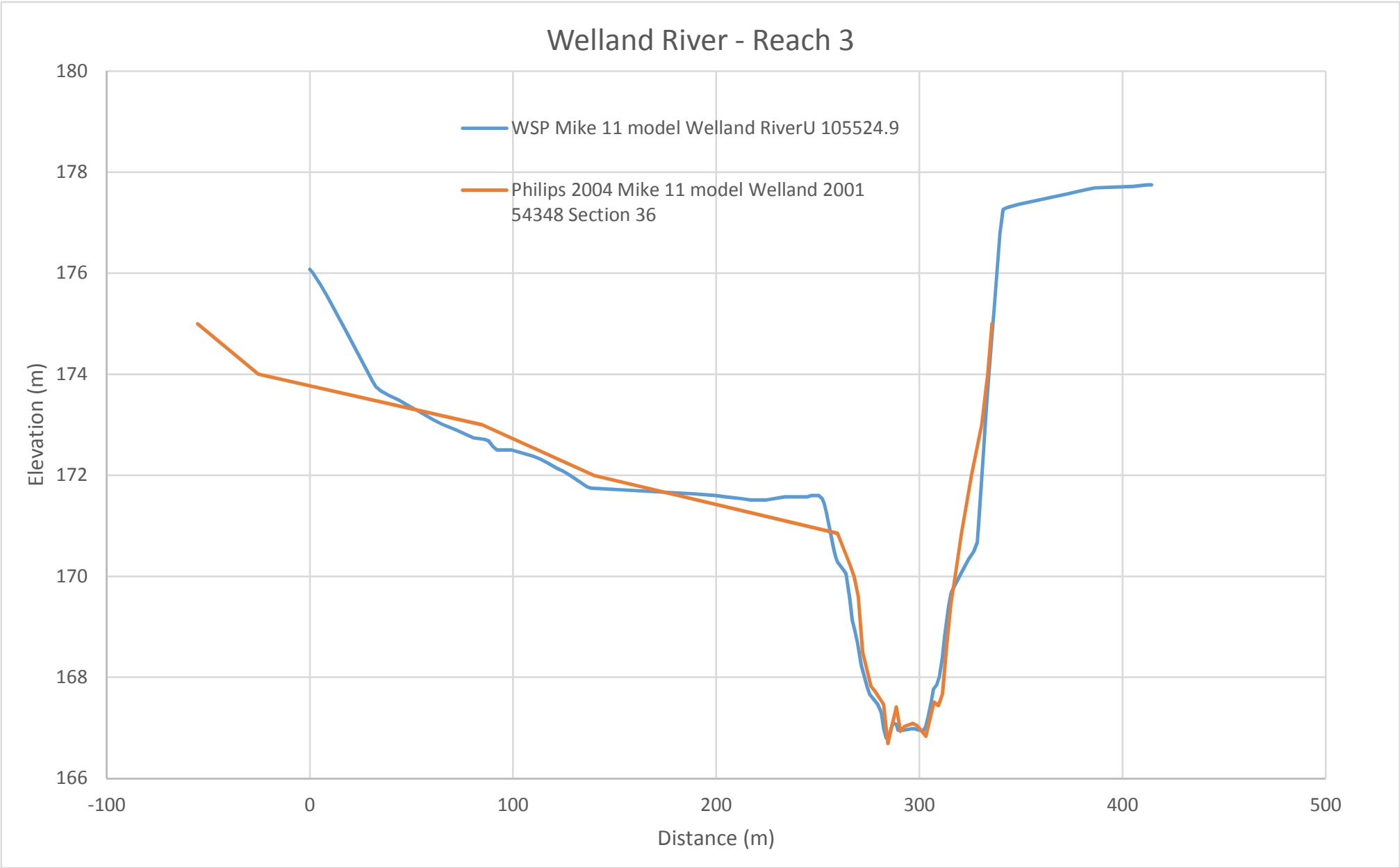

Welland River - Reach 3
WSP Mike 11 model Welland RiverU 105524.9
Philips 2004 Mike 11 model Welland 2001 54348 Section 36
Elevation (m)
180
178
176
174
172
170
168
166
-100
0
100
200
300
400
500
Distance (m)

APPENDIX

C

Hydraulic Structures - Field Invetigation

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**1 - Harrison Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Harrison Road	**Watershed Name:**	Welland River
Nearest Town:	Binbrook, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Culvert**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 5'57.92"N	
Longitude:	79°49'33.88"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	234.60 (WellandRiverU)		
Crossing Width:	9.35m		
Shape:	Arch		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	9.35		
Rise (m):	5.21		

	Elevation (m)
Road deck:	195.78
Soffit:	194.68
Upstream Invert:	189.27
Downstream Invert:	189.81

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**2 - Regional Road 56**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Regional Road 56	**Watershed Name:**	Welland River
Nearest Town:	Binbrook, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 5'59.12"N
Longitude:	79°48'48.15"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	3021.80 (WellandRiverU)		
Crossing Width:	16.0m		
Shape:	Rectangular		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	16.0		
Rise (m):	3.22		

	Elevation (m)
Road deck:	193.19
Soffit:	190.81
Upstream Invert:	187.59
Downstream Invert:	187.59

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**3 - Trimble Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Trimble Road	**Watershed Name:**	Welland River
Nearest Town:	Binbrook, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 5'32.98"N	
Longitude:	79°47'56.28"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	6938.70 (WellandRiverU)		
Crossing Width:	8.0m		
Shape:	Arched Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	8.0		
Rise (m):	2.16		

	Elevation (m)
Road deck:	189.42
Soffit:	187.89
Upstream Invert:	185.73
Downstream Invert:	185.73

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**4 - Hall Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Hall Road	**Watershed Name:**	Welland River
Nearest Town:	Binbrook, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 4'21.40"N	
Longitude:	79°46'58.39"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	12979.90 (WellandRiverU)		
Crossing Width:	8.2m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	14.0		
Rise (m):	2.96		

	Elevation (m)
Road deck:	188.40
Soffit:	186.02
Upstream Invert:	183.06
Downstream Invert:	183.00

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**5 - Private Road**	**Major Watercourse:**	Welland River
Crossing Type:	Private Road	**Minor Watercourse:**	--
Nearest Road:	Hall Road	**Watershed Name:**	Welland River
Nearest Town:	Binbrook, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 4'20.15"N	
Longitude:	79°46'59.55"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	13034.90 (WellandRiverU)		
Crossing Width:	5.1m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	9.2		
Rise (m):	3.12		

	Elevation (m)
Road deck:	186.37
Soffit:	185.52
Upstream Invert:	182.40
Downstream Invert:	182.37

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**6 - Woodburn Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Woodburn Road	**Watershed Name:**	Welland River
Nearest Town:	Caistorville, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 4'8.17"N
Longitude:	79°46'49.46"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	14077.60 (WellandRiverU)		
Crossing Width:	9.6m		
Shape:	Arched Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	15.25		
Rise (m):	4.1		

	Elevation (m)
Road deck:	188.33
Soffit:	186.32
Upstream Invert:	182.22
Downstream Invert:	182.22

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**7 - Sinclairville Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Sinclairville Road	**Watershed Name:**	Welland River
Nearest Town:	Caistorville, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 3'26.82"N
Longitude:	79°46'6.56"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	19561.80 (WellandRiverU)		
Crossing Width:	9.35m		
Shape:	Flat Soffit		
Material:	Steel		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	27.6		
Rise (m):	4.47		

	Elevation (m)
Road deck:	187.21
Soffit:	184.89
Upstream Invert:	180.42
Downstream Invert:	180.69

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**8 - Westbrook Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Westbrook Road	**Watershed Name:**	Welland River
Nearest Town:	Caistorville, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 3'10.23"N	
Longitude:	79°45'10.46"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	22690.30 (WellandRiverU)		
Crossing Width:	7.8m		
Shape:	Arched Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	12.8		
Rise (m):	4.01		

	Elevation (m)
Road deck:	186.35
Soffit:	184.30
Upstream Invert:	180.29
Downstream Invert:	180.27

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**9 - Caistorville Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Caistorville Road	**Watershed Name:**	Welland River
Nearest Town:	Caistorville, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 3'17.62"N	
Longitude:	79°43'5.11"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	28418.20 (WellandRiverU)		
Crossing Width:	15.25m		
Shape:	Arched Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	15.25		
Rise (m):	3.80		

	Elevation (m)
Road deck:	184.89
Soffit:	182.87
Upstream Invert:	179.07
Downstream Invert:	179.07

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**10 - Abingdon Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Abingdon Road	**Watershed Name:**	Welland River
Nearest Town:	Caistorville, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 2'35.35"N
Longitude:	79°41'4.23"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	33038.90 (WellandRiverU)		
Crossing Width:	7.5m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	18.9		
Rise (m):	4.04		

	Elevation (m)
Road deck:	183.58
Soffit:	181.22
Upstream Invert:	177.18
Downstream Invert:	177.18

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**11 - N Chippawa Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	N Chippawa Road	**Watershed Name:**	Welland River
Nearest Town:	Caistor Centre, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 1'54.21"N	
Longitude:	79°39'32.54"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	37100.90 (WellandRiverU)		
Crossing Width:	6.5m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	18.84		
Rise (m):	4.9		

	Elevation (m)
Road deck:	182.99
Soffit:	180.58
Upstream Invert:	175.68
Downstream Invert:	175.68

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**12 - Caistor Centre Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Caistor Centre Road	**Watershed Name:**	Welland River
Nearest Town:	Caistor Centre, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 1'34.00"N	
Longitude:	79°39'4.16"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	38209.60 (WellandRiverU)		
Crossing Width:	9m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	21.4		
Rise (m):	5.93		

	Elevation (m)
Road deck:	183.69
Soffit:	180.98
Upstream Invert:	175.05
Downstream Invert:	175.05

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**13 - Smithville Road**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Smithville Road	**Watershed Name:**	Welland River
Nearest Town:	Caistor Centre, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 1'33.38"N	
Longitude:	79°38'32.22"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	39200.60 (WellandRiverU)		
Crossing Width:	8.75m		
Shape:	Arched Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	18.3		
Rise (m):	3.32		

	Elevation (m)
Road deck:	179.98
Soffit:	177.83
Upstream Invert:	174.51
Downstream Invert:	174.51

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**14 - Church Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Church Road	**Watershed Name:**	Welland River
Nearest Town:	Caistor Centre, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 1'16.22"N
Longitude:	79°37'3.48"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	43100.80 (WellandRiverU)		
Crossing Width:	8.0m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	44.72		
Rise (m):	4.72		

	Elevation (m)
Road deck:	178.52
Soffit:	176.11
Upstream Invert:	171.39
Downstream Invert:	171.39

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**15 - S Chippawa Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	S Chippawa Road	**Watershed Name:**	Welland River
Nearest Town:	Wellandport, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 0'24.03"N	
Longitude:	79°35'35.63"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	50193.20 (WellandRiverU)		
Crossing Width:	7.5m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	32.76		
Rise (m):	5.41		

	Elevation (m)
Road deck:	178.77
Soffit:	176.05
Upstream Invert:	170.64
Downstream Invert:	170.64

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**16 - Caistor Gainsborough Townline Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Caistor Gainsborough TLine	**Watershed Name:**	Welland River
Nearest Town:	Wellandport, ON	**Tertiary Watershed:**	
Inspection Date:	October 5, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 0'5.43"N	
Longitude:	79°35'1.66"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	52164.00 (WellandRiverU)		
Crossing Width:	9.8m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	48.6		
Rise (m):	4.16		

	Elevation (m)
Road deck:	177.33
Soffit:	174.68
Upstream Invert:	170.52
Downstream Invert:	170.55

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**17 - Canborough Road**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Canborough Road	**Watershed Name:**	Welland River
Nearest Town:	Wellandport, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	42°59'33.51"N	
Longitude:	79°33'52.85"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	55881.50 (WellandRiverU)		
Crossing Width:	11.66m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	45.58		
Rise (m):	5.27		

	Elevation (m)
Road deck:	177.79
Soffit:	175.55
Upstream Invert:	170.28
Downstream Invert:	170.13

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**18 - Rail 04 (Abandoned TH&B)**	**Major Watercourse:**	Welland River
Crossing Type:	Railway	**Minor Watercourse:**	--
Nearest Road:	Canborough Road	**Watershed Name:**	Welland River
Nearest Town:	Wellandport, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	42°59'17.84"N
Longitude:	79°33'41.80"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	56463.70 (WellandRiverU)		
Crossing Width:	2.5m		
Shape:	Flat Soffit		
Material:	Wood		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	46.4		
Rise (m):	7.23		

	Elevation (m)
Road deck:	177.89
Soffit:	177.30
Upstream Invert:	170.07
Downstream Invert:	169.50

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**19 - Wellandport Road**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Wellandport Road	**Watershed Name:**	Welland River
Nearest Town:	Wellandport, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 0'16.87"N
Longitude:	79°28'54.95"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	67153.30 (WellandRiverU)		
Crossing Width:	11.6m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	50.7		
Rise (m):	6.45		

	Elevation (m)
Road deck:	177.21
Soffit:	175.23
Upstream Invert:	168.78
Downstream Invert:	168.81

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**20 - Boyle Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Boyle Road	**Watershed Name:**	Welland River
Nearest Town:	Wellandport, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	42°59'34.60"N
Longitude:	79°24'40.91"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	77477.60 (WellandRiverU)		
Crossing Width:	10.5m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	52.8		
Rise (m):	6.45		

	Elevation (m)
Road deck:	177.61
Soffit:	174.66
Upstream Invert:	168.21
Downstream Invert:	168.18

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**21 - Victoria Avenue**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Victoria Avenue	**Watershed Name:**	Welland River
Nearest Town:	Wellandport, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	42°58'41.05"N
Longitude:	79°22'39.92"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	81847.40 (WellandRiverU)		
Crossing Width:	12.7m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	50.5		
Rise (m):	6.12		

	Elevation (m)
Road deck:	177.78
Soffit:	175.41
Upstream Invert:	169.29
Downstream Invert:	168.87

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**22 - Rail 03 (TH&B)**	**Major Watercourse:**	Welland River
Crossing Type:	Railway	**Minor Watercourse:**	--
Nearest Road:	Regional Rd 27 / Hewitt Rd	**Watershed Name:**	Welland River
Nearest Town:	Welland, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	42°58'4.39"N	
Longitude:	79°21'21.51"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	84199.00 (WellandRiverU)		
Crossing Width:	4.5m		
Shape:	Flat Soffit		
Material:	Steel		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	137		
Rise (m):	6.79		

	Elevation (m)
Road deck:	177.27
Soffit:	174.46
Upstream Invert:	167.67
Downstream Invert:	167.67

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**23 - O'Reilly's Road N**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	O'Reilly's Road N	**Watershed Name:**	Welland River
Nearest Town:	Welland, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	42°58'18.80"N
Longitude:	79°19'3.85"W
Image Date:	2016
Image Elev:	

Key Map:

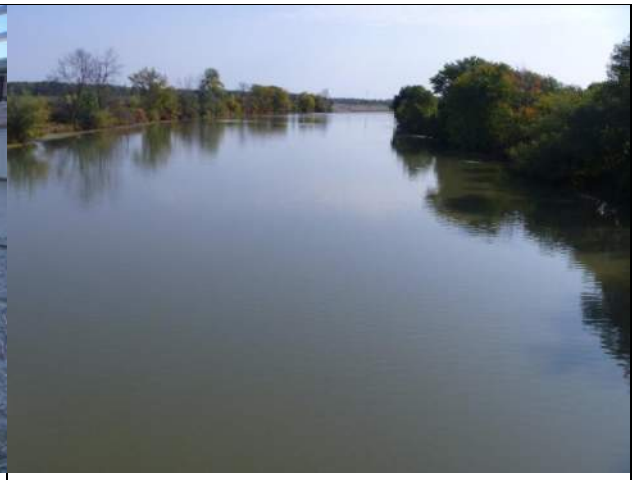
© Google Earth

Survey:	
BM No.:	
BM Elev. (m)	

MIKE 11 Chainage:	88158.70 (WellandRiverU)		
Crossing Width:	4.65m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	38.5		
Rise (m):	6.74		

	Elevation (m)
Road deck:	176.18
Soffit:	174.56
Upstream Invert:	167.82
Downstream Invert:	167.70

Upstream Photo



Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**24 - Webber Road**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Webber Road	**Watershed Name:**	Welland River
Nearest Town:	Welland, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	42°59'5.17"N
Longitude:	79°16'22.49"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	93529.10 (WellandRiverU)		
Crossing Width:	11.5m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	72.66		
Rise (m):	7.06		

	Elevation (m)
Road deck:	178.36
Soffit:	175.78
Upstream Invert:	168.72
Downstream Invert:	168.63

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**25 - Prince Charles Drive**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Prince Charles Drive	**Watershed Name:**	Welland River
Nearest Town:	Welland, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	42°59'30.57"N	
Longitude:	79°15'33.72"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	94962.0 (WellandRiverU)		
Crossing Width:	17.0m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	70.86		
Rise (m):	7.1		

	Elevation (m)
Road deck:	177.85
Soffit:	174.65
Upstream Invert:	167.55
Downstream Invert:	166.89

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**26 - Niagara Street**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Niagara Street	**Watershed Name:**	Welland River
Nearest Town:	Welland, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	42°59'36.25"N
Longitude:	79°15'9.69"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	95586.9 (WellandRiverU)		
Crossing Width:	18m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	57.4		
Rise (m):	5.39		

	Elevation (m)
Road deck:	175.99
Soffit:	173.39
Upstream Invert:	167.09
Downstream Invert:	166.90

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**27 - Old Siphon**	**Major Watercourse:**	Welland River
Crossing Type:	Siphon under Canal	**Minor Watercourse:**	--
Nearest Road:	Court House Lane	**Watershed Name:**	Welland River
Nearest Town:	Welland, ON	**Tertiary Watershed:**	
Inspection Date:	n/a	**Crew:**	R.K./K.M.

Crossing Type:	**Siphon (Culvert)**	Bridge / culvert / inline structure

Location:	
Latitude:	42°59'40.31"N
Longitude:	79°14'58.29"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	95909.6 (WellandRiverU)					
Crossing Width:	96					
Shape:	Circular (6 barrels)					
Material:	Concrete					
Footing:	Open, natural substrate					
Barrel Number:	1	2	3	4	5	6
Diameter (m):	6.7	6.7	6.7	6.7	6.7	6.7
Rise (m):	n/a	n/a	n/a	n/a	n/a	n/a

	Elevation (m)
Road deck:	n/a
Soffit:	n/a
Upstream Invert:	154.4
Downstream Invert:	154.4

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**28 - Woodlawn Road**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Woodlawn Road	**Watershed Name:**	Welland River
Nearest Town:	Welland, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 0'44.59"N
Longitude:	79°14'13.34"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	98485.6 (WellandRiverU)		
Crossing Width:	18m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	211.1		
Rise (m):	8.64		

	Elevation (m)
Road deck:	180.27
Soffit:	177.15
Upstream Invert:	168.09
Downstream Invert:	168.09

No photo available.	
Upstream Photo	Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**29 - Highway 406**	**Major Watercourse:**	Welland River
Crossing Type:	Freeway	**Minor Watercourse:**	--
Nearest Road:	Highway 406	**Watershed Name:**	Welland River
Nearest Town:	Welland, ON	**Tertiary Watershed:**	
Inspection Date:	n/a	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 1'30.10"N
Longitude:	79°13'30.28"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	100277.2 (WellandRiverU)		
Crossing Width:	23m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	120		
Rise (m):	10.88		

	Elevation (m)
Road deck:	181.68
Soffit:	178.16
Upstream Invert:	167.28
Downstream Invert:	167.28

No photo available.	No photo available.
Upstream Photo	Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**30 - Rail 02 (CNR)**	**Major Watercourse:**	Welland River
Crossing Type:	Railway	**Minor Watercourse:**	--
Nearest Road:	Highway 406	**Watershed Name:**	Welland River
Nearest Town:	Welland, ON	**Tertiary Watershed:**	
Inspection Date:	n/a	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 1'32.40"N	
Longitude:	79°13'25.51"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	100434.7 (WellandRiverU)		
Crossing Width:	4m		
Shape:	Flat Soffit		
Material:	Steel		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	115		
Rise (m):	11.13		

	Elevation (m)
Road deck:	179.50
Soffit:	178.50
Upstream Invert:	167.37
Downstream Invert:	167.37

No photo available.	No photo available.
Upstream Photo	Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**31-New Siphon**	**Major Watercourse:**	Welland River
Crossing Type:	Siphon under Canal	**Minor Watercourse:**	--
Nearest Road:	River Street	**Watershed Name:**	Welland River
Nearest Town:	Port Robinson, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Siphon (Culvert)**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 1'43.20"N
Longitude:	79°12'44.22"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	101450.4 (WellandRiverU)			
Crossing Width:	106.68			
Shape:	Rectangular (4 barrels)			
Material:	Concrete			
Footing:	Open, natural substrate			
Barrel Number:	1	2	3	4
Span (m):	5.3	5.3	5.3	5.3
Rise (m):	8.0	8.0	8.0	8.0

	Elevation (m)
Road deck:	n/a
Soffit:	n/a
Upstream Invert:	153.31
Downstream Invert:	152.78

No photo available.	
Upstream Photo	Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**32 - Rail 01 (CNR)**	**Major Watercourse:**	Welland River
Crossing Type:	Railway	**Minor Watercourse:**	--
Nearest Road:	Biggar Road	**Watershed Name:**	Welland River
Nearest Town:	Port Robinson, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 1'43.62"N	
Longitude:	79°12'18.82"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	102025.8 (WellandRiverU)		
Crossing Width:	7.3m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	91.44		
Rise (m):	9.82		

	Elevation (m)
Road deck:	179.86
Soffit:	177.01
Upstream Invert:	167.19
Downstream Invert:	167.28

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**33 - Moyer Road**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Moyer Road	**Watershed Name:**	Welland River
Nearest Town:	Port Robinson, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 2'8.55"N	
Longitude:	79°11'4.35"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	104918.1 (WellandRiverU)		
Crossing Width:	10.5m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	240.1		
Rise (m):	8.94		

	Elevation (m)
Road deck:	177.99
Soffit:	175.98
Upstream Invert:	167.04
Downstream Invert:	166.95

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**34 - Montrose Road**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Montrose Road	**Watershed Name:**	Welland River
Nearest Town:	Niagara Falls, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 2'46.37"N
Longitude:	79° 7'23.61"W
Image Date:	2016
Image Elev:	

Key Map:

© Google Earth

Survey:	
BM No.:	
BM Elev. (m)	

MIKE 11 Chainage:	110756.4 (WellandRiverU)		
Crossing Width:	10.6m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	68.0		
Rise (m):	9.64		

	Elevation (m)
Road deck:	177.42
Soffit:	174.94
Upstream Invert:	165.30
Downstream Invert:	165.09

Upstream Photo

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**35 - Queen Elizabeth Way**	**Major Watercourse:**	Welland River
Crossing Type:	Freeway	**Minor Watercourse:**	--
Nearest Road:	Queen Elizabeth Way	**Watershed Name:**	Welland River
Nearest Town:	Niagara Falls, ON	**Tertiary Watershed:**	
Inspection Date:	n/a	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 2'45.97"N
Longitude:	79° 7'19.08"W
Image Date:	2016
Image Elev:	

Key Map:

© Google Earth

Survey:	
BM No.:	
BM Elev. (m)	

MIKE 11 Chainage:	110858.9 (WellandRiverU)		
Crossing Width:	22.4m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	289		
Rise (m):	13.93		

	Elevation (m)
Road deck:	180.11
Soffit:	179.20
Upstream Invert:	165.00
Downstream Invert:	165.00

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**36 - Rail05 (Michigan Central Railway)**	**Major Watercourse:**	Welland River
Crossing Type:	Railway	**Minor Watercourse:**	--
Nearest Road:	Queen Elizabeth Way	**Watershed Name:**	Welland River
Nearest Town:	Niagara Falls, ON	**Tertiary Watershed:**	
Inspection Date:	n/a	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:		**Key Map:**
Latitude:	43° 2'45.58"N	
Longitude:	79° 7'12.32"W	
Image Date:	2016	
Image Elev:		

Survey:	
BM No.:	
BM Elev. (m)	

© Google Earth

MIKE 11 Chainage:	112.1 (WellandRiverM)		
Crossing Width:	7.2m		
Shape:	Flat Soffit		
Material:	Steel		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	70		
Rise (m):	6.45		

	Elevation (m)
Road deck:	176.60
Soffit:	174.60
Upstream Invert:	168.15
Downstream Invert:	168.30

	No photo available.
Upstream Photo	Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**37 - Stanley Avenue**	**Major Watercourse:**	Welland River
Crossing Type:	Regional Road	**Minor Watercourse:**	--
Nearest Road:	Stanley Avenue	**Watershed Name:**	Welland River
Nearest Town:	Chippawa, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 2'51.64"N
Longitude:	79° 4'59.11"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	4385.8 (WellandRiverD)		
Crossing Width:	16.7m		
Shape:	Flat Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	146.7		
Rise (m):	16.91		

	Elevation (m)
Road deck:	178.41
Soffit:	175.58
Upstream Invert:	158.67
Downstream Invert:	158.64

Upstream Photo

No photo available.

Downstream Photo

HYDRAULIC STRUCTURE INVENTORY

Structure ID:	**38 - Portage Road**	**Major Watercourse:**	Welland River
Crossing Type:	Local Road	**Minor Watercourse:**	--
Nearest Road:	Portage Road	**Watershed Name:**	Welland River
Nearest Town:	Chippawa, ON	**Tertiary Watershed:**	
Inspection Date:	October 6, 2016	**Crew:**	R.K./K.M.

Crossing Type:	**Bridge**	Bridge / culvert / inline structure

Location:	
Latitude:	43° 3'34.82"N
Longitude:	79° 3'7.15"W
Image Date:	2016
Image Elev:	

Survey:	
BM No.:	
BM Elev. (m)	

Key Map:

© Google Earth

MIKE 11 Chainage:	1332.2 (WellandRiverD)		
Crossing Width:	18.3m		
Shape:	Trapezoidal Soffit		
Material:	Concrete		
Footing:	Open, natural substrate		
Barrel Number:	1		
Span (m):	97.04		
Rise (m):	13.54		

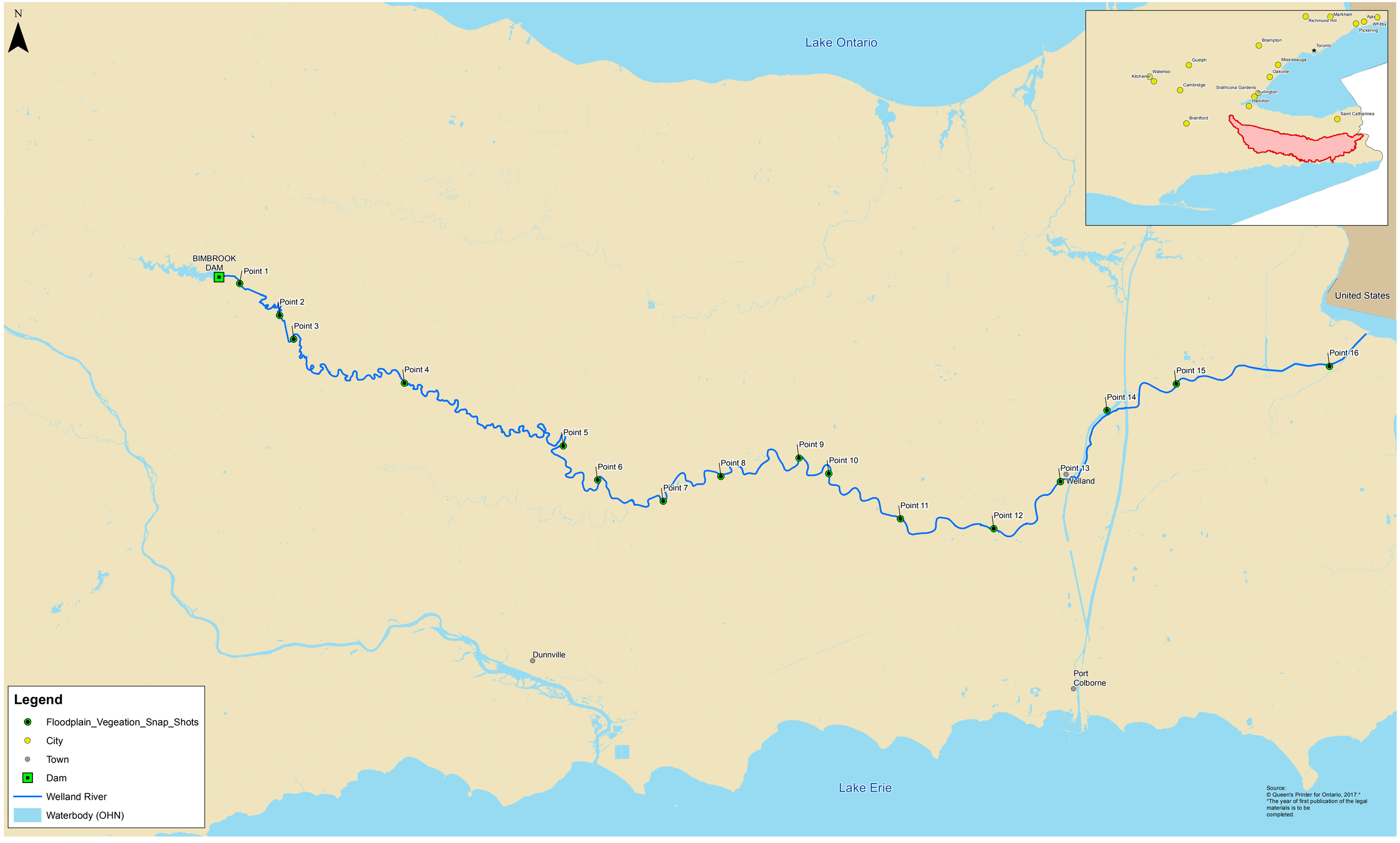
	Elevation (m)
Road deck:	175.86
Soffit:	174.13
Upstream Invert:	160.59
Downstream Invert:	160.59

Upstream Photo

Downstream Photo

APPENDIX

D Model Calibration



Appendix D-1
Welland River Hydraulic Model
Manning's n Cover Point Locations

0 1 2 3 4 5
kilometres
1:90,000

Date: August 2017

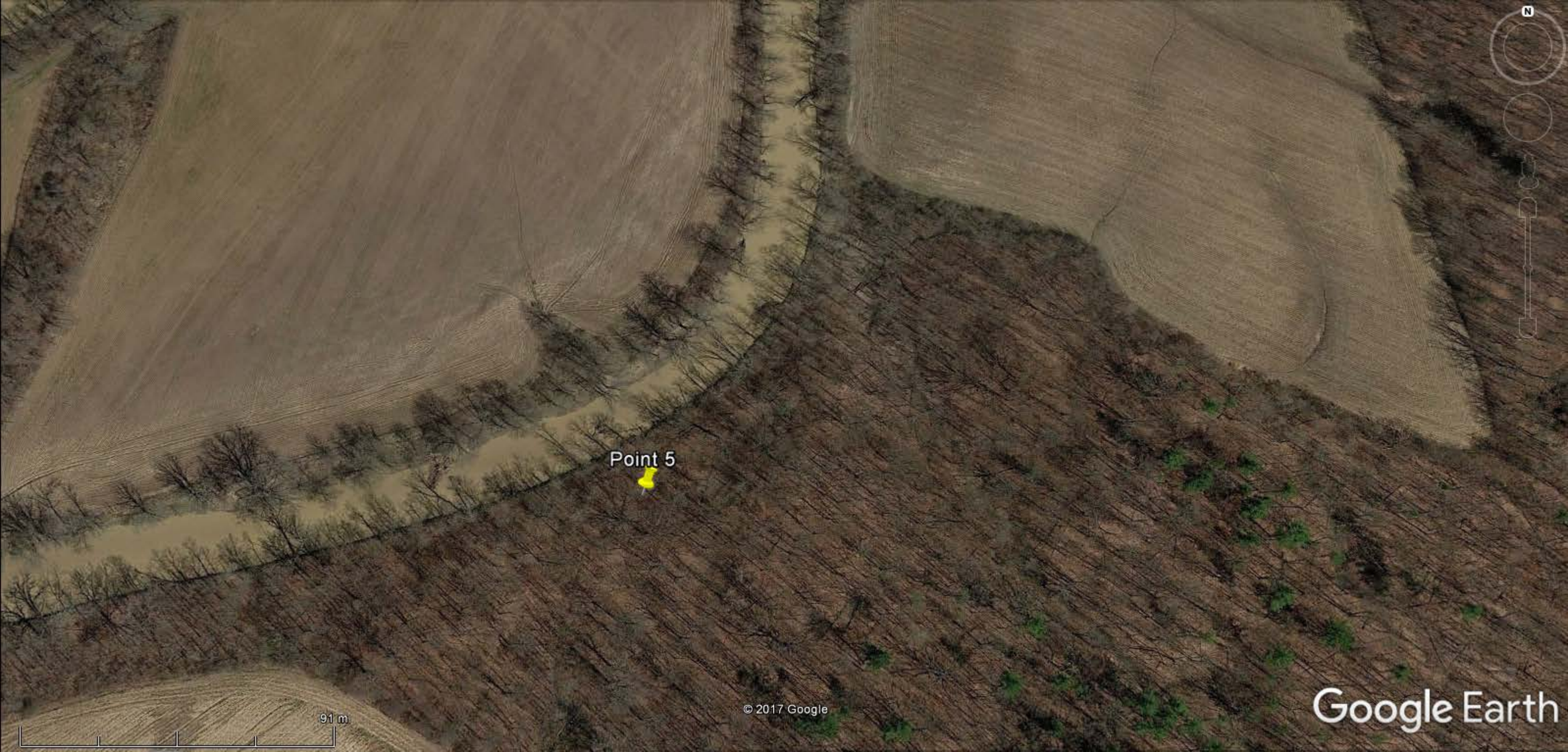
Project No: 3815516

Point 1
19 m
Google Earth

Point 2
30 m
Google Earth

Point 3
30 m
Google Earth

Point 4
30 m
Google Earth


Point 5
91 m
© 2017 Google
Google Earth

Point 6
30 m
Google Earth

Point 7
29 m
Google Earth

Point 8
29 m
Google Earth

Point 9
30 m
Google Earth

Point 10
29 m
Google Earth

Point 11
31 m
Google Earth

Point 12
31 m
© 2017 Google
Google Earth

Point 13
© 2017 Google
30 m
Google Earth

Point 14
19 m
© 2017 Google
Google Earth

Point 15
31 m
© 2017 Google
Google Earth

Point 16
30 m
Image Landsat / Copernicus
Google Earth

Summary Table - Calibration Results for Runoff Volume and Peak Flow Rate at Church Road

	Hydrology Model Resutls		Mike 11 Model Results	
Time	Peak Flow	Volume	Peak Flow	Volume
	(cms)	(m3)	(cms)	(m3)
2/10/2009 0:00	21.0	6294.6	25.0	185.3
2/10/2009 0:15	21.0	18883.8	2.2	523.6
2/10/2009 0:30	21.0	18883.8	1.6	902.4
2/10/2009 0:45	21.0	18883.8	3.2	2237.7
2/10/2009 1:00	21.0	18883.8	3.9	3289.7
2/10/2009 1:15	21.0	18883.8	3.9	3489.3
2/10/2009 1:30	21.0	18883.8	4.1	3636.4
2/10/2009 1:45	21.0	18883.8	4.1	3704.8
2/10/2009 2:00	21.0	18883.8	4.2	3788.2
2/10/2009 2:15	21.0	18883.8	4.3	3835.0
2/10/2009 2:30	21.0	18883.8	4.3	3867.4
2/10/2009 2:45	21.0	18883.8	4.3	3890.8
2/10/2009 3:00	21.0	18883.8	4.4	3933.7
2/10/2009 3:15	21.0	18883.8	4.4	3960.9
2/10/2009 3:30	21.0	18883.8	4.4	3981.8
2/10/2009 3:45	21.0	18883.8	4.5	4013.1
2/10/2009 4:00	21.0	18883.8	4.6	4070.6
2/10/2009 4:15	21.0	18883.8	4.7	4177.0
2/10/2009 4:30	21.0	18883.8	5.0	4352.9
2/10/2009 4:45	21.0	18883.8	5.3	4600.3
2/10/2009 5:00	21.0	18883.8	5.7	4969.2
2/10/2009 5:15	21.0	18883.8	6.1	5342.4
2/10/2009 5:30	21.0	18883.8	6.5	5705.1
2/10/2009 5:45	21.0	18883.8	7.0	6132.5
2/10/2009 6:00	21.0	18883.8	7.4	6486.5
2/10/2009 6:15	21.0	18883.8	7.8	6796.4
2/10/2009 6:30	21.0	18884.1	8.2	7198.0
2/10/2009 6:45	21.0	18886.2	8.5	7488.5
2/10/2009 7:00	21.0	18890.1	8.8	7749.0
2/10/2009 7:15	21.0	18896.4	9.1	8093.5
2/10/2009 7:30	21.0	18905.4	9.4	8354.8
2/10/2009 7:45	21.0	18918.3	9.7	8609.2
2/10/2009 8:00	21.1	18934.5	10.0	8849.8
2/10/2009 8:15	21.1	18954.9	10.4	9207.7
2/10/2009 8:30	21.1	18979.8	10.7	9473.7
2/10/2009 8:45	21.1	19009.8	11.0	9754.5
2/10/2009 9:00	21.2	19044.3	11.4	10022.1
2/10/2009 9:15	21.2	19084.8	11.8	10432.6
2/10/2009 9:30	21.3	19131.9	12.1	10736.2
2/10/2009 9:45	21.4	19186.5	12.5	11056.0
2/10/2009 10:00	21.4	19247.4	13.0	11402.8
2/10/2009 10:15	21.5	19316.4	13.4	11870.7
2/10/2009 10:30	21.6	19394.7	13.8	12260.0
2/10/2009 10:45	21.7	19482.6	14.3	12636.5
2/10/2009 11:00	21.8	19580.1	14.9	13206.5
2/10/2009 11:15	22.0	19687.5	15.4	13652.5
2/10/2009 11:30	22.1	19808.4	16.0	14101.6
2/10/2009 11:45	22.3	19942.8	16.7	14754.9
2/10/2009 12:00	22.4	20090.1	17.2	15250.2
2/10/2009 12:15	22.6	20247.0	17.9	15718.5
2/10/2009 12:30	22.8	20399.1	18.5	16424.4
2/10/2009 12:45	22.9	20548.2	19.1	16941.3
2/10/2009 13:00	23.1	20695.5	19.9	17453.8
2/10/2009 13:15	23.3	20840.4	20.4	18141.5
2/10/2009 13:30	23.4	20979.9	21.0	18627.2
2/10/2009 13:45	23.6	21117.6	21.7	19108.6
2/10/2009 14:00	23.7	21255.3	22.2	19776.1
2/10/2009 14:15	23.9	21387.6	22.7	20245.5
2/10/2009 14:30	24.0	21513.9	23.3	20643.9
2/10/2009 14:45	24.1	21644.4	23.9	21308.7
2/10/2009 15:00	24.3	21776.4	24.4	21759.3
2/10/2009 15:15	24.4	21909.0	24.9	22171.4
2/10/2009 15:30	24.6	22044.3	25.4	22546.1
2/10/2009 15:45	24.8	22182.6	26.0	23188.0
2/10/2009 16:00	24.9	22324.8	26.4	23557.9
2/10/2009 16:15	25.1	22471.5	26.8	23916.0
2/10/2009 16:30	25.3	22624.5	27.0	24214.2
2/10/2009 16:45	25.4	22782.9	27.6	24537.6
2/10/2009 17:00	25.6	22945.8	28.0	25034.4
2/10/2009 17:15	25.8	23115.9	28.3	25308.0
2/10/2009 17:30	26.0	23295.9	28.6	25598.6
2/10/2009 17:45	26.2	23485.8	28.9	25879.3
2/10/2009 18:00	26.4	23662.8	29.1	26103.5
2/10/2009 18:15	26.6	23805.0	29.6	26380.8
2/10/2009 18:30	26.7	23945.4	29.9	26823.7
2/10/2009 18:45	26.9	24085.5	30.2	27053.6
2/10/2009 19:00	27.0	24224.7	30.4	27274.1
2/10/2009 19:15	27.2	24363.3	30.7	27489.5
2/10/2009 19:30	27.3	24501.0	30.9	27704.8
2/10/2009 19:45	27.5	24637.5	31.1	27909.1
2/10/2009 20:00	27.6	24772.5	31.2	28054.7
2/10/2009 20:15	27.8	24906.3	31.5	28215.0
2/10/2009 20:30	27.9	25038.3	31.9	28499.6
2/10/2009 20:45	28.1	25168.2	32.0	28771.1
2/10/2009 21:00	28.2	25298.7	32.2	28906.9
2/10/2009 21:15	28.4	25430.1	32.4	29059.5
2/10/2009 21:30	28.5	25560.0	32.5	29212.9
2/10/2009 21:45	28.6	25689.0	32.7	29365.1

	Hydrology Model Resutls		Mike 11 Model Results	
Time	Peak Flow	Volume	Peak Flow	Volume
2/10/2009 22:00	28.8	25815.9	32.9	29512.2
2/10/2009 22:15	28.9	25948.8	33.0	29647.8
2/10/2009 22:30	29.1	26090.4	33.2	29774.5
2/10/2009 22:45	29.2	26229.9	33.3	29891.4
2/10/2009 23:00	29.4	26364.6	33.3	29991.0
2/10/2009 23:15	29.5	26497.5	33.4	30022.4
2/10/2009 23:30	29.7	26626.8	33.6	30144.6
2/10/2009 23:45	29.8	26752.8	33.7	30290.1
2/11/2009 0:00	29.9	26874.6	33.9	30417.2
2/11/2009 0:15	30.1	26993.1	34.0	30575.5
2/11/2009 0:30	30.2	27106.5	34.1	30671.7
2/11/2009 0:45	30.3	27216.0	34.2	30725.3
2/11/2009 1:00	30.4	27318.6	34.3	30793.0
2/11/2009 1:15	30.5	27418.5	34.3	30861.0
2/11/2009 1:30	30.6	27515.1	34.4	30925.8
2/11/2009 1:45	30.7	27604.2	34.5	30985.9
2/11/2009 2:00	30.8	27684.3	34.5	31041.1
2/11/2009 2:15	30.9	27757.2	34.6	31091.3
2/11/2009 2:30	31.0	27831.3	34.6	31136.1
2/11/2009 2:45	31.0	27900.6	34.7	31174.3
2/11/2009 3:00	31.1	27958.5	34.7	31204.8
2/11/2009 3:15	31.2	28011.3	34.7	31227.1
2/11/2009 3:30	31.2	28060.2	34.7	31241.7
2/11/2009 3:45	31.3	28102.5	34.7	31249.8
2/11/2009 4:00	31.3	28142.4	34.7	31252.3
2/11/2009 4:15	31.3	28172.1	34.7	31250.2
2/11/2009 4:30	31.4	28199.1	34.7	31243.7
2/11/2009 4:45	31.4	28225.8	34.7	31232.5
2/11/2009 5:00	31.4	28242.3	34.7	31216.9
2/11/2009 5:15	31.4	28254.6	34.7	31196.6
2/11/2009 5:30	31.4	28263.3	34.7	31171.4
2/11/2009 5:45	31.4	28275.6	34.6	31140.5
2/11/2009 6:00	31.4	28269.3	34.6	31104.8
2/11/2009 6:15	31.4	28273.5	34.5	31065.6
2/11/2009 6:30	31.5	28302.3	34.5	31027.5
2/11/2009 6:45	31.6	28360.2	34.5	30995.5
2/11/2009 7:00	31.7	28443.6	34.4	30971.2
2/11/2009 7:15	31.8	28550.4	34.4	30955.7
2/11/2009 7:30	32.0	28686.0	34.4	30950.9
2/11/2009 7:45	32.2	28851.0	34.4	30959.8
2/11/2009 8:00	32.4	29042.1	34.4	30984.8
2/11/2009 8:15	32.7	29267.1	34.5	31027.5
2/11/2009 8:30	33.0	29522.4	34.6	31090.2
2/11/2009 8:45	33.4	29808.9	34.7	31174.6
2/11/2009 9:00	33.7	30124.5	34.8	31280.8
2/11/2009 9:15	34.1	30466.5	35.0	31409.3
2/11/2009 9:30	34.5	30806.4	35.1	31546.7
2/11/2009 9:45	34.9	31149.3	35.3	31638.2
2/11/2009 10:00	35.3	31521.9	35.6	31908.2
2/11/2009 10:15	35.8	31928.7	36.1	32234.1
2/11/2009 10:30	36.3	32371.2	36.4	32624.9
2/11/2009 10:45	36.8	32835.0	36.7	32891.7
2/11/2009 11:00	37.4	33321.6	37.1	33215.4
2/11/2009 11:15	37.9	33811.2	37.5	33573.9
2/11/2009 11:30	38.5	34321.2	38.0	33959.9
2/11/2009 11:45	39.2	34867.8	38.4	34358.3
2/11/2009 12:00	39.8	35440.5	38.7	34682.4
2/11/2009 12:15	40.5	36042.6	39.5	35185.0
2/11/2009 12:30	41.2	36669.9	40.3	35963.0
2/11/2009 12:45	42.0	37328.1	40.8	36470.6
2/11/2009 13:00	42.8	38019.0	41.4	36975.9
2/11/2009 13:15	43.6	38736.3	41.9	37481.3
2/11/2009 13:30	44.4	39447.6	42.3	37947.4
2/11/2009 13:45	45.1	40151.4	43.3	38497.7
2/11/2009 14:00	45.9	40846.2	44.3	39495.9
2/11/2009 14:15	46.6	41517.3	44.9	40107.4
2/11/2009 14:30	47.3	42168.3	45.5	40665.8
2/11/2009 14:45	47.9	42772.5	46.1	41200.1
2/11/2009 15:00	48.5	43321.8	46.4	41654.7
2/11/2009 15:15	49.1	43862.1	47.2	42062.4
2/11/2009 15:30	49.7	44389.2	48.2	42924.6
2/11/2009 15:45	50.3	44902.8	48.8	43698.6
2/11/2009 16:00	50.8	45400.5	49.3	44147.6
2/11/2009 16:15	51.3	45878.4	49.8	44595.9
2/11/2009 16:30	51.8	46336.5	50.3	45046.6
2/11/2009 16:45	52.3	46776.6	50.6	45458.1
2/11/2009 17:00	52.7	47196.3	50.9	45638.6
2/11/2009 17:15	53.2	47597.7	51.5	46077.7
2/11/2009 17:30	53.5	47966.1	52.2	46663.6
2/11/2009 17:45	53.9	48279.0	52.7	47239.4
2/11/2009 18:00	54.2	48566.7	53.0	47570.8
2/11/2009 18:15	54.5	48859.8	53.4	47858.5
2/11/2009 18:30	54.9	49178.1	53.7	48186.0
2/11/2009 18:45	55.3	49542.9	54.1	48502.3
2/11/2009 19:00	55.8	49946.7	54.4	48824.8
2/11/2009 19:15	56.3	50384.1	54.8	49159.6
2/11/2009 19:30	56.7	50796.6	54.9	49348.4
2/11/2009 19:45	57.1	51193.5	55.3	49558.6
2/11/2009 20:00	57.6	51564.6	55.9	50070.5
2/11/2009 20:15	58.0	51910.2	56.5	50561.8
2/11/2009 20:30	58.3	52260.3	57.0	51058.9

	Hydrology Model Resutls		Mike 11 Model Results	
Time	Peak Flow	Volume	Peak Flow	Volume
2/11/2009 20:45	58.7	52591.8	57.3	51430.3
2/11/2009 21:00	59.0	52900.2	57.6	51686.1
2/11/2009 21:15	59.4	53208.3	57.9	51951.2
2/11/2009 21:30	59.6	53508.3	58.2	52251.5
2/11/2009 21:45	60.0	53779.2	58.6	52580.3
2/11/2009 22:00	60.2	54039.6	59.0	52916.4
2/11/2009 22:15	60.5	54297.3	59.3	53247.2
2/11/2009 22:30	60.8	54538.2	59.5	53510.8
2/11/2009 22:45	61.0	54794.4	59.7	53646.9
2/11/2009 23:00	61.3	54978.0	60.0	53821.9
2/11/2009 23:15	61.4	55224.3	60.5	54227.9
2/11/2009 23:30	61.7	55394.4	60.9	54600.2
2/11/2009 23:45	61.9	55623.9	61.3	54936.0
2/12/2009 0:00	62.1	55763.1	61.6	55282.5
2/12/2009 0:15	62.6	56013.0	61.8	55527.9
2/12/2009 0:30	63.4	56522.4	62.2	55792.8
2/12/2009 0:45	64.5	57337.2	62.6	56103.4
2/12/2009 1:00	65.9	58438.8	63.1	56552.5
2/12/2009 1:15	67.4	59756.1	63.9	57148.9
2/12/2009 1:30	68.7	61049.4	64.6	57810.0
2/12/2009 1:45	69.9	62239.8	65.1	58418.9
2/12/2009 2:00	71.1	63298.5	65.6	58816.2
2/12/2009 2:15	72.2	64311.3	66.8	59614.6
2/12/2009 2:30	73.3	65298.0	68.2	60730.6
2/12/2009 2:45	74.3	66258.9	69.3	61899.8
2/12/2009 3:00	75.3	67184.1	70.1	62762.2
2/12/2009 3:15	76.3	68087.1	70.9	63446.9
2/12/2009 3:30	77.1	68908.5	71.6	64184.4
2/12/2009 3:45	78.0	69681.0	72.1	64680.3
2/12/2009 4:00	78.8	70418.1	73.1	65230.9
2/12/2009 4:15	79.6	71140.5	74.4	66339.5
2/12/2009 4:30	80.3	71832.6	75.7	67585.7
2/12/2009 4:45	81.0	72496.2	76.6	68532.6
2/12/2009 5:00	81.7	73128.6	77.3	69236.0
2/12/2009 5:15	82.3	73726.8	77.9	69842.6
2/12/2009 5:30	82.9	74280.0	78.3	70297.1
2/12/2009 5:45	83.5	74805.3	78.7	70582.0
2/12/2009 6:00	84.0	75298.8	79.8	71345.6
2/12/2009 6:15	84.6	75806.7	80.9	72283.5
2/12/2009 6:30	85.3	76320.9	81.8	73229.2
2/12/2009 6:45	85.9	76900.2	82.4	73902.4
2/12/2009 7:00	86.6	77530.8	83.0	74442.3
2/12/2009 7:15	87.3	78174.3	83.4	74885.9
2/12/2009 7:30	88.1	78814.5	83.8	75240.1
2/12/2009 7:45	88.7	79420.8	84.0	75485.5
2/12/2009 8:00	89.3	80009.1	85.0	76019.7
2/12/2009 8:15	89.9	80543.1	85.8	76860.8
2/12/2009 8:30	90.4	81017.7	86.8	77707.6
2/12/2009 8:45	90.9	81536.1	87.4	78391.0
2/12/2009 9:00	91.4	81991.8	87.8	78854.8
2/12/2009 9:15	91.8	82370.7	88.1	79196.2
2/12/2009 9:30	92.2	82775.1	88.4	79444.2
2/12/2009 9:45	92.7	83131.5	88.6	79636.8
2/12/2009 10:00	92.9	83453.7	88.7	79771.8
2/12/2009 10:15	93.4	83775.0	89.6	80233.0
2/12/2009 10:30	93.5	84031.2	90.4	81031.7
2/12/2009 10:45	93.9	84262.2	91.2	81741.7
2/12/2009 11:00	94.0	84547.2	91.8	82378.4
2/12/2009 11:15	94.2	84650.1	92.0	82758.2
2/12/2009 11:30	94.5	84897.0	92.2	82897.3
2/12/2009 11:45	94.5	85023.3	92.4	83065.3
2/12/2009 12:00	94.7	85155.0	92.6	83238.5
2/12/2009 12:15	94.8	85269.9	92.7	83377.4
2/12/2009 12:30	94.9	85354.2	92.6	83285.5
2/12/2009 12:45	94.9	85413.6	92.5	83144.4
2/12/2009 13:00	94.9	85431.3	93.1	83503.3
2/12/2009 13:15	94.9	85383.3	93.5	83966.5
2/12/2009 13:30	94.8	85354.8	94.1	84416.6
2/12/2009 13:45	94.8	85301.4	94.5	84881.1
2/12/2009 14:00	94.7	85210.5	94.7	85130.0
2/12/2009 14:15	94.5	85076.7	94.7	85174.4
2/12/2009 14:30	94.5	85024.2	94.7	85183.6
2/12/2009 14:45	94.3	84878.7	94.8	85249.6
2/12/2009 15:00	94.1	84653.7	94.8	85311.5
2/12/2009 15:15	94.0	84554.1	94.9	85351.2
2/12/2009 15:30	93.7	84342.6	94.9	85347.6
2/12/2009 15:45	93.4	84082.5	94.7	85113.2
2/12/2009 16:00	93.3	83953.8	94.4	84804.1
2/12/2009 16:15	93.0	83690.4	94.5	84874.5
2/12/2009 16:30	92.6	83358.0	94.7	85122.3
2/12/2009 16:45	92.3	83095.5	94.9	85297.1
2/12/2009 17:00	92.0	82835.1	95.1	85509.0
2/12/2009 17:15	91.7	82499.4	95.3	85694.0
2/12/2009 17:30	91.3	82155.9	95.3	85728.9
2/12/2009 17:45	91.0	81874.8	95.2	85664.5
2/12/2009 18:00	90.6	81522.9	95.1	85420.9
2/12/2009 18:15	90.2	81171.3	94.7	85160.2
2/12/2009 18:30	89.8	80834.7	94.5	84974.6
2/12/2009 18:45	89.4	80449.5	94.3	84823.0
2/12/2009 19:00	89.0	80085.3	94.2	84683.1
2/12/2009 19:15	88.6	79752.0	94.0	84557.6

	Hydrology Model Resutls		Mike 11 Model Results	
Time	Peak Flow	Volume	Peak Flow	Volume
2/12/2009 19:30	88.1	79317.6	93.9	84438.4
2/12/2009 19:45	87.7	78960.3	93.8	84307.2
2/12/2009 20:00	87.3	78567.6	93.6	84129.0
2/12/2009 20:15	86.9	78219.0	93.3	83877.7
2/12/2009 20:30	86.4	77773.5	93.0	83585.0
2/12/2009 20:45	86.0	77390.7	92.7	83189.4
2/12/2009 21:00	85.5	76947.0	92.2	82789.3
2/12/2009 21:15	85.0	76491.3	91.8	82498.1
2/12/2009 21:30	84.5	76068.0	91.5	82304.4
2/12/2009 21:45	84.0	75628.8	91.5	82304.2
2/12/2009 22:00	83.6	75249.6	91.4	82236.1
2/12/2009 22:15	83.1	74827.5	91.3	82120.1
2/12/2009 22:30	82.6	74364.6	91.2	81975.5
2/12/2009 22:45	82.2	73945.2	91.0	81793.8
2/12/2009 23:00	81.6	73476.3	90.8	81564.3
2/12/2009 23:15	81.2	73121.7	90.5	81265.3
2/12/2009 23:30	80.8	72725.7	90.1	80914.6
2/12/2009 23:45	80.3	72298.8	89.7	80563.2
2/13/2009 0:00	79.8	71858.1	89.3	80247.4
2/13/2009 0:15	79.4	71415.6	89.0	80009.5
2/13/2009 0:30	78.9	70996.2	88.8	79733.7
2/13/2009 0:45	78.4	70605.9	88.4	79430.8
2/13/2009 1:00	78.0	70169.1	88.1	79123.1
2/13/2009 1:15	77.5	69727.8	87.7	78816.8
2/13/2009 1:30	77.0	69294.0	87.4	78506.9
2/13/2009 1:45	76.6	68940.9	87.1	78188.8
2/13/2009 2:00	76.1	68485.5	86.7	77850.1
2/13/2009 2:15	75.7	68084.7	86.3	77495.0
2/13/2009 2:30	75.2	67628.4	85.9	77126.8
2/13/2009 2:45	74.7	67186.8	85.5	76748.2
2/13/2009 3:00	74.1	66722.4	85.1	76361.3
2/13/2009 3:15	73.7	66327.6	84.6	75959.9
2/13/2009 3:30	73.3	65928.6	84.2	75538.5
2/13/2009 3:45	72.7	65484.9	83.7	75106.3
2/13/2009 4:00	72.4	65139.0	83.2	74707.3
2/13/2009 4:15	71.9	64708.8	82.8	74315.5
2/13/2009 4:30	71.5	64362.3	82.3	73901.2
2/13/2009 4:45	71.0	63942.6	81.9	73491.8
2/13/2009 5:00	70.7	63607.2	81.4	73090.8
2/13/2009 5:15	70.2	63197.4	81.0	72675.6
2/13/2009 5:30	69.9	62861.7	80.5	72257.4
2/13/2009 5:45	69.3	62409.6	80.1	71852.1
2/13/2009 6:00	69.0	62079.0	79.6	71458.0
2/13/2009 6:15	68.5	61627.8	79.2	71055.7
2/13/2009 6:30	68.1	61299.3	78.7	70615.4
2/13/2009 6:45	67.6	60887.7	78.2	70172.2
2/13/2009 7:00	67.2	60507.3	77.8	69876.4
2/13/2009 7:15	66.9	60155.4	77.5	69541.2
2/13/2009 7:30	66.4	59765.4	77.1	69132.9
2/13/2009 7:45	66.0	59421.0	76.5	68569.3
2/13/2009 8:00	65.5	58993.5	75.9	68020.7
2/13/2009 8:15	65.1	58627.8	75.3	67548.5
2/13/2009 8:30	64.7	58241.4	74.8	67098.6
2/13/2009 8:45	64.2	57827.7	74.3	66650.6
2/13/2009 9:00	63.8	57422.1	73.8	66211.2
2/13/2009 9:15	63.4	57045.0	73.3	65775.4
2/13/2009 9:30	63.0	56655.0	72.8	65336.3
2/13/2009 9:45	62.5	56252.1	72.3	64866.9
2/13/2009 10:00	62.1	55867.8	71.8	64350.0
2/13/2009 10:15	61.7	55515.3	71.2	63836.0
2/13/2009 10:30	61.3	55157.4	70.6	63326.8
2/13/2009 10:45	60.9	54785.7	70.1	62831.3
2/13/2009 11:00	60.5	54428.1	69.5	62357.5
2/13/2009 11:15	60.1	54092.1	69.0	61886.5
2/13/2009 11:30	59.7	53745.3	68.5	61397.0
2/13/2009 11:45	59.3	53388.3	67.9	60893.8
2/13/2009 12:00	58.9	53047.2	67.4	60392.8
2/13/2009 12:15	58.6	52722.0	66.8	59881.2
2/13/2009 12:30	58.2	52393.5	66.2	59249.8
2/13/2009 12:45	57.8	52054.5	65.4	58593.5
2/13/2009 13:00	57.5	51728.1	64.9	58261.3
2/13/2009 13:15	57.1	51418.5	64.5	57904.8
2/13/2009 13:30	56.8	51102.3	64.2	57718.8
2/13/2009 13:45	56.4	50777.7	64.2	57568.9
2/13/2009 14:00	56.1	50464.8	63.6	56985.9
2/13/2009 14:15	55.7	50165.4	63.0	56457.2
2/13/2009 14:30	55.4	49861.8	62.4	55945.1
2/13/2009 14:45	55.0	49550.4	61.9	55450.8
2/13/2009 15:00	54.7	49248.9	61.3	54944.0
2/13/2009 15:15	54.4	48961.5	60.8	54420.8
2/13/2009 15:30	54.1	48669.3	60.2	53903.1
2/13/2009 15:45	53.7	48370.2	59.6	53394.1
2/13/2009 16:00	53.4	48080.7	59.0	52885.6
2/13/2009 16:15	53.1	47802.3	58.5	52391.1
2/13/2009 16:30	52.8	47520.6	57.9	51887.9
2/13/2009 16:45	52.5	47232.6	57.4	51301.6
2/13/2009 17:00	52.2	46953.6	56.6	50665.6
2/13/2009 17:15	51.9	46685.1	56.1	50350.3
2/13/2009 17:30	51.6	46413.3	55.8	50122.0
2/13/2009 17:45	51.3	46132.8	55.7	49888.7
2/13/2009 18:00	50.9	45852.9	55.1	49319.4

	Hydrology Model Resutls		Mike 11 Model Results	
Time	Peak Flow	Volume	Peak Flow	Volume
2/13/2009 18:15	50.7	45587.7	54.5	48827.6
2/13/2009 18:30	50.4	45313.8	54.0	48382.4
2/13/2009 18:45	50.0	45035.4	53.5	47948.2
2/13/2009 19:00	49.7	44755.2	53.0	47530.3
2/13/2009 19:15	49.4	44453.4	52.6	47089.3
2/13/2009 19:30	49.1	44143.8	52.1	46639.5
2/13/2009 19:45	48.7	43834.2	51.6	46188.7
2/13/2009 20:00	48.4	43539.3	51.1	45727.9
2/13/2009 20:15	48.1	43262.7	50.6	45256.7
2/13/2009 20:30	47.8	42979.8	50.0	44766.3
2/13/2009 20:45	47.4	42698.7	49.5	44248.3
2/13/2009 21:00	47.1	42434.1	48.8	43777.4
2/13/2009 21:15	46.9	42175.5	48.5	43571.5
2/13/2009 21:30	46.6	41897.4	48.6	43701.5
2/13/2009 21:45	46.2	41610.0	48.4	43304.9
2/13/2009 22:00	45.9	41330.1	47.8	42807.8
2/13/2009 22:15	45.6	41063.1	47.3	42328.0
2/13/2009 22:30	45.3	40800.9	46.8	41830.1
2/13/2009 22:45	45.0	40543.2	46.2	41339.3
2/13/2009 23:00	44.8	40296.9	45.7	40867.3
2/13/2009 23:15	44.5	40058.1	45.2	40426.4
2/13/2009 23:30	44.3	39828.9	44.7	39994.3
2/13/2009 23:45	44.0	39593.1	44.2	39573.2
2/14/2009 0:00	43.7	39373.8	43.7	39172.9
2/14/2009 0:15	43.5	39162.3	43.3	38703.9
2/14/2009 0:30	43.3	38944.2	42.8	38473.6
2/14/2009 0:45	43.0	38727.9	42.8	38448.1
2/14/2009 1:00	42.8	38524.8	42.7	38183.8
2/14/2009 1:15	42.6	38329.8	42.2	37745.9
2/14/2009 1:30	42.4	38128.8	41.7	37355.3
2/14/2009 1:45	42.1	37928.4	41.3	36984.9
2/14/2009 2:00	41.9	37740.3	40.9	36657.6
2/14/2009 2:15	41.7	37557.3	40.6	36344.0
2/14/2009 2:30	41.5	37369.5	40.2	36003.0
2/14/2009 2:45	41.3	37182.0	39.8	35639.0
2/14/2009 3:00	41.1	37004.4	39.4	35233.1
2/14/2009 3:15	40.9	36831.9	38.9	34760.3
2/14/2009 3:30	40.7	36654.9	38.3	34352.5
2/14/2009 3:45	40.5	36477.6	38.1	34229.9
2/14/2009 4:00	40.3	36309.6	38.0	34115.5
2/14/2009 4:15	40.2	36146.1	37.7	33759.7
2/14/2009 4:30	40.0	35978.1	37.3	33387.0
2/14/2009 4:45	39.8	35810.1	36.9	33019.4
2/14/2009 5:00	39.6	35650.5	36.5	32667.3
2/14/2009 5:15	39.4	35494.5	36.1	32356.2
2/14/2009 5:30	39.3	35334.6	35.8	32100.6
2/14/2009 5:45	39.1	35175.3	35.5	31884.4
2/14/2009 6:00	38.9	35021.4	35.3	31664.1
2/14/2009 6:15	38.7	34866.6	35.0	31353.9
2/14/2009 6:30	38.6	34704.0	34.6	30981.5
2/14/2009 6:45	38.4	34544.7	34.2	30697.9
2/14/2009 7:00	38.2	34388.4	34.1	30629.7
2/14/2009 7:15	38.0	34233.9	34.0	30447.2
2/14/2009 7:30	37.9	34077.3	33.6	30123.4
2/14/2009 7:45	37.7	33922.5	33.3	29811.6
2/14/2009 8:00	37.5	33772.5	33.0	29504.6
2/14/2009 8:15	37.4	33625.2	32.6	29218.8
2/14/2009 8:30	37.0	33357.3	32.3	28952.5
2/14/2009 8:45	36.8	33135.0	32.0	28698.4
2/14/2009 9:00	36.6	32972.1	31.8	28471.9
2/14/2009 9:15	36.4	32800.2	31.5	28282.2
2/14/2009 9:30	36.3	32636.7	31.3	28098.6
2/14/2009 9:45	36.1	32473.8	31.1	27864.6
2/14/2009 10:00	35.9	32313.0	30.9	27722.6
2/14/2009 10:15	35.7	32154.3	30.8	27679.7
2/14/2009 10:30	35.6	31998.9	30.7	27549.8
2/14/2009 10:45	35.4	31822.8	30.5	27318.9
2/14/2009 11:00	35.2	31646.7	30.2	27103.2
2/14/2009 11:15	35.0	31467.0	30.0	26904.4
2/14/2009 11:30	34.8	31291.8	29.8	26721.8
2/14/2009 11:45	34.6	31145.4	29.6	26549.7
2/14/2009 12:00	34.4	30980.1	29.4	26360.9
2/14/2009 12:15	34.3	30832.5	29.2	26155.1
2/14/2009 12:30	34.1	30682.5	29.0	25976.5
2/14/2009 12:45	33.9	30542.4	28.8	25822.9
2/14/2009 13:00	33.8	30395.1	28.6	25651.0
2/14/2009 13:15	33.6	30264.0	28.4	25566.4
2/14/2009 13:30	33.5	30122.4	28.5	25603.1
2/14/2009 13:45	33.3	29997.6	28.5	25545.9
2/14/2009 14:00	33.2	29872.8	28.3	25363.3
2/14/2009 14:15	33.0	29729.1	28.1	25195.5
2/14/2009 14:30	32.9	29592.0	27.9	25045.8
2/14/2009 14:45	32.7	29455.8	27.7	24906.0
2/14/2009 15:00	32.6	29328.6	27.6	24779.3
2/14/2009 15:15	32.5	29205.9	27.5	24654.3
2/14/2009 15:30	32.3	29079.3	27.3	24521.4
2/14/2009 15:45	32.2	28967.1	27.2	24407.6
2/14/2009 16:00	32.1	28850.4	27.1	24315.2
2/14/2009 16:15	31.9	28724.1	27.0	24202.4
2/14/2009 16:30	31.8	28589.4	26.8	24076.4
2/14/2009 16:45	31.6	28470.0	26.8	24072.1

	Hydrology Model Resutls		Mike 11 Model Results	
Time	Peak Flow	Volume	Peak Flow	Volume
2/14/2009 17:00	31.5	28357.8	26.8	24087.1
2/14/2009 17:15	31.4	28246.2	26.7	23961.2
2/14/2009 17:30	31.3	28130.1	26.5	23797.9
2/14/2009 17:45	31.1	28014.9	26.4	23655.3
2/14/2009 18:00	31.0	27897.9	26.2	23529.8
2/14/2009 18:15	30.9	27784.5	26.1	23423.7
2/14/2009 18:30	30.7	27666.9	26.0	23327.8
2/14/2009 18:45	30.6	27551.1	25.9	23233.5
2/14/2009 19:00	30.5	27438.6	25.8	23163.9
2/14/2009 19:15	30.4	27327.6	25.7	23104.2
2/14/2009 19:30	30.2	27216.6	25.6	23027.1
2/14/2009 19:45	30.1	27108.3	25.5	22918.9
2/14/2009 20:00	30.0	26994.3	25.4	22809.3
2/14/2009 20:15	29.9	26891.1	25.3	22789.1
2/14/2009 20:30	29.8	26791.5	25.4	22821.5
2/14/2009 20:45	29.7	26691.9	25.4	22781.4
2/14/2009 21:00	29.6	26595.6	25.3	22675.2
2/14/2009 21:15	29.4	26496.9	25.1	22579.3
2/14/2009 21:30	29.3	26400.6	25.0	22499.1
2/14/2009 21:45	29.2	26307.6	25.0	22431.4
2/14/2009 22:00	29.1	26213.7	24.9	22366.5
2/14/2009 22:15	29.0	26123.7	24.8	22315.9
2/14/2009 22:30	28.9	26034.6	24.8	22279.7
2/14/2009 22:45	28.8	25947.3	24.7	22231.9
2/14/2009 23:00	28.7	25860.9	24.7	22159.0
2/14/2009 23:15	28.6	25778.1	24.6	22066.8
2/14/2009 23:30	28.6	25697.1	24.5	21950.9
2/14/2009 23:45	28.5	25618.8	24.3	21853.6
2/15/2009 0:00	28.4	25537.5	24.3	21840.0
2/15/2009 0:15	28.3	25462.2	24.3	21855.4
2/15/2009 0:30	28.2	25384.5	24.3	21826.1
2/15/2009 0:45	28.1	25308.9	24.2	21750.9
2/15/2009 1:00	28.0	25235.4	24.1	21686.5
2/15/2009 1:15	28.0	25161.9	24.1	21627.6
2/15/2009 1:30	27.9	25089.9	24.0	21585.9
2/15/2009 1:45	27.8	25020.6	24.0	21565.0
2/15/2009 2:00	27.7	24955.2	24.0	21540.8
2/15/2009 2:15	27.7	24889.2	23.9	21491.0
2/15/2009 2:30	27.6	24822.6	23.8	21426.9
2/15/2009 2:45	27.5	24758.4	23.8	21348.0
2/15/2009 3:00	27.4	24695.1	23.7	21270.9
2/15/2009 3:15	27.4	24631.8	23.6	21198.7
2/15/2009 3:30	27.3	24568.8	23.5	21120.1
2/15/2009 3:45	27.2	24506.1	23.4	21062.5
2/15/2009 4:00	27.2	24442.8	23.4	21063.7
2/15/2009 4:15	27.1	24377.7	23.5	21084.5
2/15/2009 4:30	27.0	24311.1	23.5	21097.0
2/15/2009 4:45	26.9	24245.7	23.4	21063.0
2/15/2009 5:00	26.9	24180.0	23.4	21038.8
2/15/2009 5:15	26.8	24113.4	23.4	21023.6
2/15/2009 5:30	26.7	24048.6	23.3	20996.7
2/15/2009 5:45	26.6	23983.5	23.3	20955.8
2/15/2009 6:00	26.6	23918.7	23.3	20904.3
2/15/2009 6:15	26.5	23854.2	23.2	20844.2
2/15/2009 6:30	26.4	23790.6	23.1	20791.3
2/15/2009 6:45	26.4	23731.5	23.1	20744.5
2/15/2009 7:00	26.3	23674.8	23.0	20695.9
2/15/2009 7:15	26.2	23617.8	23.0	20648.6
2/15/2009 7:30	26.2	23560.8	22.9	20604.7
2/15/2009 7:45	26.1	23504.1	22.9	20564.6
2/15/2009 8:00	26.1	23447.1	22.8	20524.8
2/15/2009 8:15	26.0	23389.5	22.8	20532.3
2/15/2009 8:30	25.9	23330.4	22.9	20564.0
2/15/2009 8:45	25.9	23271.9	22.9	20637.6
2/15/2009 9:00	25.8	23212.5	22.9	20648.8
2/15/2009 9:15	25.7	23154.0	22.9	20624.9
2/15/2009 9:30	25.7	23095.5	22.9	20582.0
2/15/2009 9:45	25.6	23037.6	22.8	20527.7
2/15/2009 10:00	25.5	22979.4	22.8	20479.4
2/15/2009 10:15	25.5	22922.7	22.7	20437.5
2/15/2009 10:30	25.4	22867.2	22.7	20396.6
2/15/2009 10:45	25.3	22812.6	22.6	20364.0
2/15/2009 11:00	25.3	22758.9	22.6	20336.7
2/15/2009 11:15	25.2	22705.8	22.6	20312.6
2/15/2009 11:30	25.2	22654.2	22.6	20287.7
2/15/2009 11:45	25.1	22603.2	22.5	20262.7
2/15/2009 12:00	25.1	22551.9	22.5	20243.3
2/15/2009 12:15	25.0	22494.3	22.5	20224.7
2/15/2009 12:30	24.9	22432.8	22.5	20190.5
2/15/2009 12:45	24.9	22374.3	22.4	20179.4
2/15/2009 13:00	24.8	22316.1	22.4	20181.9
2/15/2009 13:15	24.7	22260.9	22.4	20198.9
2/15/2009 13:30	24.7	22206.6	22.4	20175.7
2/15/2009 13:45	24.6	22154.7	22.4	20137.9
2/15/2009 14:00	24.6	22104.3	22.4	20096.3
2/15/2009 14:15	24.5	22054.5	22.3	20055.7
2/15/2009 14:30	24.5	22007.4	22.3	20018.5
2/15/2009 14:45	24.4	21960.6	22.2	19987.4
2/15/2009 15:00	24.4	21915.9	22.2	19960.7
2/15/2009 15:15	24.3	21871.8	22.2	19935.6
2/15/2009 15:30	24.3	21829.2	22.1	19912.9

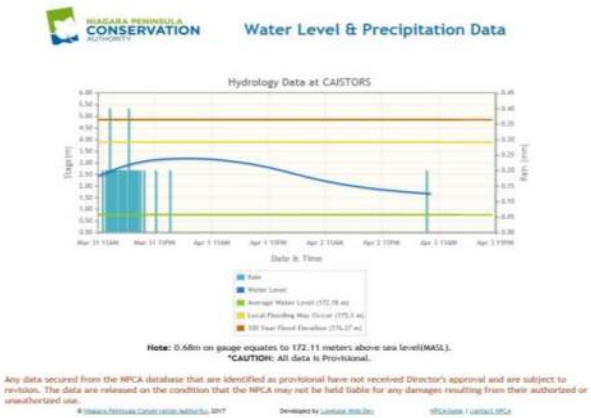
	Hydrology Model Resutls		Mike 11 Model Results	
Time	Peak Flow	Volume	Peak Flow	Volume
2/15/2009 15:45	24.2	21787.8	22.1	19899.6
2/15/2009 16:00	24.2	21747.6	22.1	19891.8
2/15/2009 16:15	24.1	21708.0	22.1	19877.5
2/15/2009 16:30	24.1	21669.3	22.1	19856.9
2/15/2009 16:45	24.0	21632.1	22.1	19833.4
2/15/2009 17:00	24.0	21595.5	22.0	19804.0
2/15/2009 17:15	24.0	21559.8	22.0	19768.9
2/15/2009 17:30	23.9	21525.6	21.9	19734.3
2/15/2009 17:45	23.9	21492.0	21.9	19706.3
2/15/2009 18:00	23.8	21460.5	21.9	19706.7
2/15/2009 18:15	23.8	21428.1	21.9	19701.8
2/15/2009 18:30	23.8	21397.5	21.9	19718.4
2/15/2009 18:45	23.7	21367.5	21.9	19728.7
2/15/2009 19:00	23.7	21338.4	21.9	19721.0
2/15/2009 19:15	23.7	21309.0	21.9	19705.1
2/15/2009 19:30	23.6	21274.8	21.9	19687.1
2/15/2009 19:45	23.6	21239.7	21.9	19673.9
2/15/2009 20:00	23.6	21204.6	21.9	19664.7
2/15/2009 20:15	23.5	21172.5	21.8	19652.2
2/15/2009 20:30	23.5	21139.8	21.8	19637.1
2/15/2009 20:45	23.5	21110.1	21.8	19621.5
2/15/2009 21:00	23.4	21081.6	21.8	19603.7
2/15/2009 21:15	23.4	21053.4	21.8	19582.3
2/15/2009 21:30	23.4	21025.8	21.7	19561.2
2/15/2009 21:45	23.3	21000.0	21.7	19541.0
2/15/2009 22:00	23.3	20974.5	21.7	19522.4
2/15/2009 22:15	23.3	20950.2	21.7	19507.8
2/15/2009 22:30	23.3	20926.8	21.7	19495.5
2/15/2009 22:45	23.2	20904.3	21.7	19484.3
2/15/2009 23:00	23.2	20882.1	21.6	19473.8
2/15/2009 23:15	23.2	20860.5	21.6	19463.0
2/15/2009 23:30	23.2	20839.8	21.6	19451.1
2/15/2009 23:45	23.1	20819.7	21.6	19436.9
2/16/2009 0:00	23.1	20799.9	21.6	19421.3
2/16/2009 0:15	23.1	20782.2	21.6	19414.1
2/16/2009 0:30	23.1	20763.3	21.6	19418.2
2/16/2009 0:45	23.0	20744.7	21.6	19420.2
2/16/2009 1:00	23.0	20727.6	21.6	19437.2
2/16/2009 1:15	23.0	20710.2	21.6	19447.8
2/16/2009 1:30	23.0	20693.1	21.6	19439.2
2/16/2009 1:45	23.0	20676.3	21.6	19423.0
2/16/2009 2:00	23.0	20660.4	21.6	19407.4
2/16/2009 2:15	22.9	20644.8	21.6	19393.6
2/16/2009 2:30	22.9	20628.9	21.5	19381.0
2/16/2009 2:45	22.9	20613.9	21.5	19368.6
2/16/2009 3:00	22.9	20599.2	21.5	19357.8
2/16/2009 3:15	22.9	20584.5	21.5	19350.3
2/16/2009 3:30	22.9	20570.1	21.5	19344.4
2/16/2009 3:45	22.8	20555.7	21.5	19339.5
2/16/2009 4:00	22.8	20541.6	21.5	19334.9
2/16/2009 4:15	22.8	20528.7	21.5	19329.4
2/16/2009 4:30	22.8	20514.9	21.5	19322.8
2/16/2009 4:45	22.8	20501.7	21.5	19313.7
2/16/2009 5:00	22.8	20488.8	21.5	19304.1
2/16/2009 5:15	22.8	20476.2	21.4	19294.9
2/16/2009 5:30	22.7	20463.3	21.4	19285.5
2/16/2009 5:45	22.7	20451.0	21.4	19276.3
2/16/2009 6:00	22.7	20439.0	21.4	19267.7
2/16/2009 6:15	22.7	20426.4	21.4	19258.3
2/16/2009 6:30	22.7	20413.8	21.4	19247.1
2/16/2009 6:45	22.7	20401.5	21.4	19235.5
2/16/2009 7:00	22.7	20389.2	21.4	19225.5
2/16/2009 7:15	22.6	20377.5	21.4	19217.5
2/16/2009 7:30	22.6	20365.2	21.3	19211.4
2/16/2009 7:45	22.6	20353.2	21.3	19206.1
2/16/2009 8:00	22.6	20341.5	21.3	19200.4
2/16/2009 8:15	22.6	20329.8	21.3	19193.5
2/16/2009 8:30	22.6	20318.4	21.3	19182.4
2/16/2009 8:45	22.6	20307.0	21.3	19186.0
2/16/2009 9:00	22.6	20295.9	21.3	19190.5
2/16/2009 9:15	22.5	20284.8	21.3	19194.8
2/16/2009 9:30	22.5	20273.7	21.3	19198.2
2/16/2009 9:45	22.5	20263.5	21.4	19224.6
2/16/2009 10:00	22.5	20253.9	21.4	19220.7
2/16/2009 10:15	22.5	20243.4	21.4	19212.7
2/16/2009 10:30	22.5	20233.8	21.3	19202.0
2/16/2009 10:45	22.5	20224.2	21.3	19190.1
2/16/2009 11:00	22.5	20214.3	21.3	19179.6
2/16/2009 11:15	22.5	20205.9	21.3	19170.6
2/16/2009 11:30	22.4	20196.3	21.3	19162.1
2/16/2009 11:45	22.4	20187.3	21.3	19154.4
2/16/2009 12:00	22.4	20178.6	21.3	19146.1
2/16/2009 12:15	22.4	20169.9	21.3	19137.5
2/16/2009 12:30	22.4	20160.3	21.3	19130.2
2/16/2009 12:45	22.4	20152.5	21.3	19124.3
2/16/2009 13:00	22.4	20143.2	21.2	19119.8
2/16/2009 13:15	22.4	20135.4	21.2	19116.6
2/16/2009 13:30	22.4	20126.1	21.2	19114.0
2/16/2009 13:45	22.4	20118.3	21.2	19112.0
2/16/2009 14:00	22.3	20109.9	21.2	19111.0
2/16/2009 14:15	22.3	20101.8	21.2	19110.3

	Hydrology Model Resutls		Mike 11 Model Results		
Time	Peak Flow	Volume	Peak Flow	Volume	
2/16/2009 14:30	22.3	20093.7	21.2	19109.3	
2/16/2009 14:45	22.3	20085.9	21.2	19108.1	
2/16/2009 15:00	22.3	20077.5	21.2	19106.3	
2/16/2009 15:15	22.3	20070.0	21.2	19103.2	
2/16/2009 15:30	22.3	20061.9	21.2	19099.4	
2/16/2009 15:45	22.3	20053.8	21.2	19096.4	
2/16/2009 16:00	22.3	20046.3	21.2	19093.8	
2/16/2009 16:15	22.3	20038.5	21.2	19091.0	
2/16/2009 16:30	22.3	20031.3	21.2	19087.4	
2/16/2009 16:45	22.2	20023.2	21.2	19082.2	
2/16/2009 17:00	22.2	20016.0	21.2	19075.7	
2/16/2009 17:15	22.2	20008.2	21.2	19068.6	
2/16/2009 17:30	22.2	20000.7	21.2	19062.0	
2/16/2009 17:45	22.2	19993.5	21.2	19056.2	
2/16/2009 18:00	22.2	19985.7	21.2	19051.1	
2/16/2009 18:15	22.2	19978.8	21.2	19046.2	
2/16/2009 18:30	22.2	19971.3	21.2	19040.7	
2/16/2009 18:45	22.2	19963.8	21.2	19035.5	
2/16/2009 19:00	22.2	19956.9	21.1	19031.0	
2/16/2009 19:15	22.2	19949.7	21.1	19027.3	
2/16/2009 19:30	22.2	19942.2	21.1	19024.3	
2/16/2009 19:45	22.1	19934.1	21.1	19021.6	
2/16/2009 20:00	22.1	19926.9	21.1	19018.9	
2/16/2009 20:15	22.1	19919.4	21.1	19016.9	
2/16/2009 20:30	22.1	19911.6	21.1	19015.3	
2/16/2009 20:45	22.1	19904.7	21.1	19014.0	
2/16/2009 21:00	22.1	19897.2	21.1	19013.4	
2/16/2009 21:15	22.1	19890.0	21.1	19005.4	
2/16/2009 21:30	22.1	19883.1	21.1	19007.5	
2/16/2009 21:45	22.1	19875.6	21.1	19015.3	
2/16/2009 22:00	22.1	19869.0	21.1	19018.9	
2/16/2009 22:15	22.1	19861.2	21.1	19021.5	
2/16/2009 22:30	22.1	19854.0	21.1	19023.7	
					different
Total Volume (m3)		25373766.9		24851723.1	-2.10%
Max Peak Flow (cms)	94.9		95.3		0.34%

Summary Table - Water Leve at Caistors Corners Gauge (West Lincoln, also referred as Church Road gauge)

*Water Elevation = Monitoring depth value + 172.11m -0.68m (Datum @ Caistors, value from NPCA website)

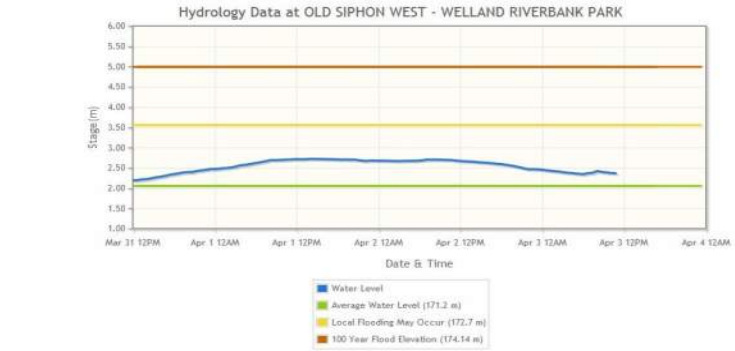
	NPCA Monintoring station		Mike 11 Model Results
Time	Value	Observed Water Elevation	Simulated Water Elevation
	(m)	(m)	(m)
2/10/2009 0:00	2.74	174.17	172.18
2/10/2009 1:00	2.75	174.18	172.43
2/10/2009 2:00	2.76	174.19	172.50
2/10/2009 3:00	2.76	174.19	172.54
2/10/2009 4:00	2.77	174.20	172.62
2/10/2009 5:00	2.77	174.20	172.76
2/10/2009 6:00	2.78	174.21	172.89
2/10/2009 7:00	2.78	174.21	173.00
2/10/2009 8:00	2.78	174.21	173.10
2/10/2009 9:00	2.78	174.21	173.21
2/10/2009 10:00	2.78	174.21	173.33
2/10/2009 11:00	2.77	174.20	173.46
2/10/2009 12:00	2.77	174.20	173.61
2/10/2009 13:00	2.77	174.20	173.74
2/10/2009 14:00	2.77	174.20	173.85
2/10/2009 15:00	2.80	174.23	173.94
2/10/2009 16:00	2.83	174.26	174.02
2/10/2009 17:00	2.86	174.29	174.09
2/10/2009 18:00	2.89	174.32	174.14
2/10/2009 19:00	2.93	174.36	174.19
2/10/2009 20:00	2.99	174.42	174.22
2/10/2009 21:00	3.04	174.47	174.25
2/10/2009 22:00	3.09	174.52	174.28
2/10/2009 23:00	3.12	174.55	174.31
2/11/2009 0:00	3.14	174.57	174.32
2/11/2009 1:00	3.16	174.59	174.33
2/11/2009 2:00	3.18	174.61	174.34
2/11/2009 3:00	3.21	174.64	174.35
2/11/2009 4:00	3.23	174.66	174.35
2/11/2009 5:00	3.27	174.70	174.35
2/11/2009 6:00	3.29	174.72	174.35
2/11/2009 7:00	3.32	174.75	174.36
2/11/2009 8:00	3.35	174.78	174.37
2/11/2009 9:00	3.37	174.80	174.40
2/11/2009 10:00	3.37	174.80	174.43
2/11/2009 11:00	3.14	174.57	174.49
2/11/2009 12:00	3.39	174.82	174.55
2/11/2009 13:00	3.41	174.84	174.62
2/11/2009 14:00	3.44	174.87	174.69
2/11/2009 15:00	3.46	174.89	174.74
2/11/2009 16:00	3.48	174.91	174.79
2/11/2009 17:00	3.51	174.94	174.83
2/11/2009 18:00	3.54	174.97	174.86
2/11/2009 19:00	3.55	174.98	174.91
2/11/2009 20:00	3.57	175.00	174.93
2/11/2009 21:00	3.59	175.02	174.96
2/11/2009 22:00	3.61	175.04	174.99
2/11/2009 23:00	3.64	175.07	175.02
2/12/2009 0:00	3.68	175.11	175.04
2/12/2009 1:00	3.74	175.17	175.09
2/12/2009 2:00	3.79	175.22	175.14
2/12/2009 3:00	3.79	175.22	175.20
2/12/2009 4:00	3.84	175.27	175.24
2/12/2009 5:00	3.88	175.31	175.31
2/12/2009 6:00	3.91	175.34	175.34
2/12/2009 7:00	3.93	175.36	175.40
2/12/2009 8:00	3.97	175.40	175.44
2/12/2009 9:00	4.12	175.55	175.49
2/12/2009 10:00	4.16	175.59	175.52
2/12/2009 11:00	4.19	175.62	175.56
2/12/2009 12:00	4.25	175.68	175.60
2/12/2009 13:00	4.25	175.68	175.63
2/12/2009 14:00	4.25	175.68	175.65
2/12/2009 15:00	4.27	175.70	175.69
2/12/2009 16:00	4.28	175.71	175.71
2/12/2009 17:00	4.29	175.72	175.73
2/12/2009 18:00	4.30	175.73	175.75
2/12/2009 19:00	4.31	175.74	175.76
2/12/2009 20:00	4.31	175.74	175.78
2/12/2009 21:00	4.32	175.75	175.80
2/12/2009 22:00	4.31	175.74	175.80
2/12/2009 23:00	4.31	175.74	175.81
2/13/2009 0:00	4.30	175.73	175.81
2/13/2009 1:00	4.29	175.72	175.81
2/13/2009 2:00	4.27	175.70	175.81
2/13/2009 3:00	4.25	175.68	175.81
2/13/2009 4:00	4.24	175.67	175.80
2/13/2009 5:00	4.22	175.65	175.80
2/13/2009 6:00	4.19	175.62	175.79
2/13/2009 7:00	4.17	175.60	175.77
2/13/2009 8:00	4.14	175.57	175.76
2/13/2009 9:00	4.12	175.55	175.75
2/13/2009 10:00	4.09	175.52	175.73
2/13/2009 11:00	4.06	175.49	175.71
2/13/2009 12:00	4.03	175.46	175.70
2/13/2009 13:00	4.00	175.43	175.67
2/13/2009 14:00	3.97	175.40	175.64
2/13/2009 15:00	3.94	175.37	175.62
2/13/2009 16:00	3.91	175.34	175.60
2/13/2009 17:00	3.88	175.31	175.57
2/13/2009 18:00	3.85	175.28	175.54
2/13/2009 19:00	3.81	175.24	175.52
2/13/2009 20:00	3.78	175.21	175.50
2/13/2009 21:00	3.75	175.18	175.46
2/13/2009 22:00	3.72	175.15	175.43
2/13/2009 23:00	3.68	175.11	175.40
2/14/2009 0:00	3.65	175.08	175.37



Summary Table - Water Leve at Old Siphon West (Welland Riverbank Park, located at the upstream end of the Old Siphon)

*Water Elevation = Monitoring depth value + 169.15m (Datum @ Old Siphon West, value from NPCA website)

	NPCA Monintoring station		Mike 11 Model Results
Time	Value	Observed Water Elevation	Simulated Water Elevation
	(m)	(m)	(m)
2/10/2009 0:00	2.33	171.48	166.815
2/10/2009 1:00	2.34	171.49	166.815
2/10/2009 2:00	2.35	171.5	166.837
2/10/2009 3:00	2.35	171.5	166.863
2/10/2009 4:00	2.36	171.51	166.921
2/10/2009 5:00	2.36	171.51	166.981
2/10/2009 6:00	2.36	171.51	167.409
2/10/2009 7:00	2.37	171.52	168.962
2/10/2009 8:00	2.37	171.52	169.593
2/10/2009 9:00	2.38	171.53	169.601
2/10/2009 10:00	2.38	171.53	169.932
2/10/2009 11:00	2.38	171.53	170.529
2/10/2009 12:00	2.38	171.53	170.77
2/10/2009 13:00	2.38	171.53	170.858
2/10/2009 14:00	2.37	171.52	170.952
2/10/2009 15:00	2.37	171.52	171.022
2/10/2009 16:00	2.37	171.52	171.06
2/10/2009 17:00	2.38	171.53	171.09
2/10/2009 18:00	2.4	171.55	171.132
2/10/2009 19:00	2.42	171.57	171.164
2/10/2009 20:00	2.43	171.58	171.207
2/10/2009 21:00	2.44	171.59	171.245
2/10/2009 22:00	2.46	171.61	171.267
2/10/2009 23:00	2.48	171.63	171.301
2/11/2009 0:00	2.49	171.64	171.335
2/11/2009 1:00	2.52	171.67	171.353
2/11/2009 2:00	2.53	171.68	171.38
2/11/2009 3:00	2.55	171.7	171.426
2/11/2009 4:00	2.57	171.72	171.44
2/11/2009 5:00	2.58	171.73	171.455
2/11/2009 6:00	2.6	171.75	171.503
2/11/2009 7:00	2.62	171.77	171.531
2/11/2009 8:00	2.64	171.79	171.555
2/11/2009 9:00	2.65	171.8	171.618
2/11/2009 10:00	2.66	171.81	171.648
2/11/2009 11:00	2.67	171.82	171.711
2/11/2009 12:00	2.68	171.83	171.742
2/11/2009 13:00	2.7	171.85	171.797
2/11/2009 14:00	2.73	171.88	171.823
2/11/2009 15:00	2.77	171.92	171.854
2/11/2009 16:00	2.8	171.95	171.903
2/11/2009 17:00	2.83	171.98	171.928
2/11/2009 18:00	2.85	172	171.987
2/11/2009 19:00	2.88	172.03	172.023
2/11/2009 20:00	2.9	172.05	172.072
2/11/2009 21:00	2.95	172.1	172.107
2/11/2009 22:00	3.02	172.17	172.142
2/11/2009 23:00	3.09	172.24	172.187
2/12/2009 0:00	3.14	172.29	172.302
2/12/2009 1:00	3.17	172.32	172.396
2/12/2009 2:00	3.21	172.36	172.446
2/12/2009 3:00	3.25	172.4	172.507
2/12/2009 4:00	3.29	172.44	172.572
2/12/2009 5:00	3.33	172.48	172.623
2/12/2009 6:00	3.37	172.52	172.703
2/12/2009 7:00	3.43	172.58	172.787
2/12/2009 8:00	3.49	172.64	172.838
2/12/2009 9:00	3.53	172.68	172.901
2/12/2009 10:00	3.56	172.71	172.97
2/12/2009 11:00	3.6	172.75	173.023
2/12/2009 12:00	3.63	172.78	173.087
2/12/2009 13:00	3.66	172.81	173.14
2/12/2009 14:00	3.7	172.85	173.197
2/12/2009 15:00	3.72	172.87	173.252
2/12/2009 16:00	3.75	172.9	173.304
2/12/2009 17:00	3.76	172.91	173.356
2/12/2009 18:00	3.78	172.93	173.401
2/12/2009 19:00	3.8	172.95	173.452
2/12/2009 20:00	3.81	172.96	173.496
2/12/2009 21:00	3.83	172.98	173.536
2/12/2009 22:00	3.84	172.99	173.584
2/12/2009 23:00	3.85	173	173.61
2/13/2009 0:00	3.86	173.01	173.648
2/13/2009 1:00	3.87	173.02	173.684
2/13/2009 2:00	3.88	173.03	173.704
2/13/2009 3:00	3.89	173.04	173.733
2/13/2009 4:00	3.9	173.05	173.771
2/13/2009 5:00	3.91	173.06	173.781
2/13/2009 6:00	3.92	173.07	173.791
2/13/2009 7:00	3.93	173.08	173.807
2/13/2009 8:00	3.93	173.08	173.821
2/13/2009 9:00	3.94	173.09	173.832
2/13/2009 10:00	3.94	173.09	173.84
2/13/2009 11:00	3.94	173.09	173.847
2/13/2009 12:00	3.95	173.1	173.854
2/13/2009 13:00	3.95	173.1	173.856
2/13/2009 14:00	3.95	173.1	173.855
2/13/2009 15:00	3.95	173.1	173.85
2/13/2009 16:00	3.95	173.1	173.844
2/13/2009 17:00	3.96	173.11	173.836



Note: 0m on gauge equates to 169.15 meters above sea level(MASL).
***CAUTION:** All data is Provisional.

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2/13/2009 18:00	3.97	173.12	173.826
2/13/2009 19:00	3.97	173.12	173.813
2/13/2009 20:00	3.96	173.11	173.796
2/13/2009 21:00	3.96	173.11	173.786
2/13/2009 22:00	3.95	173.1	173.78
2/13/2009 23:00	3.95	173.1	173.771
2/14/2009 0:00	3.94	173.09	173.739
2/14/2009 1:00	3.93	173.08	173.713
2/14/2009 2:00	3.92	173.07	173.691
2/14/2009 3:00	3.92	173.07	173.681
2/14/2009 4:00	3.91	173.06	173.657
2/14/2009 5:00	3.9	173.05	173.622
2/14/2009 6:00	3.89	173.04	173.597
2/14/2009 7:00	3.89	173.04	173.586
2/14/2009 8:00	3.88	173.03	173.548
2/14/2009 9:00	3.87	173.02	173.51
2/14/2009 10:00	3.86	173.01	173.489
2/14/2009 11:00	3.84	172.99	173.461
2/14/2009 12:00	3.83	172.98	173.419
2/14/2009 13:00	3.81	172.96	173.396
2/14/2009 14:00	3.79	172.94	173.368
2/14/2009 15:00	3.77	172.92	173.322
2/14/2009 16:00	3.75	172.9	173.295
2/14/2009 17:00	3.74	172.89	173.271
2/14/2009 18:00	3.72	172.87	173.224
2/14/2009 19:00	3.7	172.85	173.194
2/14/2009 20:00	3.68	172.83	173.172
2/14/2009 21:00	3.66	172.81	173.124
2/14/2009 22:00	3.64	172.79	173.096
2/14/2009 23:00	3.62	172.77	173.079
2/15/2009 0:00	3.6	172.75	173.03

Summary Table - Calibration Results for Runoff Volume and Peak Flow Rate at Church Road

	Hydrology Model Resutls		Mike 11 Model Results (Channel Manning's n 0.035)		Mike 11 Model Results (Channel Manning's n 0.02)		Mike 11 Model Results (Channel Manning's n 0.025)	
Time	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)
2/10/2009 0:00	21.0	6294.6	25.0	135.8	25.0	205.0	25.0	185.3
2/10/2009 0:15	21.0	18883.8	0.5	346.3	2.7	705.2	2.2	523.6
2/10/2009 0:30	21.0	18883.8	0.7	469.2	2.7	1467.9	1.6	902.4
2/10/2009 0:45	21.0	18883.8	1.8	1068.2	4.1	3119.1	3.2	2237.7
2/10/2009 1:00	21.0	18883.8	3.0	2190.3	4.2	3799.3	3.9	3289.7
2/10/2009 1:15	21.0	18883.8	3.4	2931.4	4.3	3822.6	3.9	3489.3
2/10/2009 1:30	21.0	18883.8	3.6	3147.4	4.4	3968.2	4.1	3636.4
2/10/2009 1:45	21.0	18883.8	3.7	3258.8	4.5	3996.6	4.1	3704.8
2/10/2009 2:00	21.0	18883.8	3.8	3389.3	4.5	4027.7	4.2	3788.2
2/10/2009 2:15	21.0	18883.8	3.9	3428.9	4.6	4101.4	4.3	3835.0
2/10/2009 2:30	21.0	18883.8	3.9	3517.9	4.6	4107.7	4.3	3867.4
2/10/2009 2:45	21.0	18883.8	4.0	3560.5	4.6	4123.4	4.3	3890.8
2/10/2009 3:00	21.0	18883.8	4.0	3592.5	4.6	4146.3	4.4	3933.7
2/10/2009 3:15	21.0	18883.8	4.1	3642.3	4.7	4188.2	4.4	3960.9
2/10/2009 3:30	21.0	18883.8	4.1	3687.5	4.8	4275.4	4.4	3981.8
2/10/2009 3:45	21.0	18883.8	4.1	3709.3	5.1	4448.9	4.5	4013.1
2/10/2009 4:00	21.0	18883.8	4.2	3730.7	5.5	4715.9	4.6	4070.6
2/10/2009 4:15	21.0	18883.8	4.2	3751.5	6.0	5161.3	4.7	4177.0
2/10/2009 4:30	21.0	18883.8	4.2	3772.8	6.4	5577.9	5.0	4352.9
2/10/2009 4:45	21.0	18883.8	4.2	3798.2	7.0	5987.1	5.3	4600.3
2/10/2009 5:00	21.0	18883.8	4.3	3833.4	7.4	6508.5	5.7	4969.2
2/10/2009 5:15	21.0	18883.8	4.4	3891.5	7.8	6879.0	6.1	5342.4
2/10/2009 5:30	21.0	18883.8	4.5	4005.1	8.4	7253.0	6.5	5705.1
2/10/2009 5:45	21.0	18883.8	4.7	4147.6	8.7	7656.3	7.0	6132.5
2/10/2009 6:00	21.0	18883.8	4.9	4337.7	9.0	7954.3	7.4	6486.5
2/10/2009 6:15	21.0	18883.8	5.2	4575.1	9.5	8245.6	7.8	6796.4
2/10/2009 6:30	21.0	18884.1	5.6	4838.9	9.7	8645.4	8.2	7198.0
2/10/2009 6:45	21.0	18886.2	5.9	5198.1	10.1	8918.9	8.5	7488.5
2/10/2009 7:00	21.0	18890.1	6.3	5505.0	10.3	9200.2	8.8	7749.0
2/10/2009 7:15	21.0	18896.4	6.6	5794.0	10.8	9503.4	9.1	8093.5
2/10/2009 7:30	21.0	18905.4	7.0	6152.2	11.1	9869.9	9.4	8354.8
2/10/2009 7:45	21.0	18918.3	7.3	6422.4	11.5	10157.5	9.7	8609.2
2/10/2009 8:00	21.1	18934.5	7.6	6666.3	11.8	10467.0	10.0	8849.8
2/10/2009 8:15	21.1	18954.9	7.9	6993.7	12.3	10786.6	10.4	9207.7
2/10/2009 8:30	21.1	18979.8	8.2	7242.6	12.7	11272.1	10.7	9473.7
2/10/2009 8:45	21.1	19009.8	8.4	7479.0	13.2	11651.8	11.0	9754.5
2/10/2009 9:00	21.2	19044.3	8.8	7784.6	13.6	12049.9	11.4	10022.1
2/10/2009 9:15	21.2	19084.8	9.1	8042.3	14.3	12579.8	11.8	10432.6
2/10/2009 9:30	21.3	19131.9	9.3	8274.1	14.8	13086.6	12.1	10736.2
2/10/2009 9:45	21.4	19186.5	9.7	8526.0	15.3	13557.3	12.5	11056.0
2/10/2009 10:00	21.4	19247.4	9.9	8835.5	16.1	14059.0	13.0	11402.8
2/10/2009 10:15	21.5	19316.4	10.2	9074.9	16.6	14693.8	13.4	11870.7
2/10/2009 10:30	21.6	19394.7	10.5	9309.0	17.1	15165.3	13.8	12260.0
2/10/2009 10:45	21.7	19482.6	10.9	9636.6	17.8	15594.2	14.3	12636.5
2/10/2009 11:00	21.8	19580.1	11.2	9920.9	18.3	16241.9	14.9	13206.5
2/10/2009 11:15	22.0	19687.5	11.5	10190.4	18.8	16675.2	15.4	13652.5
2/10/2009 11:30	22.1	19808.4	11.9	10483.1	19.3	17082.8	16.0	14101.6
2/10/2009 11:45	22.3	19942.8	12.2	10867.3	20.0	17743.5	16.7	14754.9
2/10/2009 12:00	22.4	20090.1	12.6	11182.8	20.4	18181.0	17.2	15250.2
2/10/2009 12:15	22.6	20247.0	13.1	11507.7	20.8	18604.8	17.9	15718.5
2/10/2009 12:30	22.8	20399.1	13.5	11980.1	21.5	18987.7	18.5	16424.4
2/10/2009 12:45	22.9	20548.2	14.0	12361.0	22.0	19609.1	19.1	16941.3
2/10/2009 13:00	23.1	20695.5	14.5	12752.7	22.5	20011.5	19.9	17453.8
2/10/2009 13:15	23.3	20840.4	15.0	13299.2	22.9	20437.9	20.4	18141.5
2/10/2009 13:30	23.4	20979.9	15.5	13732.1	23.7	20889.1	21.0	18627.2
2/10/2009 13:45	23.6	21117.6	16.2	14205.0	24.1	21514.9	21.7	19108.6
2/10/2009 14:00	23.7	21255.3	16.7	14769.0	24.6	21912.3	22.2	19776.1
2/10/2009 14:15	23.9	21387.6	17.1	15224.1	24.9	22305.6	22.7	20245.5
2/10/2009 14:30	24.0	21513.9	17.9	15793.0	25.5	22642.3	23.3	20643.9
2/10/2009 14:45	24.1	21644.4	18.5	16367.9	26.0	23256.9	23.9	21308.7
2/10/2009 15:00	24.3	21776.4	19.0	16841.7	26.5	23646.3	24.4	21759.3
2/10/2009 15:15	24.4	21909.0	19.7	17470.7	27.0	24066.9	24.9	22171.4
2/10/2009 15:30	24.6	22044.3	20.3	18000.6	27.2	24403.7	25.4	22546.1
2/10/2009 15:45	24.8	22182.6	20.6	18426.5	28.0	24856.3	26.0	23188.0
2/10/2009 16:00	24.9	22324.8	21.4	18948.6	28.4	25378.8	26.4	23557.9
2/10/2009 16:15	25.1	22471.5	21.8	19453.2	28.7	25700.5	26.8	23916.0
2/10/2009 16:30	25.3	22624.5	22.3	19858.2	29.1	26022.2	27.0	24214.2
2/10/2009 16:45	25.4	22782.9	22.9	20253.7	29.4	26322.6	27.6	24537.6
2/10/2009 17:00	25.6	22945.8	23.3	20812.2	29.6	26538.4	28.0	25034.4
2/10/2009 17:15	25.8	23115.9	23.8	21195.8	30.1	26879.7	28.3	25308.0
2/10/2009 17:30	26.0	23295.9	24.1	21535.0	30.6	27364.2	28.6	25598.6
2/10/2009 17:45	26.2	23485.8	24.7	21903.7	30.9	27695.5	28.9	25879.3
2/10/2009 18:00	26.4	23662.8	25.0	22362.1	31.2	27966.4	29.1	26103.5
2/10/2009 18:15	26.6	23805.0	25.4	22684.7	31.5	28234.3	29.6	26380.8
2/10/2009 18:30	26.7	23945.4	25.7	22985.8	31.8	28483.1	29.9	26823.7
2/10/2009 18:45	26.9	24085.5	26.0	23225.9	32.0	28702.8	30.2	27053.6
2/10/2009 19:00	27.0	24224.7	26.5	23659.1	32.1	28831.4	30.4	27274.1
2/10/2009 19:15	27.2	24363.3	26.8	23973.1	32.5	29048.0	30.7	27489.5
2/10/2009 19:30	27.3	24501.0	27.1	24241.1	32.8	29364.1	30.9	27704.8
2/10/2009 19:45	27.5	24637.5	27.3	24474.8	33.1	29692.2	31.1	27909.1
2/10/2009 20:00	27.6	24772.5	27.5	24669.2	33.3	29903.8	31.2	28054.7
2/10/2009 20:15	27.8	24906.3	27.8	24830.6	33.5	30066.2	31.5	28215.0
2/10/2009 20:30	27.9	25038.3	28.2	25205.5	33.7	30225.2	31.9	28499.6
2/10/2009 20:45	28.1	25168.2	28.4	25446.5	33.8	30375.2	32.0	28771.1
2/10/2009 21:00	28.2	25298.7	28.6	25656.6	34.0	30522.0	32.2	28906.9

	Hydrology Model Resutls		Mike 11 Model Results (Channel Manning's n 0.035)		Mike 11 Model Results (Channel Manning's n 0.02)		Mike 11 Model Results (Channel Manning's n 0.025)	
Time	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)
2/10/2009 21:15	28.4	25430.1	28.8	25852.9	34.2	30669.0	32.4	29059.5
2/10/2009 21:30	28.5	25560.0	29.0	26035.3	34.3	30815.2	32.5	29212.9
2/10/2009 21:45	28.6	25689.0	29.2	26199.8	34.5	30961.5	32.7	29365.1
2/10/2009 22:00	28.8	25815.9	29.4	26348.1	34.6	31077.2	32.9	29512.2
2/10/2009 22:15	28.9	25948.8	29.5	26456.0	34.7	31167.8	33.0	29647.8
2/10/2009 22:30	29.1	26090.4	29.8	26667.6	34.9	31321.2	33.2	29774.5
2/10/2009 22:45	29.2	26229.9	30.0	26927.2	35.1	31516.4	33.3	29891.4
2/10/2009 23:00	29.4	26364.6	30.2	27074.8	35.3	31670.4	33.3	29991.0
2/10/2009 23:15	29.5	26497.5	30.3	27206.7	35.4	31819.2	33.4	30022.4
2/10/2009 23:30	29.7	26626.8	30.4	27324.9	35.5	31942.7	33.6	30144.6
2/10/2009 23:45	29.8	26752.8	30.5	27433.8	35.6	32017.6	33.7	30290.1
2/11/2009 0:00	29.9	26874.6	30.6	27535.7	35.6	32065.3	33.9	30417.2
2/11/2009 0:15	30.1	26993.1	30.8	27631.3	35.7	32083.7	34.0	30575.5
2/11/2009 0:30	30.2	27106.5	30.9	27723.8	35.7	32108.1	34.1	30671.7
2/11/2009 0:45	30.3	27216.0	31.0	27813.0	35.7	32134.2	34.2	30725.3
2/11/2009 1:00	30.4	27318.6	31.0	27899.8	35.7	32158.7	34.3	30793.0
2/11/2009 1:15	30.5	27418.5	31.1	27983.2	35.8	32180.0	34.3	30861.0
2/11/2009 1:30	30.6	27515.1	31.2	28059.7	35.8	32196.6	34.4	30925.8
2/11/2009 1:45	30.7	27604.2	31.3	28128.3	35.8	32207.8	34.5	30985.9
2/11/2009 2:00	30.8	27684.3	31.3	28186.3	35.8	32213.7	34.5	31041.1
2/11/2009 2:15	30.9	27757.2	31.4	28204.8	35.8	32213.5	34.6	31091.3
2/11/2009 2:30	31.0	27831.3	31.5	28311.1	35.8	32206.9	34.6	31136.1
2/11/2009 2:45	31.0	27900.6	31.6	28399.1	35.8	32195.3	34.7	31174.3
2/11/2009 3:00	31.1	27958.5	31.7	28487.8	35.8	32178.5	34.7	31204.8
2/11/2009 3:15	31.2	28011.3	31.8	28586.3	35.7	32155.8	34.7	31227.1
2/11/2009 3:30	31.2	28060.2	31.8	28622.7	35.7	32127.8	34.7	31241.7
2/11/2009 3:45	31.3	28102.5	31.9	28665.0	35.7	32094.6	34.7	31249.8
2/11/2009 4:00	31.3	28142.4	31.9	28705.1	35.6	32056.6	34.7	31252.3
2/11/2009 4:15	31.3	28172.1	32.0	28742.4	35.6	32013.5	34.7	31250.2
2/11/2009 4:30	31.4	28199.1	32.0	28776.9	35.5	31964.0	34.7	31243.7
2/11/2009 4:45	31.4	28225.8	32.0	28809.7	35.5	31908.3	34.7	31232.5
2/11/2009 5:00	31.4	28242.3	32.1	28840.1	35.4	31847.2	34.7	31216.9
2/11/2009 5:15	31.4	28254.6	32.1	28867.8	35.3	31778.5	34.7	31196.6
2/11/2009 5:30	31.4	28263.3	32.1	28892.8	35.3	31700.9	34.7	31171.4
2/11/2009 5:45	31.4	28275.6	32.1	28914.6	35.2	31618.2	34.6	31140.5
2/11/2009 6:00	31.4	28269.3	32.2	28932.9	35.1	31532.6	34.6	31104.8
2/11/2009 6:15	31.4	28273.5	32.2	28947.7	35.0	31444.4	34.5	31065.6
2/11/2009 6:30	31.5	28302.3	32.2	28962.1	34.9	31360.3	34.5	31027.5
2/11/2009 6:45	31.6	28360.2	32.2	28981.3	34.8	31286.1	34.5	30995.5
2/11/2009 7:00	31.7	28443.6	32.2	29007.0	34.7	31223.0	34.4	30971.2
2/11/2009 7:15	31.8	28550.4	32.3	29040.4	34.7	31172.3	34.4	30955.7
2/11/2009 7:30	32.0	28686.0	32.3	29082.4	34.6	31137.0	34.4	30950.9
2/11/2009 7:45	32.2	28851.0	32.4	29135.2	34.6	31120.8	34.4	30959.8
2/11/2009 8:00	32.4	29042.1	32.5	29203.0	34.6	31127.4	34.4	30984.8
2/11/2009 8:15	32.7	29267.1	32.6	29281.9	34.7	31159.7	34.5	31027.5
2/11/2009 8:30	33.0	29522.4	32.7	29373.1	34.7	31220.7	34.6	31090.2
2/11/2009 8:45	33.4	29808.9	32.8	29479.3	34.9	31313.0	34.7	31174.6
2/11/2009 9:00	33.7	30124.5	33.0	29603.3	35.0	31437.9	34.8	31280.8
2/11/2009 9:15	34.1	30466.5	33.1	29746.9	35.2	31597.7	35.0	31409.3
2/11/2009 9:30	34.5	30806.4	33.3	29910.1	35.4	31790.0	35.1	31546.7
2/11/2009 9:45	34.9	31149.3	33.5	30089.2	35.7	32015.9	35.3	31638.2
2/11/2009 10:00	35.3	31521.9	33.7	30276.5	36.0	32272.2	35.6	31908.2
2/11/2009 10:15	35.8	31928.7	34.0	30441.6	36.3	32552.5	36.1	32234.1
2/11/2009 10:30	36.3	32371.2	34.4	30782.0	36.5	32804.7	36.4	32624.9
2/11/2009 10:45	36.8	32835.0	34.8	31192.6	37.0	33036.1	36.7	32891.7
2/11/2009 11:00	37.4	33321.6	35.2	31496.1	37.6	33526.8	37.1	33215.4
2/11/2009 11:15	37.9	33811.2	35.5	31818.4	38.2	34116.6	37.5	33573.9
2/11/2009 11:30	38.5	34321.2	35.9	32162.0	38.6	34536.5	38.0	33959.9
2/11/2009 11:45	39.2	34867.8	36.4	32528.0	39.1	34972.3	38.4	34358.3
2/11/2009 12:00	39.8	35440.5	36.8	32934.4	39.6	35431.0	38.7	34682.4
2/11/2009 12:15	40.5	36042.6	37.3	33340.7	40.0	35858.7	39.5	35185.0
2/11/2009 12:30	41.2	36669.9	37.7	33736.1	40.8	36288.2	40.3	35963.0
2/11/2009 12:45	42.0	37328.1	38.1	34059.2	41.9	37211.7	40.8	36470.6
2/11/2009 13:00	42.8	38019.0	39.0	34703.4	42.5	37941.8	41.4	36975.9
2/11/2009 13:15	43.6	38736.3	39.6	35348.4	43.1	38518.4	41.9	37481.3
2/11/2009 13:30	44.4	39447.6	40.1	35857.7	43.6	39090.5	42.3	37947.4
2/11/2009 13:45	45.1	40151.4	40.7	36363.3	44.4	39523.3	43.3	38497.7
2/11/2009 14:00	45.9	40846.2	41.2	36868.9	45.6	40513.2	44.3	39495.9
2/11/2009 14:15	46.6	41517.3	41.8	37350.3	46.2	41315.9	44.9	40107.4
2/11/2009 14:30	47.3	42168.3	42.1	37784.6	47.0	41944.4	45.5	40665.8
2/11/2009 14:45	47.9	42772.5	42.8	38192.7	47.5	42576.3	46.1	41200.1
2/11/2009 15:00	48.5	43321.8	43.7	38981.1	48.3	43050.5	46.4	41654.7
2/11/2009 15:15	49.1	43862.1	44.2	39582.3	49.5	44042.1	47.2	42062.4
2/11/2009 15:30	49.7	44389.2	44.8	40053.1	50.2	44936.8	48.2	42924.6
2/11/2009 15:45	50.3	44902.8	45.3	40524.4	50.8	45434.0	48.8	43698.6
2/11/2009 16:00	50.8	45400.5	45.8	40969.9	51.3	45909.8	49.3	44147.6
2/11/2009 16:15	51.3	45878.4	46.2	41390.8	51.5	46270.8	49.8	44595.9
2/11/2009 16:30	51.8	46336.5	46.6	41780.0	52.2	46630.6	50.3	45046.6
2/11/2009 16:45	52.3	46776.6	46.9	42017.3	53.2	47424.7	50.6	45458.1
2/11/2009 17:00	52.7	47196.3	47.5	42512.5	54.0	48276.2	50.9	45638.6
2/11/2009 17:15	53.2	47597.7	48.3	43124.1	54.4	48800.6	51.5	46077.7
2/11/2009 17:30	53.5	47966.1	48.6	43608.9	54.9	49181.0	52.2	46663.6
2/11/2009 17:45	53.9	48279.0	49.0	43921.0	55.3	49558.8	52.7	47239.4
2/11/2009 18:00	54.2	48566.7	49.3	44230.3	55.5	49860.1	53.0	47570.8
2/11/2009 18:15	54.5	48859.8	49.6	44526.2	55.7	50045.8	53.4	47858.5
2/11/2009 18:30	54.9	49178.1	50.0	44813.1	56.1	50259.9	53.7	48186.0
2/11/2009 18:45	55.3	49542.9	50.3	45096.3	56.6	50721.7	54.1	48502.3

	Hydrology Model Resutls		Mike 11 Model Results (Channel Manning's n 0.035)		Mike 11 Model Results (Channel Manning's n 0.02)		Mike 11 Model Results (Channel Manning's n 0.025)	
Time	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)
2/11/2009 19:00	55.8	49946.7	50.6	45382.0	57.2	51226.6	54.4	48824.8
2/11/2009 19:15	56.3	50384.1	50.9	45674.0	57.8	51786.2	54.8	49159.6
2/11/2009 19:30	56.7	50796.6	51.0	45804.9	58.3	52254.0	54.9	49348.4
2/11/2009 19:45	57.1	51193.5	51.6	46198.3	58.7	52643.0	55.3	49558.6
2/11/2009 20:00	57.6	51564.6	52.2	46675.8	59.0	52963.6	55.9	50070.5
2/11/2009 20:15	58.0	51910.2	52.6	47194.5	59.5	53331.9	56.5	50561.8
2/11/2009 20:30	58.3	52260.3	52.9	47465.2	59.9	53742.2	57.0	51058.9
2/11/2009 20:45	58.7	52591.8	53.2	47707.8	60.2	54065.4	57.3	51430.3
2/11/2009 21:00	59.0	52900.2	53.5	47978.6	60.5	54309.1	57.6	51686.1
2/11/2009 21:15	59.4	53208.3	53.8	48246.4	60.9	54585.3	57.9	51951.2
2/11/2009 21:30	59.6	53508.3	54.0	48503.2	61.5	55090.3	58.2	52251.5
2/11/2009 21:45	60.0	53779.2	54.3	48745.5	62.0	55556.8	58.6	52580.3
2/11/2009 22:00	60.2	54039.6	54.5	48973.8	62.5	56059.5	59.0	52916.4
2/11/2009 22:15	60.5	54297.3	54.8	49188.3	62.9	56464.0	59.3	53247.2
2/11/2009 22:30	60.8	54538.2	54.9	49343.4	63.2	56759.5	59.5	53510.8
2/11/2009 22:45	61.0	54794.4	55.0	49387.1	63.5	57013.8	59.7	53646.9
2/11/2009 23:00	61.3	54978.0	55.5	49740.9	63.7	57238.5	60.0	53821.9
2/11/2009 23:15	61.4	55224.3	55.9	50106.5	64.0	57479.3	60.5	54227.9
2/11/2009 23:30	61.7	55394.4	56.4	50523.3	64.3	57763.8	60.9	54600.2
2/11/2009 23:45	61.9	55623.9	56.7	50878.6	64.6	58045.1	61.3	54936.0
2/12/2009 0:00	62.1	55763.1	56.8	51054.0	64.8	58255.0	61.6	55282.5
2/12/2009 0:15	62.6	56013.0	57.0	51226.5	65.0	58444.2	61.8	55527.9
2/12/2009 0:30	63.4	56522.4	57.3	51461.4	65.3	58654.1	62.2	55792.8
2/12/2009 0:45	64.5	57337.2	57.8	51791.9	66.0	59051.6	62.6	56103.4
2/12/2009 1:00	65.9	58438.8	58.3	52214.8	66.8	59755.3	63.1	56552.5
2/12/2009 1:15	67.4	59756.1	58.9	52726.8	67.9	60592.8	63.9	57148.9
2/12/2009 1:30	68.7	61049.4	59.5	53290.0	68.9	61585.3	64.6	57810.0
2/12/2009 1:45	69.9	62239.8	60.0	53827.3	69.8	62432.2	65.1	58418.9
2/12/2009 2:00	71.1	63298.5	60.3	54081.1	70.5	63153.5	65.6	58816.2
2/12/2009 2:15	72.2	64311.3	61.3	54733.8	71.3	63837.8	66.8	59614.6
2/12/2009 2:30	73.3	65298.0	62.3	55593.4	72.2	64600.7	68.2	60730.6
2/12/2009 2:45	74.3	66258.9	63.1	56515.2	73.0	65339.8	69.3	61899.8
2/12/2009 3:00	75.3	67184.1	63.7	57072.7	74.4	66318.1	70.1	62762.2
2/12/2009 3:15	76.3	68087.1	64.3	57602.2	76.0	67686.5	70.9	63446.9
2/12/2009 3:30	77.1	68908.5	64.9	58156.6	77.3	69018.0	71.6	64184.4
2/12/2009 3:45	78.0	69681.0	65.5	58720.5	78.2	69966.3	72.1	64680.3
2/12/2009 4:00	78.8	70418.1	65.9	59201.2	79.0	70754.7	73.1	65230.9
2/12/2009 4:15	79.6	71140.5	66.5	59439.0	79.7	71425.3	74.4	66339.5
2/12/2009 4:30	80.3	71832.6	67.5	60271.8	80.2	71917.4	75.7	67585.7
2/12/2009 4:45	81.0	72496.2	68.7	61308.0	81.5	72753.5	76.6	68532.6
2/12/2009 5:00	81.7	73128.6	69.3	62151.3	82.9	73950.1	77.3	69236.0
2/12/2009 5:15	82.3	73726.8	69.9	62645.0	83.9	75094.2	77.9	69842.6
2/12/2009 5:30	82.9	74280.0	70.5	63156.1	84.6	75845.5	78.3	70297.1
2/12/2009 5:45	83.5	74805.3	71.1	63685.3	85.1	76394.1	78.7	70582.0
2/12/2009 6:00	84.0	75298.8	71.4	64170.1	85.6	76840.3	79.8	71345.6
2/12/2009 6:15	84.6	75806.7	71.8	64345.7	85.9	77151.1	80.9	72283.5
2/12/2009 6:30	85.3	76320.9	72.9	65135.5	86.6	77514.9	81.8	73229.2
2/12/2009 6:45	85.9	76900.2	74.1	66139.5	87.5	78336.8	82.4	73902.4
2/12/2009 7:00	86.6	77530.8	74.7	66974.6	88.6	79252.7	83.0	74442.3
2/12/2009 7:15	87.3	78174.3	75.2	67444.9	89.4	80153.0	83.4	74885.9
2/12/2009 7:30	88.1	78814.5	75.8	67962.6	90.0	80736.3	83.8	75240.1
2/12/2009 7:45	88.7	79420.8	76.3	68466.9	90.4	81161.8	84.0	75485.5
2/12/2009 8:00	89.3	80009.1	76.9	68942.9	90.7	81498.3	85.0	76019.7
2/12/2009 8:15	89.9	80543.1	77.0	69237.4	90.9	81753.4	85.8	76860.8
2/12/2009 8:30	90.4	81017.7	77.8	69550.5	91.1	81928.3	86.8	77707.6
2/12/2009 8:45	90.9	81536.1	79.0	70508.6	91.7	82157.9	87.4	78391.0
2/12/2009 9:00	91.4	81991.8	79.8	71517.4	92.6	82893.5	87.8	78854.8
2/12/2009 9:15	91.8	82370.7	80.2	71973.6	93.4	83685.5	88.1	79196.2
2/12/2009 9:30	92.2	82775.1	80.6	72378.0	94.3	84521.0	88.4	79444.2
2/12/2009 9:45	92.7	83131.5	81.1	72787.2	94.8	85132.4	88.6	79636.8
2/12/2009 10:00	92.9	83453.7	81.5	73173.8	95.2	85508.8	88.7	79771.8
2/12/2009 10:15	93.4	83775.0	81.7	73452.2	95.4	85753.4	89.6	80233.0
2/12/2009 10:30	93.5	84031.2	81.8	73382.3	95.5	85921.4	90.4	81031.7
2/12/2009 10:45	93.9	84262.2	82.7	74016.4	95.6	86041.4	91.2	81741.7
2/12/2009 11:00	94.0	84547.2	83.7	74903.4	95.7	86101.6	91.8	82378.4
2/12/2009 11:15	94.2	84650.1	84.0	75514.9	95.9	86137.9	92.0	82758.2
2/12/2009 11:30	94.5	84897.0	84.4	75777.0	96.3	86503.6	92.2	82897.3
2/12/2009 11:45	94.5	85023.3	84.7	76060.0	96.8	86914.8	92.4	83065.3
2/12/2009 12:00	94.7	85155.0	85.0	76331.5	97.3	87341.7	92.6	83238.5
2/12/2009 12:15	94.8	85269.9	85.2	76585.6	97.7	87805.4	92.7	83377.4
2/12/2009 12:30	94.9	85354.2	85.4	76777.3	98.0	88084.3	92.6	83285.5
2/12/2009 12:45	94.9	85413.6	85.3	76600.7	98.1	88240.4	92.5	83144.4
2/12/2009 13:00	94.9	85431.3	86.0	77068.1	98.2	88333.3	93.1	83503.3
2/12/2009 13:15	94.9	85383.3	86.8	77697.4	98.2	88392.4	93.5	83966.5
2/12/2009 13:30	94.8	85354.8	87.3	78373.5	98.3	88431.1	94.1	84416.6
2/12/2009 13:45	94.8	85301.4	87.4	78581.0	98.3	88447.9	94.5	84881.1
2/12/2009 14:00	94.7	85210.5	87.5	78709.3	98.3	88445.9	94.7	85130.0
2/12/2009 14:15	94.5	85076.7	87.7	78870.5	98.3	88377.2	94.7	85174.4
2/12/2009 14:30	94.5	85024.2	87.9	79041.7	98.1	88255.3	94.7	85183.6
2/12/2009 14:45	94.3	84878.7	88.1	79200.1	98.4	88452.5	94.8	85249.6
2/12/2009 15:00	94.1	84653.7	88.2	79331.3	98.6	88659.6	94.8	85311.5
2/12/2009 15:15	94.0	84554.1	88.2	79185.1	98.7	88766.5	94.9	85351.2
2/12/2009 15:30	93.7	84342.6	88.2	79104.6	98.8	88840.0	94.9	85347.6
2/12/2009 15:45	93.4	84082.5	88.6	79563.2	98.9	88959.4	94.7	85113.2
2/12/2009 16:00	93.3	83953.8	89.3	80089.8	98.9	88997.9	94.4	84804.1
2/12/2009 16:15	93.0	83690.4	89.7	80597.2	98.9	88937.4	94.5	84874.5
2/12/2009 16:30	92.6	83358.0	89.7	80668.6	98.8	88825.5	94.7	85122.3

	Hydrology Model Resutls		Mike 11 Model Results (Channel Manning's n 0.035)		Mike 11 Model Results (Channel Manning's n 0.02)		Mike 11 Model Results (Channel Manning's n 0.025)	
Time	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)
2/12/2009 16:45	92.3	83095.5	89.6	80670.4	98.6	88677.2	94.9	85297.1
2/12/2009 17:00	92.0	82835.1	89.7	80683.2	98.4	88501.5	95.1	85509.0
2/12/2009 17:15	91.7	82499.4	89.7	80693.1	98.2	88237.1	95.3	85694.0
2/12/2009 17:30	91.3	82155.9	89.7	80705.0	97.9	88000.8	95.3	85728.9
2/12/2009 17:45	91.0	81874.8	89.7	80716.7	97.7	87819.7	95.2	85664.5
2/12/2009 18:00	90.6	81522.9	89.7	80710.7	97.5	87654.4	95.1	85420.9
2/12/2009 18:15	90.2	81171.3	89.7	80662.3	97.3	87493.1	94.7	85160.2
2/12/2009 18:30	89.8	80834.7	89.5	80308.8	97.1	87296.0	94.5	84974.6
2/12/2009 18:45	89.4	80449.5	89.3	80207.8	96.9	87050.1	94.3	84823.0
2/12/2009 19:00	89.0	80085.3	89.4	80425.7	96.6	86709.5	94.2	84683.1
2/12/2009 19:15	88.6	79752.0	89.7	80573.0	96.1	86211.6	94.0	84557.6
2/12/2009 19:30	88.1	79317.6	90.0	80869.8	95.5	85699.3	93.9	84438.4
2/12/2009 19:45	87.7	78960.3	90.1	81041.4	94.9	85238.4	93.8	84307.2
2/12/2009 20:00	87.3	78567.6	90.0	80941.7	94.5	84878.9	93.6	84129.0
2/12/2009 20:15	86.9	78219.0	89.9	80820.2	94.2	84786.2	93.3	83877.7
2/12/2009 20:30	86.4	77773.5	89.7	80732.3	94.2	84749.5	93.0	83585.0
2/12/2009 20:45	86.0	77390.7	89.7	80655.4	94.1	84610.7	92.7	83189.4
2/12/2009 21:00	85.5	76947.0	89.6	80560.3	93.9	84428.2	92.2	82789.3
2/12/2009 21:15	85.0	76491.3	89.4	80428.5	93.7	84211.8	91.8	82498.1
2/12/2009 21:30	84.5	76068.0	89.3	80265.9	93.4	83933.0	91.5	82304.4
2/12/2009 21:45	84.0	75628.8	89.1	80105.0	93.1	83616.9	91.5	82304.2
2/12/2009 22:00	83.6	75249.6	88.9	79963.1	92.7	83321.8	91.4	82236.1
2/12/2009 22:15	83.1	74827.5	88.8	79837.8	92.5	83074.3	91.3	82120.1
2/12/2009 22:30	82.6	74364.6	88.6	79721.3	92.1	82768.2	91.2	81975.5
2/12/2009 22:45	82.2	73945.2	88.5	79599.2	91.8	82433.4	91.0	81793.8
2/12/2009 23:00	81.6	73476.3	88.4	79474.8	91.4	82087.4	90.8	81564.3
2/12/2009 23:15	81.2	73121.7	88.2	79287.0	91.0	81735.5	90.5	81265.3
2/12/2009 23:30	80.8	72725.7	87.9	78992.7	90.6	81366.4	90.1	80914.6
2/12/2009 23:45	80.3	72298.8	87.6	78753.5	90.2	80961.6	89.7	80563.2
2/13/2009 0:00	79.8	71858.1	87.5	78696.5	89.7	80557.1	89.3	80247.4
2/13/2009 0:15	79.4	71415.6	87.4	78604.3	89.3	80149.6	89.0	80009.5
2/13/2009 0:30	78.9	70996.2	87.3	78435.7	88.8	79729.3	88.8	79733.7
2/13/2009 0:45	78.4	70605.9	87.0	78243.5	88.3	79274.0	88.4	79430.8
2/13/2009 1:00	78.0	70169.1	86.8	78061.2	87.8	78801.0	88.1	79123.1
2/13/2009 1:15	77.5	69727.8	86.7	77996.3	87.3	78346.6	87.7	78816.8
2/13/2009 1:30	77.0	69294.0	86.6	77888.8	86.8	77883.9	87.4	78506.9
2/13/2009 1:45	76.6	68940.9	86.5	77724.2	86.3	77414.8	87.1	78188.8
2/13/2009 2:00	76.1	68485.5	86.3	77515.3	85.8	76966.6	86.7	77850.1
2/13/2009 2:15	75.7	68084.7	86.0	77243.3	85.3	76540.9	86.3	77495.0
2/13/2009 2:30	75.2	67628.4	85.7	76996.3	84.8	76081.2	85.9	77126.8
2/13/2009 2:45	74.7	67186.8	85.4	76761.9	84.3	75618.8	85.5	76748.2
2/13/2009 3:00	74.1	66722.4	85.2	76531.6	83.8	75174.7	85.1	76361.3
2/13/2009 3:15	73.7	66327.6	84.9	76298.3	83.3	74709.8	84.6	75959.9
2/13/2009 3:30	73.3	65928.6	84.6	76046.6	82.7	74218.0	84.2	75538.5
2/13/2009 3:45	72.7	65484.9	84.3	75768.6	82.2	73729.6	83.7	75106.3
2/13/2009 4:00	72.4	65139.0	84.0	75465.6	81.7	73247.0	83.2	74707.3
2/13/2009 4:15	71.9	64708.8	83.7	75133.2	81.1	72788.6	82.8	74315.5
2/13/2009 4:30	71.5	64362.3	83.3	74768.0	80.6	72343.0	82.3	73901.2
2/13/2009 4:45	71.0	63942.6	82.9	74388.5	80.1	71856.6	81.9	73491.8
2/13/2009 5:00	70.7	63607.2	82.4	74009.8	79.6	71378.2	81.4	73090.8
2/13/2009 5:15	70.2	63197.4	82.0	73641.7	79.0	70907.6	81.0	72675.6
2/13/2009 5:30	69.9	62861.7	81.6	73287.6	78.5	70491.9	80.5	72257.4
2/13/2009 5:45	69.3	62409.6	81.2	72948.2	78.1	70108.3	80.1	71852.1
2/13/2009 6:00	69.0	62079.0	80.9	72625.5	77.7	69790.7	79.6	71458.0
2/13/2009 6:15	68.5	61627.8	80.5	72317.0	77.5	69590.3	79.2	71055.7
2/13/2009 6:30	68.1	61299.3	80.2	72010.4	77.1	69157.8	78.7	70615.4
2/13/2009 6:45	67.6	60887.7	79.8	71700.3	76.6	68539.1	78.2	70172.2
2/13/2009 7:00	67.2	60507.3	79.5	71388.4	75.7	67829.8	77.8	69876.4
2/13/2009 7:15	66.9	60155.4	79.1	71075.1	75.0	67231.8	77.5	69541.2
2/13/2009 7:30	66.4	59765.4	78.8	70763.2	74.4	66674.1	77.1	69132.9
2/13/2009 7:45	66.0	59421.0	78.5	70451.6	73.8	66125.8	76.5	68569.3
2/13/2009 8:00	65.5	58993.5	78.1	70130.8	73.2	65593.7	75.9	68020.7
2/13/2009 8:15	65.1	58627.8	77.7	69792.1	72.6	65044.4	75.3	67548.5
2/13/2009 8:30	64.7	58241.4	77.4	69435.0	72.0	64552.7	74.8	67098.6
2/13/2009 8:45	64.2	57827.7	76.9	69066.7	71.5	64106.6	74.3	66650.6
2/13/2009 9:00	63.8	57422.1	76.5	68697.1	71.0	63612.0	73.8	66211.2
2/13/2009 9:15	63.4	57045.0	76.1	68315.5	70.4	63055.7	73.3	65775.4
2/13/2009 9:30	63.0	56655.0	75.7	67921.2	69.7	62459.9	72.8	65336.3
2/13/2009 9:45	62.5	56252.1	75.3	67544.2	69.1	61873.9	72.3	64866.9
2/13/2009 10:00	62.1	55867.8	74.8	67177.2	68.4	61237.4	71.8	64350.0
2/13/2009 10:15	61.7	55515.3	74.4	66802.0	67.6	60459.7	71.2	63836.0
2/13/2009 10:30	61.3	55157.4	74.0	66360.7	66.8	59806.7	70.6	63326.8
2/13/2009 10:45	60.9	54785.7	73.5	65880.0	66.2	59443.9	70.1	62831.3
2/13/2009 11:00	60.5	54428.1	72.9	65460.3	65.8	59050.6	69.5	62357.5
2/13/2009 11:15	60.1	54092.1	72.6	65161.8	65.4	58690.7	69.0	61886.5
2/13/2009 11:30	59.7	53745.3	72.2	64820.1	65.2	58655.0	68.5	61397.0
2/13/2009 11:45	59.3	53388.3	71.8	64440.1	65.1	58293.3	67.9	60893.8
2/13/2009 12:00	58.9	53047.2	71.4	64038.6	64.3	57461.8	67.4	60392.8
2/13/2009 12:15	58.6	52722.0	70.9	63732.0	63.4	56775.7	66.8	59881.2
2/13/2009 12:30	58.2	52393.5	70.8	63546.4	62.7	56152.1	66.2	59249.8
2/13/2009 12:45	57.8	52054.5	70.3	63019.4	62.0	55515.2	65.4	58593.5
2/13/2009 13:00	57.5	51728.1	69.7	62553.5	61.4	54945.3	64.9	58261.3
2/13/2009 13:15	57.1	51418.5	69.3	62119.6	60.8	54420.8	64.5	57904.8
2/13/2009 13:30	56.8	51102.3	68.8	61691.4	60.2	53928.2	64.2	57718.8
2/13/2009 13:45	56.4	50777.7	68.3	61267.2	59.7	53447.9	64.2	57568.9
2/13/2009 14:00	56.1	50464.8	67.8	60848.0	59.1	52928.1	63.6	56985.9
2/13/2009 14:15	55.7	50165.4	67.4	60438.4	58.5	52313.1	63.0	56457.2

	Hydrology Model Resutls		Mike 11 Model Results (Channel Manning's n 0.035)		Mike 11 Model Results (Channel Manning's n 0.02)		Mike 11 Model Results (Channel Manning's n 0.025)	
Time	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)
2/13/2009 14:30	55.4	49861.8	66.9	60026.7	57.7	51551.0	62.4	55945.1
2/13/2009 14:45	55.0	49550.4	66.5	59593.4	56.9	51083.1	61.9	55450.8
2/13/2009 15:00	54.7	49248.9	66.0	59148.1	56.6	50738.2	61.3	54944.0
2/13/2009 15:15	54.4	48961.5	65.5	58700.0	56.2	50508.6	60.8	54420.8
2/13/2009 15:30	54.1	48669.3	65.0	58254.0	56.2	50359.9	60.2	53903.1
2/13/2009 15:45	53.7	48370.2	64.5	57821.2	55.6	49665.0	59.6	53394.1
2/13/2009 16:00	53.4	48080.7	64.0	57396.3	54.9	49118.8	59.0	52885.6
2/13/2009 16:15	53.1	47802.3	63.5	56968.7	54.3	48643.4	58.5	52391.1
2/13/2009 16:30	52.8	47520.6	63.1	56543.6	53.8	48148.1	57.9	51887.9
2/13/2009 16:45	52.5	47232.6	62.6	56125.2	53.2	47608.3	57.4	51301.6
2/13/2009 17:00	52.2	46953.6	62.1	55711.2	52.6	47030.8	56.6	50665.6
2/13/2009 17:15	51.9	46685.1	61.7	55285.3	51.9	46439.6	56.1	50350.3
2/13/2009 17:30	51.6	46413.3	61.2	54831.3	51.3	45845.8	55.8	50122.0
2/13/2009 17:45	51.3	46132.8	60.7	54354.7	50.6	45171.2	55.7	49888.7
2/13/2009 18:00	50.9	45852.9	60.1	53808.3	49.7	44520.0	55.1	49319.4
2/13/2009 18:15	50.7	45587.7	59.6	53481.7	49.3	44294.7	54.5	48827.6
2/13/2009 18:30	50.4	45313.8	59.3	53188.4	49.1	44124.9	54.0	48382.4
2/13/2009 18:45	50.0	45035.4	58.9	52963.0	49.1	43975.4	53.5	47948.2
2/13/2009 19:00	49.7	44755.2	58.8	52769.2	48.5	43396.0	53.0	47530.3
2/13/2009 19:15	49.4	44453.4	58.4	52342.3	47.9	42904.6	52.6	47089.3
2/13/2009 19:30	49.1	44143.8	57.9	51925.5	47.4	42414.5	52.1	46639.5
2/13/2009 19:45	48.7	43834.2	57.5	51518.8	46.9	41938.0	51.6	46188.7
2/13/2009 20:00	48.4	43539.3	57.0	51102.7	46.3	41474.0	51.1	45727.9
2/13/2009 20:15	48.1	43262.7	56.5	50676.1	45.8	41019.2	50.6	45256.7
2/13/2009 20:30	47.8	42979.8	56.1	50263.2	45.3	40546.4	50.0	44766.3
2/13/2009 20:45	47.4	42698.7	55.6	49876.4	44.8	40054.6	49.5	44248.3
2/13/2009 21:00	47.1	42434.1	55.2	49501.3	44.2	39452.8	48.8	43777.4
2/13/2009 21:15	46.9	42175.5	54.8	49116.7	43.6	39109.0	48.5	43571.5
2/13/2009 21:30	46.6	41897.4	54.4	48720.4	43.5	39105.7	48.6	43701.5
2/13/2009 21:45	46.2	41610.0	53.9	48317.6	43.4	38776.2	48.4	43304.9
2/13/2009 22:00	45.9	41330.1	53.5	47922.9	42.7	38102.6	47.8	42807.8
2/13/2009 22:15	45.6	41063.1	53.0	47533.9	42.0	37585.4	47.3	42328.0
2/13/2009 22:30	45.3	40800.9	52.6	47130.6	41.5	37111.7	46.8	41830.1
2/13/2009 22:45	45.0	40543.2	52.1	46683.9	41.0	36653.5	46.2	41339.3
2/13/2009 23:00	44.8	40296.9	51.6	46273.7	40.5	36221.3	45.7	40867.3
2/13/2009 23:15	44.5	40058.1	51.3	46085.4	40.0	35792.0	45.2	40426.4
2/13/2009 23:30	44.3	39828.9	51.2	46012.2	39.5	35400.5	44.7	39994.3
2/13/2009 23:45	44.0	39593.1	51.0	45694.4	39.1	35034.0	44.2	39573.2
2/14/2009 0:00	43.7	39373.8	50.6	45286.2	38.7	34666.7	43.7	39172.9
2/14/2009 0:15	43.5	39162.3	50.1	44840.7	38.2	34337.0	43.3	38703.9
2/14/2009 0:30	43.3	38944.2	49.6	44385.9	38.4	34404.1	42.8	38473.6
2/14/2009 0:45	43.0	38727.9	49.1	43946.7	38.3	34339.0	42.8	38448.1
2/14/2009 1:00	42.8	38524.8	48.6	43516.7	37.9	33868.3	42.7	38183.8
2/14/2009 1:15	42.6	38329.8	48.1	43094.3	37.4	33463.1	42.2	37745.9
2/14/2009 1:30	42.4	38128.8	47.7	42690.9	37.0	33095.3	41.7	37355.3
2/14/2009 1:45	42.1	37928.4	47.2	42304.7	36.6	32703.7	41.3	36984.9
2/14/2009 2:00	41.9	37740.3	46.8	41937.1	36.1	32294.9	40.9	36657.6
2/14/2009 2:15	41.7	37557.3	46.4	41581.8	35.7	31907.3	40.6	36344.0
2/14/2009 2:30	41.5	37369.5	46.0	41226.2	35.3	31556.0	40.2	36003.0
2/14/2009 2:45	41.3	37182.0	45.6	40852.4	34.9	31230.8	39.8	35639.0
2/14/2009 3:00	41.1	37004.4	45.2	40470.3	34.5	30906.2	39.4	35233.1
2/14/2009 3:15	40.9	36831.9	44.8	40245.7	34.2	30733.9	38.9	34760.3
2/14/2009 3:30	40.7	36654.9	44.6	40113.5	34.3	30791.2	38.3	34352.5
2/14/2009 3:45	40.5	36477.6	44.6	40025.1	34.2	30738.8	38.1	34229.9
2/14/2009 4:00	40.3	36309.6	44.3	39752.8	34.0	30504.5	38.0	34115.5
2/14/2009 4:15	40.2	36146.1	44.0	39438.7	33.8	30255.7	37.7	33759.7
2/14/2009 4:30	40.0	35978.1	43.6	39124.8	33.5	29980.5	37.3	33387.0
2/14/2009 4:45	39.8	35810.1	43.3	38827.2	33.2	29687.1	36.9	33019.4
2/14/2009 5:00	39.6	35650.5	43.0	38543.7	32.8	29384.2	36.5	32667.3
2/14/2009 5:15	39.4	35494.5	42.7	38236.8	32.5	29077.8	36.1	32356.2
2/14/2009 5:30	39.3	35334.6	42.3	37907.8	32.1	28792.5	35.8	32100.6
2/14/2009 5:45	39.1	35175.3	41.9	37550.0	31.8	28503.4	35.5	31884.4
2/14/2009 6:00	38.9	35021.4	41.5	37180.3	31.5	28209.3	35.3	31664.1
2/14/2009 6:15	38.7	34866.6	41.1	36815.5	31.3	28098.2	35.0	31353.9
2/14/2009 6:30	38.6	34704.0	40.7	36443.4	31.3	28136.2	34.6	30981.5
2/14/2009 6:45	38.4	34544.7	40.3	36055.5	31.2	28013.9	34.2	30697.9
2/14/2009 7:00	38.2	34388.4	39.9	35789.3	31.0	27830.1	34.1	30629.7
2/14/2009 7:15	38.0	34233.9	39.7	35644.7	30.8	27640.2	34.0	30447.2
2/14/2009 7:30	37.9	34077.3	39.6	35585.9	30.6	27432.7	33.6	30123.4
2/14/2009 7:45	37.7	33922.5	39.5	35389.9	30.4	27210.9	33.3	29811.6
2/14/2009 8:00	37.5	33772.5	39.2	35137.8	30.1	26994.0	33.0	29504.6
2/14/2009 8:15	37.4	33625.2	38.9	34875.5	29.9	26772.8	32.6	29218.8
2/14/2009 8:30	37.0	33357.3	38.6	34609.9	29.6	26556.7	32.3	28952.5
2/14/2009 8:45	36.8	33135.0	38.3	34346.4	29.4	26343.0	32.0	28698.4
2/14/2009 9:00	36.6	32972.1	38.0	34082.1	29.1	26155.3	31.8	28471.9
2/14/2009 9:15	36.4	32800.2	37.7	33825.4	29.0	26112.9	31.5	28282.2
2/14/2009 9:30	36.3	32636.7	37.5	33595.4	29.1	26148.3	31.3	28098.6
2/14/2009 9:45	36.1	32473.8	37.2	33377.1	29.0	26050.9	31.1	27864.6
2/14/2009 10:00	35.9	32313.0	37.0	33122.1	28.9	25889.7	30.9	27722.6
2/14/2009 10:15	35.7	32154.3	36.6	32833.3	28.7	25721.8	30.8	27679.7
2/14/2009 10:30	35.6	31998.9	36.3	32496.4	28.5	25558.5	30.7	27549.8
2/14/2009 10:45	35.4	31822.8	35.9	32219.0	28.3	25395.3	30.5	27318.9
2/14/2009 11:00	35.2	31646.7	35.7	32114.8	28.1	25234.1	30.2	27103.2
2/14/2009 11:15	35.0	31467.0	35.7	32075.4	27.9	25064.6	30.0	26904.4
2/14/2009 11:30	34.8	31291.8	35.5	31858.7	27.8	24910.6	29.8	26721.8
2/14/2009 11:45	34.6	31145.4	35.2	31586.1	27.6	24764.0	29.6	26549.7
2/14/2009 12:00	34.4	30980.1	34.9	31330.3	27.4	24616.7	29.4	26360.9

	Hydrology Model Resutls		Mike 11 Model Results (Channel Manning's n 0.035)		Mike 11 Model Results (Channel Manning's n 0.02)		Mike 11 Model Results (Channel Manning's n 0.025)	
Time	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)
2/14/2009 12:15	34.3	30832.5	34.7	31096.8	27.3	24565.1	29.2	26155.1
2/14/2009 12:30	34.1	30682.5	34.4	30876.5	27.4	24625.8	29.0	25976.5
2/14/2009 12:45	33.9	30542.4	34.2	30666.1	27.4	24610.9	28.8	25822.9
2/14/2009 13:00	33.8	30395.1	34.0	30459.9	27.3	24508.8	28.6	25651.0
2/14/2009 13:15	33.6	30264.0	33.7	30254.9	27.2	24389.4	28.4	25566.4
2/14/2009 13:30	33.5	30122.4	33.5	30042.0	27.0	24254.6	28.5	25603.1
2/14/2009 13:45	33.3	29997.6	33.3	29836.0	26.9	24102.1	28.5	25545.9
2/14/2009 14:00	33.2	29872.8	33.0	29645.9	26.7	23952.1	28.3	25363.3
2/14/2009 14:15	33.0	29729.1	32.8	29428.2	26.5	23806.8	28.1	25195.5
2/14/2009 14:30	32.9	29592.0	32.6	29188.0	26.4	23673.1	27.9	25045.8
2/14/2009 14:45	32.7	29455.8	32.4	29082.4	26.2	23549.6	27.7	24906.0
2/14/2009 15:00	32.6	29328.6	32.3	29096.1	26.1	23441.4	27.6	24779.3
2/14/2009 15:15	32.5	29205.9	32.3	28956.9	26.0	23354.0	27.5	24654.3
2/14/2009 15:30	32.3	29079.3	32.0	28712.4	26.0	23376.7	27.3	24521.4
2/14/2009 15:45	32.2	28967.1	31.8	28475.2	26.1	23455.9	27.2	24407.6
2/14/2009 16:00	32.1	28850.4	31.5	28259.3	26.0	23383.8	27.1	24315.2
2/14/2009 16:15	31.9	28724.1	31.3	28061.4	25.9	23263.3	27.0	24202.4
2/14/2009 16:30	31.8	28589.4	31.1	27881.6	25.8	23143.7	26.8	24076.4
2/14/2009 16:45	31.6	28470.0	30.9	27715.3	25.7	23030.9	26.8	24072.1
2/14/2009 17:00	31.5	28357.8	30.7	27554.2	25.5	22916.0	26.8	24087.1
2/14/2009 17:15	31.4	28246.2	30.5	27392.4	25.4	22809.8	26.7	23961.2
2/14/2009 17:30	31.3	28130.1	30.3	27232.0	25.3	22732.4	26.5	23797.9
2/14/2009 17:45	31.1	28014.9	30.2	27075.0	25.2	22670.8	26.4	23655.3
2/14/2009 18:00	31.0	27897.9	30.0	26919.8	25.2	22605.5	26.2	23529.8
2/14/2009 18:15	30.9	27784.5	29.8	26743.0	25.1	22520.9	26.1	23423.7
2/14/2009 18:30	30.7	27666.9	29.6	26661.3	25.0	22448.9	26.0	23327.8
2/14/2009 18:45	30.6	27551.1	29.7	26705.1	25.0	22461.3	25.9	23233.5
2/14/2009 19:00	30.5	27438.6	29.7	26672.6	25.0	22508.5	25.8	23163.9
2/14/2009 19:15	30.4	27327.6	29.5	26469.8	25.0	22461.5	25.7	23104.2
2/14/2009 19:30	30.2	27216.6	29.3	26253.2	24.9	22373.8	25.6	23027.1
2/14/2009 19:45	30.1	27108.3	29.1	26049.6	24.8	22281.0	25.5	22918.9
2/14/2009 20:00	30.0	26994.3	28.8	25857.2	24.7	22186.8	25.4	22809.3
2/14/2009 20:15	29.9	26891.1	28.6	25676.4	24.6	22108.9	25.3	22789.1
2/14/2009 20:30	29.8	26791.5	28.4	25511.8	24.5	22051.3	25.4	22821.5
2/14/2009 20:45	29.7	26691.9	28.3	25362.6	24.5	22001.5	25.4	22781.4
2/14/2009 21:00	29.6	26595.6	28.1	25222.1	24.4	21956.0	25.3	22675.2
2/14/2009 21:15	29.4	26496.9	27.9	25085.5	24.4	21908.9	25.1	22579.3
2/14/2009 21:30	29.3	26400.6	27.8	24966.9	24.3	21863.4	25.0	22499.1
2/14/2009 21:45	29.2	26307.6	27.7	24864.1	24.3	21805.6	25.0	22431.4
2/14/2009 22:00	29.1	26213.7	27.6	24759.5	24.2	21775.4	24.9	22366.5
2/14/2009 22:15	29.0	26123.7	27.4	24651.7	24.2	21802.1	24.8	22315.9
2/14/2009 22:30	28.9	26034.6	27.5	24666.2	24.2	21776.5	24.8	22279.7
2/14/2009 22:45	28.8	25947.3	27.5	24735.5	24.2	21693.4	24.7	22231.9
2/14/2009 23:00	28.7	25860.9	27.5	24615.8	24.0	21591.4	24.7	22159.0
2/14/2009 23:15	28.6	25778.1	27.2	24416.1	23.9	21504.5	24.6	22066.8
2/14/2009 23:30	28.6	25697.1	27.0	24233.5	23.9	21448.5	24.5	21950.9
2/14/2009 23:45	28.5	25618.8	26.8	24063.4	23.8	21410.5	24.3	21853.6
2/15/2009 0:00	28.4	25537.5	26.6	23906.7	23.8	21373.3	24.3	21840.0
2/15/2009 0:15	28.3	25462.2	26.5	23763.7	23.7	21323.7	24.3	21855.4
2/15/2009 0:30	28.2	25384.5	26.3	23635.6	23.7	21267.7	24.3	21826.1
2/15/2009 0:45	28.1	25308.9	26.2	23518.0	23.6	21206.5	24.2	21750.9
2/15/2009 1:00	28.0	25235.4	26.1	23402.2	23.5	21130.0	24.1	21686.5
2/15/2009 1:15	28.0	25161.9	25.9	23299.6	23.4	21047.4	24.1	21627.6
2/15/2009 1:30	27.9	25089.9	25.8	23219.0	23.4	21010.9	24.0	21585.9
2/15/2009 1:45	27.8	25020.6	25.8	23152.9	23.4	21020.5	24.0	21565.0
2/15/2009 2:00	27.7	24955.2	25.7	23086.2	23.4	21015.6	24.0	21540.8
2/15/2009 2:15	27.7	24889.2	25.6	22989.1	23.3	20968.2	23.9	21491.0
2/15/2009 2:30	27.6	24822.6	25.5	22956.5	23.3	20922.3	23.8	21426.9
2/15/2009 2:45	27.5	24758.4	25.6	23000.2	23.2	20882.9	23.8	21348.0
2/15/2009 3:00	27.4	24695.1	25.6	22997.5	23.2	20846.5	23.7	21270.9
2/15/2009 3:15	27.4	24631.8	25.5	22876.4	23.1	20817.5	23.6	21198.7
2/15/2009 3:30	27.3	24568.8	25.3	22747.9	23.1	20788.8	23.5	21120.1
2/15/2009 3:45	27.2	24506.1	25.2	22627.8	23.1	20762.5	23.4	21062.5
2/15/2009 4:00	27.2	24442.8	25.1	22516.1	23.1	20730.3	23.4	21063.7
2/15/2009 4:15	27.1	24377.7	25.0	22415.1	23.0	20679.4	23.5	21084.5
2/15/2009 4:30	27.0	24311.1	24.9	22323.5	22.9	20616.5	23.5	21097.0
2/15/2009 4:45	26.9	24245.7	24.8	22235.8	22.9	20547.7	23.4	21063.0
2/15/2009 5:00	26.9	24180.0	24.7	22150.5	22.8	20481.1	23.4	21038.8
2/15/2009 5:15	26.8	24113.4	24.6	22069.1	22.7	20426.9	23.4	21023.6
2/15/2009 5:30	26.7	24048.6	24.5	22000.9	22.7	20424.3	23.3	20996.7
2/15/2009 5:45	26.6	23983.5	24.4	21949.5	22.8	20462.3	23.3	20955.8
2/15/2009 6:00	26.6	23918.7	24.4	21907.3	22.8	20494.0	23.3	20904.3
2/15/2009 6:15	26.5	23854.2	24.3	21854.2	22.8	20482.1	23.2	20844.2
2/15/2009 6:30	26.4	23790.6	24.2	21779.1	22.7	20451.5	23.1	20791.3
2/15/2009 6:45	26.4	23731.5	24.1	21703.0	22.7	20411.5	23.1	20744.5
2/15/2009 7:00	26.3	23674.8	24.1	21700.9	22.7	20375.8	23.0	20695.9
2/15/2009 7:15	26.2	23617.8	24.2	21730.0	22.6	20349.7	23.0	20648.6
2/15/2009 7:30	26.2	23560.8	24.2	21733.1	22.6	20320.1	22.9	20604.7
2/15/2009 7:45	26.1	23504.1	24.1	21665.9	22.6	20285.7	22.9	20564.6
2/15/2009 8:00	26.1	23447.1	24.0	21596.1	22.5	20246.3	22.8	20524.8
2/15/2009 8:15	26.0	23389.5	24.0	21533.5	22.5	20202.0	22.8	20532.3
2/15/2009 8:30	25.9	23330.4	23.9	21479.0	22.4	20155.4	22.9	20564.0
2/15/2009 8:45	25.9	23271.9	23.8	21431.1	22.4	20111.0	22.9	20637.6
2/15/2009 9:00	25.8	23212.5	23.8	21386.3	22.3	20075.3	22.9	20648.8
2/15/2009 9:15	25.7	23154.0	23.7	21341.0	22.3	20046.0	22.9	20624.9
2/15/2009 9:30	25.7	23095.5	23.7	21296.7	22.3	20017.3	22.9	20582.0
2/15/2009 9:45	25.6	23037.6	23.6	21264.6	22.2	20005.7	22.8	20527.7

	Hydrology Model Resutls		Mike 11 Model Results (Channel Manning's n 0.035)		Mike 11 Model Results (Channel Manning's n 0.02)		Mike 11 Model Results (Channel Manning's n 0.025)	
Time	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)	(cms)	(m3)
2/15/2009 10:00	25.5	22979.4	23.6	21244.5	22.3	20020.5	22.8	20479.4
2/15/2009 10:15	25.5	22922.7	23.6	21219.3	22.3	20069.5	22.7	20437.5
2/15/2009 10:30	25.4	22867.2	23.6	21181.1	22.3	20082.9	22.7	20396.6
2/15/2009 10:45	25.3	22812.6	23.5	21133.1	22.3	20061.9	22.6	20364.0
2/15/2009 11:00	25.3	22758.9	23.5	21071.7	22.3	20024.4	22.6	20336.7
2/15/2009 11:15	25.2	22705.8	23.4	21001.8	22.2	19977.8	22.6	20312.6
2/15/2009 11:30	25.2	22654.2	23.3	20934.2	22.2	19935.9	22.6	20287.7
2/15/2009 11:45	25.1	22603.2	23.3	20939.7	22.1	19904.0	22.5	20262.7
2/15/2009 12:00	25.1	22551.9	23.3	20954.2	22.1	19879.1	22.5	20243.3
2/15/2009 12:15	25.0	22494.3	23.3	20995.8	22.1	19861.7	22.5	20224.7
2/15/2009 12:30	24.9	22432.8	23.3	20967.2	22.1	19846.7	22.5	20190.5
2/15/2009 12:45	24.9	22374.3	23.3	20915.5	22.0	19841.5	22.4	20179.4
2/15/2009 13:00	24.8	22316.1	23.2	20865.4	22.0	19842.5	22.4	20181.9
2/15/2009 13:15	24.7	22260.9	23.2	20817.2	22.0	19835.2	22.4	20198.9
2/15/2009 13:30	24.7	22206.6	23.1	20770.7	22.0	19816.8	22.4	20175.7
2/15/2009 13:45	24.6	22154.7	23.1	20732.6	22.0	19793.8	22.4	20137.9
2/15/2009 14:00	24.6	22104.3	23.0	20706.6	22.0	19766.6	22.4	20096.3
2/15/2009 14:15	24.5	22054.5	23.0	20687.2	21.9	19733.6	22.3	20055.7
2/15/2009 14:30	24.5	22007.4	23.0	20660.1	21.9	19702.5	22.3	20018.5
2/15/2009 14:45	24.4	21960.6	22.9	20626.2	21.9	19670.2	22.2	19987.4
2/15/2009 15:00	24.4	21915.9	22.9	20585.7	21.9	19675.6	22.2	19960.7
2/15/2009 15:15	24.3	21871.8	22.8	20538.3	21.9	19672.0	22.2	19935.6
2/15/2009 15:30	24.3	21829.2	22.8	20489.8	21.9	19679.5	22.1	19912.9
2/15/2009 15:45	24.2	21787.8	22.7	20443.6	21.9	19714.0	22.1	19899.6
2/15/2009 16:00	24.2	21747.6	22.7	20396.9	21.9	19692.2	22.1	19891.8
2/15/2009 16:15	24.1	21708.0	22.6	20348.0	21.9	19676.3	22.1	19877.5
2/15/2009 16:30	24.1	21669.3	22.6	20296.9	21.9	19663.5	22.1	19856.9
2/15/2009 16:45	24.0	21632.1	22.5	20261.2	21.8	19657.4	22.1	19833.4
2/15/2009 17:00	24.0	21595.5	22.5	20279.8	21.8	19649.0	22.0	19804.0
2/15/2009 17:15	24.0	21559.8	22.6	20296.2	21.8	19633.8	22.0	19768.9
2/15/2009 17:30	23.9	21525.6	22.6	20342.2	21.8	19617.4	21.9	19734.3
2/15/2009 17:45	23.9	21492.0	22.6	20331.5	21.8	19601.4	21.9	19706.3
2/15/2009 18:00	23.8	21460.5	22.6	20303.4	21.8	19581.6	21.9	19706.7
2/15/2009 18:15	23.8	21428.1	22.5	20280.4	21.7	19562.0	21.9	19701.8
2/15/2009 18:30	23.8	21397.5	22.5	20259.9	21.7	19544.2	21.9	19718.4
2/15/2009 18:45	23.7	21367.5	22.5	20234.9	21.7	19529.2	21.9	19728.7
2/15/2009 19:00	23.7	21338.4	22.5	20207.2	21.7	19518.4	21.9	19721.0
2/15/2009 19:15	23.7	21309.0	22.4	20176.8	21.7	19509.9	21.9	19705.1
2/15/2009 19:30	23.6	21274.8	22.4	20140.8	21.7	19500.9	21.9	19687.1
2/15/2009 19:45	23.6	21239.7	22.4	20109.4	21.7	19492.7	21.9	19673.9
2/15/2009 20:00	23.6	21204.6	22.3	20082.0	21.7	19484.0	21.9	19664.7
2/15/2009 20:15	23.5	21172.5	22.3	20055.4	21.6	19474.6	21.8	19652.2
2/15/2009 20:30	23.5	21139.8	22.3	20029.3	21.6	19463.7	21.8	19637.1
2/15/2009 20:45	23.5	21110.1	22.2	20004.0	21.6	19451.9	21.8	19621.5
2/15/2009 21:00	23.4	21081.6	22.2	19980.8	21.6	19441.7	21.8	19603.7
2/15/2009 21:15	23.4	21053.4	22.2	19959.7	21.6	19417.6	21.8	19582.3
2/15/2009 21:30	23.4	21025.8	22.2	19937.9	21.6	19403.0	21.7	19561.2
2/15/2009 21:45	23.3	21000.0	22.1	19915.4	21.6	19411.8	21.7	19541.0
2/15/2009 22:00	23.3	20974.5	22.1	19891.3	21.6	19410.7	21.7	19522.4
2/15/2009 22:15	23.3	20950.2	22.1	19867.6	21.6	19405.1	21.7	19507.8
2/15/2009 22:30	23.3	20926.8	22.1	19845.3	21.6	19409.1	21.7	19495.5
2/15/2009 22:45	23.2	20904.3	22.1	19837.6	21.6	19434.1	21.7	19484.3
2/15/2009 23:00	23.2	20882.1	22.1	19869.9	21.6	19409.9	21.6	19473.8
2/15/2009 23:15	23.2	20860.5	22.1	19889.7	21.6	19391.6	21.6	19463.0
2/15/2009 23:30	23.2	20839.8	22.2	19936.4	21.5	19376.1	21.6	19451.1
2/15/2009 23:45	23.1	20819.7	22.2	19934.6	21.5	19363.8	21.6	19436.9
2/16/2009 0:00	23.1	20799.9	22.1	19905.2	21.5	19355.8	21.6	19421.3
2/16/2009 0:15	23.1	20782.2	22.1	19872.8	21.5	19347.7	21.6	19414.1
2/16/2009 0:30	23.1	20763.3	22.1	19844.2	21.5	19339.5	21.6	19418.2
2/16/2009 0:45	23.0	20744.7	22.0	19818.2	21.5	19330.5	21.6	19420.2
2/16/2009 1:00	23.0	20727.6	22.0	19795.2	21.5	19319.8	21.6	19437.2
2/16/2009 1:15	23.0	20710.2	22.0	19774.5	21.5	19307.2	21.6	19447.8
2/16/2009 1:30	23.0	20693.1	22.0	19757.0	21.4	19293.4	21.6	19439.2
2/16/2009 1:45	23.0	20676.3	21.9	19741.9	21.4	19280.1	21.6	19423.0
2/16/2009 2:00	23.0	20660.4	21.9	19727.7	21.4	19268.0	21.6	19407.4
2/16/2009 2:15	22.9	20644.8	21.9	19715.7	21.4	19257.5	21.6	19393.6
2/16/2009 2:30	22.9	20628.9	21.9	19703.5	21.4	19247.9	21.5	19381.0
2/16/2009 2:45	22.9	20613.9	21.9	19690.7	21.4	19238.8	21.5	19368.6
2/16/2009 3:00	22.9	20599.2	21.9	19680.5	21.4	19229.3	21.5	19357.8
2/16/2009 3:15	22.9	20584.5	21.9	19673.1	21.4	19218.3	21.5	19350.3
2/16/2009 3:30	22.9	20570.1	21.9	19665.4	21.3	19209.3	21.5	19344.4
2/16/2009 3:45	22.8	20555.7	21.8	19655.7	21.3	19203.0	21.5	19339.5
2/16/2009 4:00	22.8	20541.6	21.8	19644.4	21.3	19198.7	21.5	19334.9
2/16/2009 4:15	22.8	20528.7	21.8	19631.6	21.3	19196.2	21.5	19329.4
2/16/2009 4:30	22.8	20514.9	21.8	19612.3	21.3	19194.2	21.5	19322.8
2/16/2009 4:45	22.8	20501.7	21.8	19588.6	21.3	19190.9	21.5	19313.7
2/16/2009 5:00	22.8	20488.8	21.8	19562.8	21.3	19186.2	21.5	19304.1
2/16/2009 5:15	22.8	20476.2	21.7	19535.6	21.3	19180.6	21.4	19294.9
2/16/2009 5:30	22.7	20463.3	21.7	19515.8	21.3	19176.7	21.4	19285.5
2/16/2009 5:45	22.7	20451.0	21.7	19526.0	21.3	19173.6	21.4	19276.3
2/16/2009 6:00	22.7	20439.0	21.7	19529.3	21.3	19170.0	21.4	19267.7
2/16/2009 6:15	22.7	20426.4	21.7	19539.5	21.3	19159.8	21.4	19258.3
2/16/2009 6:30	22.7	20413.8	21.8	19571.5	21.3	19138.1	21.4	19247.1
2/16/2009 6:45	22.7	20401.5	21.8	19574.7	21.3	19134.3	21.4	19235.5
2/16/2009 7:00	22.7	20389.2	21.7	19567.1	21.3	19139.3	21.4	19225.5
2/16/2009 7:15	22.6	20377.5	21.7	19556.4	21.3	19135.0	21.4	19217.5
2/16/2009 7:30	22.6	20365.2	21.7	19543.4	21.3	19130.0	21.3	19211.4

	Hydrology Model Resutls		Mike 11 Model Results (Channel Manning's n 0.035)			Mike 11 Model Results (Channel Manning's n 0.02)			Mike 11 Model Results (Channel Manning's n 0.025)		
Time	Peak Flow	Volume	Peak Flow	Volume		Peak Flow	Volume		Peak Flow	Volume	
	(cms)	(m3)	(cms)	(m3)		(cms)	(m3)		(cms)	(m3)	
2/16/2009 7:45	22.6	20353.2	21.7	19530.2		21.3	19126.0		21.3	19206.1	
2/16/2009 8:00	22.6	20341.5	21.7	19519.4		21.2	19122.1		21.3	19200.4	
2/16/2009 8:15	22.6	20329.8	21.7	19510.5		21.2	19118.2		21.3	19193.5	
2/16/2009 8:30	22.6	20318.4	21.7	19501.8		21.2	19113.9		21.3	19182.4	
2/16/2009 8:45	22.6	20307.0	21.7	19492.5		21.3	19118.2		21.3	19186.0	
2/16/2009 9:00	22.6	20295.9	21.7	19482.9		21.3	19126.1		21.3	19190.5	
2/16/2009 9:15	22.5	20284.8	21.6	19472.1		21.3	19127.6		21.3	19194.8	
2/16/2009 9:30	22.5	20273.7	21.6	19459.8		21.3	19122.2		21.3	19198.2	
2/16/2009 9:45	22.5	20263.5	21.6	19446.2		21.2	19110.4		21.4	19224.6	
2/16/2009 10:00	22.5	20253.9	21.6	19432.2		21.2	19105.9		21.4	19220.7	
2/16/2009 10:15	22.5	20243.4	21.6	19418.3		21.2	19103.2		21.4	19212.7	
2/16/2009 10:30	22.5	20233.8	21.6	19409.2		21.2	19101.2		21.3	19202.0	
2/16/2009 10:45	22.5	20224.2	21.6	19400.8		21.2	19100.7		21.3	19190.1	
2/16/2009 11:00	22.5	20214.3	21.6	19392.0		21.2	19100.7		21.3	19179.6	
2/16/2009 11:15	22.5	20205.9	21.5	19384.0		21.2	19100.7		21.3	19170.6	
2/16/2009 11:30	22.4	20196.3	21.5	19377.0		21.2	19099.7		21.3	19162.1	
2/16/2009 11:45	22.4	20187.3	21.5	19371.0		21.2	19097.6		21.3	19154.4	
2/16/2009 12:00	22.4	20178.6	21.5	19365.2		21.2	19094.2		21.3	19146.1	
2/16/2009 12:15	22.4	20169.9	21.5	19358.9		21.2	19089.5		21.3	19137.5	
2/16/2009 12:30	22.4	20160.3	21.5	19351.7		21.2	19085.7		21.3	19130.2	
2/16/2009 12:45	22.4	20152.5	21.5	19342.8		21.2	19083.0		21.3	19124.3	
2/16/2009 13:00	22.4	20143.2	21.5	19332.4		21.2	19081.1		21.2	19119.8	
2/16/2009 13:15	22.4	20135.4	21.5	19321.9		21.2	19078.5		21.2	19116.6	
2/16/2009 13:30	22.4	20126.1	21.5	19310.9		21.2	19073.0		21.2	19114.0	
2/16/2009 13:45	22.4	20118.3	21.5	19299.1		21.2	19066.1		21.2	19112.0	
2/16/2009 14:00	22.3	20109.9	21.5	19307.3		21.2	19059.0		21.2	19111.0	
2/16/2009 14:15	22.3	20101.8	21.5	19316.3		21.2	19052.2		21.2	19110.3	
2/16/2009 14:30	22.3	20093.7	21.5	19318.7		21.2	19045.6		21.2	19109.3	
2/16/2009 14:45	22.3	20085.9	21.5	19327.5		21.2	19040.0		21.2	19108.1	
2/16/2009 15:00	22.3	20077.5	21.5	19346.2		21.2	19035.4		21.2	19106.3	
2/16/2009 15:15	22.3	20070.0	21.5	19343.1		21.1	19030.4		21.2	19103.2	
2/16/2009 15:30	22.3	20061.9	21.5	19334.0		21.1	19025.2		21.2	19099.4	
2/16/2009 15:45	22.3	20053.8	21.5	19323.1		21.1	19021.0		21.2	19096.4	
2/16/2009 16:00	22.3	20046.3	21.5	19312.1		21.1	19017.9		21.2	19093.8	
2/16/2009 16:15	22.3	20038.5	21.5	19301.3		21.1	19015.2		21.2	19091.0	
2/16/2009 16:30	22.3	20031.3	21.4	19290.9		21.1	19012.8		21.2	19087.4	
2/16/2009 16:45	22.2	20023.2	21.4	19281.2		21.1	19011.0		21.2	19082.2	
2/16/2009 17:00	22.2	20016.0	21.4	19272.8		21.1	19009.5		21.2	19075.7	
2/16/2009 17:15	22.2	20008.2	21.4	19265.9		21.1	19008.3		21.2	19068.6	
2/16/2009 17:30	22.2	20000.7	21.4	19260.8		21.1	19007.0		21.2	19062.0	
2/16/2009 17:45	22.2	19993.5	21.4	19257.2		21.1	19006.0		21.2	19056.2	
2/16/2009 18:00	22.2	19985.7	21.4	19255.5		21.1	19005.3		21.2	19051.1	
2/16/2009 18:15	22.2	19978.8	21.4	19254.3		21.1	19004.9		21.2	19046.2	
2/16/2009 18:30	22.2	19971.3	21.4	19252.3		21.1	19004.3		21.2	19040.7	
2/16/2009 18:45	22.2	19963.8	21.4	19249.3		21.1	19003.5		21.2	19035.5	
2/16/2009 19:00	22.2	19956.9	21.4	19245.1		21.1	19003.5		21.1	19031.0	
2/16/2009 19:15	22.2	19949.7	21.4	19240.8		21.1	19003.5		21.1	19027.3	
2/16/2009 19:30	22.2	19942.2	21.4	19236.2		21.1	19004.2		21.1	19024.3	
2/16/2009 19:45	22.1	19934.1	21.4	19231.1		21.1	19005.2		21.1	19021.6	
2/16/2009 20:00	22.1	19926.9	21.4	19225.4		21.1	19005.9		21.1	19018.9	
2/16/2009 20:15	22.1	19919.4	21.4	19219.6		21.1	19006.2		21.1	19016.9	
2/16/2009 20:30	22.1	19911.6	21.4	19214.0		21.1	19006.2		21.1	19015.3	
2/16/2009 20:45	22.1	19904.7	21.3	19208.3		21.1	19005.5		21.1	19014.0	
2/16/2009 21:00	22.1	19897.2	21.3	19201.7		21.1	19004.8		21.1	19013.4	
2/16/2009 21:15	22.1	19890.0	21.3	19194.2		21.1	19003.6		21.1	19005.4	
2/16/2009 21:30	22.1	19883.1	21.3	19186.6		21.1	19000.3		21.1	19007.5	
2/16/2009 21:45	22.1	19875.6	21.3	19179.5		21.1	18996.0		21.1	19015.3	
2/16/2009 22:00	22.1	19869.0	21.3	19173.2		21.1	18992.1		21.1	19018.9	
2/16/2009 22:15	22.1	19861.2	21.3	19167.5		21.1	18988.5		21.1	19021.5	
2/16/2009 22:30	22.1	19854.0	21.3	19162.2		21.1	18985.1		21.1	19023.7	
					different			different			different
Total Volume (m3)		25373766.9		24626084.7	-3.04%		24958329.9	-1.66%		24851723.1	-2.10%
Max Peak Flow (cms)	94.9		90.1		-5.39%	98.9		4.01%	95.3		0.34%

Summary Table - Water Leve at Caistors Corners Gauge (West Lincoln, also referred as Church Road gauge)

*Water Elevation = Monitoring depth value + 172.11m -0.68m (Datum @ Caistors, value from NPCA website)

	NPCA Monintoring station		Mike 11 Model Results (Channel Manning's n 0.035)	Mike 11 Model Results (Channel Manning's n 0.02)	Mike 11 Model Results (Channel Manning's n 0.025)
Time	Value	Observed Water Elevation	Simulated Water Elevation	Simulated Water Elevation	Simulated Water Elevation
	(m)	(m)	(m)	(m)	(m)
2/10/2009 0:00	2.74	174.17	172.12	172.21	172.18
2/10/2009 1:00	2.75	174.18	172.45	172.40	172.43
2/10/2009 2:00	2.76	174.19	172.59	172.44	172.50
2/10/2009 3:00	2.76	174.19	172.64	172.50	172.54
2/10/2009 4:00	2.77	174.20	172.68	172.64	172.62
2/10/2009 5:00	2.77	174.20	172.74	172.77	172.76
2/10/2009 6:00	2.78	174.21	172.86	172.88	172.89
2/10/2009 7:00	2.78	174.21	173.00	172.98	173.00
2/10/2009 8:00	2.78	174.21	173.12	173.09	173.10
2/10/2009 9:00	2.78	174.21	173.23	173.21	173.21
2/10/2009 10:00	2.78	174.21	173.35	173.33	173.33
2/10/2009 11:00	2.77	174.20	173.47	173.45	173.46
2/10/2009 12:00	2.77	174.20	173.60	173.55	173.61
2/10/2009 13:00	2.77	174.20	173.75	173.65	173.74
2/10/2009 14:00	2.77	174.20	173.89	173.74	173.85
2/10/2009 15:00	2.80	174.23	174.02	173.82	173.94
2/10/2009 16:00	2.83	174.26	174.13	173.89	174.02
2/10/2009 17:00	2.86	174.29	174.23	173.94	174.09
2/10/2009 18:00	2.89	174.32	174.31	173.99	174.14
2/10/2009 19:00	2.93	174.36	174.38	174.02	174.19
2/10/2009 20:00	2.99	174.42	174.44	174.05	174.22
2/10/2009 21:00	3.04	174.47	174.48	174.08	174.25
2/10/2009 22:00	3.09	174.52	174.52	174.11	174.28
2/10/2009 23:00	3.12	174.55	174.54	174.12	174.31
2/11/2009 0:00	3.14	174.57	174.57	174.13	174.32
2/11/2009 1:00	3.16	174.59	174.59	174.13	174.33
2/11/2009 2:00	3.18	174.61	174.60	174.14	174.34
2/11/2009 3:00	3.21	174.64	174.61	174.14	174.35
2/11/2009 4:00	3.23	174.66	174.62	174.13	174.35
2/11/2009 5:00	3.27	174.70	174.63	174.13	174.35
2/11/2009 6:00	3.29	174.72	174.64	174.12	174.35
2/11/2009 7:00	3.32	174.75	174.65	174.12	174.36
2/11/2009 8:00	3.35	174.78	174.66	174.13	174.37
2/11/2009 9:00	3.37	174.80	174.69	174.16	174.40
2/11/2009 10:00	3.37	174.80	174.72	174.21	174.43
2/11/2009 11:00	3.14	174.57	174.76	174.26	174.49
2/11/2009 12:00	3.39	174.82	174.81	174.34	174.55
2/11/2009 13:00	3.41	174.84	174.86	174.42	174.62
2/11/2009 14:00	3.44	174.87	174.91	174.50	174.69
2/11/2009 15:00	3.46	174.89	174.96	174.56	174.74
2/11/2009 16:00	3.48	174.91	175.00	174.62	174.79
2/11/2009 17:00	3.51	174.94	175.03	174.67	174.83
2/11/2009 18:00	3.54	174.97	175.07	174.71	174.86
2/11/2009 19:00	3.55	174.98	175.11	174.74	174.91
2/11/2009 20:00	3.57	175.00	175.14	174.78	174.93
2/11/2009 21:00	3.59	175.02	175.17	174.82	174.96
2/11/2009 22:00	3.61	175.04	175.20	174.84	174.99
2/11/2009 23:00	3.64	175.07	175.22	174.87	175.02
2/12/2009 0:00	3.68	175.11	175.25	174.91	175.04
2/12/2009 1:00	3.74	175.17	175.29	174.94	175.09
2/12/2009 2:00	3.79	175.22	175.33	175.01	175.14
2/12/2009 3:00	3.79	175.22	175.38	175.05	175.20
2/12/2009 4:00	3.84	175.27	175.43	175.12	175.24
2/12/2009 5:00	3.88	175.31	175.48	175.17	175.31
2/12/2009 6:00	3.91	175.34	175.52	175.22	175.34
2/12/2009 7:00	3.93	175.36	175.57	175.26	175.40
2/12/2009 8:00	3.97	175.40	175.62	175.31	175.44
2/12/2009 9:00	4.12	175.55	175.67	175.34	175.49
2/12/2009 10:00	4.16	175.59	175.71	175.38	175.52
2/12/2009 11:00	4.19	175.62	175.76	175.42	175.56
2/12/2009 12:00	4.25	175.68	175.80	175.44	175.60
2/12/2009 13:00	4.25	175.68	175.84	175.47	175.63
2/12/2009 14:00	4.25	175.68	175.87	175.50	175.65
2/12/2009 15:00	4.27	175.70	175.91	175.52	175.69
2/12/2009 16:00	4.28	175.71	175.94	175.53	175.71
2/12/2009 17:00	4.29	175.72	175.97	175.55	175.73
2/12/2009 18:00	4.30	175.73	176.00	175.56	175.75
2/12/2009 19:00	4.31	175.74	176.02	175.59	175.76
2/12/2009 20:00	4.31	175.74	176.04	175.60	175.78
2/12/2009 21:00	4.32	175.75	176.06	175.61	175.80
2/12/2009 22:00	4.31	175.74	176.08	175.62	175.80
2/12/2009 23:00	4.31	175.74	176.09	175.62	175.81
2/13/2009 0:00	4.30	175.73	176.11	175.62	175.81
2/13/2009 1:00	4.29	175.72	176.11	175.61	175.81
2/13/2009 2:00	4.27	175.70	176.12	175.61	175.81
2/13/2009 3:00	4.25	175.68	176.12	175.61	175.81
2/13/2009 4:00	4.24	175.67	176.12	175.60	175.80
2/13/2009 5:00	4.22	175.65	176.12	175.59	175.80
2/13/2009 6:00	4.19	175.62	176.12	175.57	175.79
2/13/2009 7:00	4.17	175.60	176.12	175.55	175.77
2/13/2009 8:00	4.14	175.57	176.12	175.53	175.76
2/13/2009 9:00	4.12	175.55	176.11	175.51	175.75
2/13/2009 10:00	4.09	175.52	176.10	175.49	175.73
2/13/2009 11:00	4.06	175.49	176.09	175.46	175.71
2/13/2009 12:00	4.03	175.46	176.07	175.44	175.70
2/13/2009 13:00	4.00	175.43	176.06	175.41	175.67
2/13/2009 14:00	3.97	175.40	176.04	175.39	175.64
2/13/2009 15:00	3.94	175.37	176.03	175.36	175.62
2/13/2009 16:00	3.91	175.34	176.01	175.33	175.60
2/13/2009 17:00	3.88	175.31	176.00	175.30	175.57
2/13/2009 18:00	3.85	175.28	175.98	175.27	175.54
2/13/2009 19:00	3.81	175.24	175.96	175.23	175.52
2/13/2009 20:00	3.78	175.21	175.94	175.20	175.50
2/13/2009 21:00	3.75	175.18	175.92	175.16	175.46
2/13/2009 22:00	3.72	175.15	175.90	175.13	175.43
2/13/2009 23:00	3.68	175.11	175.87	175.10	175.40
2/14/2009 0:00	3.65	175.08	175.84	175.06	175.37

Summary Table - Water Leve at Old Siphon West (Welland Riverbank Park, located at the upstream end of the Old Siphon)

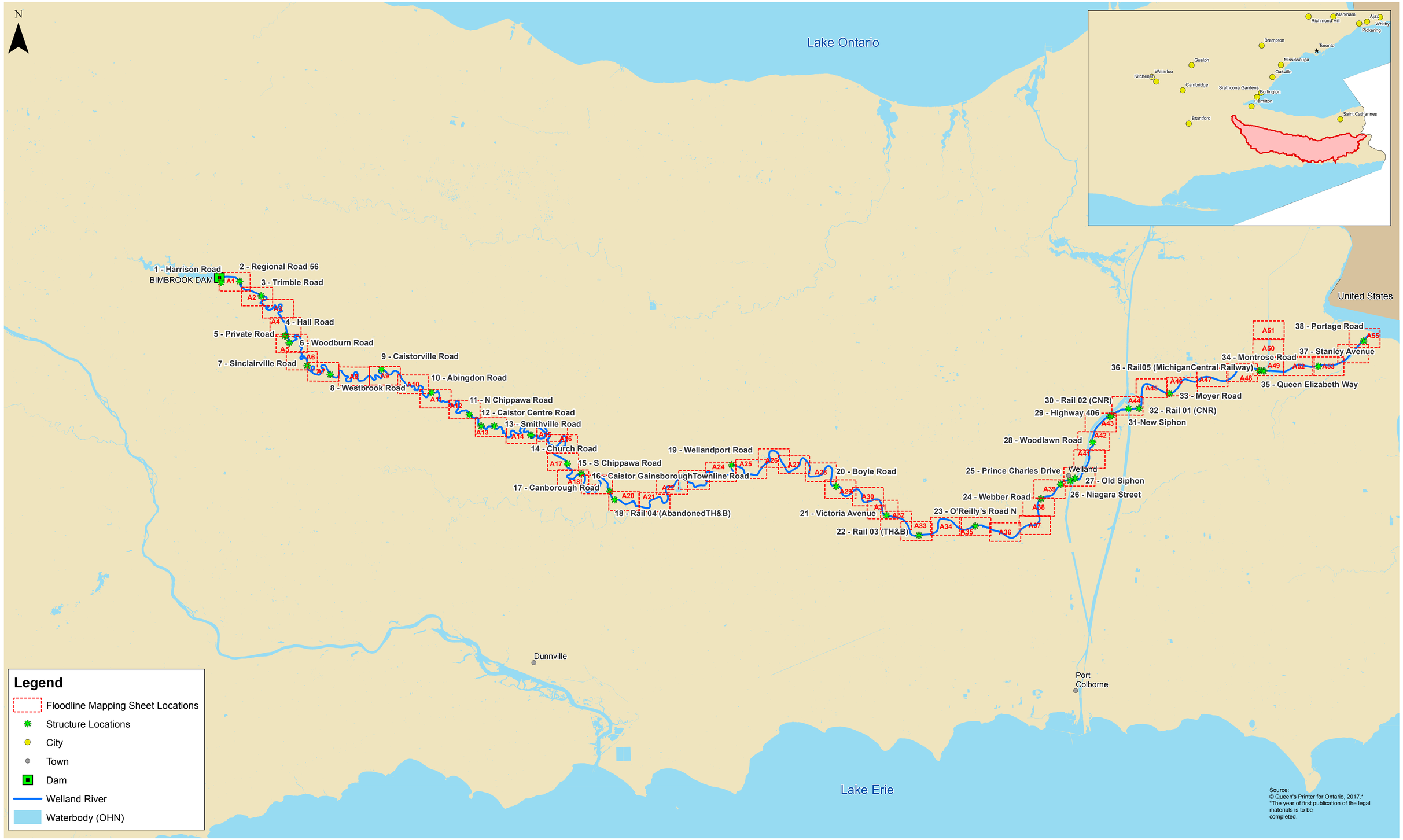
*Water Elevation = Monitoring depth value + 169.15m (Datum @ Old Siphon West, value from NPCA website)

	NPCA Monintoring station		Mike 11 Model Results (Channel Manning's n 0.035)	Mike 11 Model Results (Channel Manning's n 0.02)	Mike 11 Model Results (Channel Manning's n 0.025)
Time	Value	Observed Water Elevation	Simulated Water Elevation	Simulated Water Elevation	Simulated Water Elevation
	(m)	(m)	(m)	(m)	(m)
2/10/2009 0:00	2.33	171.48	166.815	166.815	166.815
2/10/2009 1:00	2.34	171.49	166.815	166.815	166.815
2/10/2009 2:00	2.35	171.5	166.838	166.835	166.837
2/10/2009 3:00	2.35	171.5	166.865	166.863	166.863
2/10/2009 4:00	2.36	171.51	166.92	166.919	166.921
2/10/2009 5:00	2.36	171.51	166.971	166.985	166.981
2/10/2009 6:00	2.36	171.51	167.071	168.04	167.409
2/10/2009 7:00	2.37	171.52	168.335	169.273	168.962
2/10/2009 8:00	2.37	171.52	169.323	169.523	169.593
2/10/2009 9:00	2.38	171.53	169.655	169.559	169.601
2/10/2009 10:00	2.38	171.53	169.699	170.394	169.932
2/10/2009 11:00	2.38	171.53	169.888	170.752	170.529
2/10/2009 12:00	2.38	171.53	170.439	170.841	170.77
2/10/2009 13:00	2.38	171.53	170.712	170.932	170.858
2/10/2009 14:00	2.37	171.52	170.844	171.011	170.952
2/10/2009 15:00	2.37	171.52	170.936	171.043	171.022
2/10/2009 16:00	2.37	171.52	171.012	171.079	171.06
2/10/2009 17:00	2.38	171.53	171.054	171.104	171.09
2/10/2009 18:00	2.4	171.55	171.091	171.148	171.132
2/10/2009 19:00	2.42	171.57	171.141	171.17	171.164
2/10/2009 20:00	2.43	171.58	171.175	171.212	171.207
2/10/2009 21:00	2.44	171.59	171.227	171.247	171.245
2/10/2009 22:00	2.46	171.61	171.256	171.266	171.267
2/10/2009 23:00	2.48	171.63	171.291	171.296	171.301
2/11/2009 0:00	2.49	171.64	171.33	171.329	171.335
2/11/2009 1:00	2.52	171.67	171.352	171.346	171.353
2/11/2009 2:00	2.53	171.68	171.392	171.361	171.38
2/11/2009 3:00	2.55	171.7	171.426	171.389	171.426
2/11/2009 4:00	2.57	171.72	171.445	171.428	171.44
2/11/2009 5:00	2.58	171.73	171.477	171.443	171.455
2/11/2009 6:00	2.6	171.75	171.514	171.457	171.503
2/11/2009 7:00	2.62	171.77	171.547	171.503	171.531
2/11/2009 8:00	2.64	171.79	171.608	171.54	171.555
2/11/2009 9:00	2.65	171.8	171.646	171.569	171.618
2/11/2009 10:00	2.66	171.81	171.705	171.631	171.648
2/11/2009 11:00	2.67	171.82	171.747	171.661	171.711
2/11/2009 12:00	2.68	171.83	171.81	171.718	171.742
2/11/2009 13:00	2.7	171.85	171.855	171.745	171.797
2/11/2009 14:00	2.73	171.88	171.896	171.77	171.823
2/11/2009 15:00	2.77	171.92	171.935	171.829	171.854
2/11/2009 16:00	2.8	171.95	171.975	171.843	171.903
2/11/2009 17:00	2.83	171.98	172.015	171.881	171.928
2/11/2009 18:00	2.85	172	172.072	171.934	171.987
2/11/2009 19:00	2.88	172.03	172.125	171.96	172.023
2/11/2009 20:00	2.9	172.05	172.172	172.02	172.072
2/11/2009 21:00	2.95	172.1	172.211	172.038	172.107
2/11/2009 22:00	3.02	172.17	172.259	172.095	172.142
2/11/2009 23:00	3.09	172.24	172.301	172.128	172.187
2/12/2009 0:00	3.14	172.29	172.414	172.229	172.302
2/12/2009 1:00	3.17	172.32	172.526	172.322	172.396
2/12/2009 2:00	3.21	172.36	172.581	172.369	172.446
2/12/2009 3:00	3.25	172.4	172.65	172.437	172.507
2/12/2009 4:00	3.29	172.44	172.702	172.513	172.572
2/12/2009 5:00	3.33	172.48	172.765	172.543	172.623
2/12/2009 6:00	3.37	172.52	172.852	172.627	172.703
2/12/2009 7:00	3.43	172.58	172.922	172.715	172.787
2/12/2009 8:00	3.49	172.64	172.977	172.753	172.838
2/12/2009 9:00	3.53	172.68	173.059	172.828	172.901
2/12/2009 10:00	3.56	172.71	173.111	172.885	172.97
2/12/2009 11:00	3.6	172.75	173.167	172.942	173.023
2/12/2009 12:00	3.63	172.78	173.243	173.017	173.087
2/12/2009 13:00	3.66	172.81	173.282	173.05	173.14
2/12/2009 14:00	3.7	172.85	173.358	173.124	173.197
2/12/2009 15:00	3.72	172.87	173.406	173.158	173.252
2/12/2009 16:00	3.75	172.9	173.464	173.226	173.304
2/12/2009 17:00	3.76	172.91	173.517	173.258	173.356
2/12/2009 18:00	3.78	172.93	173.563	173.326	173.401
2/12/2009 19:00	3.8	172.95	173.618	173.35	173.452
2/12/2009 20:00	3.81	172.96	173.66	173.416	173.496
2/12/2009 21:00	3.83	172.98	173.706	173.438	173.536
2/12/2009 22:00	3.84	172.99	173.754	173.462	173.584
2/12/2009 23:00	3.85	173	173.778	173.513	173.61
2/13/2009 0:00	3.86	173.01	173.835	173.529	173.648
2/13/2009 1:00	3.87	173.02	173.857	173.547	173.684
2/13/2009 2:00	3.88	173.03	173.887	173.601	173.704
2/13/2009 3:00	3.89	173.04	173.934	173.615	173.733
2/13/2009 4:00	3.9	173.05	173.953	173.626	173.771
2/13/2009 5:00	3.91	173.06	173.968	173.637	173.781
2/13/2009 6:00	3.92	173.07	174.007	173.646	173.791
2/13/2009 7:00	3.93	173.08	174.042	173.661	173.807
2/13/2009 8:00	3.93	173.08	174.051	173.687	173.821
2/13/2009 9:00	3.94	173.09	174.059	173.695	173.832
2/13/2009 10:00	3.94	173.09	174.073	173.697	173.84
2/13/2009 11:00	3.94	173.09	174.097	173.695	173.847
2/13/2009 12:00	3.95	173.1	174.119	173.688	173.854
2/13/2009 13:00	3.95	173.1	174.132	173.671	173.856
2/13/2009 14:00	3.95	173.1	174.142	173.657	173.855
2/13/2009 15:00	3.95	173.1	174.146	173.647	173.85

	NPCA Monintoring station		Mike 11 Model Results (Channel Manning's n 0.035)	Mike 11 Model Results (Channel Manning's n 0.02)	Mike 11 Model Results (Channel Manning's n 0.025)
Time	Value	Observed Water Elevation	Simulated Water Elevation	Simulated Water Elevation	Simulated Water Elevation
	(m)	(m)	(m)	(m)	(m)
2/13/2009 16:00	3.95	173.1	174.147	173.638	173.844
2/13/2009 17:00	3.96	173.11	174.147	173.629	173.836
2/13/2009 18:00	3.97	173.12	174.147	173.621	173.826
2/13/2009 19:00	3.97	173.12	174.147	173.612	173.813
2/13/2009 20:00	3.96	173.11	174.146	173.599	173.796
2/13/2009 21:00	3.96	173.11	174.145	173.55	173.786
2/13/2009 22:00	3.95	173.1	174.141	173.53	173.78
2/13/2009 23:00	3.95	173.1	174.131	173.517	173.771
2/14/2009 0:00	3.94	173.09	174.118	173.497	173.739
2/14/2009 1:00	3.93	173.08	174.101	173.448	173.713
2/14/2009 2:00	3.92	173.07	174.081	173.429	173.691
2/14/2009 3:00	3.92	173.07	174.067	173.418	173.681
2/14/2009 4:00	3.91	173.06	174.058	173.353	173.657
2/14/2009 5:00	3.9	173.05	174.052	173.329	173.622
2/14/2009 6:00	3.89	173.04	174.049	173.317	173.597
2/14/2009 7:00	3.89	173.04	174.031	173.252	173.586
2/14/2009 8:00	3.88	173.03	174	173.23	173.548
2/14/2009 9:00	3.87	173.02	173.971	173.217	173.51
2/14/2009 10:00	3.86	173.01	173.958	173.152	173.489
2/14/2009 11:00	3.84	172.99	173.951	173.126	173.461
2/14/2009 12:00	3.83	172.98	173.934	173.111	173.419
2/14/2009 13:00	3.81	172.96	173.899	173.045	173.396
2/14/2009 14:00	3.79	172.94	173.868	173.022	173.368
2/14/2009 15:00	3.77	172.92	173.856	172.99	173.322
2/14/2009 16:00	3.75	172.9	173.846	172.937	173.295
2/14/2009 17:00	3.74	172.89	173.811	172.919	173.271
2/14/2009 18:00	3.72	172.87	173.772	172.875	173.224
2/14/2009 19:00	3.7	172.85	173.759	172.833	173.194
2/14/2009 20:00	3.68	172.83	173.746	172.815	173.172
2/14/2009 21:00	3.66	172.81	173.71	172.76	173.124
2/14/2009 22:00	3.64	172.79	173.673	172.73	173.096
2/14/2009 23:00	3.62	172.77	173.659	172.717	173.079
2/15/2009 0:00	3.6	172.75	173.638	172.669	173.03

APPENDIX

E Floodplain Maps



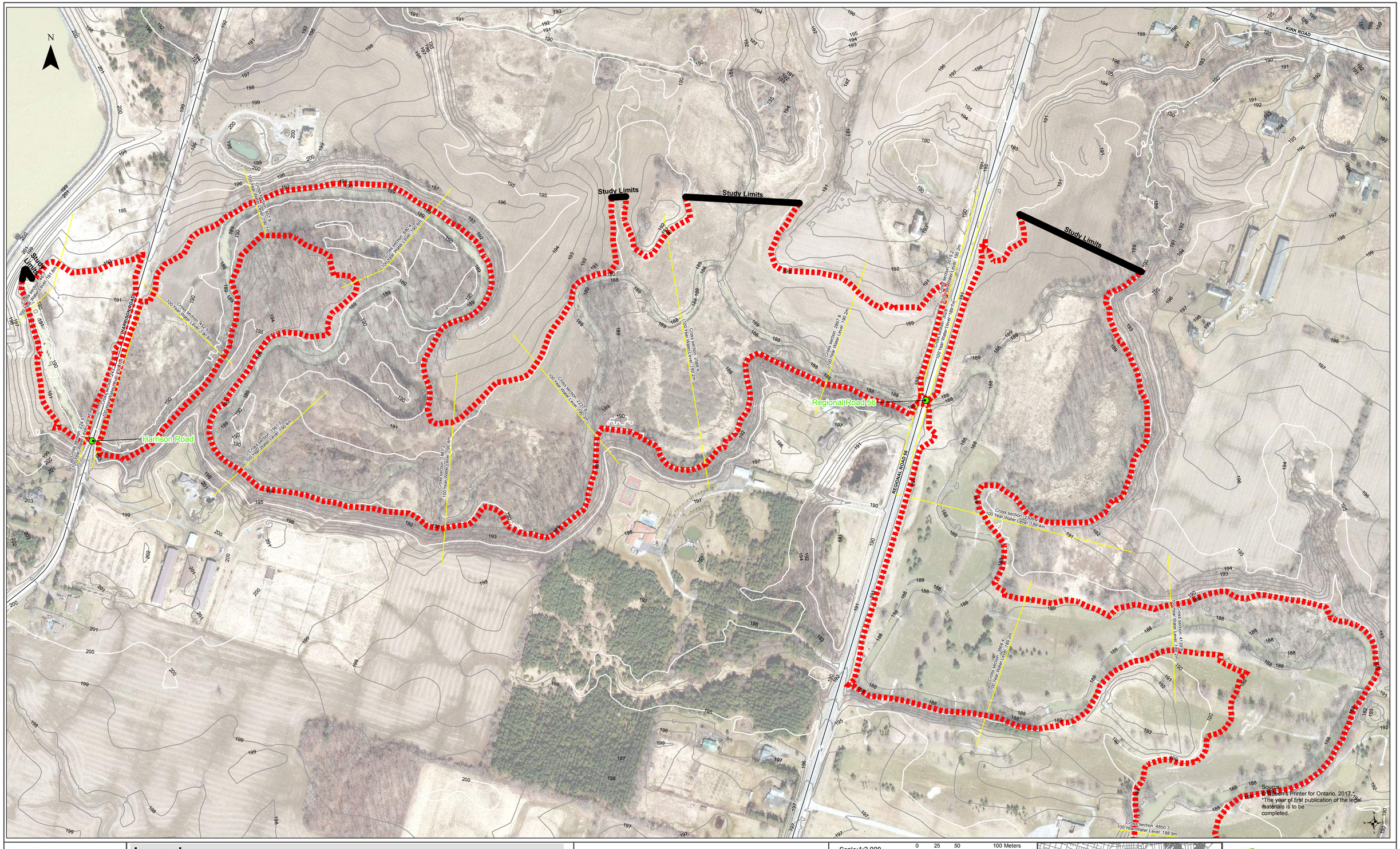
Index Figure
Welland River Hydraulic Model
Floodline Mapping Sheet Locations

0 1 2 3 4 5
kilometres
1:90,000

Date: October 2018

Project No: 3815516

J:\1441 Projects by Job Number\3815815516-000 WELLAND RIVER FLOODPLAIN\Hydraulic\GIS\Floodline Sub\2018\Floodline Index Figure.mxd 18 Oct 2018



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

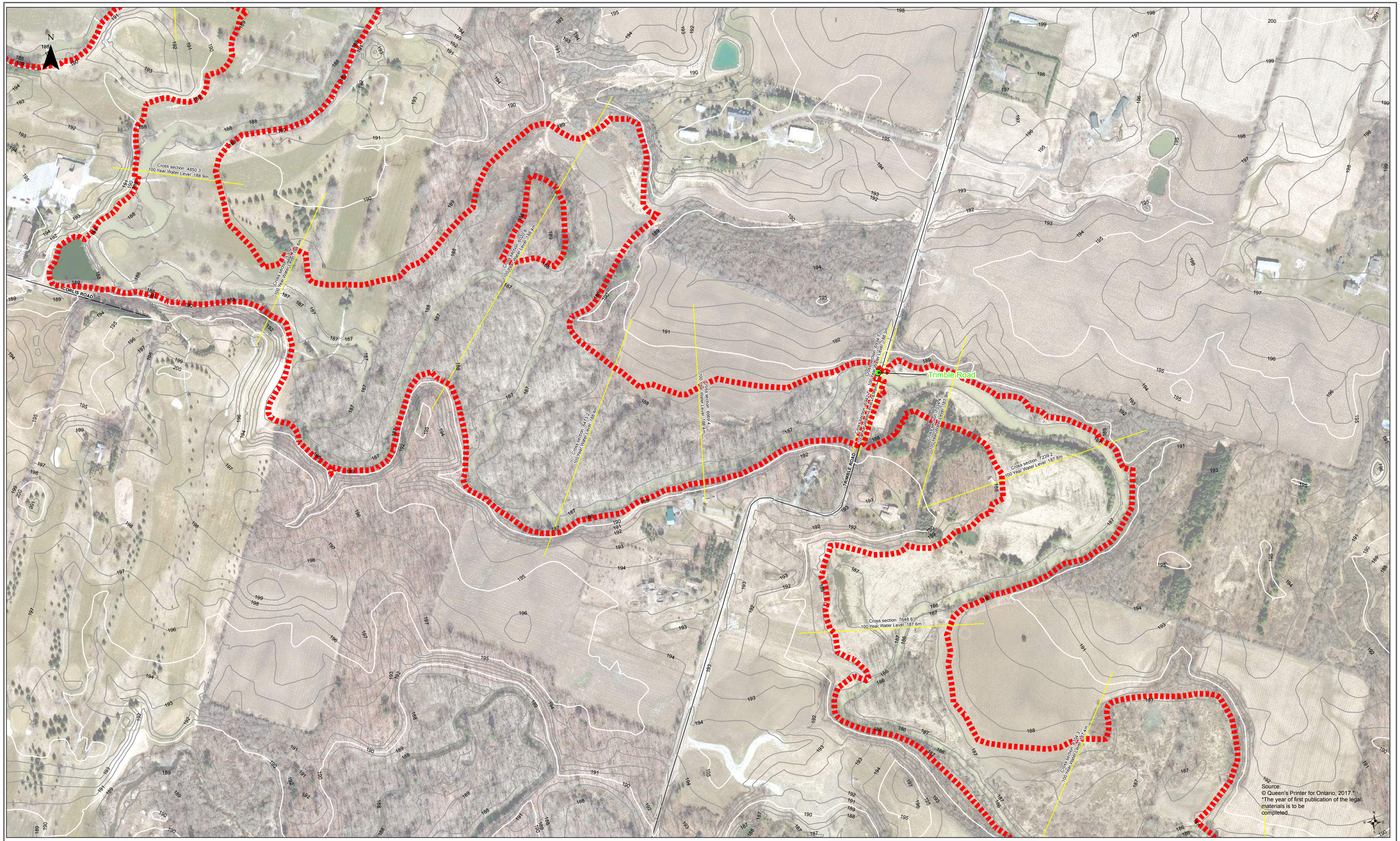
Figure A1
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

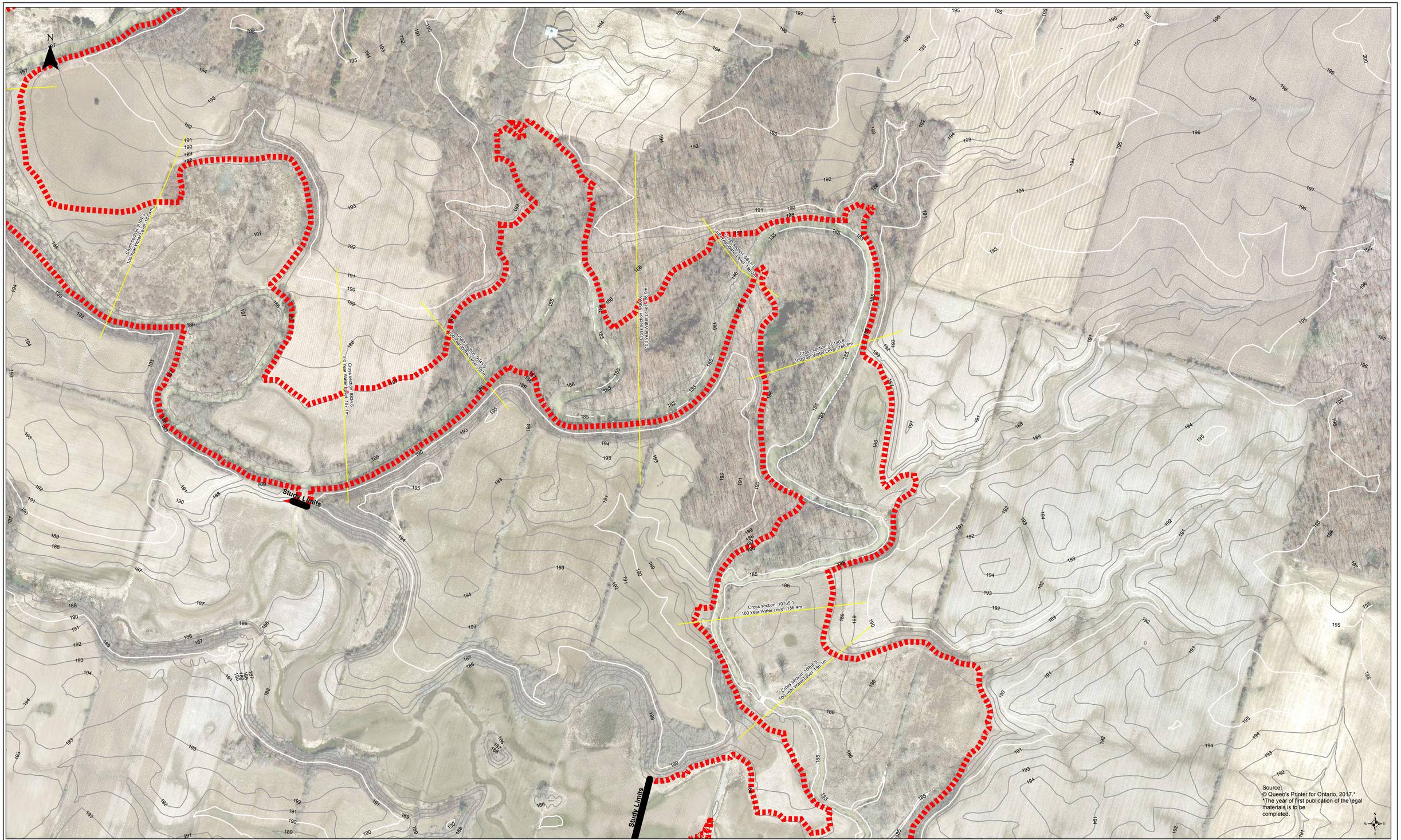
Figure A2
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Contour - 5m interval
- Road
- Structures
- Mike 11 Cross-sections
- Contour - 1m interval
- Study Limits

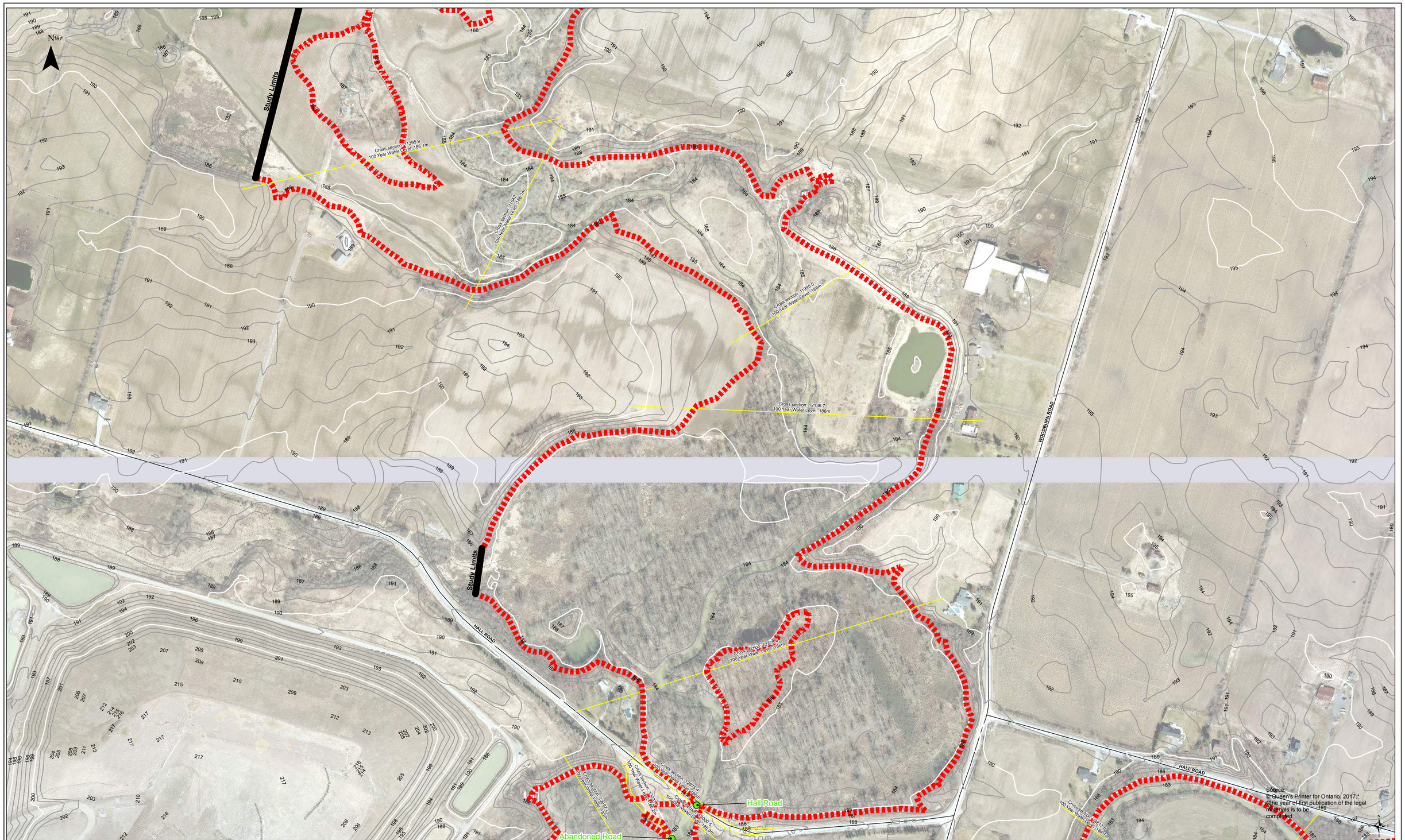
Figure A3
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

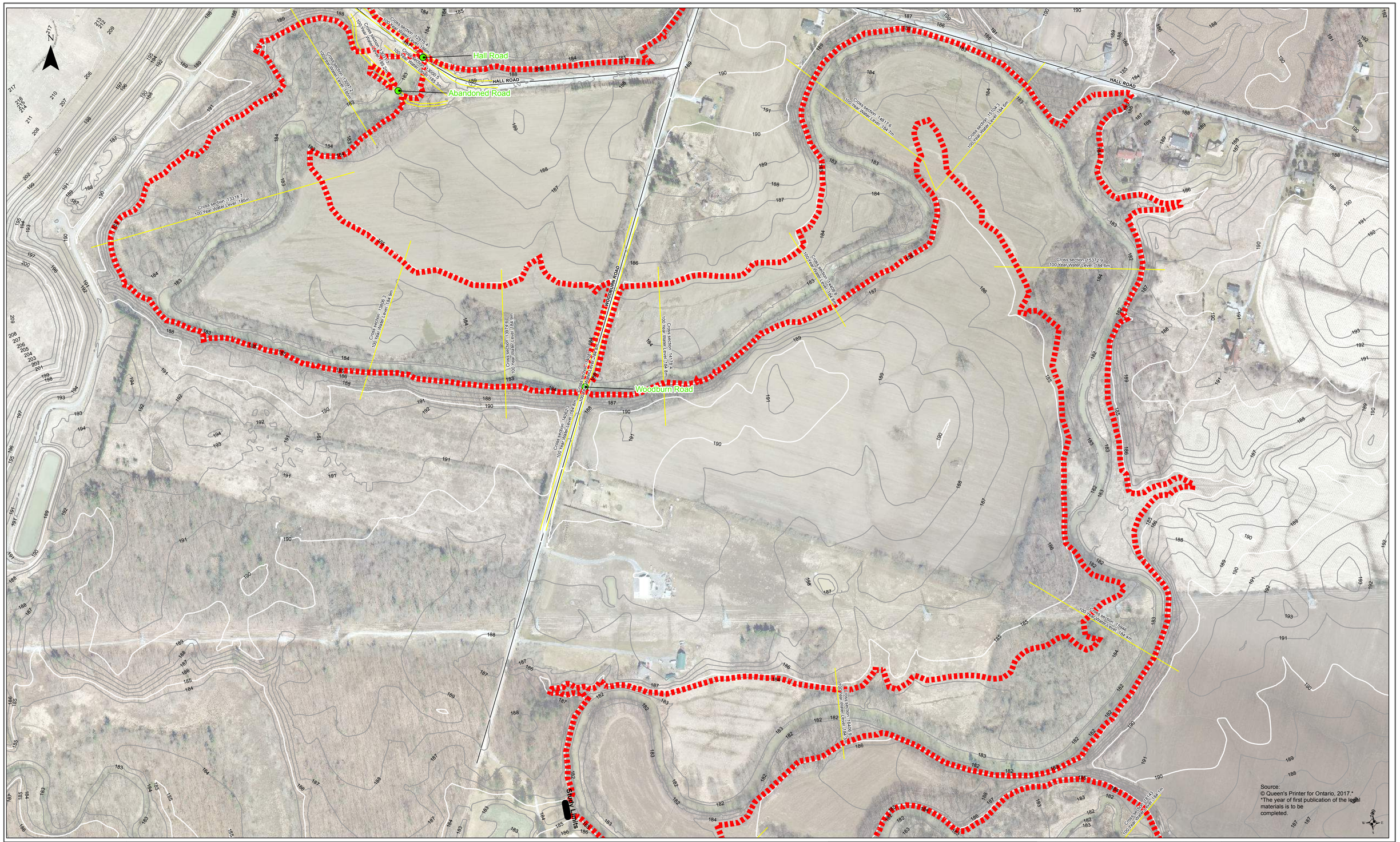
Figure A4
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

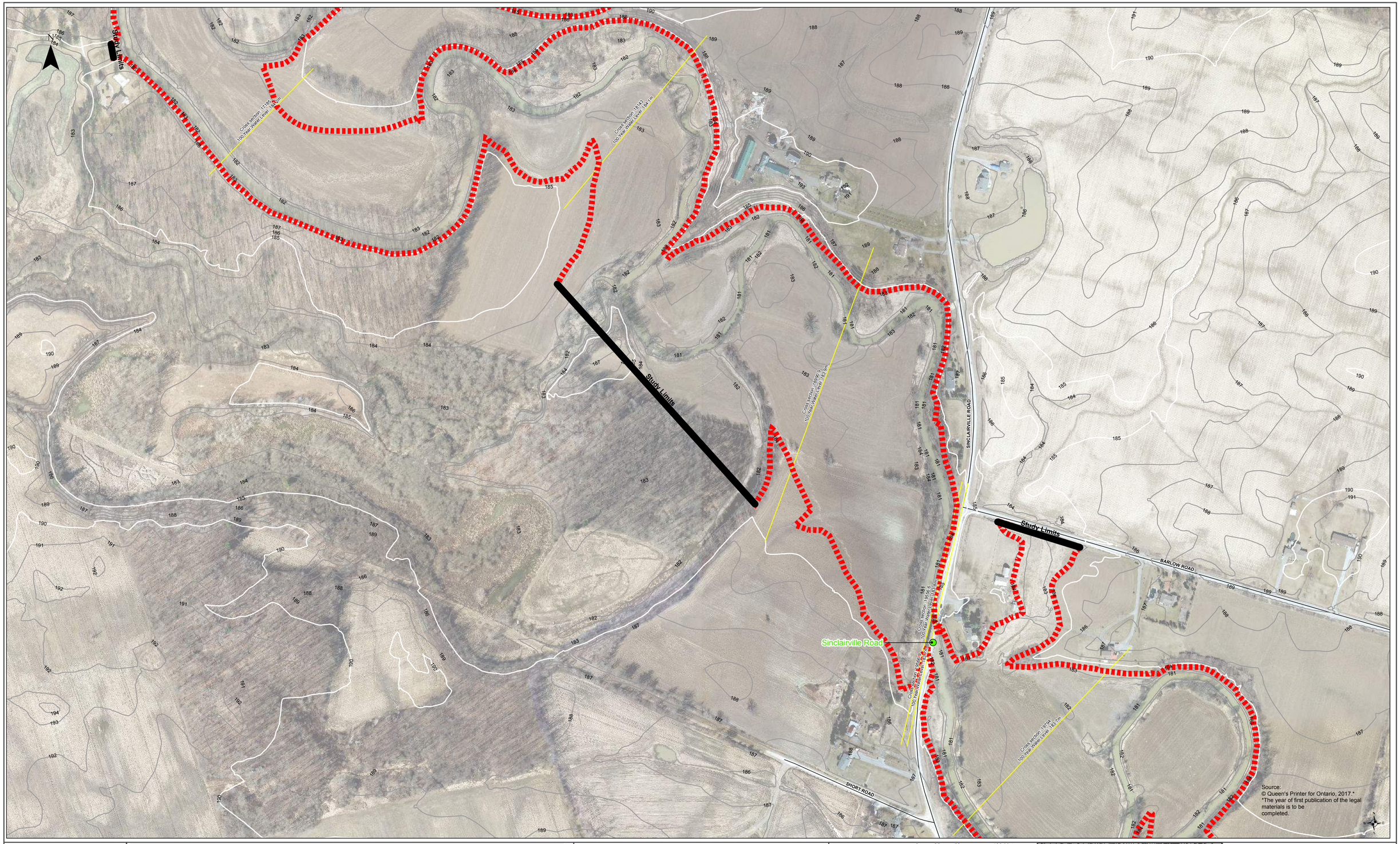
Figure A5
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

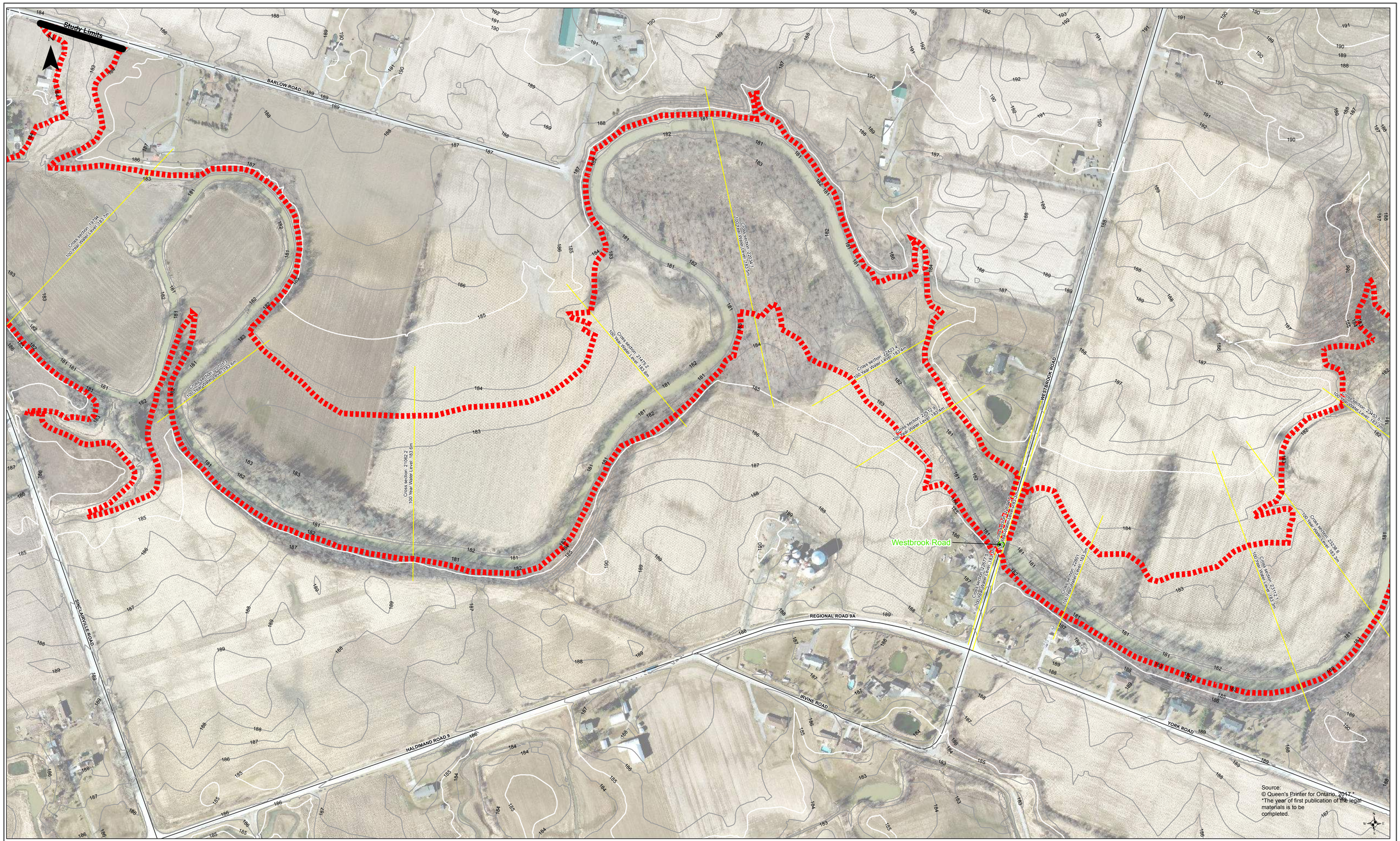
Figure A6
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

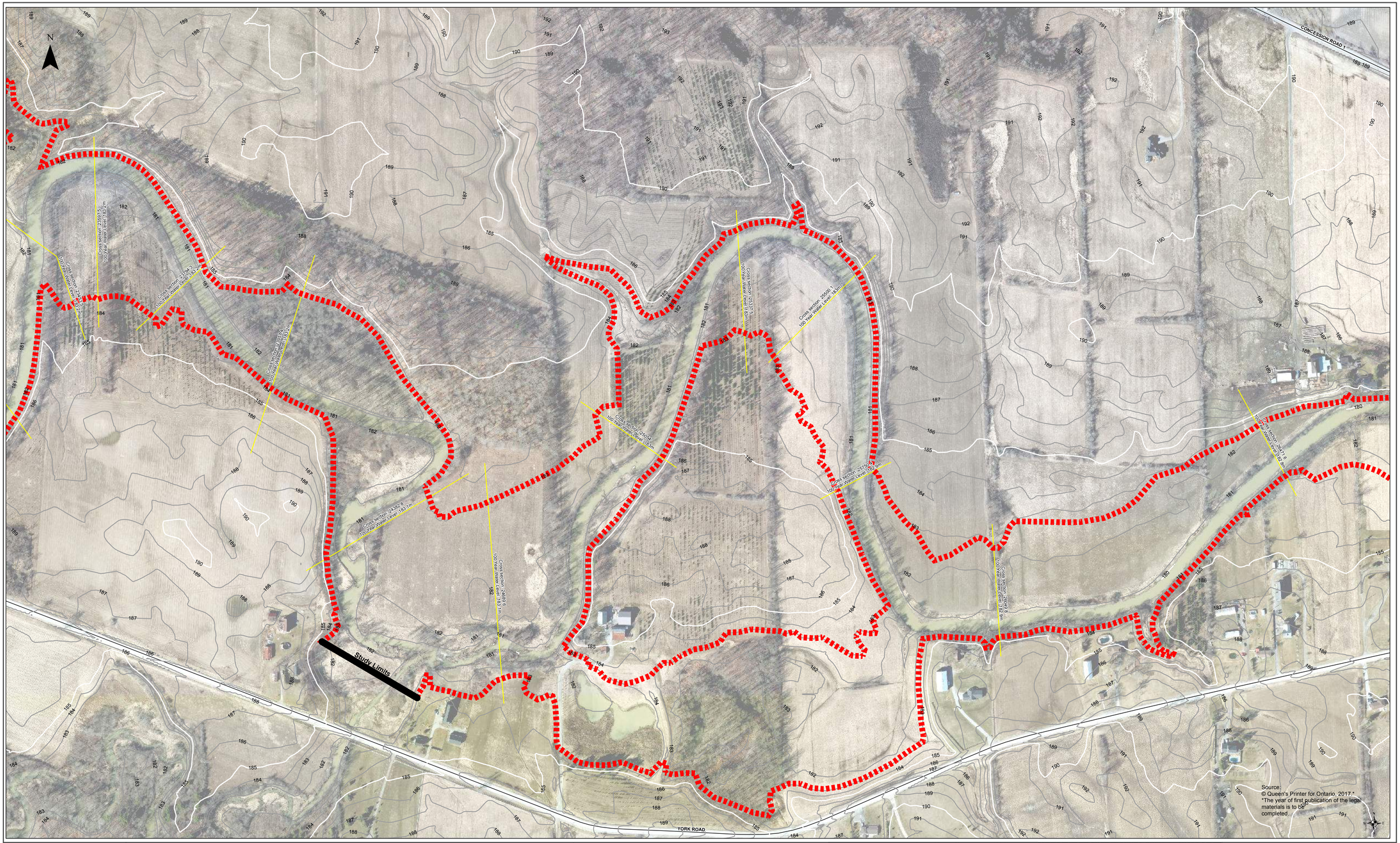
Figure A7
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

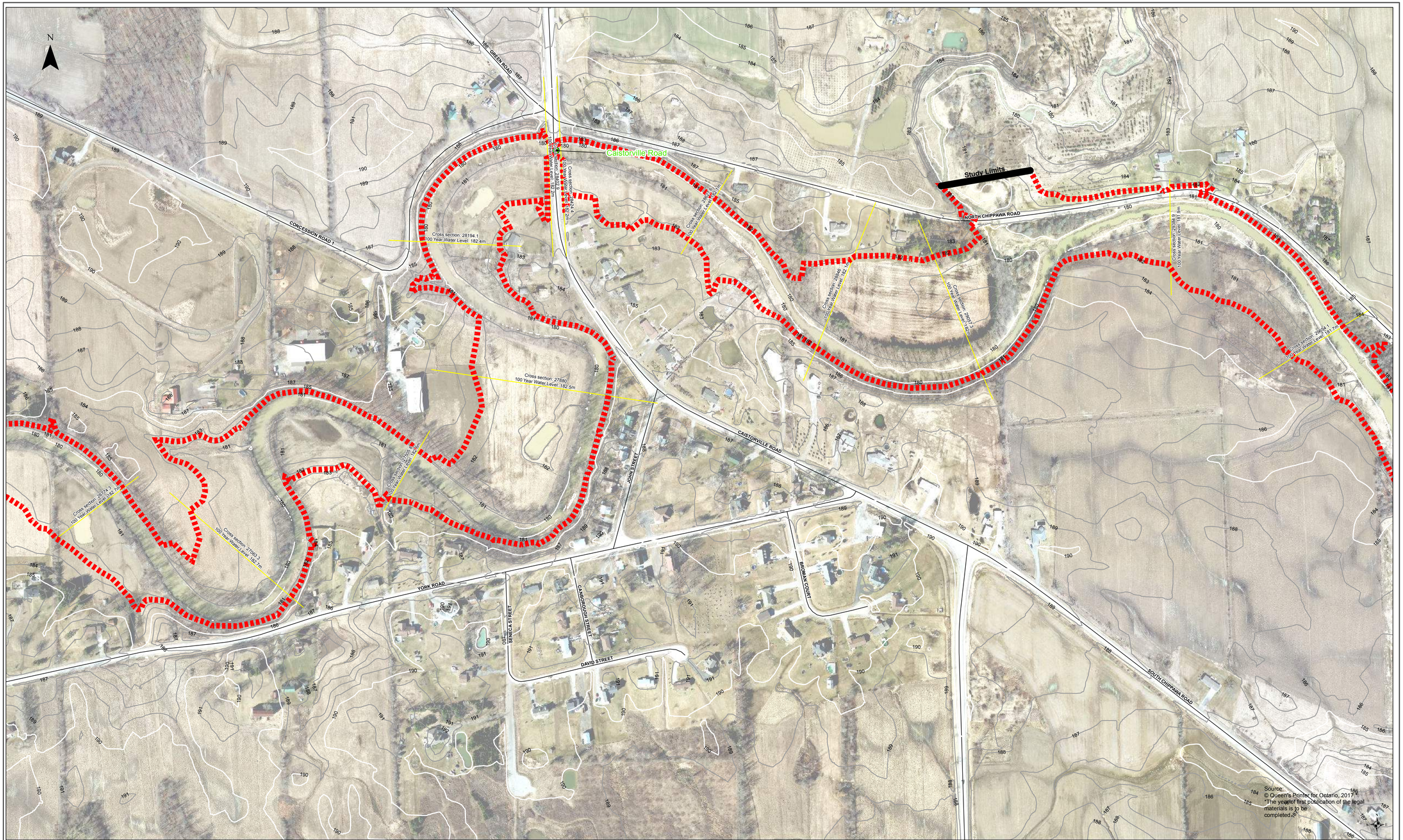
Figure A8
Welland River Watershed
Floodline Mapping

Scale:1:2,000 — 0 25 50 100 Meters

Date: October 2018 — Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

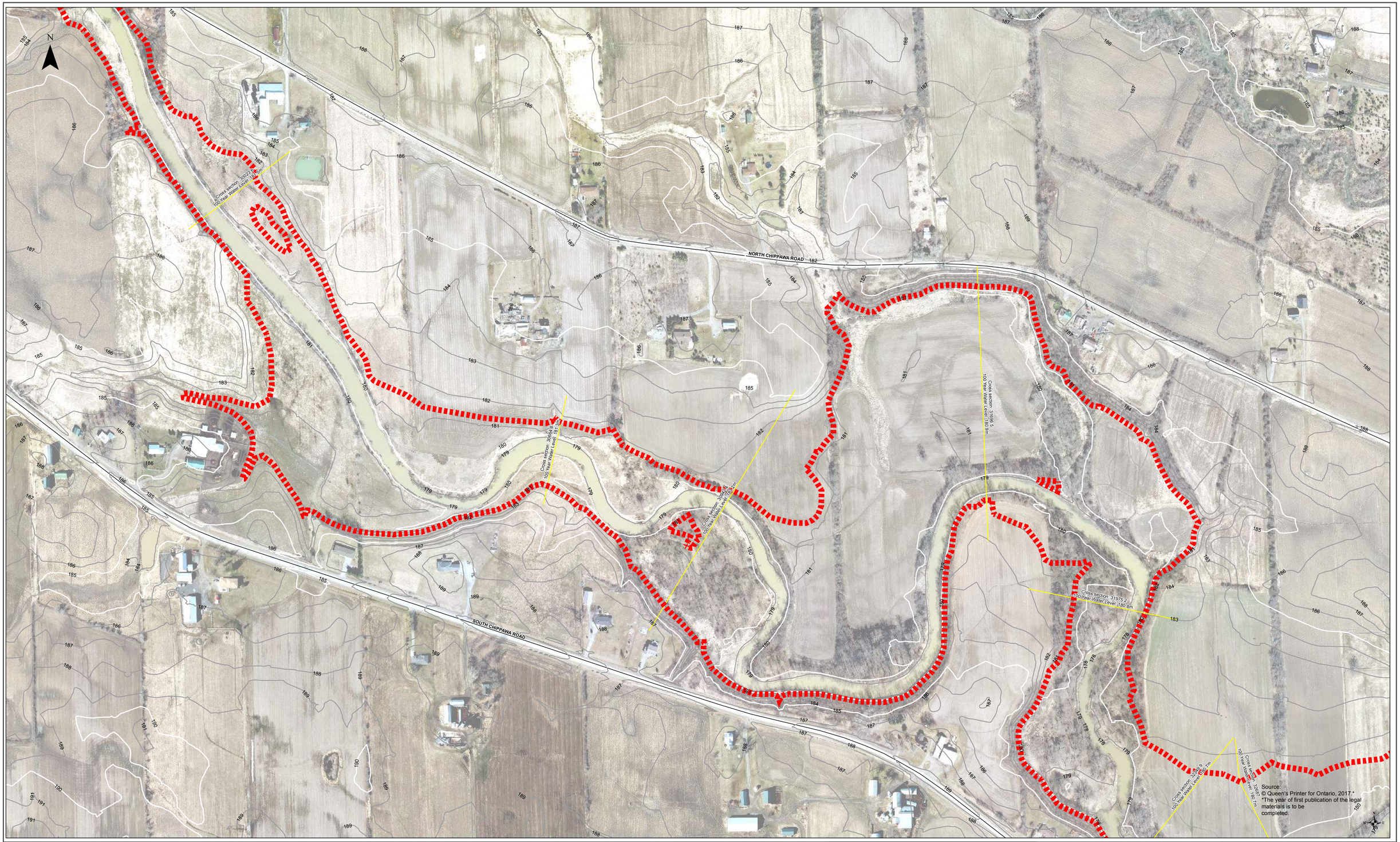
Figure A9
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

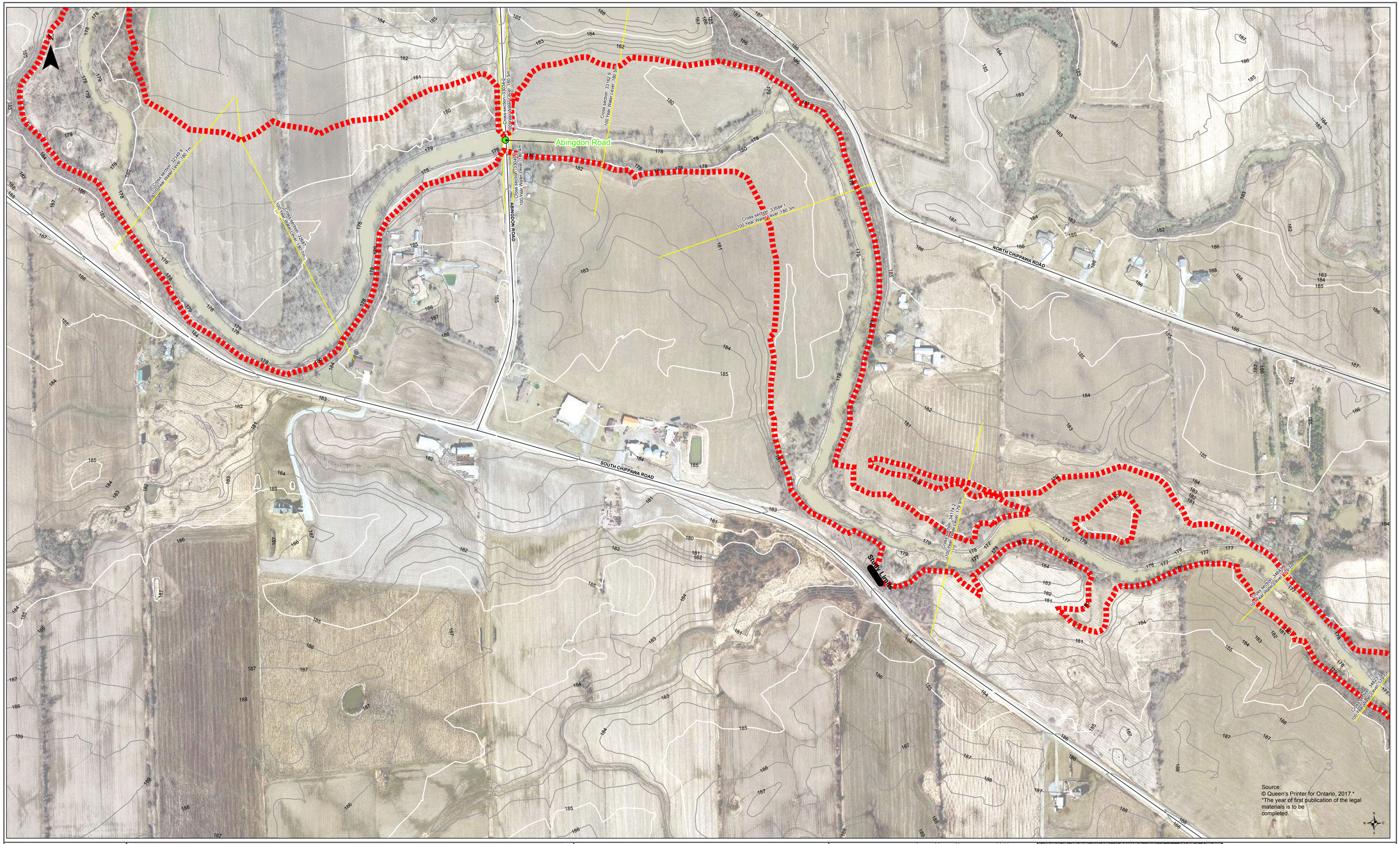
Figure A10
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

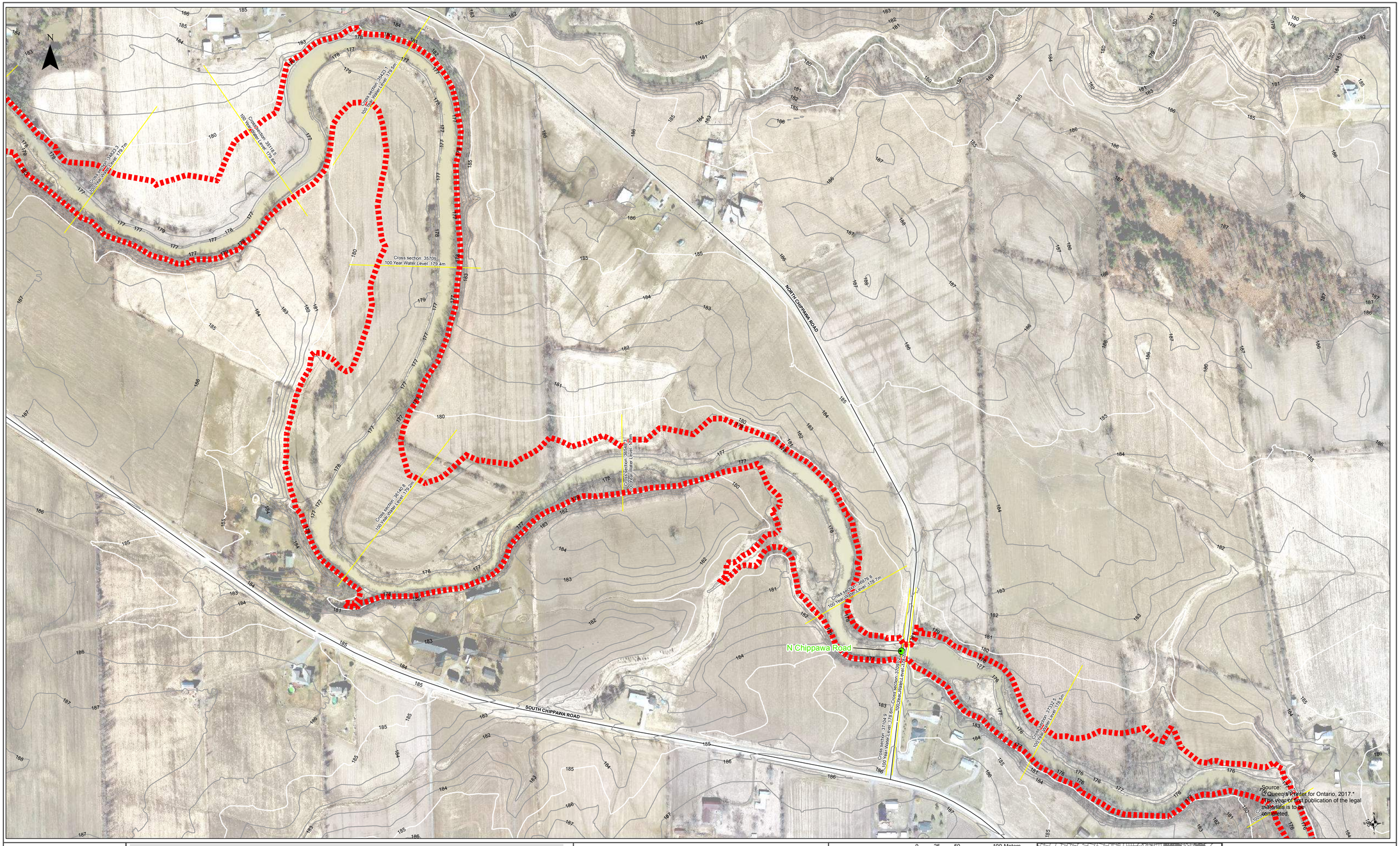
Figure A11
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

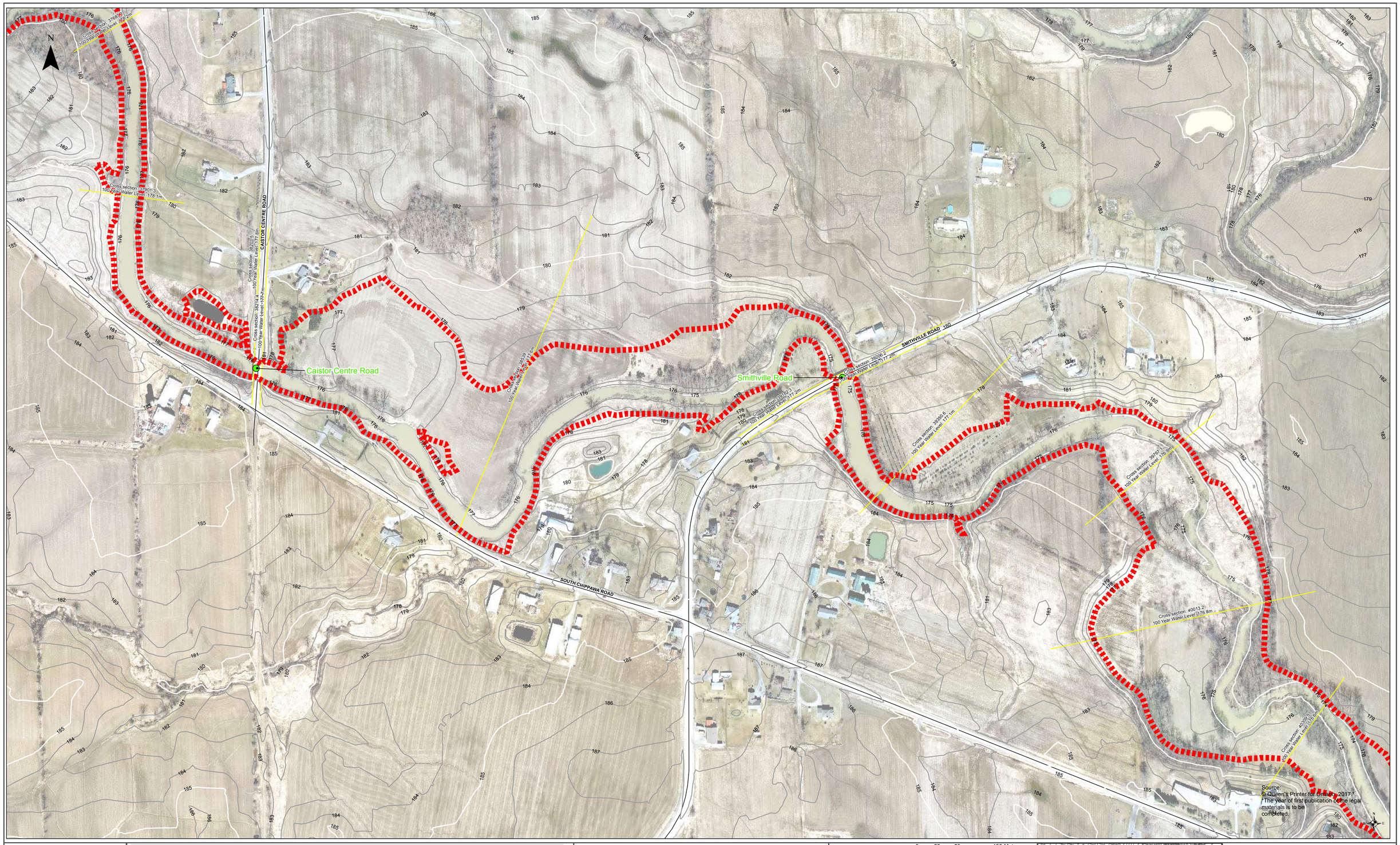
Figure A12
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

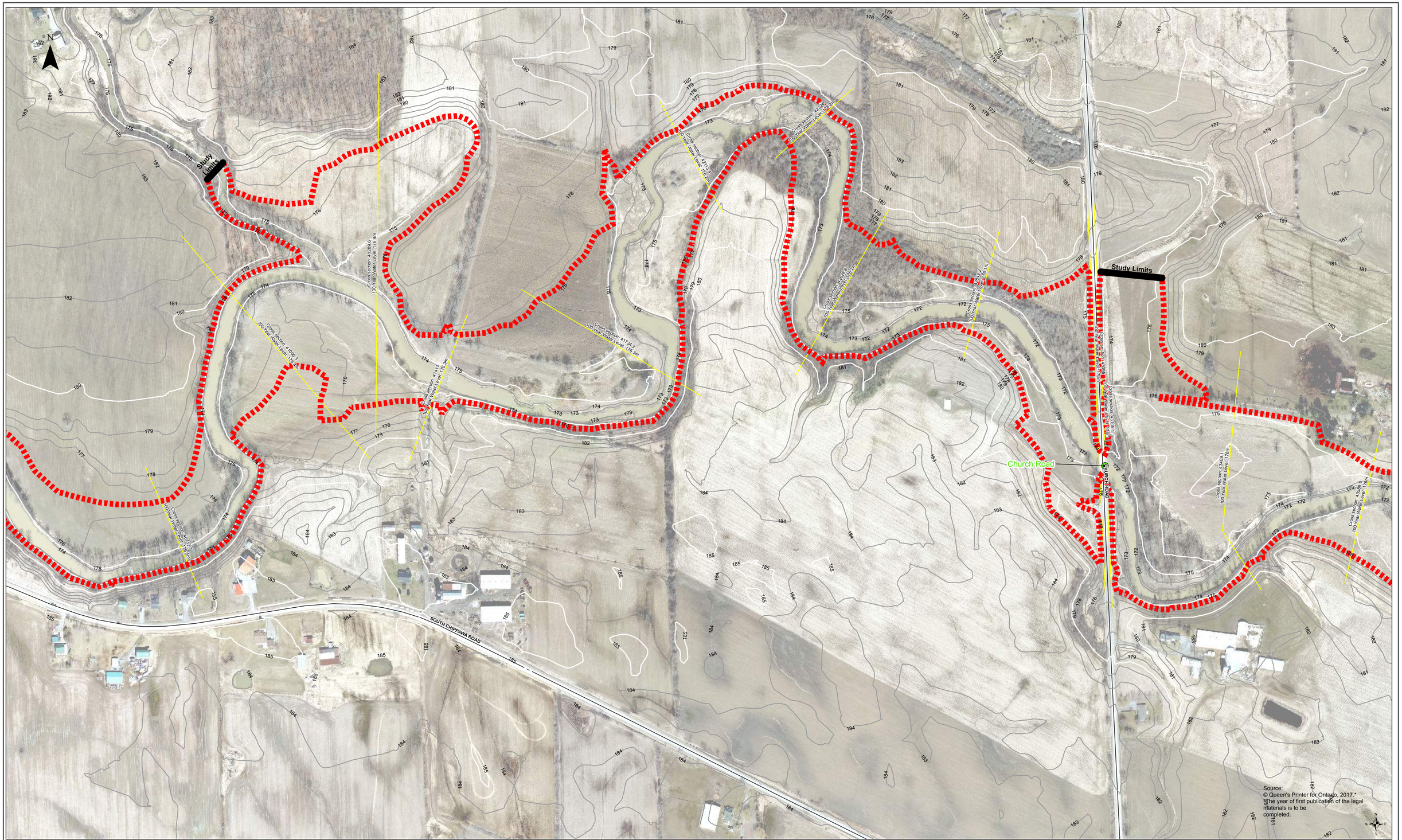
Figure A13
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A14
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

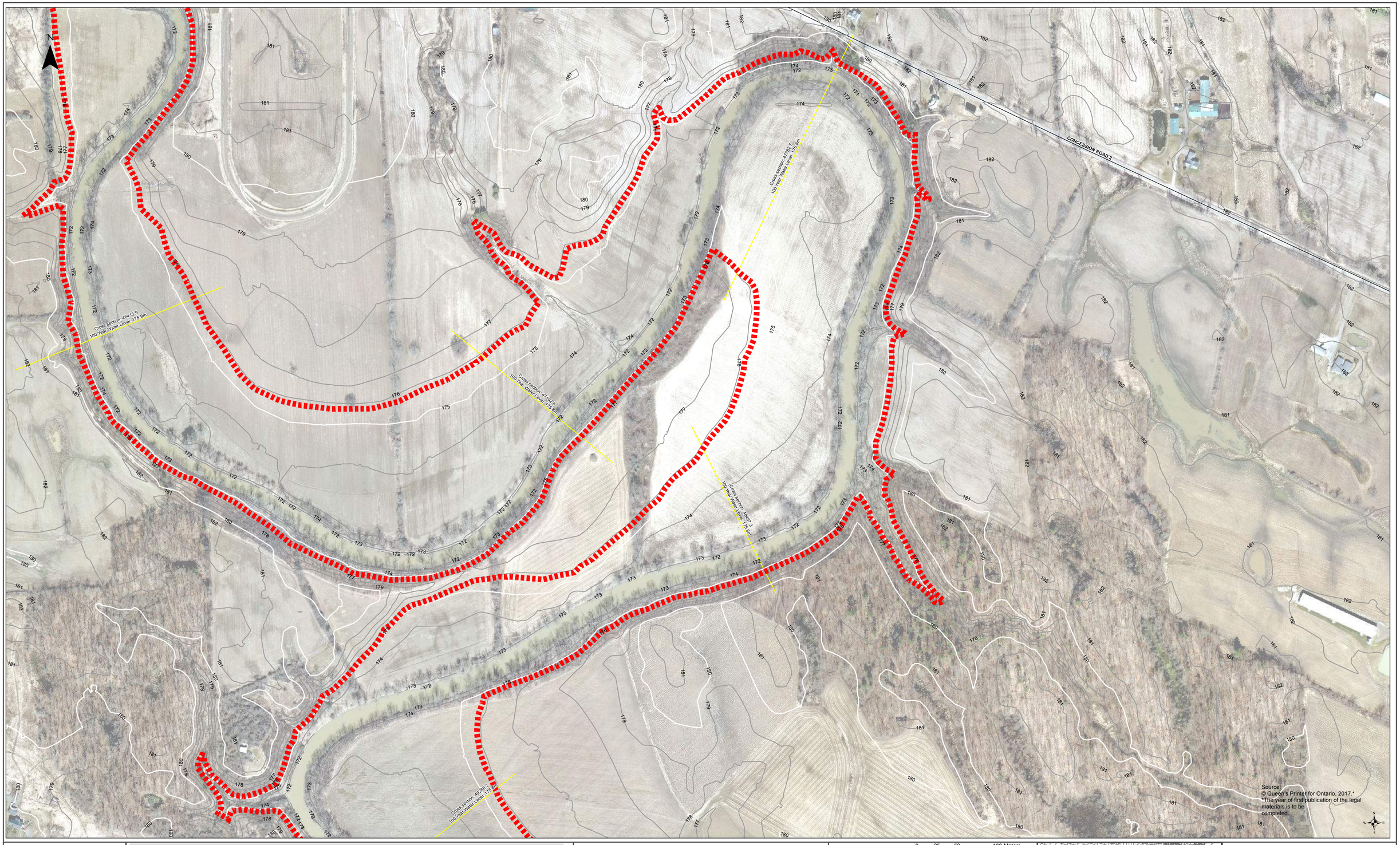
Figure A15
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

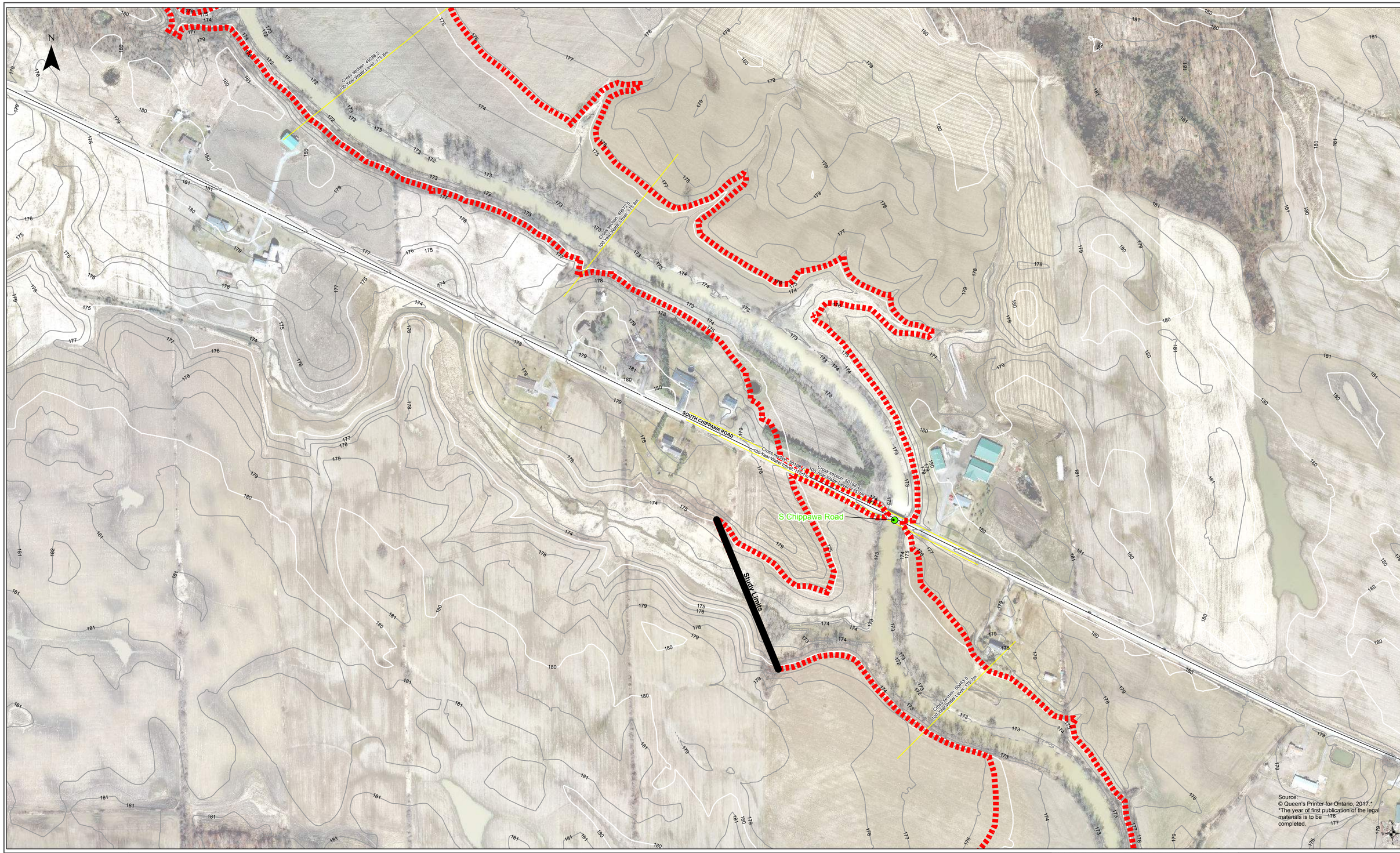
Figure A16
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



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Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

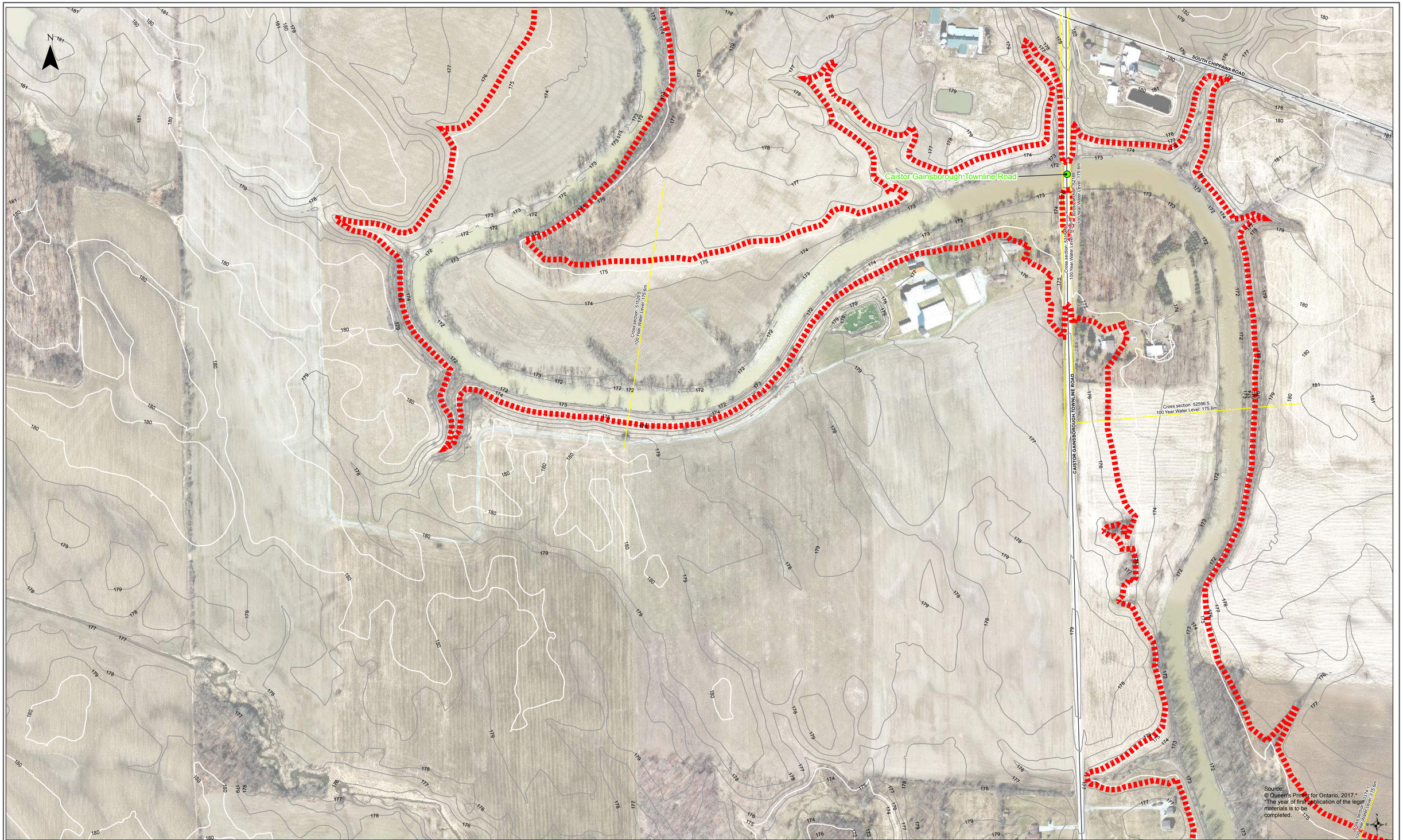
Figure A17
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

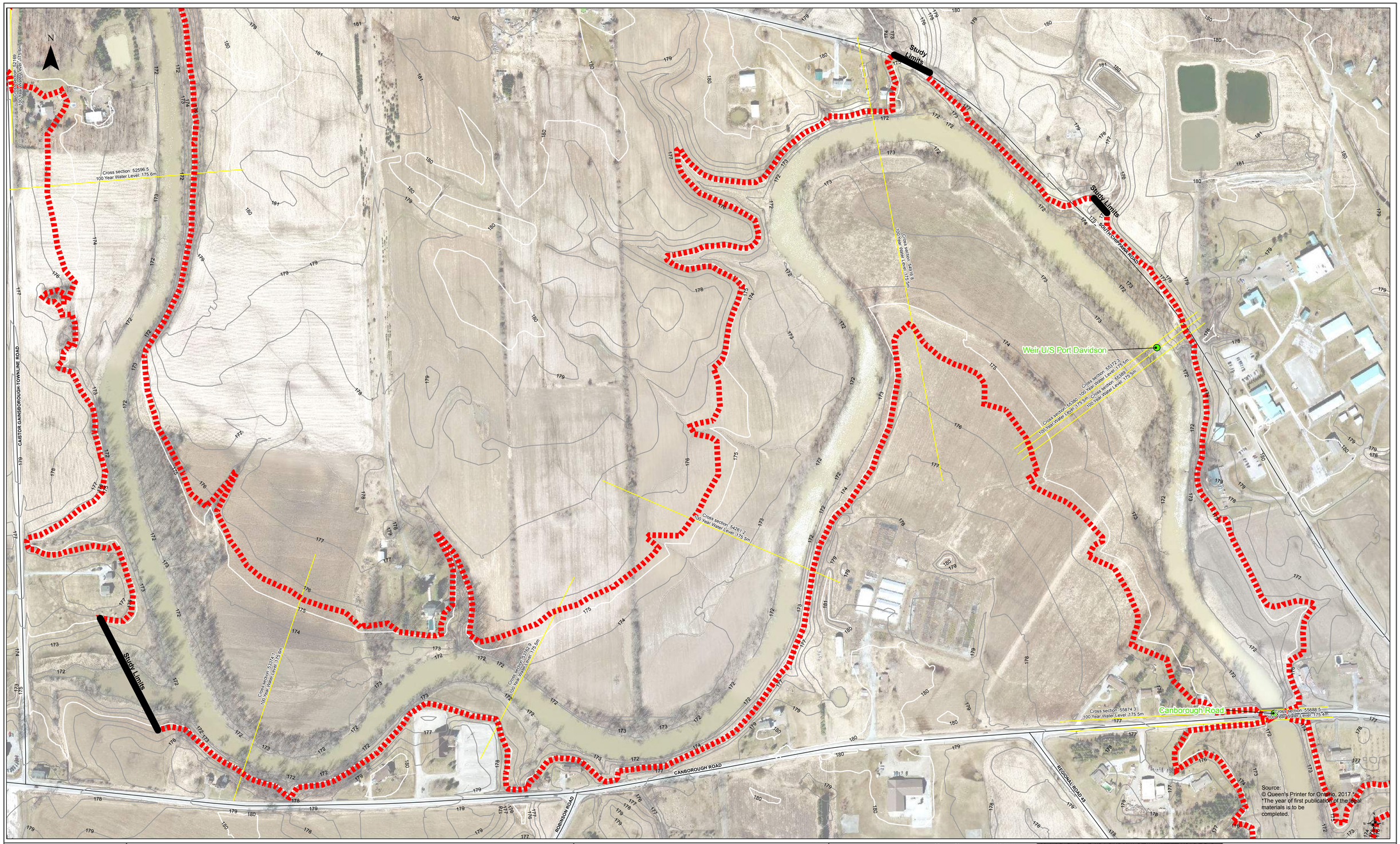
Figure A18
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

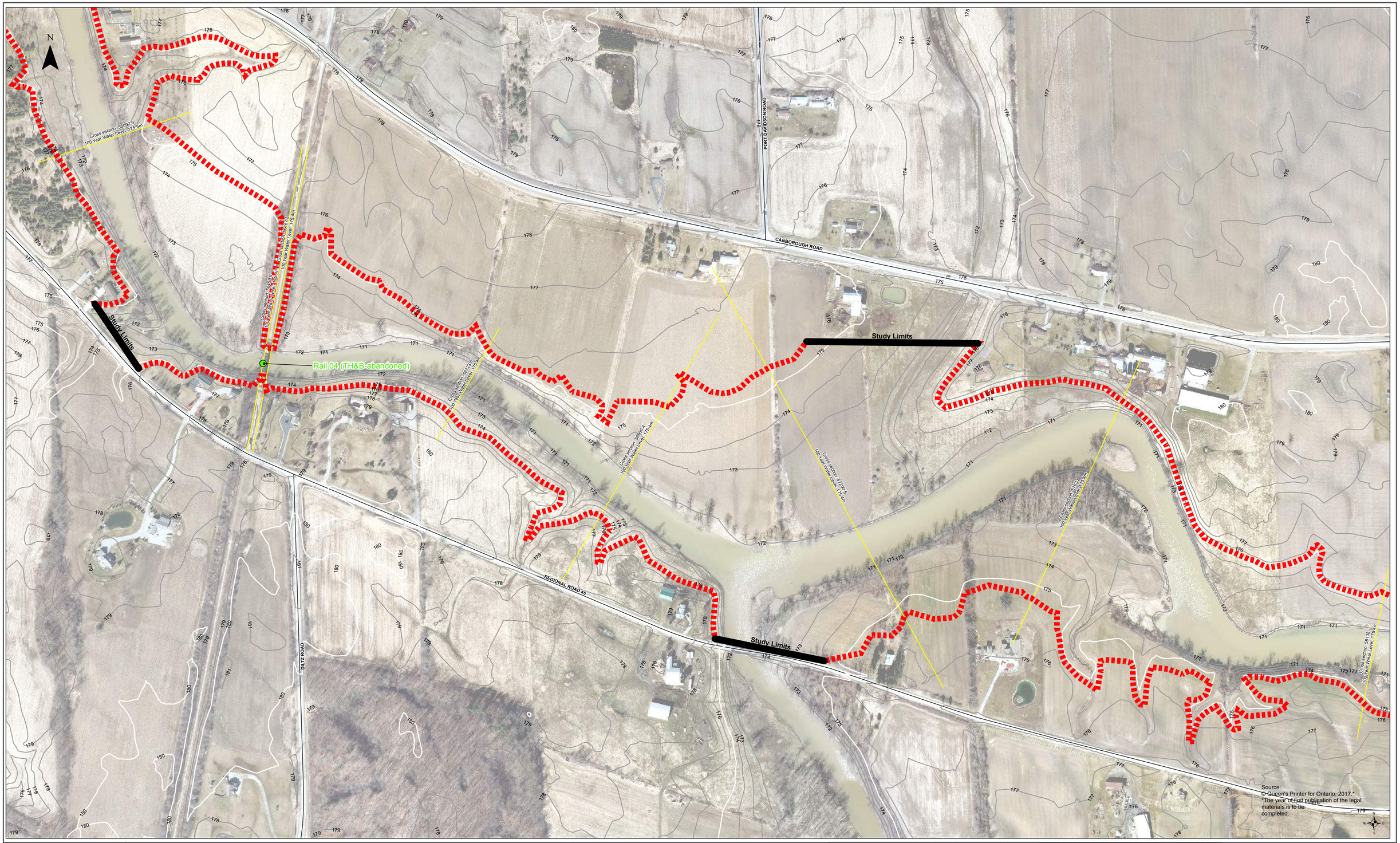
Figure A19
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A20
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

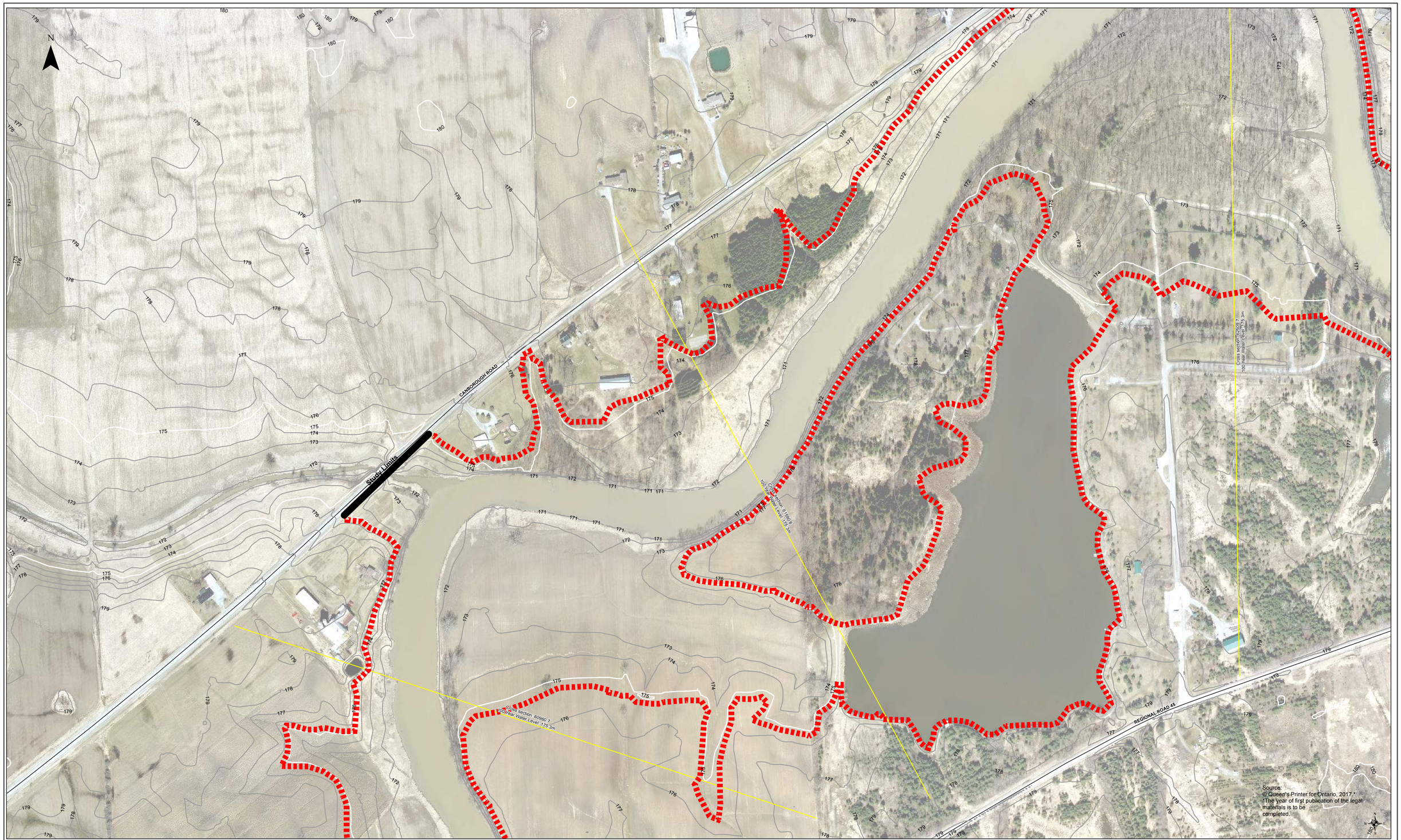
Figure A21
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A22
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

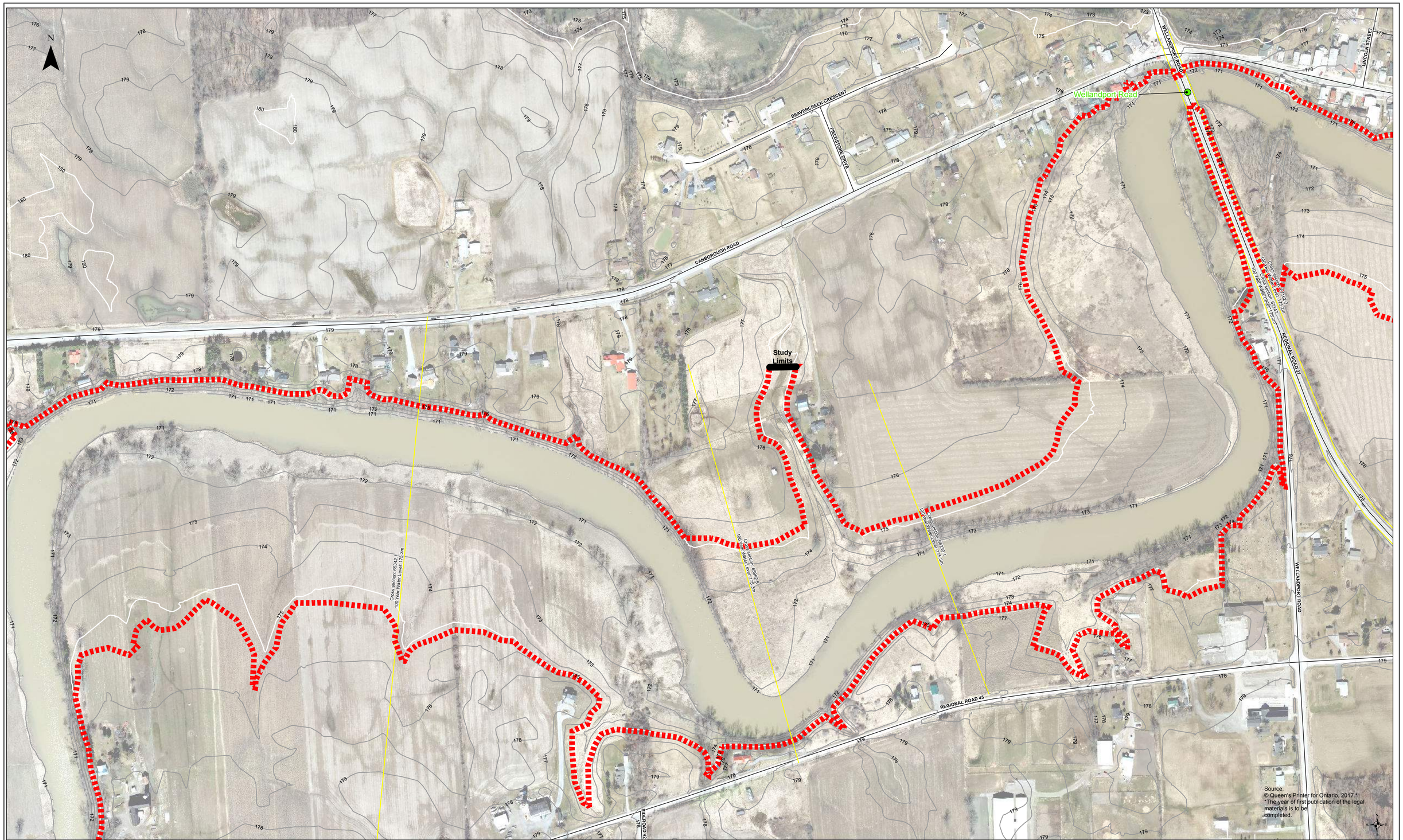
Figure A23
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

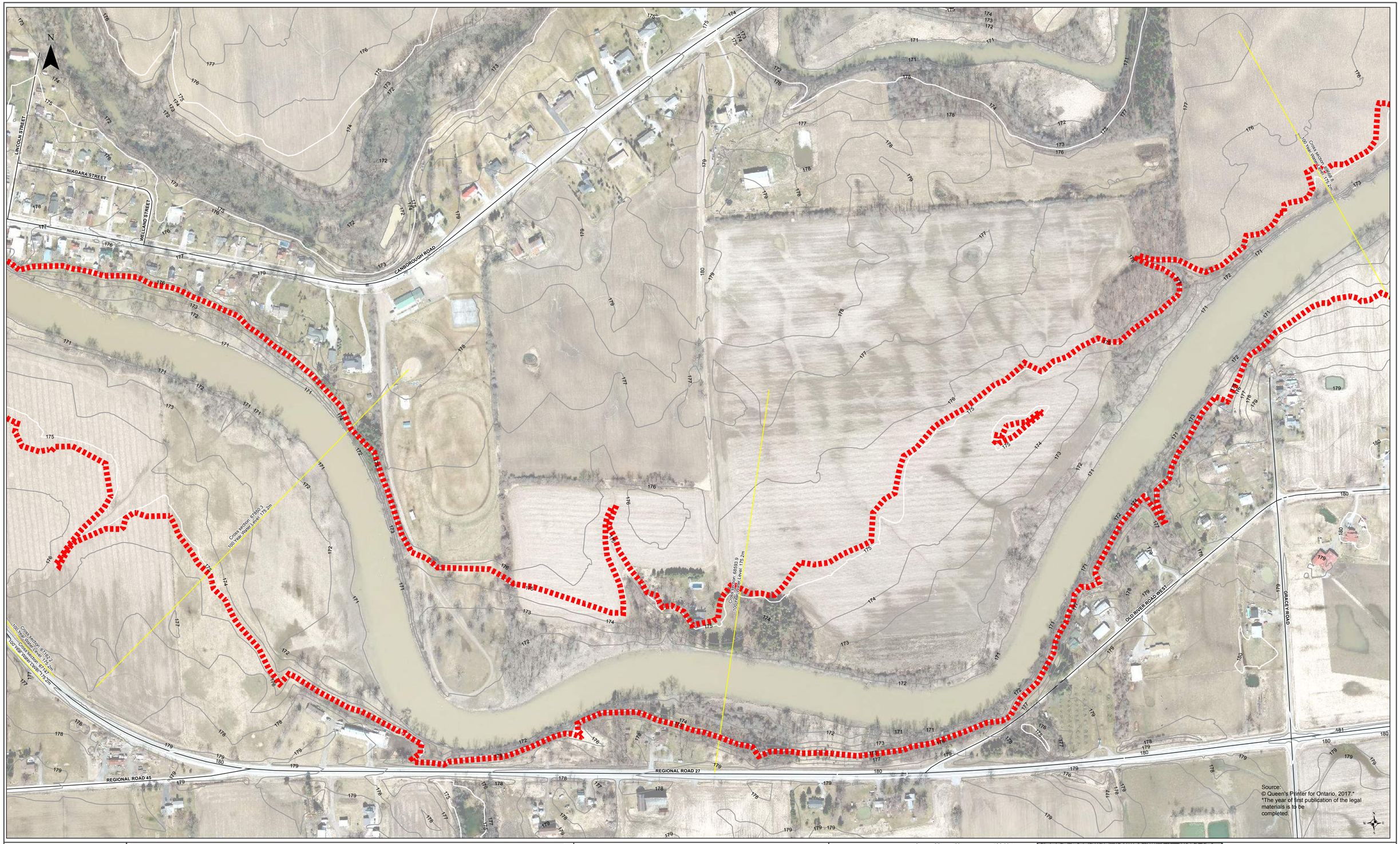
Figure A24
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

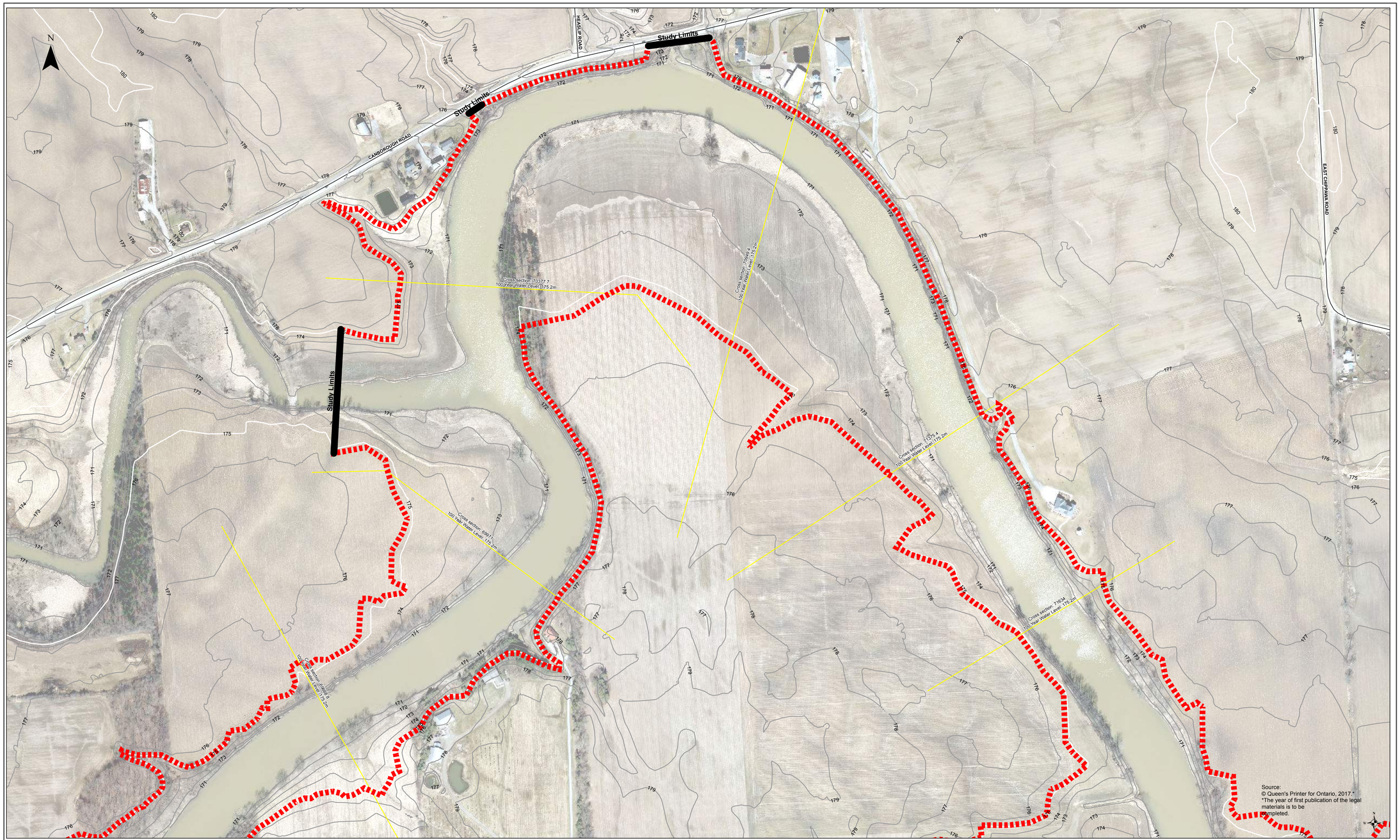
Figure A25
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

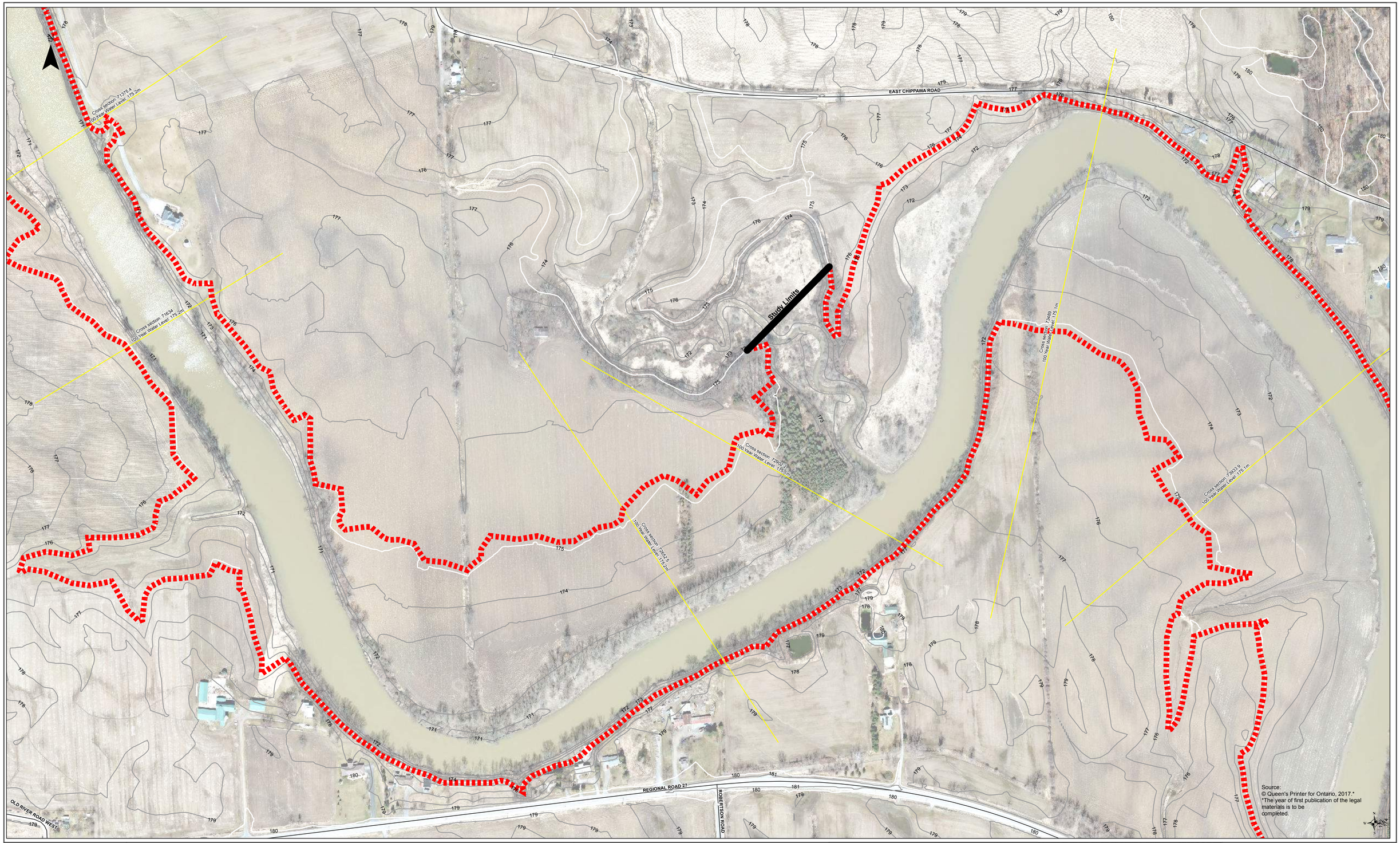
Figure A26
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

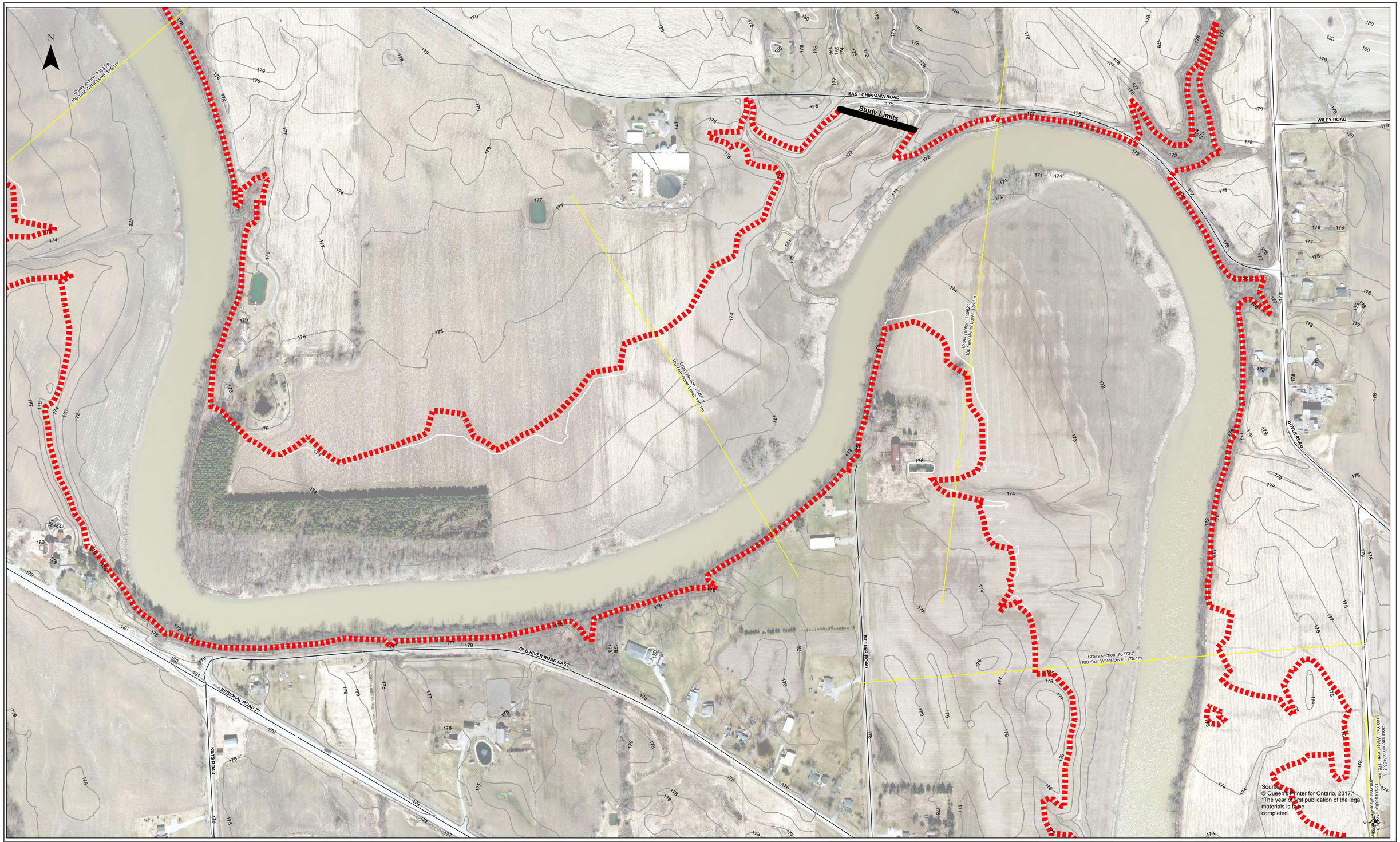
Figure A27
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

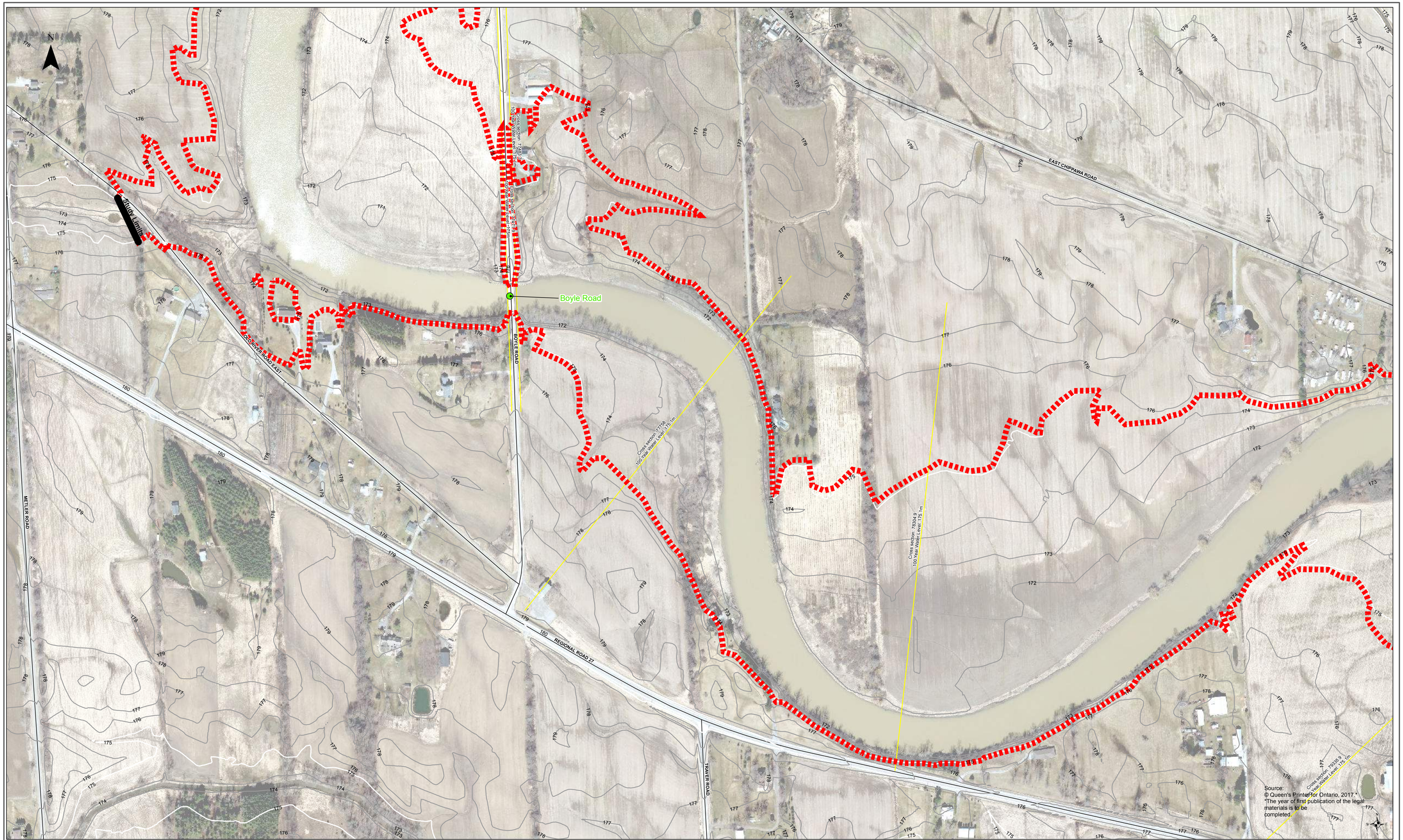
Figure A28
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

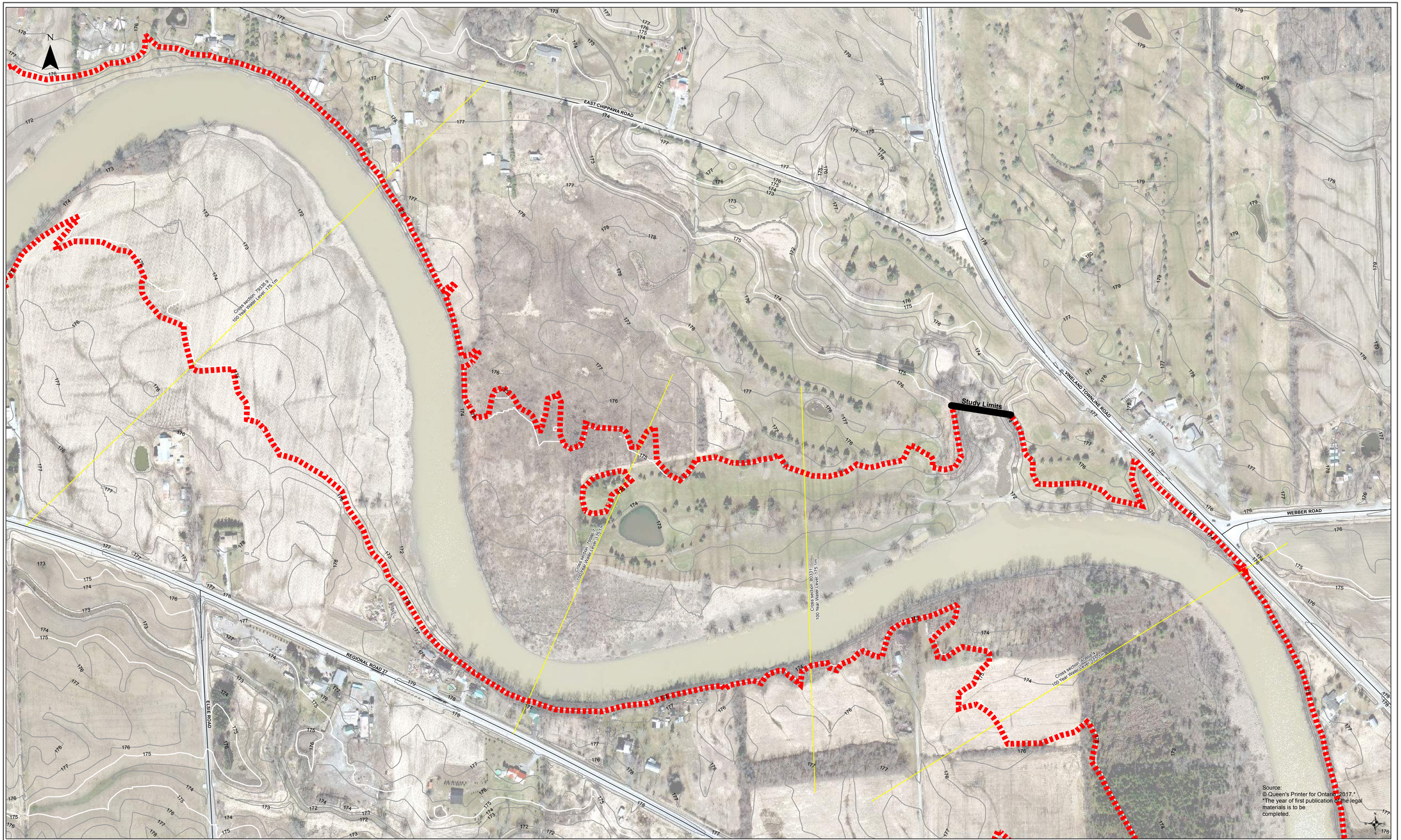
Figure A29
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

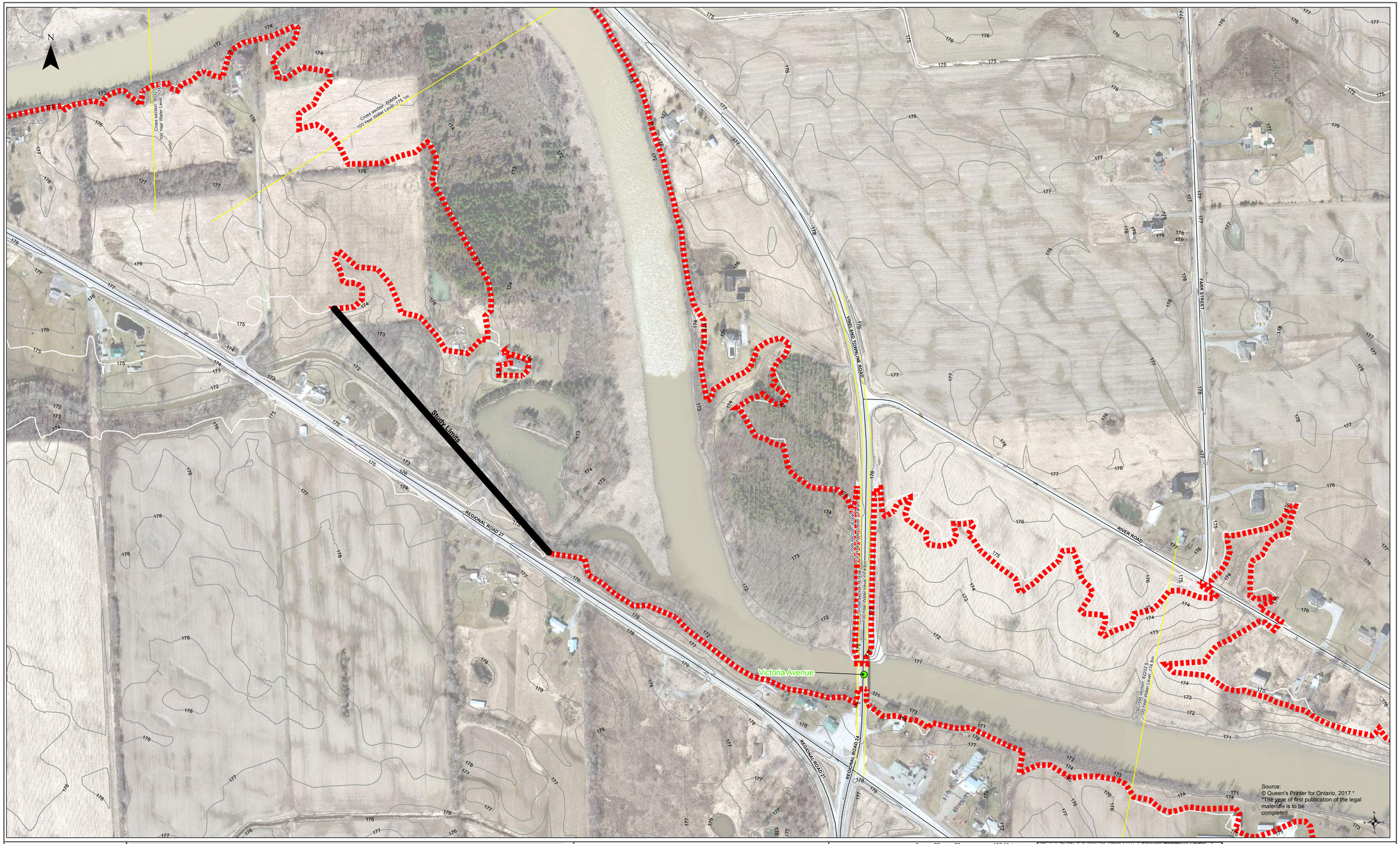
Figure A30
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

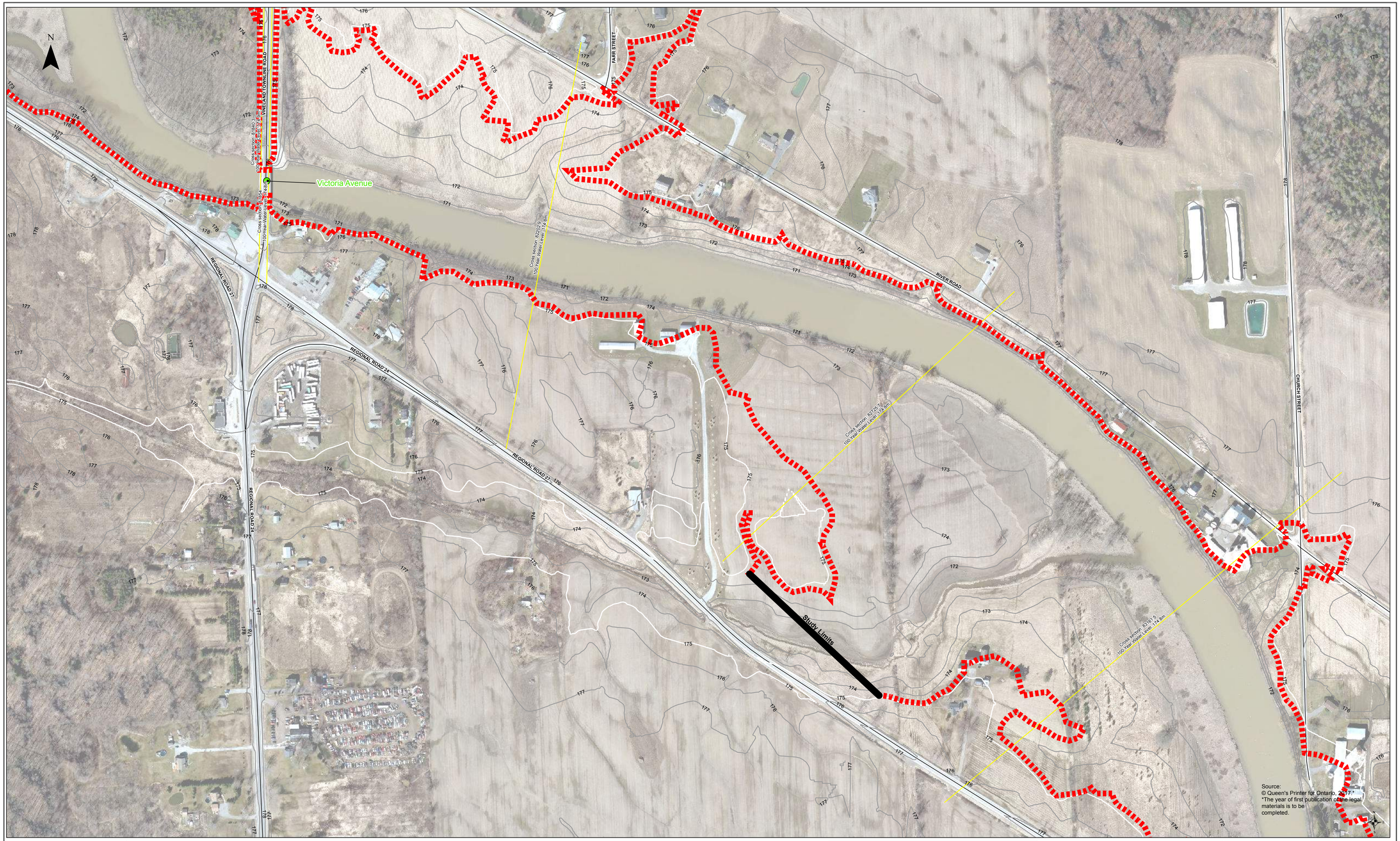
Figure A31
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

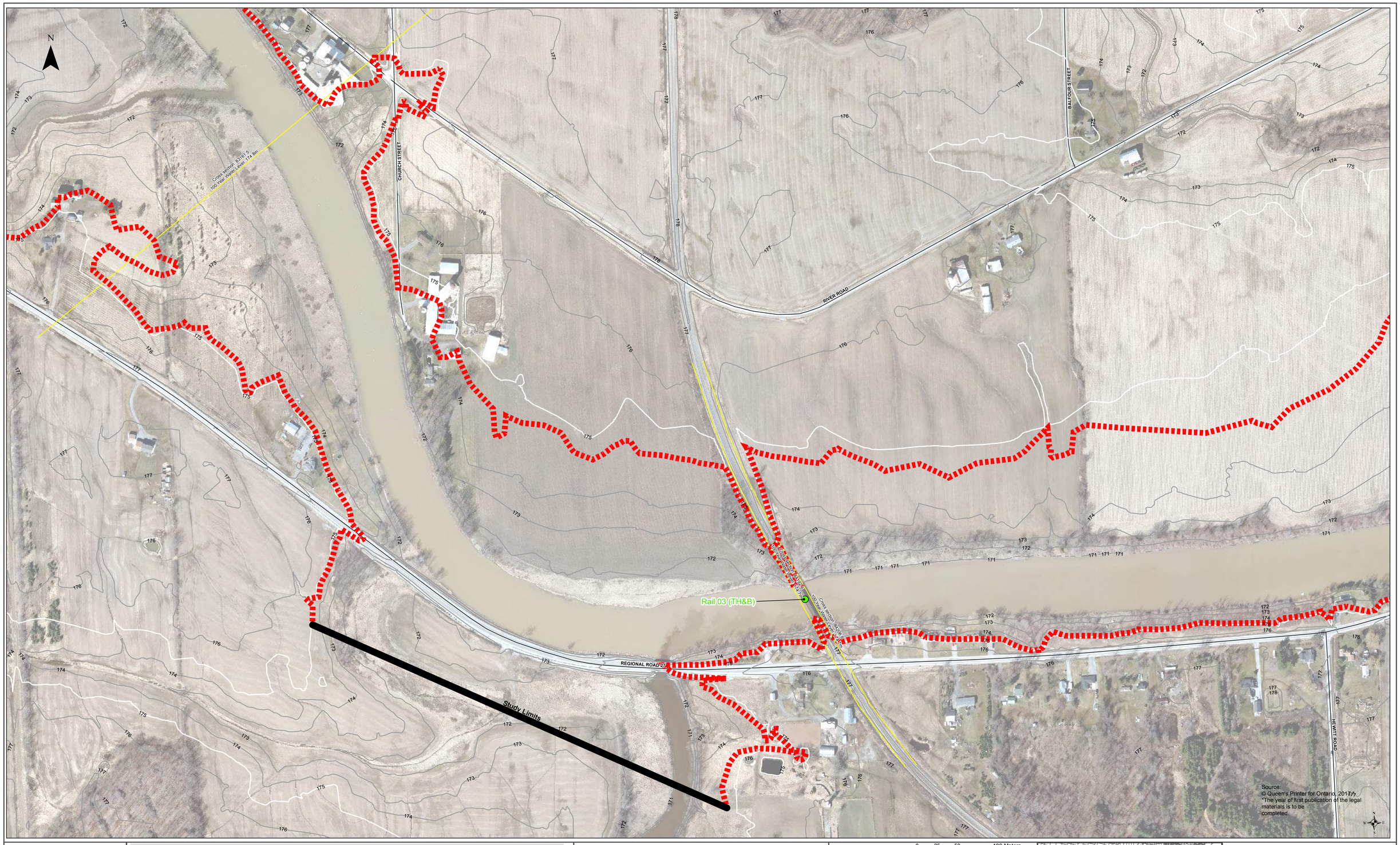
Figure A32
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A33
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

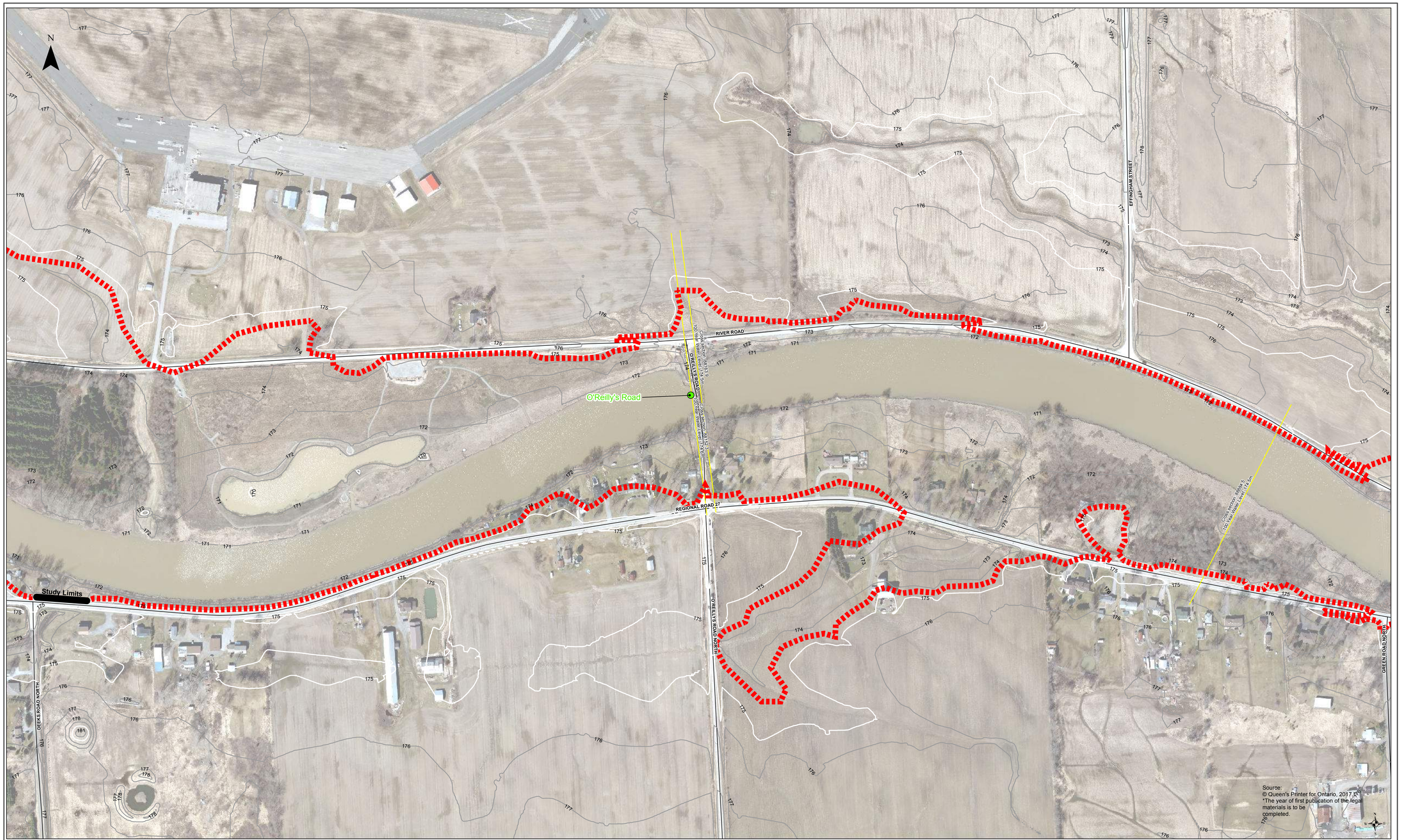
Figure A34
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

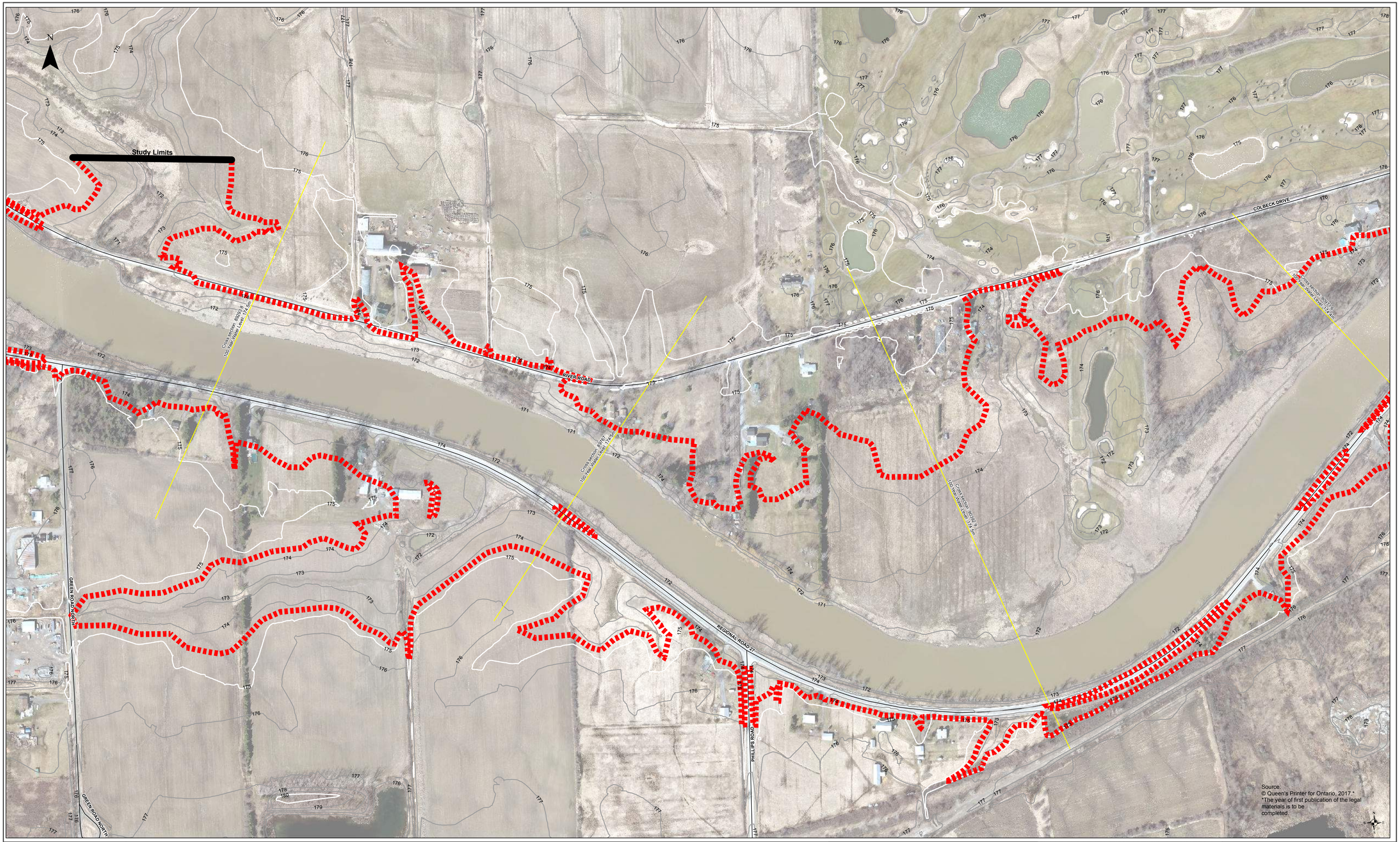
Figure A35
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



wsp

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

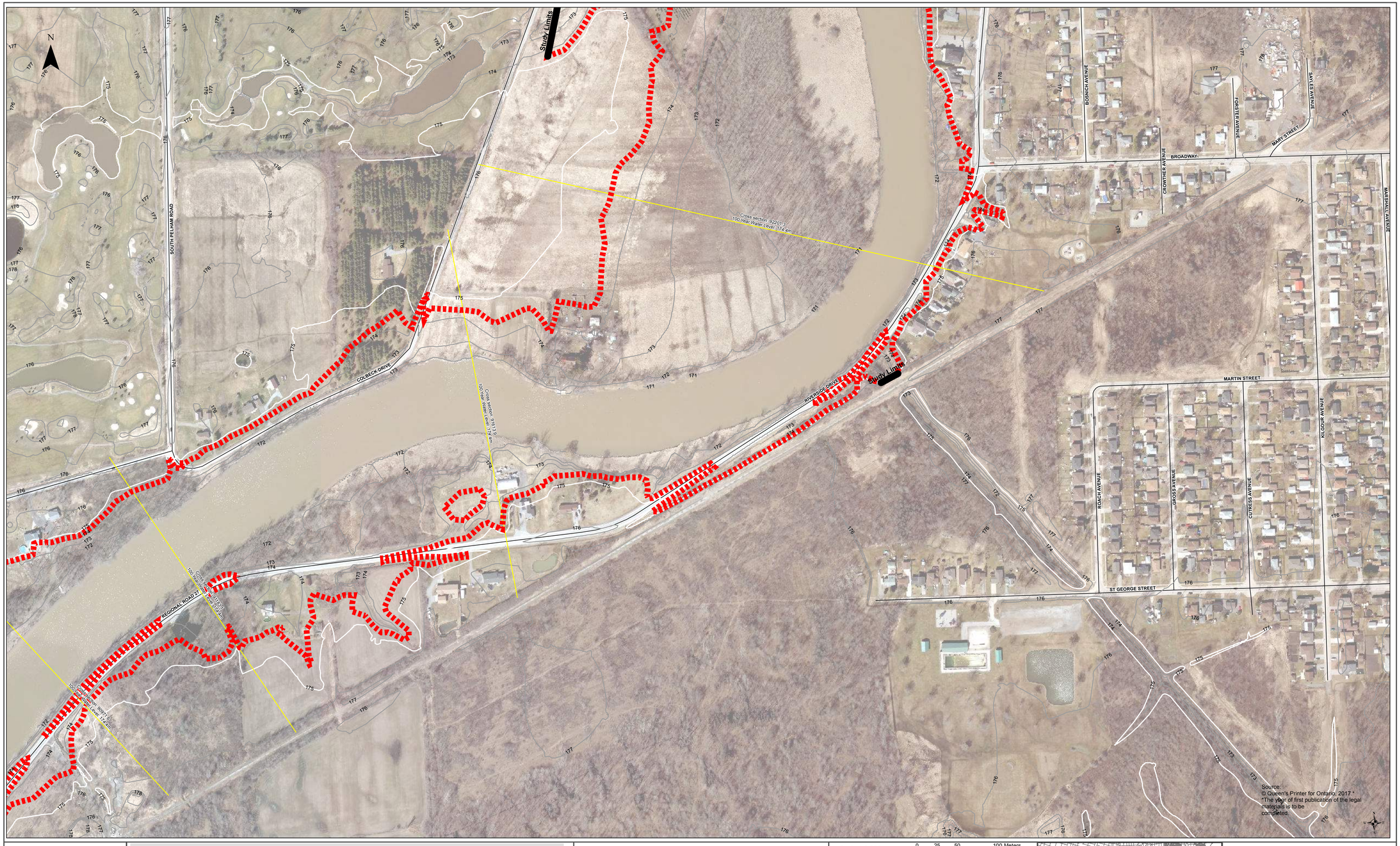
Figure A36
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A37
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A38
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

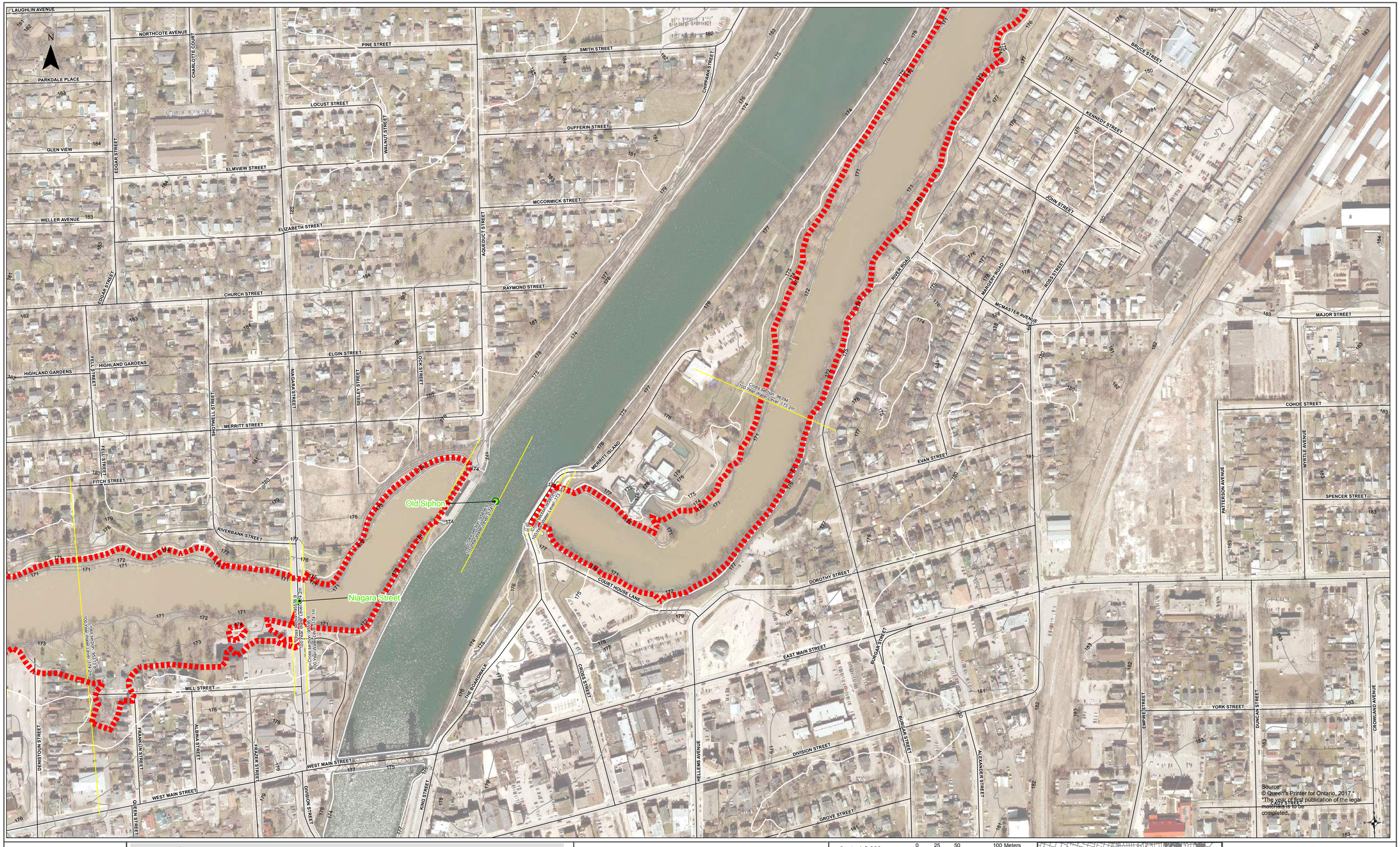
Figure A39
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A40
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A41
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A42
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A43
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A44
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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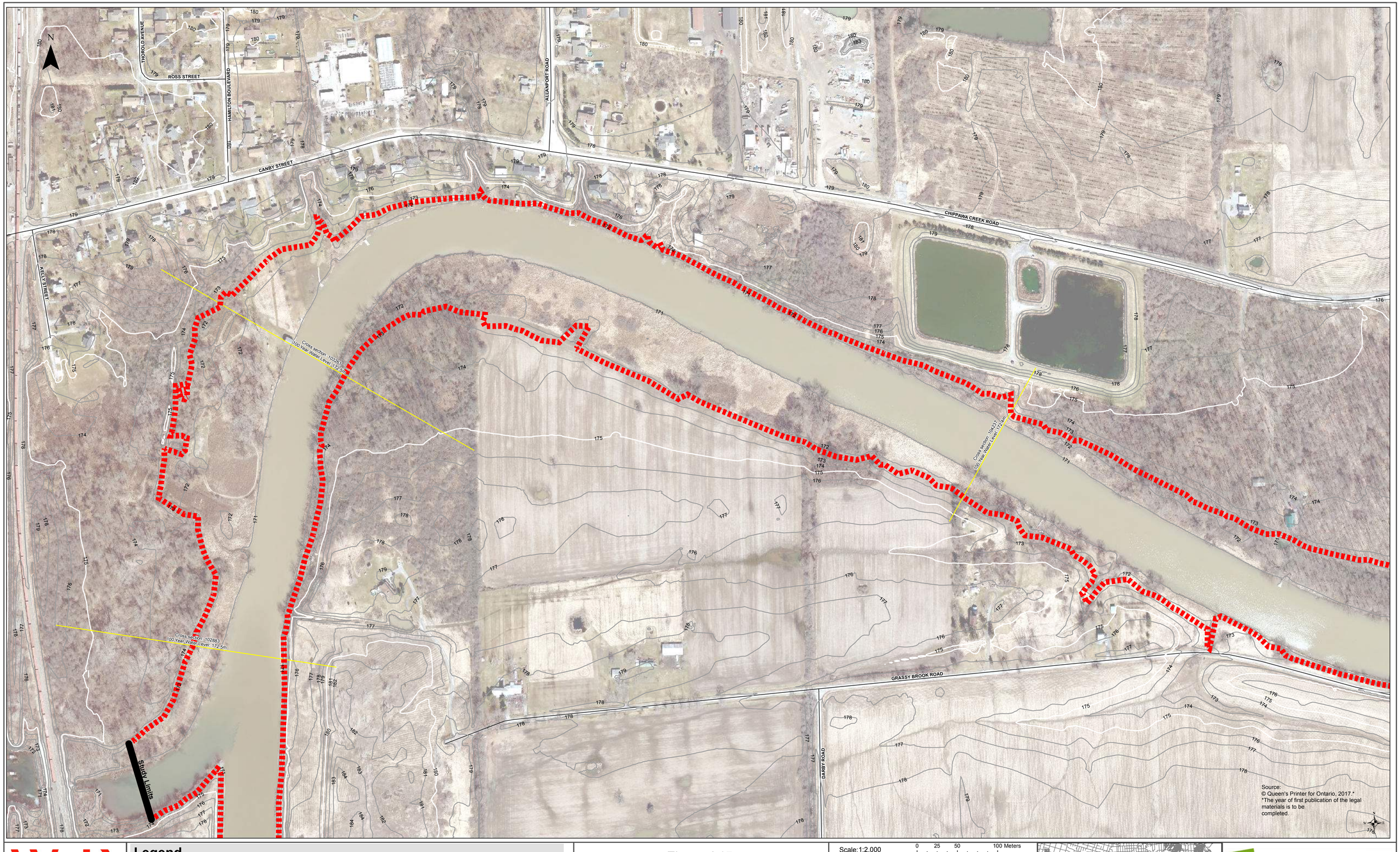

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A45
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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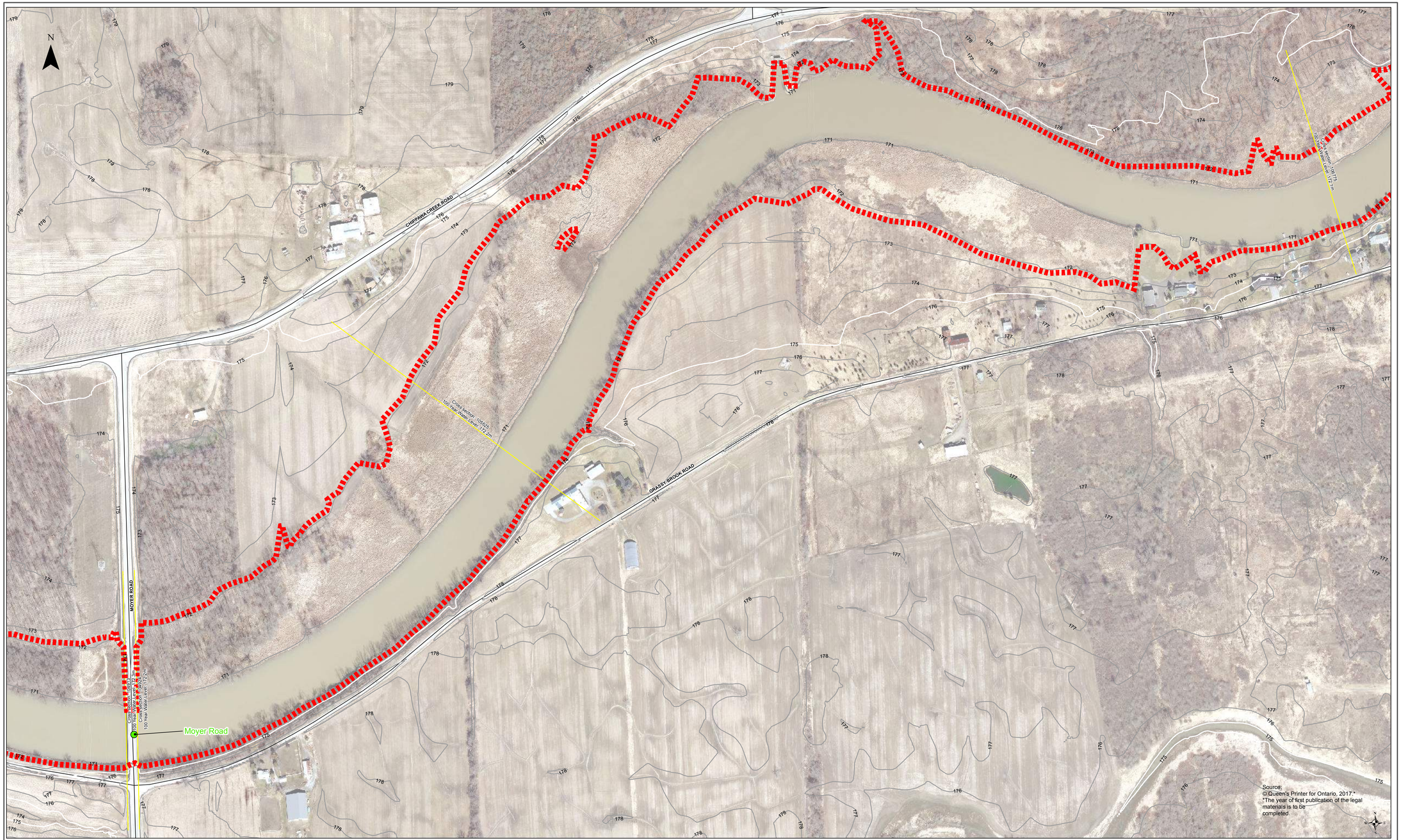

Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A46
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY

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Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A47
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY

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Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A48
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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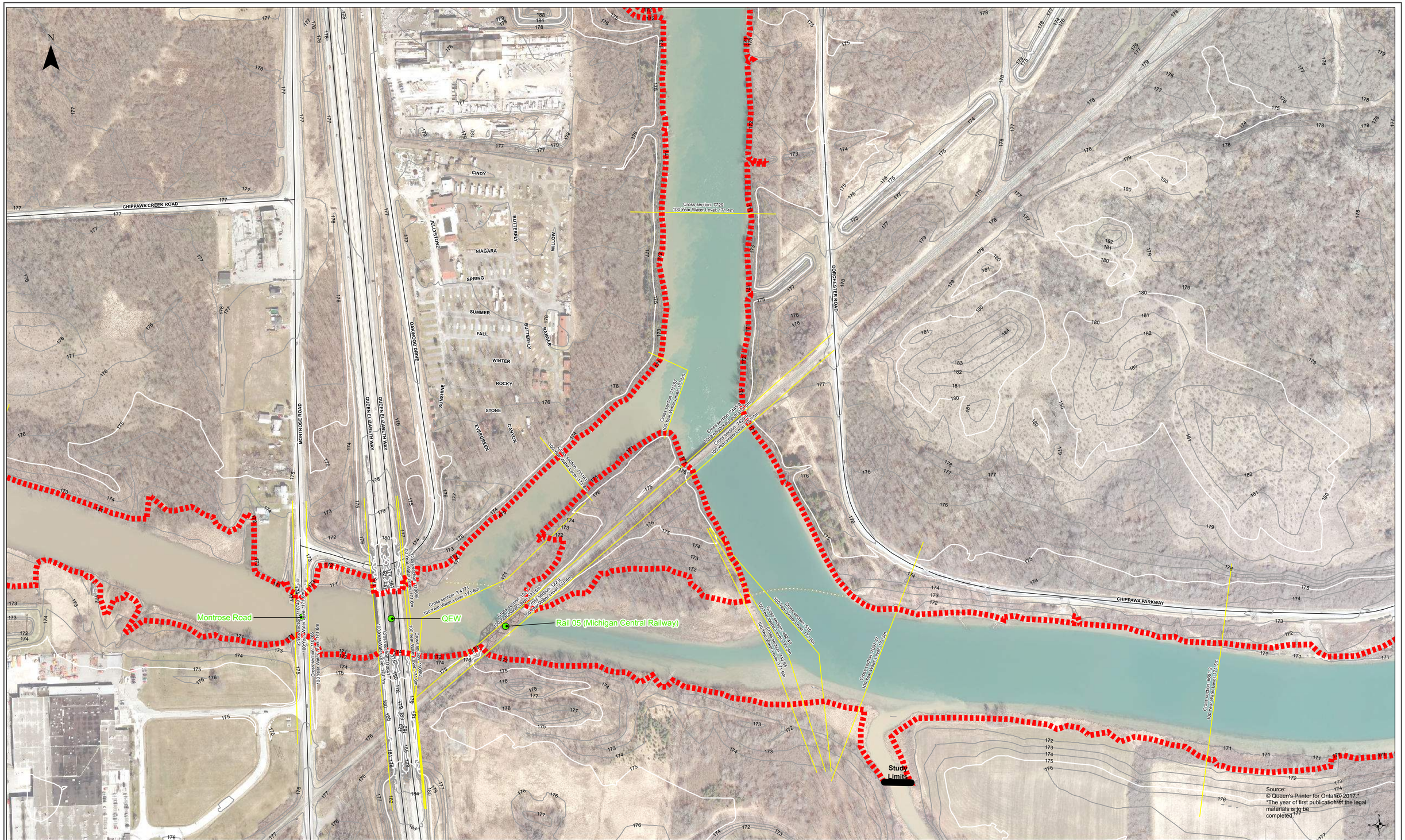

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Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

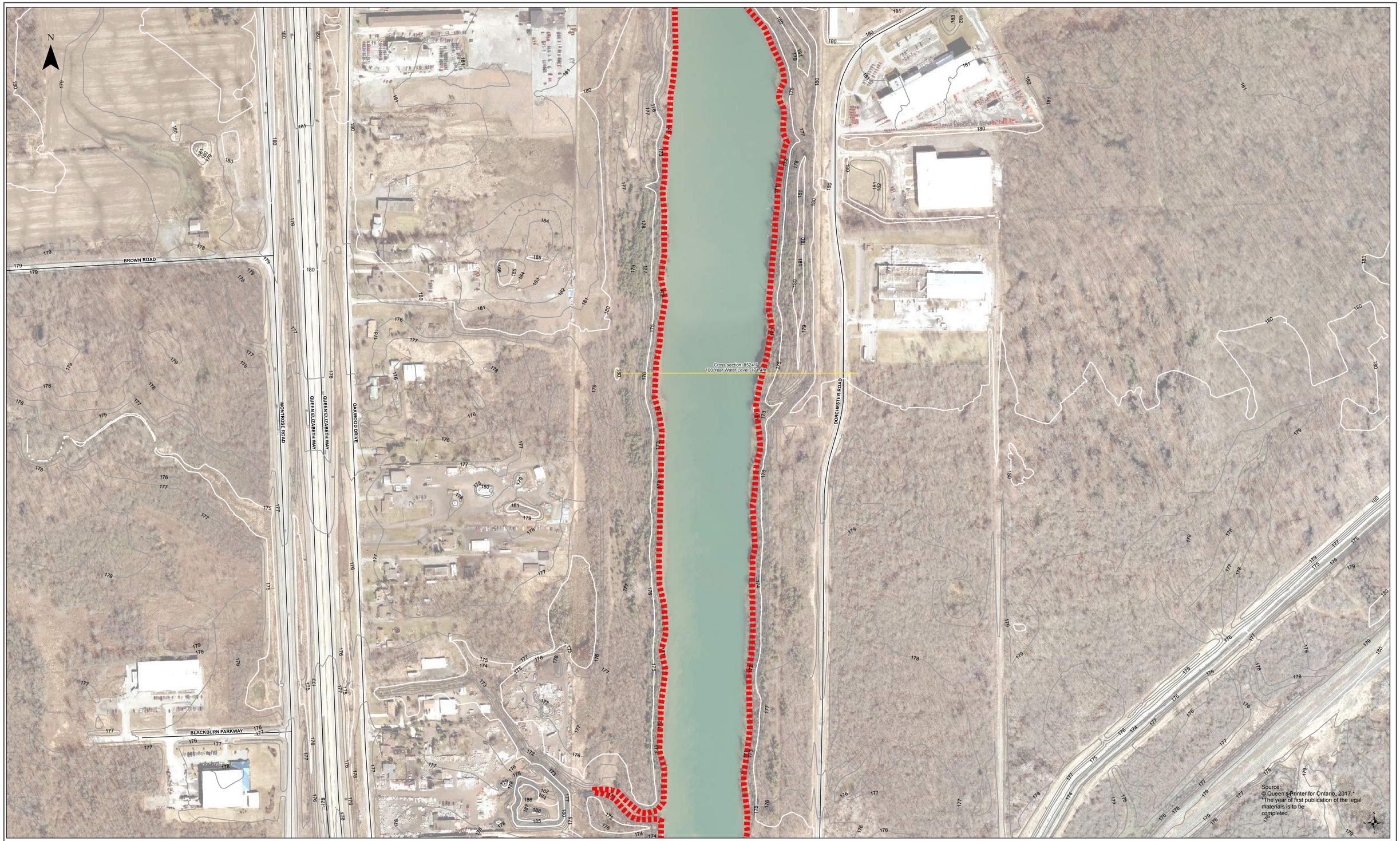
Figure A49
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

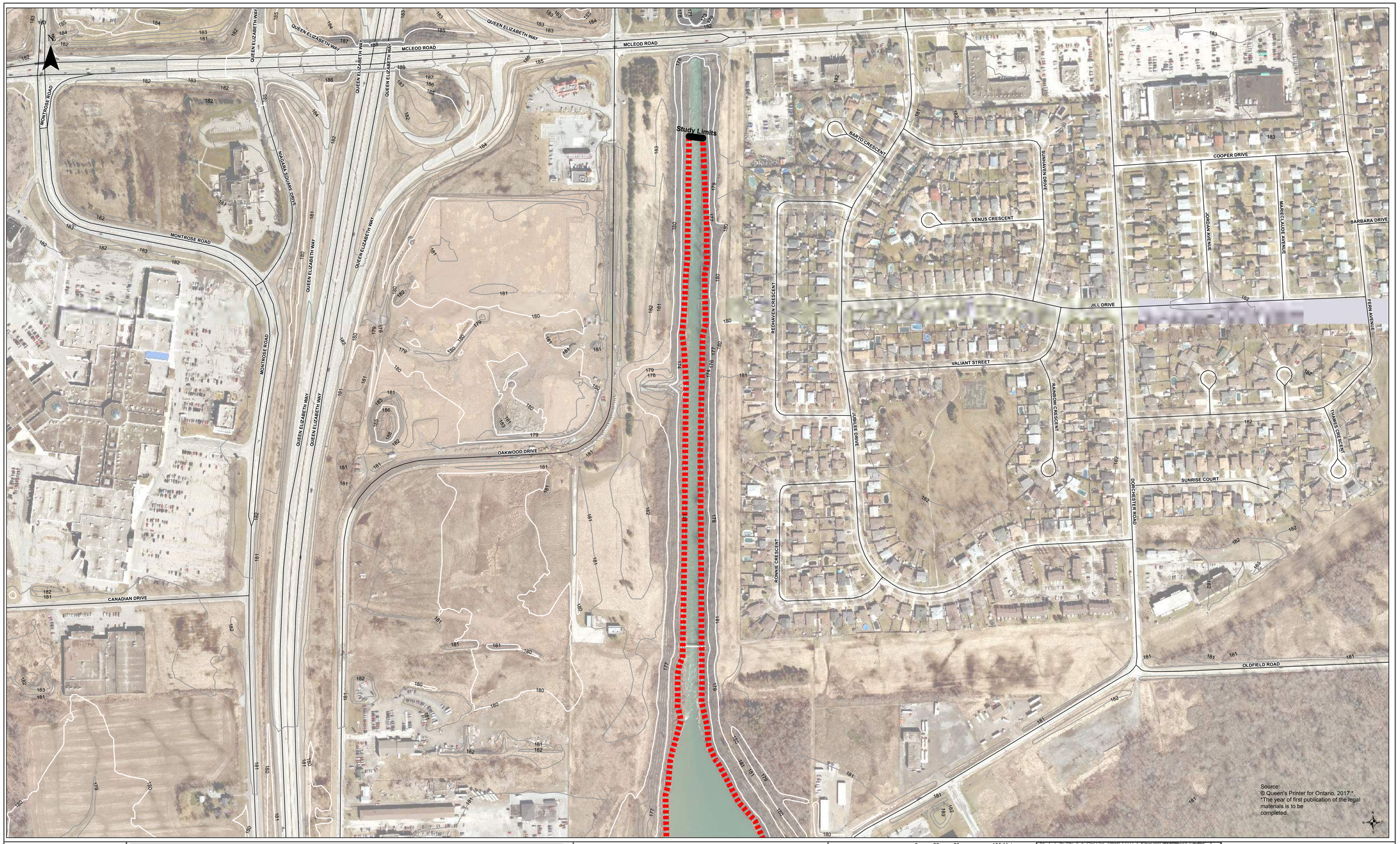
Figure A50
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A51
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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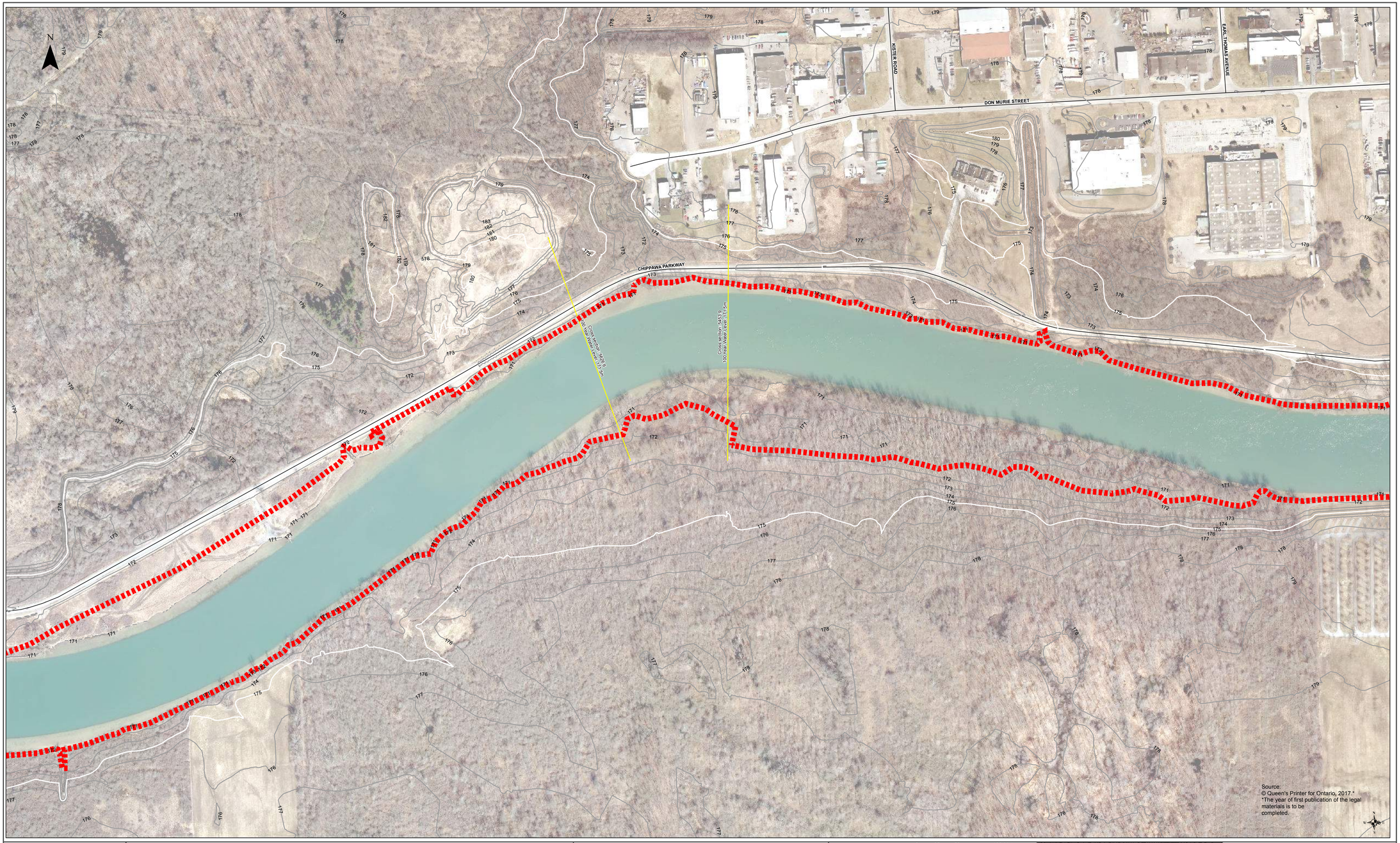

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- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A52
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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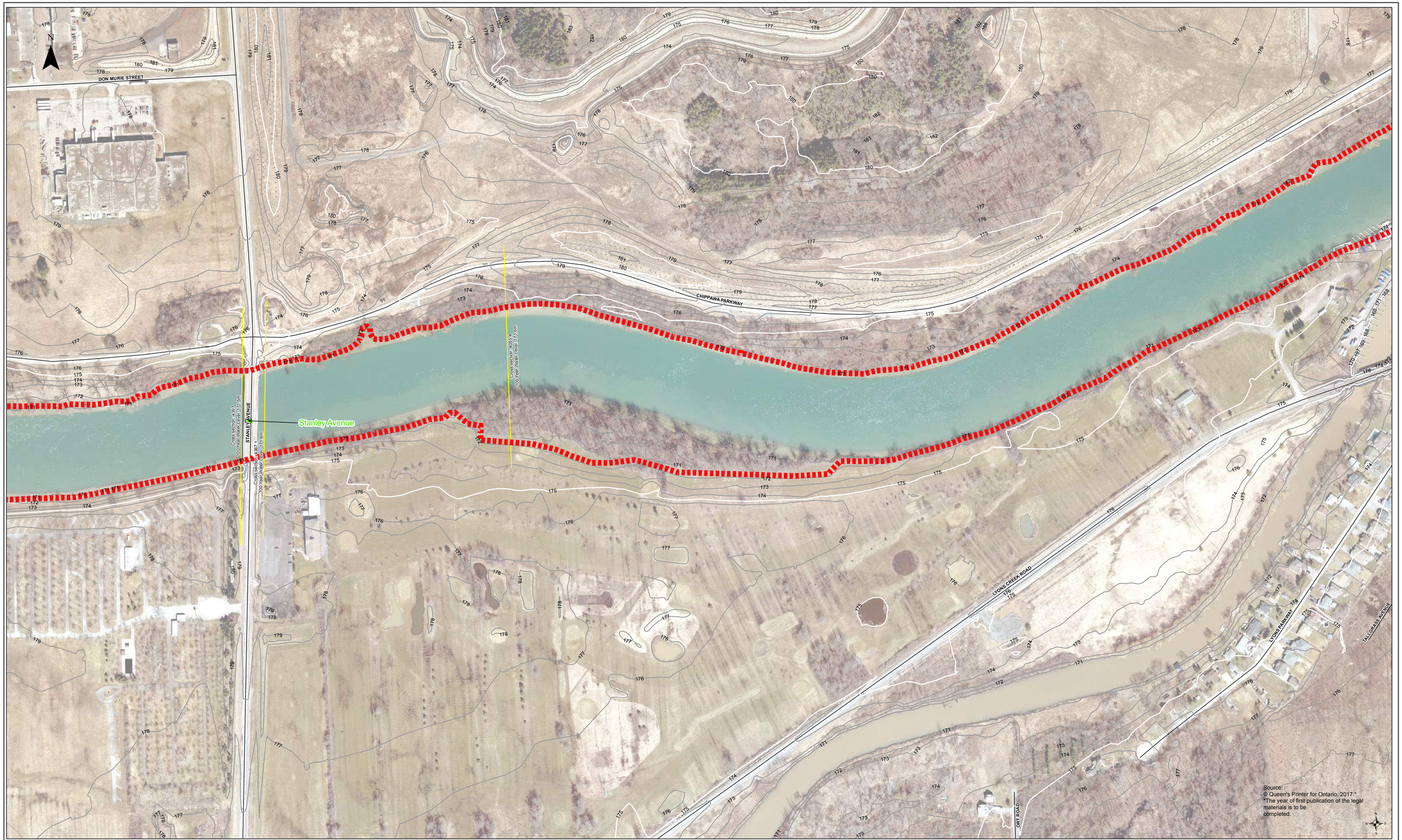

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Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

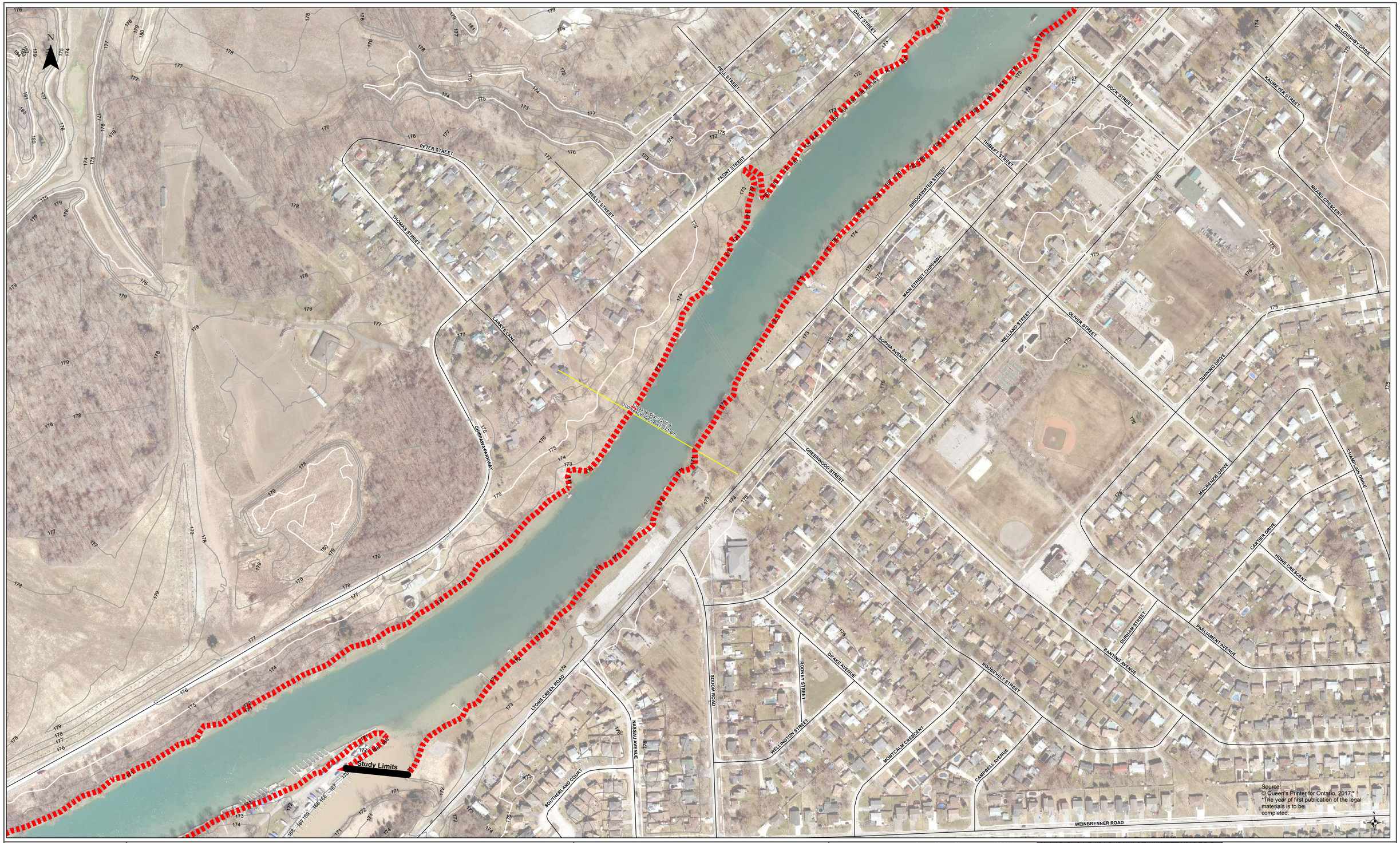
Figure A53
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
Contour - NPCA 2010 1 Meter Contour
Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

NIAGARA PENINSULA CONSERVATION AUTHORITY



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Legend

- Floodline
- Mike 11 Cross-sections
- Contour - 5m interval
- Contour - 1m interval
- Road
- Study Limits
- Structures

Figure A54
Welland River Watershed
Floodline Mapping

Scale:1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
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Support Digital Terrain Model in 3km tiles drawing
Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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Legend

- Floodline
- Contour - 5m interval
- Road
- Structures
- Mike 11 Cross-sections
- Contour - 1m interval
- Study Limits

Figure A55
Welland River Watershed
Floodline Mapping

Scale: 1:2,000 (0 25 50 100 Meters)

Date: October 2018 Project No: 3815516

Sources:
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Aerial Photo - NPCA 2010 Ortho 20km Mosaics

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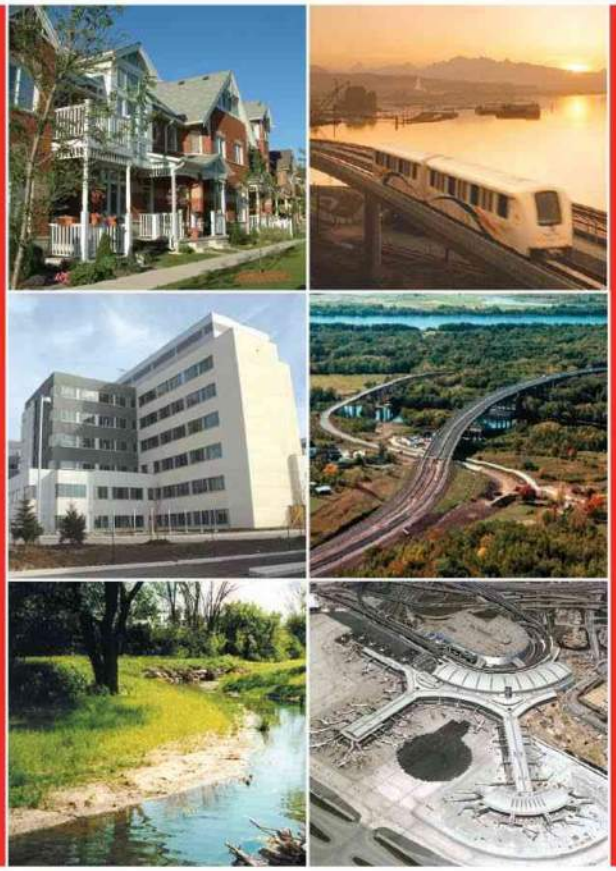
APPENDIX

F

Hydrology Report

MMM Group Limited



Phase I Hydrology Report

Welland River Regulatory Flood Plain Mapping

Niagara Peninsula Conservation Authority

38-15516

May 2017

MMM GROUP

MMM Group Limited
100 Commerce Valley Drive West
Thornhill, ON Canada L3T 0A1
t: 905.882.1100 | f: 905.882.0055

www.mmm.ca

May 3, 2017

MMM Project Number: 38-15516

Steve Miller, P.Eng.
Manager, Water Resources & Restoration
Niagara Peninsula Conservation Authority
250 Thorold Road West, 3rd Floor
Welland, Ontario L3C 3W2

Dear Mr. Miller,

Subject: Final Phase I Hydrology Report – Welland River Regulatory Flood Plain Mapping

We are pleased to submit the final Phase I Hydrology Report to support the study of Regulatory floodplain mapping updates for the Welland River. The final report has been prepared in accordance with the tasks identified in the Terms of Reference (TOR), and has been revised to address all comments received during the project meeting on March 6, 2017 and from your email sent on April 28, 2017.

The report describes the methodology and presents the results of the hydrologic model development, calibration and validation for the subject watershed. A 100-year rainfall/snowmelt event was established based on an actual storm event occurred on February 2009. A hydrological simulation of the developed 100-year flow event (Regulatory event) was performed to provide corresponding hydrological input (i.e., hydrographs) to the hydraulic model for the purposes of updating the Regulatory floodplain for the Welland River (next Phase of the study).

We would like to express our gratitude to Mr. Rob Bishop, president of RBWater Inc., for his involvement as a Senior Project Advisor on Hydrology for this exciting project. We also wish to thank the NPCA staff for their invaluable assistance in acquiring the necessary background information required to complete the study.

We trust that our submission is complete and meets all your requirements.

Yours very truly,

MMM GROUP LIMITED

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

LICENSED PROFESSIONAL ENGINEER
A. Z. ZHUGE
100133894
MAY 3, 2017
PROVINCE OF ONTARIO

COMMUNITIES
TRANSPORTATION
BUILDINGS
INFRASTRUCTURE

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1.0 INTRODUCTION

1.1 Background

The purpose of the study is to establish updated Regulatory floodplain mapping for the Welland River from the Binbrook Dam in Hamilton to the Niagara River in Niagara Falls. The 100-year flood profile is used by the Niagara Peninsula Conservation Authority to regulate development within the floodplain, as mandated by the Conservation Authority's Act. The study was completed through detailed hydrological modelling followed by dynamic hydraulic modelling and related analyses of flood hazards.

The Phase I Hydrology Report describes the methodology and presents the results of the hydrologic model development, calibration and validation for the subject watershed. A hydrological simulation of the 100-year flow event was developed to provide corresponding hydrological input (i.e., hydrographs) to the hydraulic model for the purposes of updating the Regulatory floodplain for the Welland River.

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

1.2 Description of the Study Area

The Welland River is approximately 135 kilometres in length, and drains a watershed area of approximately 990 square kilometres in size. As illustrated in **Figure 1.1**, the river flows in an easterly direction from its headwaters in Ancaster to its historical physical outlet at the Niagara River. The lower section of the river, from Port Davidson in the Township of West Lincoln downstream, has a almost no gradient (only 4 m drop over 80 kilometres) and is prone to flooding. Many hydraulic structures (dams, bridges, weirs, and two siphons that carry the river under the Welland Shipping Canal) have been built on this river and the hydraulics of flow (e.g. backwater effects and flooding) are further complicated due to operations of the power generating stations on the Niagara River.

1.3 Relevant Previous Studies

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

- Welland River Study (Canada/Ontario Flood Damage Reduction Program), Dillon, 1985.
- Watershed Flood Damage Assessment Study (Canada/Ontario Flood Damage Reduction Program), Cuming Cockburn Ltd., 1988.

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Figure 1.1
Welland River Watershed Map

0 2 4 6 8 10
kilometres
1:130,000

Date: May 2017

Project No: 3815516

- Watershed Hydrology Study, Marshall Macklin Monaghan 1989.
- Binbrook Dam, Dam Safety Review Report, Klohn Cripen, 2003.
- Binbrook Dam, Probable Maximum Flood – Dam Break Analysis and Inundation Mapping, Klohn Cripen, 2004.
- Welland River Water Level Fluctuation Study, Philips Engineering Limited, 2004.
- Central Welland River Floodplain Mapping Study, Aquafor Beech Limited, June 2012
- Floodline Mapping Study of the Main Branch of the Welland River Watershed: Hydrologic Characterization, John Perdikaris, May 2012
- Binbrook Dam Operations and Maintenance Manual, NPCA, 2013

2.0 DEVELOPMENT OF HYDROLOGICAL MODEL

2.1 Fundamentals of Hydrological Modelling for Welland River

The ultimate purpose of the hydrological model for the subject Welland River was to determine 100-Year flows along watercourses at a variety of flow points of interest (i.e., road crossing/culverts, confluence of tributary with main branch, hydraulic structures, locations where flows are dramatically changed from upstream, etc.).

Historical records confirm that only 3 out of 57 maximum annual peak flows at the EC-WSC[1] streamflow gauge on the Welland River below Caistor Corners (ID 02HA007) occurred between May and October. This is the period of the year when the direct rainfall-runoff responses could be represented by a hydrological model using design storms rainfalls as its input. The majority of the maximum annual peak flows were recorded during winter and spring seasons, when snow melt contributes extensive amounts of the runoff from catchments to the receiving watercourse. Typically, a deterministic hydrological model would be developed for the watershed to simulate the runoff responses along the water courses in accordance with the defined 100-year design storm events. However, due to these typical characteristics of a rural watershed in Ontario, the corresponding flows from a hydrological model generated by simulating the 100-year design storm are not necessarily the peak flow rates for a 1 in 100 year return period.

The 100-Year peak runoff rate can be statistically calculated by frequency analysis based on 57 years of continuous flow data collected at the EC-WSC streamflow gauge on the Welland River below Caistor Corners (ID 02HA007 from 1958-2014). In order to correctly determine the corresponding 100-year flows along Welland River at all other flow points, it was essential to develop a proper hydrological model for the entire Welland River watershed. Model calibration and validation was performed to ensure that reliable results would be produced by the established hydrological model for the subject watershed.

A detailed discussion on the analysis of recorded historical data including the results from the frequency analysis is included in **Section 3.2**. The following sections describe the methodology used to complete different aspects of the model development.

2.2 Model Selection

Visual OTTHYMO 4.0 (VO4) was selected to model the hydrology of the Welland River. OTTHYMO89 (an older version of VOH) was previously developed for the entire watershed in 1989. The VO4 is the latest update to the Visual OTTHYMO (VOH) model which has well established rural and urban catchment

[1] EC-WSC means Environment Canada-Water Survey of Canada

routines to simulate both rural and urban hydrology. VO4 has Geographic Information System (GIS) capabilities that allow the use of mapping data to manage model data.

The VOH model has been widely used for Watershed Studies, Sub-watershed Studies, Master Drainage Plans, Functional Stormwater Management Plans, Site Plans, and Stormwater Management Pond Design in Southern Ontario. The model has also been accepted as a valid hydrologic simulation model by most municipal governments, the Association of Conservation Authorities of Ontario, the Ministry of Municipal Affairs, the Ministry of Natural Resources, the Ministry of the Environment and Climate Change, and the Ministry of Transportation.

VO4 applies the following techniques (commands) to simulate the rainfall-runoff responses:

- **NASHYD** - *the Nash unit hydrograph* was applied to simulate runoff response from those land use areas designated as agricultural, rural, open space or parkland;
- **STANDHYD** - *the Standard unit hydrograph* was applied to simulate 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 RESERVOIR** - was used to route hydrographs through Stormwater Management facilities and any other significant ponds, lakes, etc.; and
- **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 most up-to-date topographic information. The detailed discretization takes into account several key factors including flow nodes, road crossings/culverts, streamflow gauges, and hydraulic structures, etc.

For flood plain mapping purposes, the catchments for the hydrological model of the Welland River watershed were discretized on a sub-watershed basis. The size of the catchments generally falls between approximately 2 km^2 and 106 km^2, with an average area of approximately 27 km^2. **Table 2.1** includes the description of these catchments (i.e., sub-watersheds) with their areas, lengths and slopes. A summary of the watershed discretization is presented in **Table 2.2**. The frequency histogram of the catchment areas is shown in **Figure 2.1**. The watershed delineation along with the stream network is shown on **Figure 2.2**. **Appendix A** includes the summary of the catchment areas for the watershed.

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Figure 2.2
Welland River Watershed
Catchment Boundary Map

0 1 2 3 4 5
kilometres
1:90,000

Date: May 2017

Project No: 3815516

Table 2.1 Catchment Description

Subwatershed Name	Catchment ID *	Area (km^2)	Slope (%)	Length (km)
Wilson Creek	14	6.44	0.213	5.76
Draper	36	8.86	0.911	7.34
Sucker Creek	22	11.16	0.211	8.18
Grassy Brook	32	13.15	0.102	12.79
Little Forks Creeks	24	13.48	0.066	11.79
West Wolf Creek	2	13.86	0.227	11.90
Thompson Creek	30	14.59	0.154	7.04
Wolf Creek	9	23.54	0.228	13.77
Buckhorn Creek	5	24.35	0.212	13.81
Elsie Creek	7	25.59	0.191	13.52
Moore's Creek	12	33.28	0.203	15.38
Coyle	27	40.70	0.767	11.22
Upper Forks Creek	26	65.66	0.022	16.38
Beaver Creek	20	72.75	0.124	20.27
Lyons Creek	33	80.30	0.046	18.30
Upper Oswego Creek (u/s of Oswego Gauge)	17	81.21	0.155	19.92
Lower Oswego Creek	34	103.37	0.092	31.28
Lower Forks Creek	35	105.66	0.024	17.54
Local Drainage to Main Branch	19	2.18	0.007	3.10
Local Drainage to Main Branch	8	3.69	0.262	5.62
Local Drainage to Main Branch	21	3.93	0.274	4.71
Local Drainage to Main Branch	28	5.18	0.073	5.63
Local Drainage to Main Branch	6	5.39	0.185	6.95
Local Drainage to Main Branch	4	5.85	0.199	7.76
Local Drainage to Main Branch	10	8.02	0.271	3.94
Local Drainage to Main Branch	11	9.00	0.052	9.94
Local Drainage to Main Branch	29	9.47	0.044	9.26
Local Drainage to Main Branch	15	10.53	0.136	6.40
Local Drainage to Main Branch	31	11.26	0.073	7.16
Local Drainage to Main Branch	18	11.61	0.077	10.98
Local Drainage to Main Branch	25	13.78	0.086	9.21
Local Drainage to Main Branch	13	17.21	0.174	11.33
Local Drainage to Main Branch	23	19.58	0.133	8.52
Local Drainage to Main Branch	16	22.89	0.058	11.65
Local Drainage to Main Branch	37	25.21	0.005	8.03
Local Drainage to Main Branch	3	26.87	0.271	13.23
Local Drainage to Main Branch	1	43.11	0.179	25.99

* Note that "Catchment ID" presents the numbers used in the GIS database to describe each catchments. Different ID numbers are assigned to be used in the VO4 model

Table 2.2 Watershed Discretization Summary

Watershed	Drainage Area (km^2)	No. of Catchments	Minimum Catchment Size (km^2)	Maximum Catchment Size (km^2)	Average Catchment Size (km^2)
Welland River	993	37	2.2	105.7	26.8

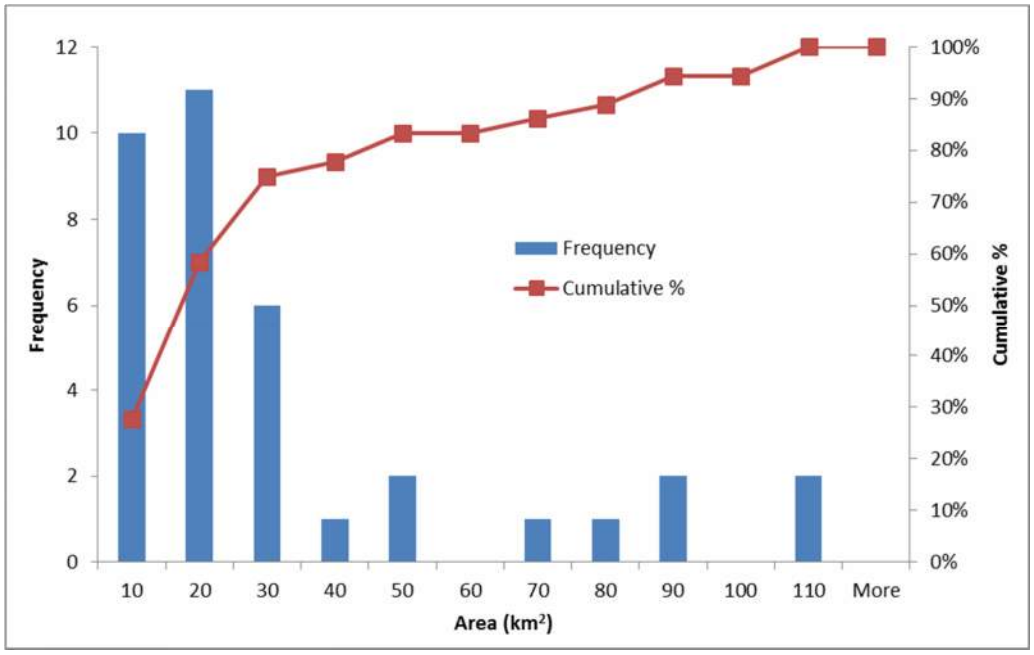

Figure 2.1 Frequency Histogram of the Catchments for Welland River Hydrological Model

2.4 Catchment Parameters

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 typically 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. It should be noted that in the methodology used in this study, antecedent moisture conditions were determined for actual events from the actual conditions prior to the events. The AMC II values were derived for each sub-catchment from the land use and soils distribution to give an initial standard spatial distribution of runoff characteristics across the study area.

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.

2.4.1 Land Use

Land use plays a significant role in the hydrologic response of a watershed. For the subject floodplain mapping study, the analysis is based on the existing land uses. A map including existing land uses for the study area was developed and provided by NPCA 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 study watershed are shown in **Figure 2.3**.

2.4.2 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, including "Water", were placed in Group D to reflect their often saturated state. An overall soils map showing the hydrologic soil groups for soil types in the study area is included in **Figure 2.4**. **Table 2.3** presents a list of the soil series with their assigned HSGs for the study area.

2.4.3 Runoff Curve Numbers (CNs)

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 2.5**). The curve numbers used in the lookup table are for AMC II conditions, and were taken from standard published values. 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.

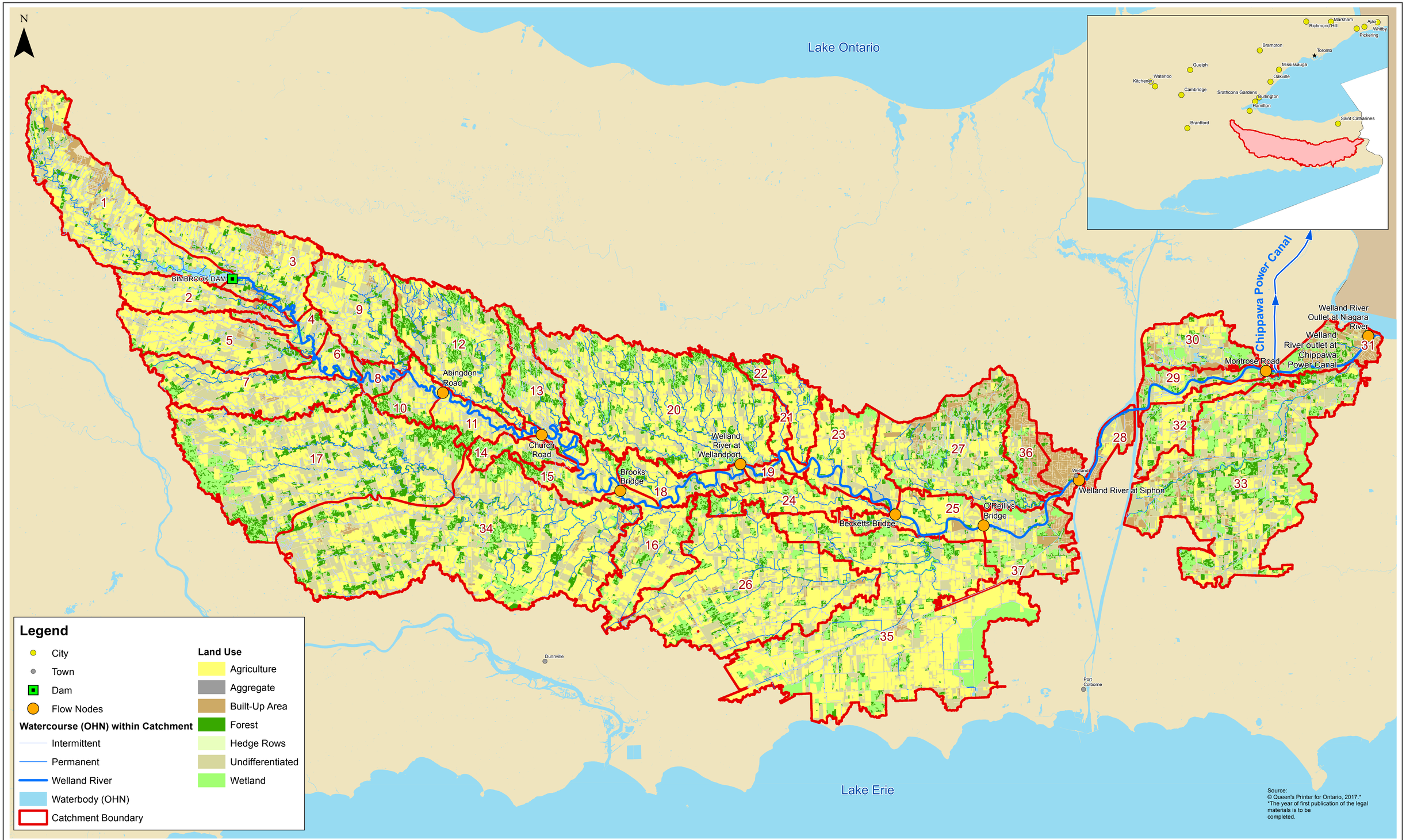

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Figure 2.3
Welland River Watershed
Existing Land Use Map

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kilometres
1:90,000

Date: May 2017

Project No: 3815516

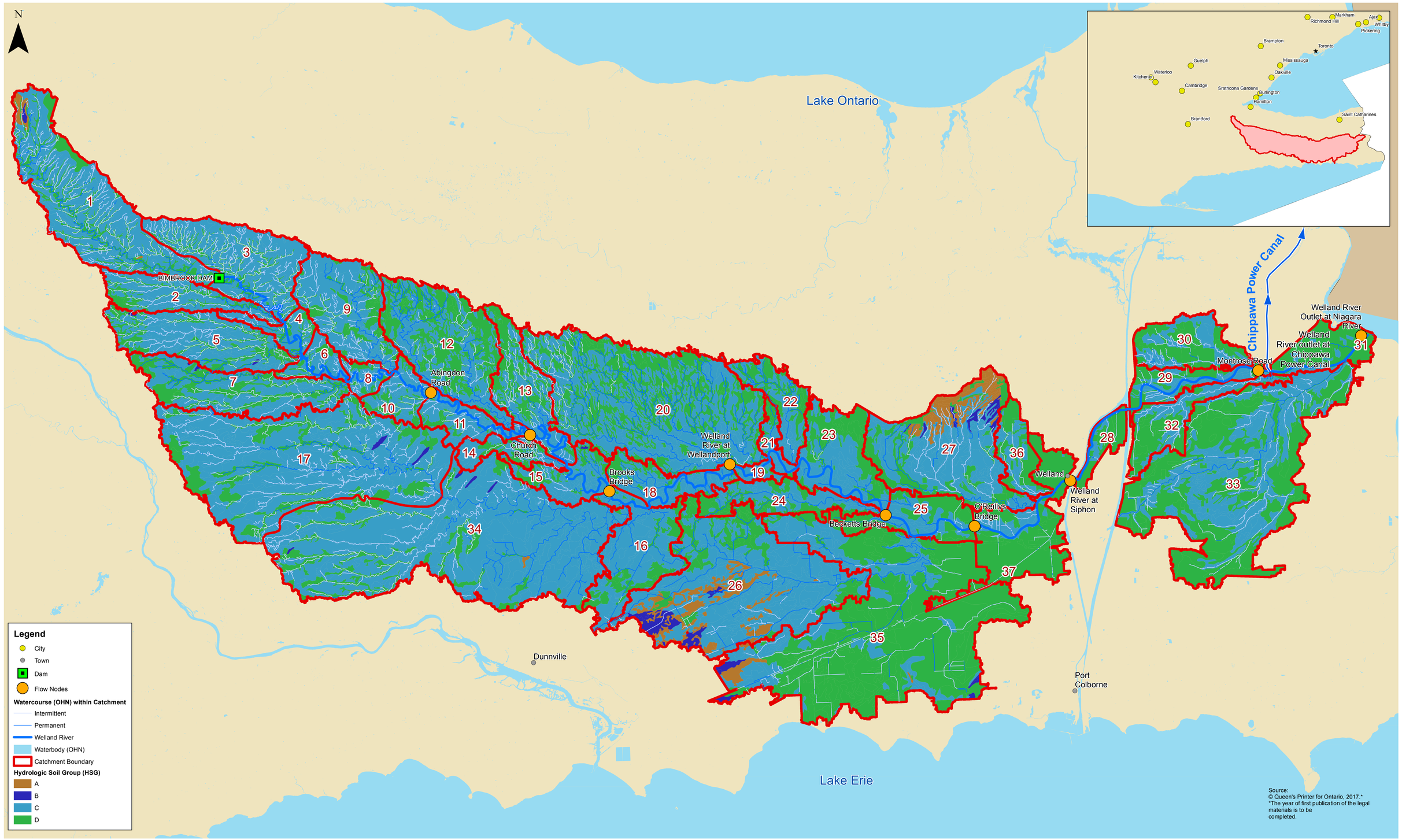

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Figure 2.4
Welland River Watershed
Soils Map

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kilometres
1:90,000

Date: May 2017

Project No: 3815516

Table 2.4 Summary of Soil Information

Soil Series	Hydrologic Soil Groups (HSG)	Soil Series	Hydrologic Soil Groups (HSG)
ALBERTON SILTY CLAY LOAM	D	MARSH	D
ALLUVIUM	C	MUCK	D
BERRIEN	C	NIAGARA	C
BEVERLY	C	ONEIDA	C
BINBROOK SILT LOAM	C	ONTARIO	C
BRADY	B	ORGANICS	D
BRANT	B	ORGANICS - QUARRY	D
BRANTFORD	C	PEEL	C
BROOKE	C	PLAINFIELD	A
CASHEL - HEAVY RED PHASE	C	SENECA	B
CHINGUACOUSY	C	SILVER HILL	B
COLWOOD	C	SMITHVILLE	C
FARMINGTON	B	SPRINGVALE SANDY LOAM	A
FLAMBOROUGH	C	TAVISTOCK	C
FONTHILL	A	TOLEDO	D
FOX	A	TUSCOLA	C
FRANKTOWN	B	URBAN LAND	C
GRAVEL PIT	C	VINELAND	B
GRIMSBY	A	VITTORIA	C
HALDIMAND	C	WALSINGHAM	A
JEDDO - LOAMY RED PHASE	D	WATER	D
LINCOLN	D	WATERIN	C
LOWBANKS	B	WAUSEON	C
MALTON - HEAVY RED PHASE	D	WELLAND	D
MAPLEWOOD	C		

Table 2.5 Curve Number Lookup Table

Land Cover	A	B	C	D
Forest	36	60	73	79
Marsh	36	60	73	79
Swamp / Open Water / Bog	36	60	73	79
Mono	36	60	73	79
Shoreline	36	60	73	79
Built Up Pervious	49	69	79	84
Idle Land	49	69	79	84
Orchards	49	69	79	84
Vineyards	49	69	79	84
Hedge Rows / Plantations	61	73	81	84
Crop / Agriculture / Rural	65	75	82	86
Extraction	77	86	91	94
Built Up Impervious	98	98	98	98
Transportation	98	98	98	98

The weighted average curve numbers were used to determine the initial abstraction (*Ia*) for each catchment. The initial abstraction is that part of the rainfall/snowmelt that is intercepted by vegetation or surface depressions prior to the initiation of runoff. Numerous studies have found that the original SCS empirical equation, *Ia* = 0.2 *S*, (where *S* is the potential maximum retention of the soil defined as *S* = 25400/*CN* – 254) overestimates the abstractions, especially for lower values of curve numbers (e.g., Ponce, 1989). Therefore, the guidelines provided in the Visual OTTHYMO Model Hydraulic Reference for computing *Ia* were used for this study.

The guidelines are as follows:

- CN ≤ 70, IA = 0.075 S
- 70 < CN ≤ 80, IA = 0.1 S
- 80 < CN ≤ 90, IA = 0.15 S
- CN > 90, IA = 0.2 S.

Other pertinent information for the model included weighted average slope and length for the catchments, which were determined from the Digital Terrain Model (DTM) and catchment geometry. Time to peak (Tp) was calculated based on the Airport Formula as per the VOH technical manual. The watershed parameters as computed were reviewed and adjusted according to the results of the calibration.

The initial watershed parameters are tabulated in **Appendix A**.

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 channel routing sections, reach lengths and reach slopes were derived directly from the DTM. 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 for the water courses. A total of 20 channel routing sections are included in the present model. The locations and overall length of the channel routing sections are provided in **Appendix B.**

Note that the routing of flows through Route Channel required special consideration, in particular along reaches having extremely flat slopes (So < 0.0004). As channel slopes lessen, assumptions made to develop many of the common channel routing algorithms will be violated. Ponce (1978) established a numerical criterion to judge the likely applicability of various routing models. For example, a full dynamic wave solution would be required for channel routing, if the following criterion is not satisfied for channels with slopes (So) < 0.0004:

$$TS_o\left(\frac{g}{d_o}\right)^{1/2} \geq 30$$

Where T is the duration of the hydrograph, and d_o is a reference flow depth. There are a number of "flat" reaches within the study area that do not satisfy the above equation and would require a dynamic wave solution for channel routing. Consequently, a full dynamic hydraulic modelling was performed to determine the flood elevations along the Welland River. The resulting hydrographs of each sub-watersheds (catchments) from the hydrological model simulation were used as input to the hydraulic model.

However in order to complete the hydrological computation for the subject watershed, channel routings still needed to be included in the hydrological model. Therefore, the best use was made of the available methods in the hydrologic models to minimize any errors in routing.

Two methods are available for flood routing in VOH. The routing commands available in the VO4 Model are the Variable Storage Coefficient (VSC) and the Muskingum-Cunge (MC). The Muskingum-Cunge (MC) algorithm uses a simplification of the kinematic-wave model, which is appropriate only if the channel slope exceeds 0.002 (0.2 %) (USACE, 2000). Furthermore, the Muskingum-Cunge (MC) algorithm in VO4 was found to be unstable and quite unpredictable according to initial trial runs performed for the present study. Therefore, the Variable Storage Coefficient (VSC) method was adopted for all the 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, the method may not be suited for routing flows through long reaches. The FRS Study found that the VSC method resulted in over-attenuated peak flows on long "flat" reaches.

Again, as indicated previously, a full dynamic hydraulic modelling will be used to determine the flood elevations along the Welland River. The resulting hydrographs from each sub-watershed (catchment) will provide inputs to the hydraulic model. Consequently, the simulation errors due to the limitations of the hydrologic channel routing included in the hydrological model will be eliminated in the subsequent phase. In addition, the model calibration focused on catchment parameters (e.g., Time to Peak value and number of linear reservoirs used in NASHYD, etc.). Those parameters for channel routing (e.g., Manning's N) were not included in the hydrological model calibration process.

2.6 Reservoir Routing

Binbrook Dam is the only storage facility included in the hydrological model for the Welland River watershed. The Binbrook Dam is located on the headwaters of the Welland River in the City of Hamilton. The 1,150 m long and 11.3 m high earthen dyke was constructed in 1971 by NPCA. The Binbrook Dam creates an artificial lake (Lake Niapenco) which covers approximately 174 ha and stretches 5.4 km in

length. The primary outlet of the storage is a 2.4m diameter concrete “morning glory” spillway. The emergency overflow goes through a 107 m wide grass-lined spillway.

The storage-discharge relationship for Binbrook Dam was established based on data included in the “ Binbrook Dam Operations and Maintenance Manual” prepared by NPCA dated December 2013. The discharges from the storage include the outflows from both the morning glory spillway and the emergency spillway, together with flows from two valves (i.e., 30-inch and 16-inch). Detailed information regarding the Binbrook Dam storage routing is included in **Appendix C**.

2.7 Welland River Flow Reversal

A century ago, the Niagara River provided a natural outlet for the very mild sloping Welland River. In the early 1920’s, the Welland River flow reversal was accomplished by dredging the last 6 km of the Welland River. The water has then been diverted from Niagara River to the Chippawa Power Canal as the new outlet of the Welland River. Numbers of studies and reports were prepared by NPCA and OPG to monitor the water levels and quantify flows to the Power Canal, in order to understand and study the effects of hydro operations. Therefore, for the purpose of hydrological modelling, the outlet of the Welland River was set to be at the confluence of Chippawa Power Canal (approximately 6 km west of the Welland River and downstream of Montrose Gauge). Inclusion of the flows from Niagara River to the Power Canal is beyond the scope of the current hydrological study for the Welland River. The boundary conditions (i.e., water elevations under various conditions) at upstream end of flow reversal at Niagara River and downstream end at Chippawa Power Canal will be established in the dynamic hydraulic model, which will be used to determine the flood elevations along the study water courses.

2.8 Summary of Model Setup

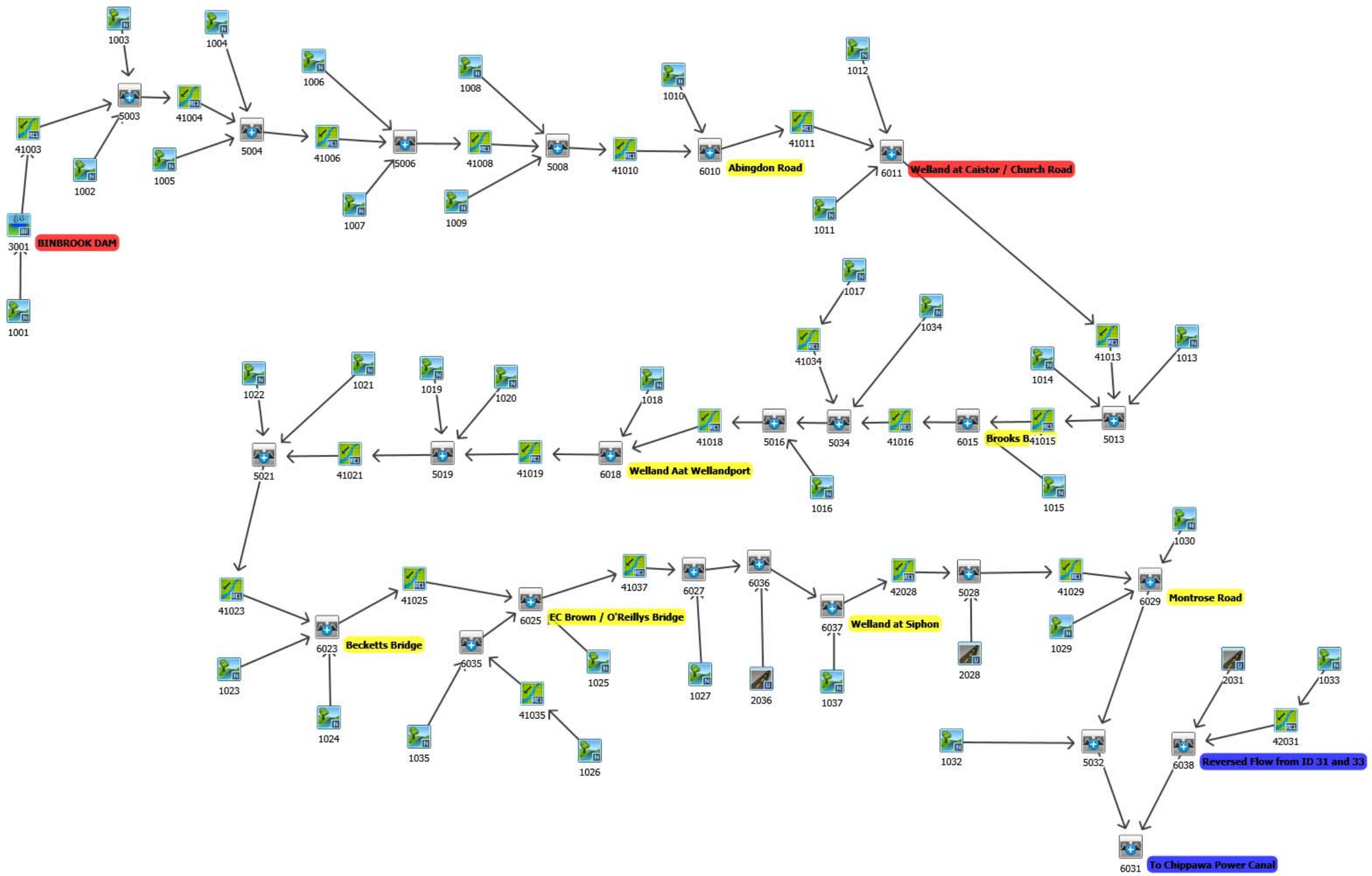
In summary, the base VO4 model for the Welland River watershed was setup using a total of 37 catchments. **Table 2.6** provides a summary of the commands included in the resulting model. The schematic of the developed VO4 hydrological model is shown in **Figure 2.5**.

Table 2.6 Summary of Model Commands

Command Elements	Number	Description
NASHYD	34	To simulate runoff from natural and open space areas.
STANDHYD	3	To simulate runoff from urban areas
ROUTE CHANNEL	20	To route hydrographs using the variable storage coefficient (VSC) method through open channel
ROUTE RESERVOIR	1	To simulate the flows from Binbrook Dam
ADDHYD	23	To add two hydrographs.

Figure 2.5 VO4.0 Schematic – Welland River Hydrology

River Outlet at Chippawa Power Canal



3.0 HYDROLOGICAL MODEL CALIBRATION AND VALIDATION

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 the 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, a 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 Analysis of Streamflow and Precipitation Data

3.2.1 Available Streamflow and Precipitation Data

The calibration and validation process requires concurrent streamflow and rainfall data. There are a total of 11 precipitation gauges located within the vicinity of the study watershed, 5 streamflow gauges located on the main branch of the Welland River, and 2 streamflow gauges on tributaries of the Welland River (i.e., Big Forks Creek and Oswego Creek). **Figure 3.1** shows the locations of these gauges. **Table 3.1** summarizes the details of the streamflow gauges and precipitation gauges associated with the study watershed.

Table 3.1 Available Data Gauges

Gauge	Name	Available Data From	Available Data To	Available Data Period (Years)	Time Step	Data Provided by
Precipitation	WELLAND RIVER AT WELLANDPORT	5/6/2010	12/3/2015	5 Years	15 Min	NPCA
	WELLAND RIVER AT CAISTORS	1/19/2012	12/3/2015	4 Years	15 Min	NPCA
	OSWEGO CREEK	6/23/2009	12/3/2015	7 Years	Hourly	NPCA
	WELLAND RIVER AT BINBROOK	7/7/2009	12/3/2015	7 Years	15 Min	NPCA
	BIG FORKS CREEK	1/5/2012	11/5/2015	4 Years	15 Min	NPCA
	NIAGARA FALLS	1/25/2012	12/3/2015	4 Years	5 Min	NPCA
	WELLANDWWTP	3/15/2011	10/31/2015	5 Years	5 Min	NPCA
	RUIGROK	1/1/2012	12/3/2015	4 Years	15 Min	NPCA
	EC BROWN	5/28/2012	12/3/2015	4 Years	15 Min	NPCA
	EC HAMILTON AIRPORT (ID 6153194)	1959	2015	57 Years	Hourly	EC*
	EC WELLAND (ID 6139445)	1872	2015	144 Years	Hourly to Daily	EC*
Streamflow	BIG FORKS	11/3/2011	12/7/2015	5 Years	15 Min	NPCA
	WELLAND RIVER AT EC BROWN	9/4/2014	11/26/2015	2 Years	15 Min	NPCA
	WELLAND RIVER AT WELLANDPORT	3/3/2010	12/6/2015	6 Years	15 Min	NPCA
	OSWEGO	10/13/2009	9/11/2015	7 Years	Hourly, 15 Min	NPCA
	WELLAND RIVER AT SOUTHBROOK	7/14/2009	10/23/2015	7 Years	Hourly, 15 Min	NPCA
	WELLAND RIVER AT BINBROOK	7/7/2009	12/4/2015	7 Years	15 Min	NPCA
	EC WELLAND RIVER BELOW CAISTOR CORNERS (ID 02HA007)	1958	2014	57 Years	Hourly	EC - WSC

* Available Data from EC's Weather Station includes Precipitation, Temperature and Snow Depth on Ground.

As previously indicated in **Section 2.1**, due to the mainly rural characteristics of the watershed, typical "design storms" when used in computational hydrological simulations do not necessarily produce peak flows with the corresponding flow return periods for the Welland River. In order to correctly predict flows along all flow point locations on the Welland River, the hydrological models were developed and calibrated based on a number of selected historical annual extreme flows recorded at a long term reliable streamflow gauges. These selected flow events must be able to provide equivalent statistical results with those based on the entire available historical data. Consequently, data from the Environmental Canada WSC's gauge at Welland River below Caistor Corners (ID 02HA007) was used for the modelling purposes. This gauge

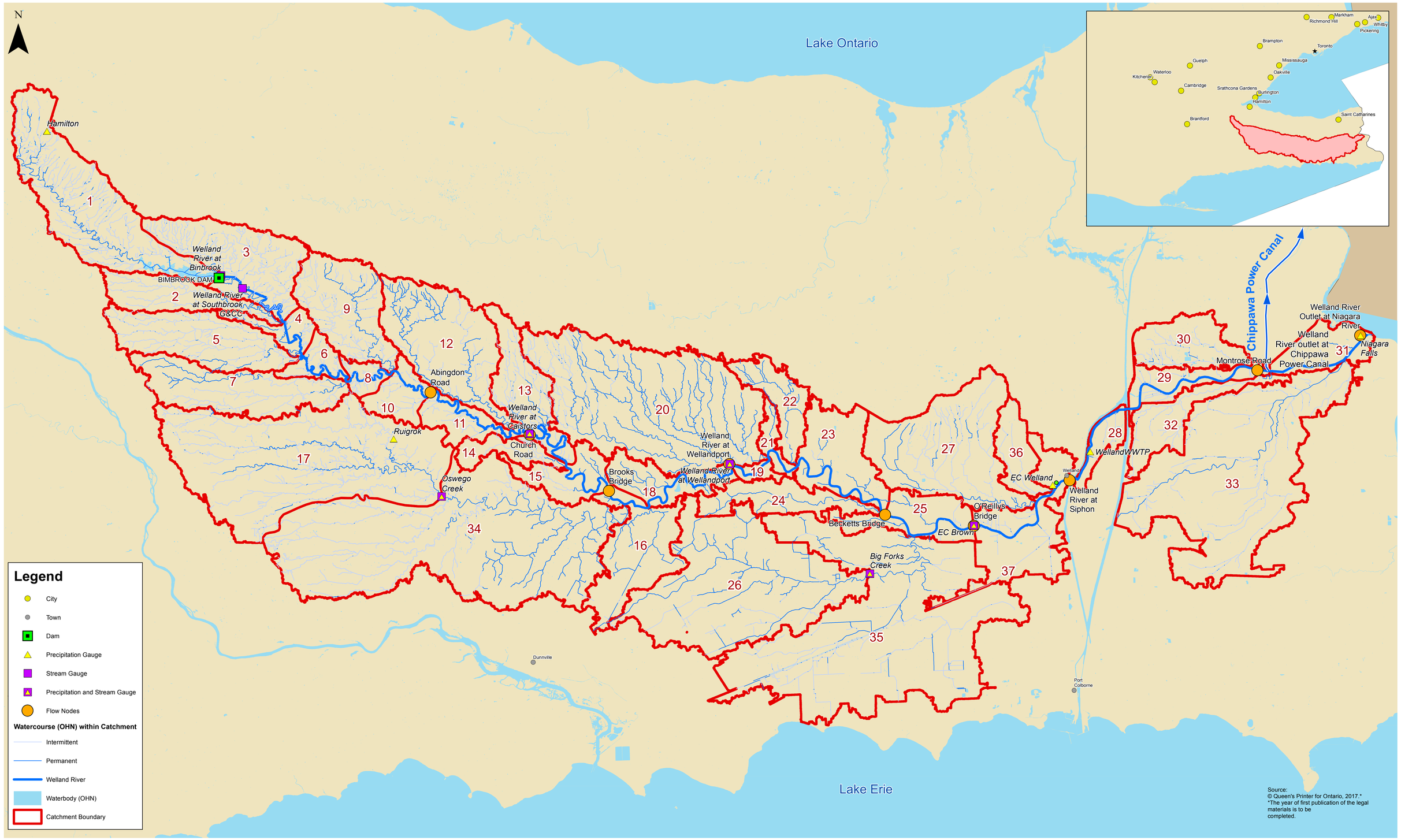


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Figure 3.1
Welland River Watershed
Precipitation and Streamflow Gauges Map

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kilometres
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Date: May 2017

Project No: 3815516

has 57 years of records and is located upstream in the watershed to avoid any backwater effects from the Niagara River. The following **Section 3.2.2** describes the selection of the annual extreme flow events in detail.

In general, the spatial distribution of the rainfall over a large scaled watershed is often highly non-uniform. Significant spatial variation of the rainfall may be observed at different rain gauge locations. However, considering the location of streamflow gauge on the Welland River below Caistor Corners, Environmental Canada's precipitation gauge at Hamilton Airport (ID 6153194) was selected for use in the study. This weather station was established and operated by Environmental Canada. It has 57 years of continuous hourly records for precipitation and measured snow depth on the ground, and provides corresponding rainfall events for the selected annual extreme flow events for the streamflow gauge at Welland River below Caistor Corners.

Note that beside the selected streamflow and precipitation gauges, data from some other available gauges (listed in **Table 3.1**) was also used for the purpose of additional model validation, which will be discussed in detail in **Section 4.5**.

3.2.2 Selection of Rainfall-Runoff Events for Model Calibration

Environment Canada WSC's streamflow gauge on the Welland River below Caistor Corners (ID 02HA007) has recorded annual extreme daily flows for a period of 57 years from 1958 to 2014 and instantaneous peak flows for a slightly shorter period (i.e., 40 years). This provides an excellent basis for an accurate calculation of the 1 in 100 year annual peak flow (regulatory flow) and flows of other return periods at that location. The calculation method used was single station flood frequency analysis. Hence the purpose of the model calibration was to ensure that the model could accurately reproduce the calculated regulatory flow and the remainder of the flow frequency curve. It would have been computationally arduous to model all 57 peak annual flow events and, in fact, not feasible due to lack of available short term precipitation data for all events, Hence an investigation was completed to determine if a selected subset of the data could be used to calculate the observed frequency curve sufficiently accurately. It was found that a subset of 15 events selected from the range of observed peak annual flows would reproduce the frequency curve based on all 57 flows if the selected events were assigned a return period/"plotting position" based equal to that which they had in the complete set.

Using this approach, 15 annual extreme daily flow events were identified as listed in **Table 3.2**. **Figure 3.2** shows a comparison of regression equations of Annual Extreme Daily Flow (Qt) vs Kt based on EV1 Kfactors and Empirical plotting positions). As shown in **Figure 3.2**, flow frequency analysis comparison confirms that the selected 15 annual extreme daily flows result equivalent regression curve with it based on a total 57 annual extreme daily flows. Details of the frequency analysis are included in **Appendix D**. The results shown in Figure 3.2 were based on the use of frequency factors for the EV1 distribution (Chow, 1960) to allow the analysis to be completed with the assigned empirical return periods. This cannot be achieved with a standard flood frequency analysis program as return periods would be automatically assigned based on the events rank in a series of only 15 points.

Table 3.2 Selected Annual Extreme Daily Flows

Year	Month (MM) – Day (DD)	Annual Maximum Daily Flow – AMDF (m3/s)	Rank	Empirical T[2]	EV1 Kfactor
2008	12--28	82.5	1	29.00	2.16
2009	02--12	81.3	2	19.33	1.84
1990	12--30	73.7	3	11.60	1.43
2007	03--15	73.2	4	8.29	1.15
2001	02--11	72.9	5	7.25	1.04
2006	12--02	64.9	6	6.44	0.94
1976	03--06	61.7	7	5.27	0.77
2013	01--14	57.7	8	4.83	0.69
2012	10--31	56.5	9	4.14	0.55
1995	11--12	53.1	10	3.63	0.43
1996	04--14	48.2	11	2.52	0.08
1991	03--28	46.5	12	2.15	-0.09
2014	05--16	42.6	13	1.76	-0.32
1999	11--03	35.6	14	1.38	-0.65
2002	05--14	28.8	15	1.12	-1.09

[2] As noted, the "Empirical T is the return period of the selected event based on all 57 years of data, e.g. the first event in Table 3.2 is the second highest event recorded in the 57 year period and has an empirical probability of 2 / (57 + 1) or equivalently a T = 58/2, i.e. 29. Note that the largest event could not be used due to lack of hourly precipitation data for the period when it occurred in 1962.

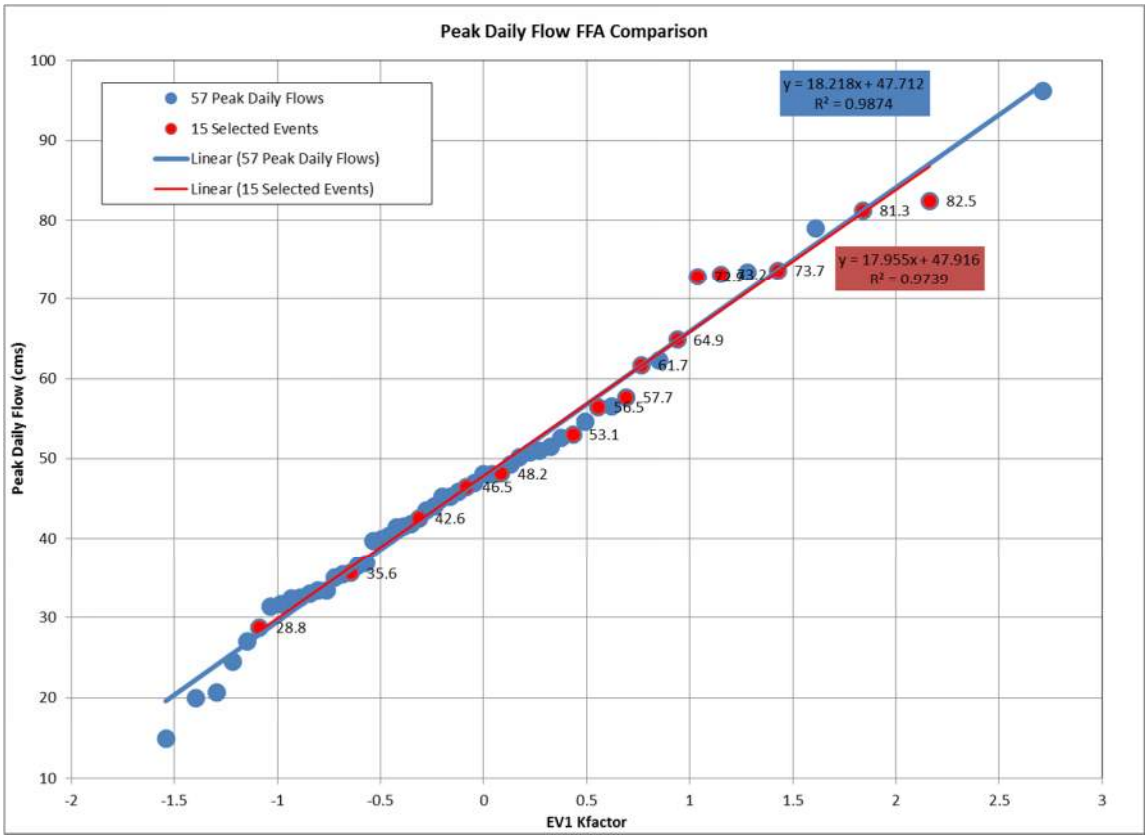

Figure 3.2 Comparison of Flow Frequency Analysis based on Annual Extreme Flows at EC Welland River below Caistor Corners

3.2.3 Inclusion of Effects of Snowmelt in Hydrological Modeling

The majority of the selected flow events occur during winter or spring seasons when snow melting provides a significant contribution to the generated runoff in the receiving water courses. Relevant snow hydrology literature and research papers have been reviewed to understand the theoretical methodology and develop an approach to estimate the equivalent water content for the snow fall depth. As a rule of thumb, the 1 mm rainfall is equivalent to 10 mm (i.e., 1 cm) snow. However, from experience, the 1 in 10 rule is not adequate as the relative density of new snow is very definitely a function of the air temperature (Schroeter, 2007). Consequently, the following formula was used to compute the equivalent water content of snow:

$$SNOWE = SNOW \cdot \alpha \cdot e^{\beta \cdot TAIR}$$

where, SNOWE is the equivalent snow water content (in mm);

SNOW is the observed snow fall depth (in mm), measured as the difference between the two consequent recorded depths of snow on ground;

TAIR is the mean daily air temperature in degrees C; and

α and β are empirical constants and equal to 0.12 and 0.08 respectively (Schroeter, 2007).

The calculated equivalent snow water contents were added to the recorded rainfall depths to compete the precipitation data for the rainfall-runoff calibration events.

3.2.4 Summary of Selected Rainfall-Runoff Events

Table 3.3 summarizes the selected 15 rainfall-runoff events for the hydrological model calibration. More detailed information is included in **Appendix E**.

Table 3.3 Summary of Selected Rainfall-Runoff Events

#	Event ID	Year	Period		Precipitation Data				Streamflow Data *		Total Runoff / Total Precipitation (%)
			From	To	Rain Depth (mm)	Equivalent Snowwater Depth (mm)	Total Precipitation Depth (mm)	Peak Preciptation Intensity (mm/hr)	Total Runoff Depth (mm)	Peak Discharge Rate (m^3/s)	
1	4	1976	3/3/76 7:00 PM	3/8/76 11:00 PM	34.8	16.6	51.4	12.7	44.0	55.1	86%
2	6	1990	12/28/90 1:00 AM	12/31/90 11:00 PM	67.9	9.7	77.6	6.8	48.7	80.8	63%
3	7	1995	11/10/95 1:00 AM	11/14/95 11:00 PM	47.6	0.0	47.6	4.6	36.0	45.3	76%
4	9	2001	2/8/01 1:00 AM	2/14/01 6:00 PM	41.1	17.5	58.6	10.8	45.9	63.4	78%
5	10	2002	5/11/02 12:00 PM	5/16/02 11:00 PM	34.8	0.0	34.8	3.0	19.8	30.1	57%
6	12	2006	11/30/06 12:00 AM	12/4/06 11:00 PM	57.0	0.0	57.0	7.9	50.7	71.9	89%
7	13	2007	3/13/07 12:00 AM	3/17/07 11:00 PM	0.0	53.7	53.7	7.7	49.5	73.7	92%
8	14	2008	12/24/08 1:00 AM	12/30/08 10:00 PM	10.8	11.3	22.1	8.7	9.9	27.0	45%
9	15	2009	2/10/09 12:00 AM	2/14/09 6:00 PM	33.6	33.3	66.9	21.0	57.3	78.2	86%
10	16	2013	1/12/13 12:00 AM	1/16/13 11:00 PM	44.5	0.0	44.5	38.0	36.7	56.8	83%
11	18	1991	3/27/91 12:00 AM	3/31/91 11:00 PM	36.1	0.0	36.1	10.9	30.7	50.0	85%
12	19	1996	4/12/96 12:00 AM	4/16/96 11:00 PM	67.3	0.0	67.3	6.1	42.2	57.9	63%
13	21	1999	11/2/99 12:00 AM	11/6/99 11:00 PM	58.8	0.0	58.8	7.9	30.9	44.6	53%
14	22	2012	10/29/12 12:00 AM	11/2/12 11:00 PM	48.0	0.0	48.0	4.7	36.4	53.8	76%
15	23	2014	5/13/14 12:00 AM	5/15/14 5:00 AM	20.9	0.0	20.9	19.0	12.7	30.4	61%

* Baseflow Subtracted

3.3 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 A**.

- **Identify suitable rainfall events.**

  Identify rainfall events at rain gauge. Once an event was identified, the concurrent streamflow data at the associated flow gauge was used to develop a flood (runoff) hydrograph. The selected 15 events are listed in **Table 3.3**.

  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 Visual OTTHYMO (VOH), 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). OTTHYMO is a single event simulation model, there is no other way of establishing antecedent conditions.

  It should be noted that the initial conditions are prescribed (AMC II or AMC III) for design event simulations. Hence there is no need to establish a predictive relationship for antecedent conditions through the calibration process.

  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

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

- **Determine proper multiplication factors**

For each calibration event, the optimization was achieved by applying a multiplication factor uniformly across all catchments and routing reaches within the calibration sub-watershed (catchment) to the calibration parameters until an optimum multiplier was found for each type of parameter. Based on various previous hydrology studies, the calibration parameters and their lower and upper bounds of multipliers were determined. **Table 3.4** shows the identified calibration parameters with their lower and upper multipliers applied. Note that there are no STANDHYD commands assigned for the catchments upstream of the identified streamflow gauge. Calibration of the parameters of STANDHYDs is not applicable. In addition, as previously discussed in **Section 2.5**, a full dynamic hydraulic modelling will be used to determine the flood elevations along the Welland River. As such, the calibration did not include those parameters for channel routing (e.g., Manning's N).

Table 3.4 Boundaries of Calibration Multiplier Coefficients

VO4 Command	Parameter	Lower Multiplier	Upper Multiplier
NASHYD	*N (Default = 3)*	0.5	1.5
	Tp	0.5	1.5

- **Sensitivity Analysis**

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

- **Model Validation.**

Typically, once optimum multipliers of the identified parameters are determined, validation is required to provide a rigorous check on the "soundness" of the calibrated hydrologic model. After a successful validation, the calibrated model can then be used to simulate a variety of design storms and identified Regional storms with the initial soil conditions prescribed accordingly (e.g., AMC II for 2 to 100-year design storms and AMC III for Regional storms). As described previously, the design storm approach was not implemented in the current Welland River hydrology study. A total of 15 events were used to calibrate and validate the model in order to verify its ability to reproduce the observed annual peak flow frequency curve. Further validation of the model was performed by using the data at the Oswego Creek stream gauge (refer to **Section 4.2**).

- **Simulation of 100-Year Event For Regulatory Floodplain Mapping**

To determine the 100-year flows for the regulatory floodplain mapping, a synthetic rainfall/snowmelt-runoff simulation was established based on an actual event. The peak flows at the streamflow gauge location given by the hydrological model for this synthetic rainfall/snowmelt event were simulated to be equivalent to the 100-year peak flow as determined by the statistical analysis of the long term

historical data recorded at the flow gauge. This additional step was required because the subsequent dynamic hydraulic model simulations require hydrographs as inputs rather than only peak flows for a steady state model such as HEC-RAS. The calibrated model was then used to determine flows at other flow points along Welland River using the synthetic rainfall/snowmelt event as input. **Section 5.0** discusses this topic in details.

4.0 CALIBRATION RESULTS AND DISCUSSION

4.1 Calibration Results

In summary, the observed hydrograph shapes were very well reproduced by the calibrated model. The results confirm that the calibration exercise was successful. **Table 4.1** presents the resulting parameter multiplier coefficients to achieve optimization. The corresponding calibration results are summarized in **Table 4.2**. For illustration purposes, comparisons of hydrographs for the 7 selected most significant events are shown in **Figures 4.1 through 4.7**. A complete set of data including calibration results, summary tables and detailed comparisons of the hydrographs for all 15 selected events are included in **Appendix F**.

Table 4.1 Calibration Multiplier Coefficient

#	Events ID	Year	VO4 RUN #	Multiplier - CN - NASHYD	Multiplier - N - NASHYD	Multiplier - Tp - NASHYD
1	4	1976	4.05.REV	1.185	0.7	1.35
2	6	1990	6.04.REV	1.1	0.9	1.2
3	7	1995	7.04.REV	1.17	0.55	1.7
4	9	2001	9.03.REV	1.3	0.7	1.3
5	10	2002	10.04.REV	1.13	1	1.3
6	12	2006	12.04.REV	1.18	0.75	1.3
7	13	2007	13.04.REV	1.185	0.7	1.35
8	14	2008	14.02.REV	1.185	0.8	1.2
9	15	2009	15.04.REV	1.18	0.6	1.25
10	16	2013	16.03.REV	1.18	0.7	1.5
11	18	1991	18.03.REV	1.185	0.9	1.1
12	19	1996	19.03.REV	1.05	0.7	1.5
13	21	1999	21.03.REV	1.05	0.57	1.5
14	22	2012	22.03.REV	1.17	0.8	1.3
15	23	2014	23.01.REV	1.185	1	1

Table 4.2 Calibration Results

#	Events ID	Runoff Volume *			Peak Flow Rate *		
		Observed - 10^6 m^3	Simulated - 10^6 m^3	Difference - %	Observed - m^3/s	Simulated - m^3/s	Difference - %
1	4	10.13	9.65	-5%	55.1	53.6	-3%
2	6	11.20	12.29	10%	80.8	77.5	-4%
3	7	8.29	8.13	-2%	45.3	44.2	-2%
4	9	10.57	10.15	-4%	63.4	62.1	-2%
5	10	4.55	4.56	0%	30.1	29.7	-1%
6	12	11.66	10.67	-8%	71.9	69.9	-3%
7	13	11.38	10.17	-11%	73.7	71.5	-3%
8	14	2.29	3.39	48%	27.0	27.2	1%
9	15	13.18	12.79	-3%	78.2	74.0	-5%
10	16	8.45	7.99	-5%	56.8	54.6	-4%
11	18	7.06	6.41	-9%	50.0	48.3	-3%
12	19	9.70	8.91	-8%	57.9	56.8	-2%
13	21	7.11	7.12	0%	44.6	43.6	-2%
14	22	8.37	8.26	-1%	53.8	52.2	-3%
15	23	2.91	3.25	12%	30.4	30.0	-1%
Average				1%			-3%

*Base flow Subtracted.

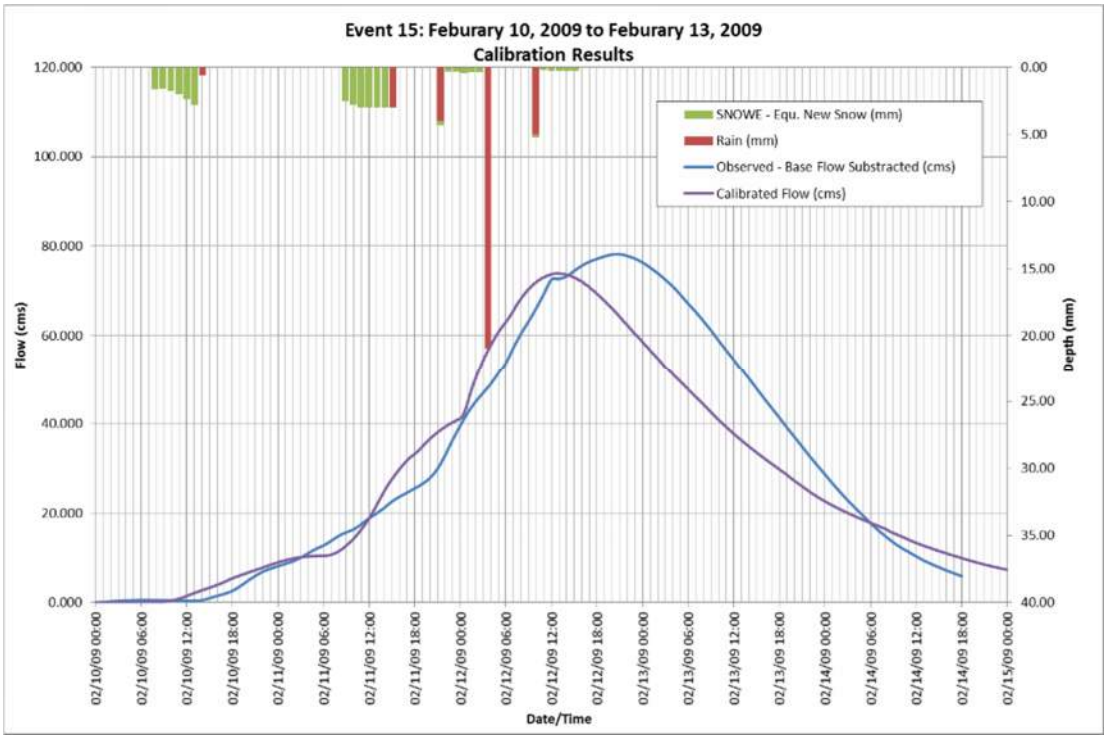

Figure 4.1 Hydrograph Comparison – Event ID 15 (Feb 2009)

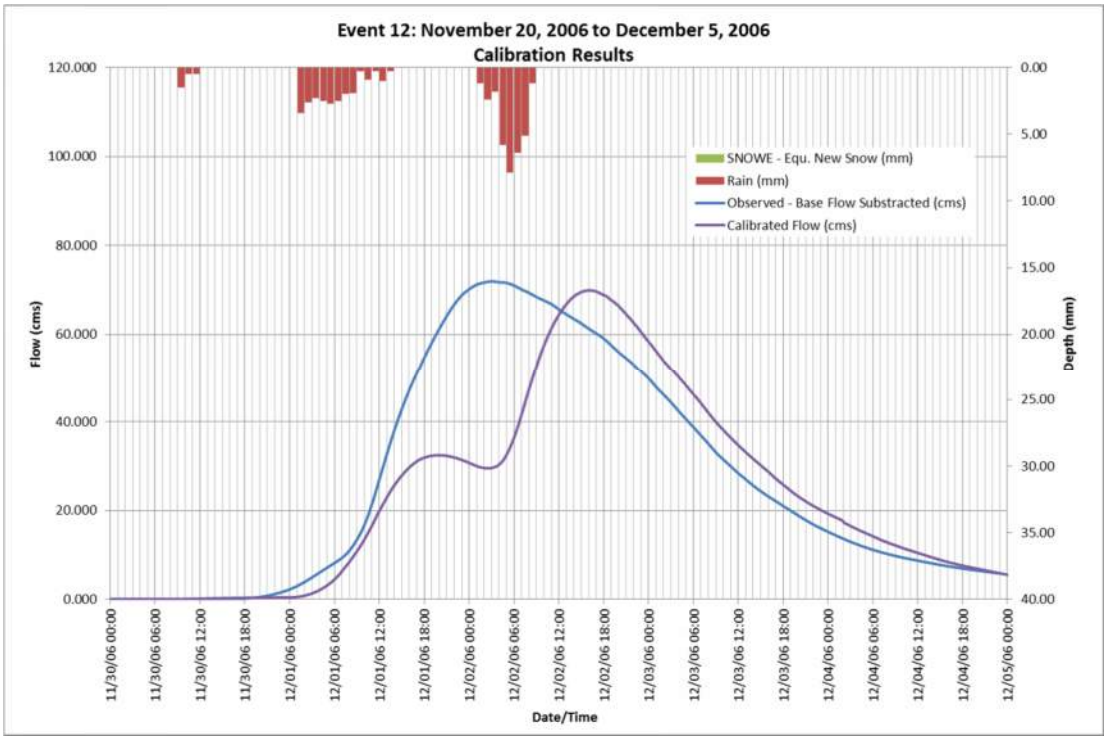

Figure 4.2 Hydrograph Comparison – Event ID 12 (Dec 2006)

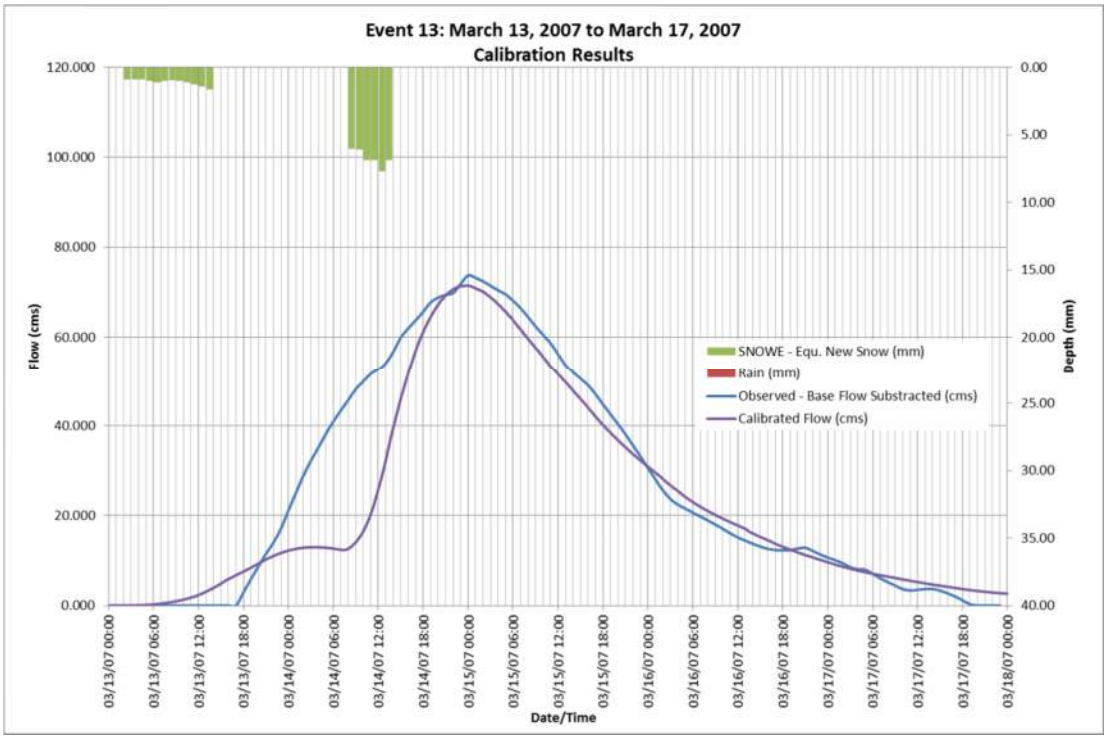

Figure 4.3 Hydrograph Comparison – Event ID 13 (Mar 2007)

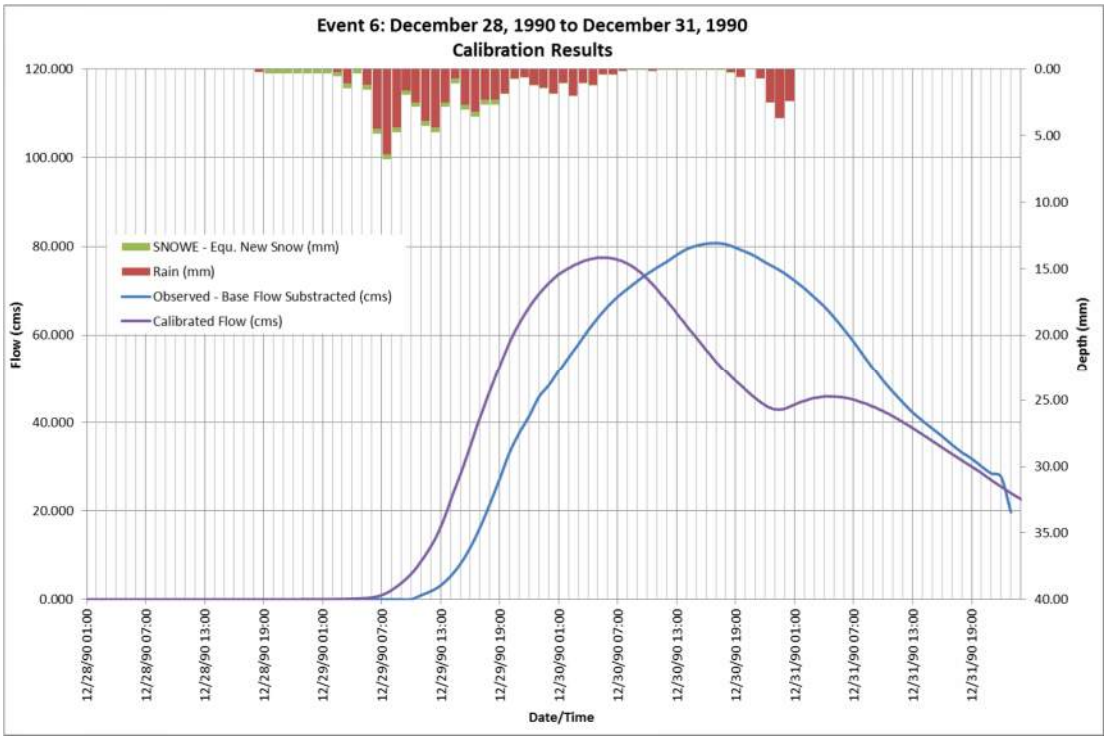

Figure 4.4 Hydrograph Comparison – Event ID 6 (Dec 1990)

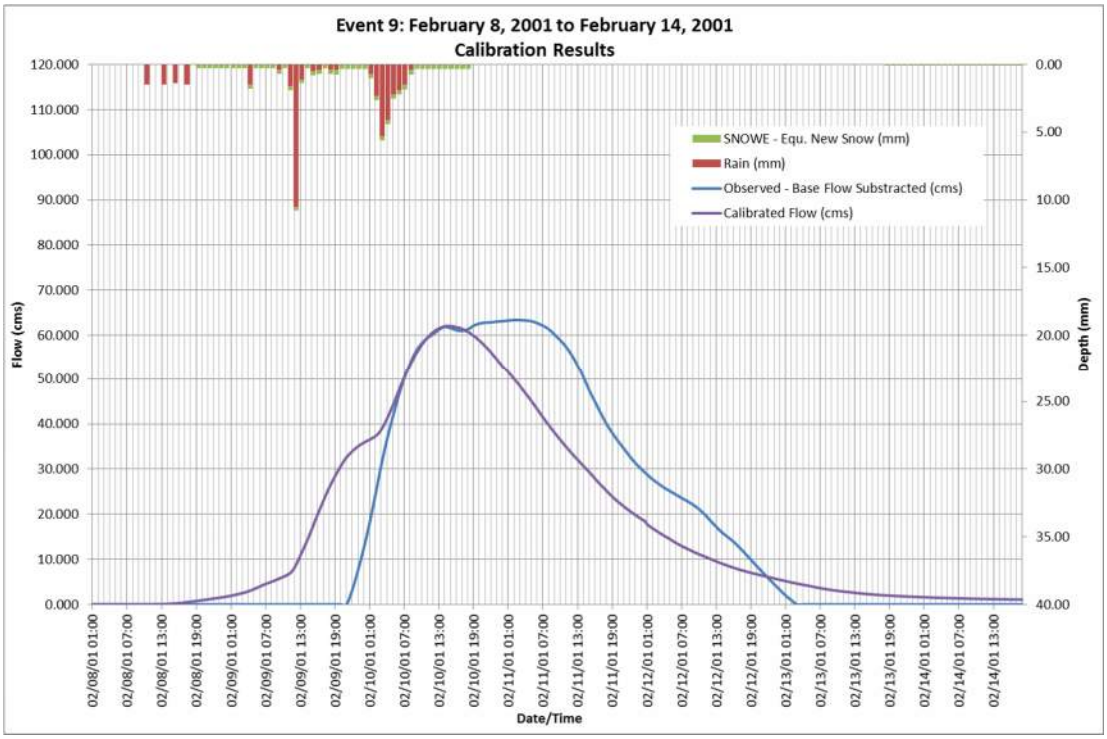

Figure 4.5 Hydrograph Comparison – Event ID 9 (Feb 2001)

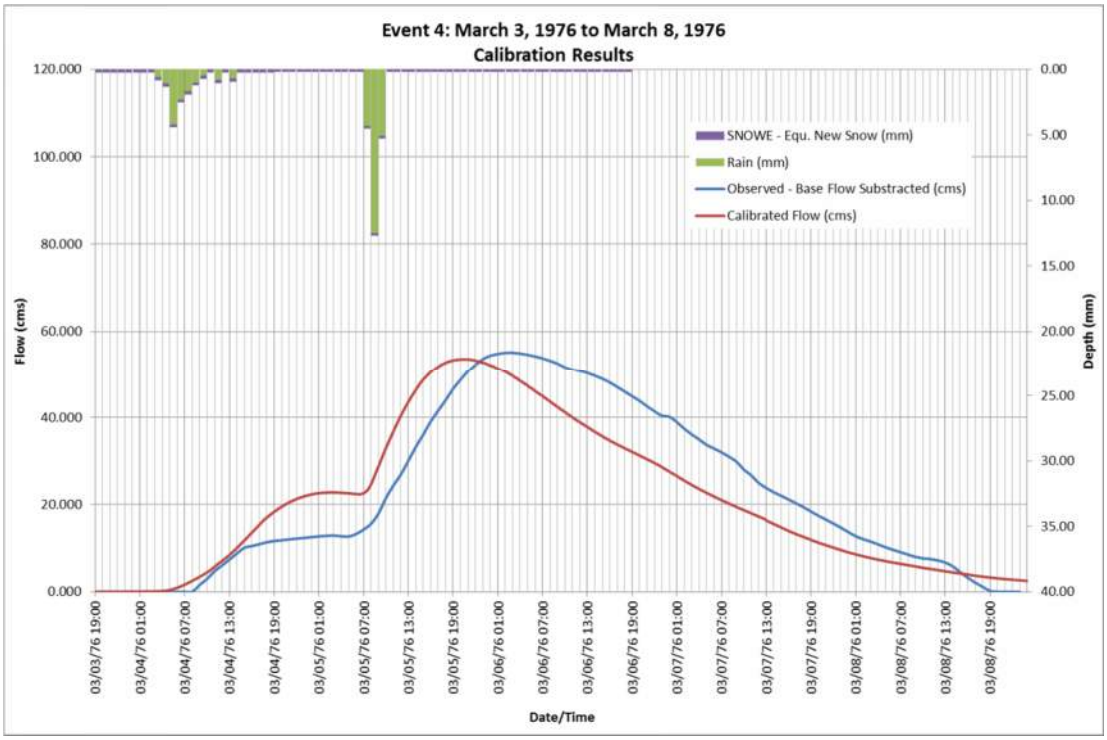

Figure 4.6 Hydrograph Comparison – Event ID 4 (Mar 1976)

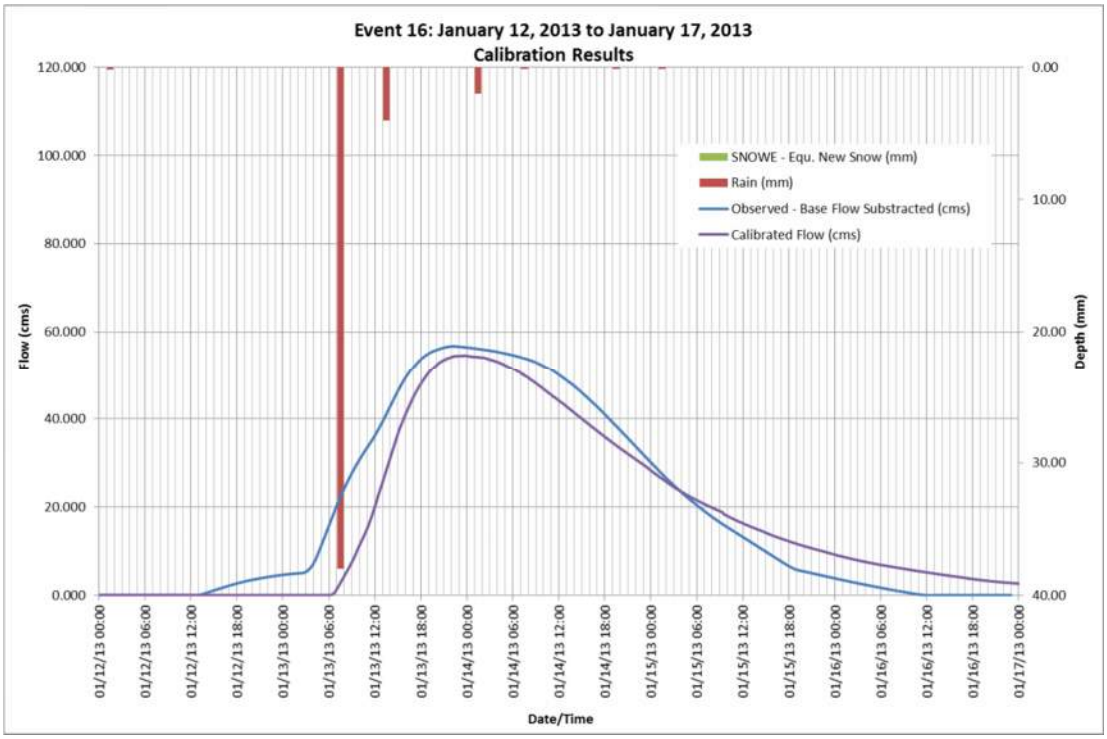

Figure 4.7 Hydrograph Comparison – Event ID 16 (Jan 2013)

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

- Generally, very high CN values (i.e., saturated soil conditions) were required to be assigned for the soils in order to meet the runoff volume comparison criteria for the majority of the events. Since these events occur during the season when a snow covered ground surface is present or in the late winter/early spring, saturated soil conditions were anticipated.
- The calibration results confirm that the criteria as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002) are fully achieved. The simulated volumes are within +20% to -10% of the measured volumes (13 out of 15 events) and the simulated peak flows are within +25% to -15% of the measured values (all 15 events).
- Excitingly, the observed hydrograph shapes were very well reproduced for all calibration events. Statistically, the average simulated peak flows for calibration events are within 3% of their respective observed values.

4.2 Further Validation at Oswego Creek Stream Flow Gauge

The calibrated model was further validated by comparing the simulated hydrograph with that observed at Oswego Creek stream flow gauge for the February 2009 Event (Event ID# 15). The streamflow gauge at Oswego Creek is currently operated and maintained by Environmental Canada (ID 02HA024). It is located at Canboro and receiving runoff from upper Oswego sub-watershed. Concurrent hourly streamflow at this gauge during February 2009 event was used for the comparison. Figure 4.7 shows a comparison of resulting simulated hydrology with observed flows recorded at the gauge for the event. It confirms that the simulated hydrographs for February 2009 events agree quite well with the observed data at EC streamflow gauge of Oswego Creek at Canboro (ID 02HA024). Detailed related information is included in **Appendix G**.

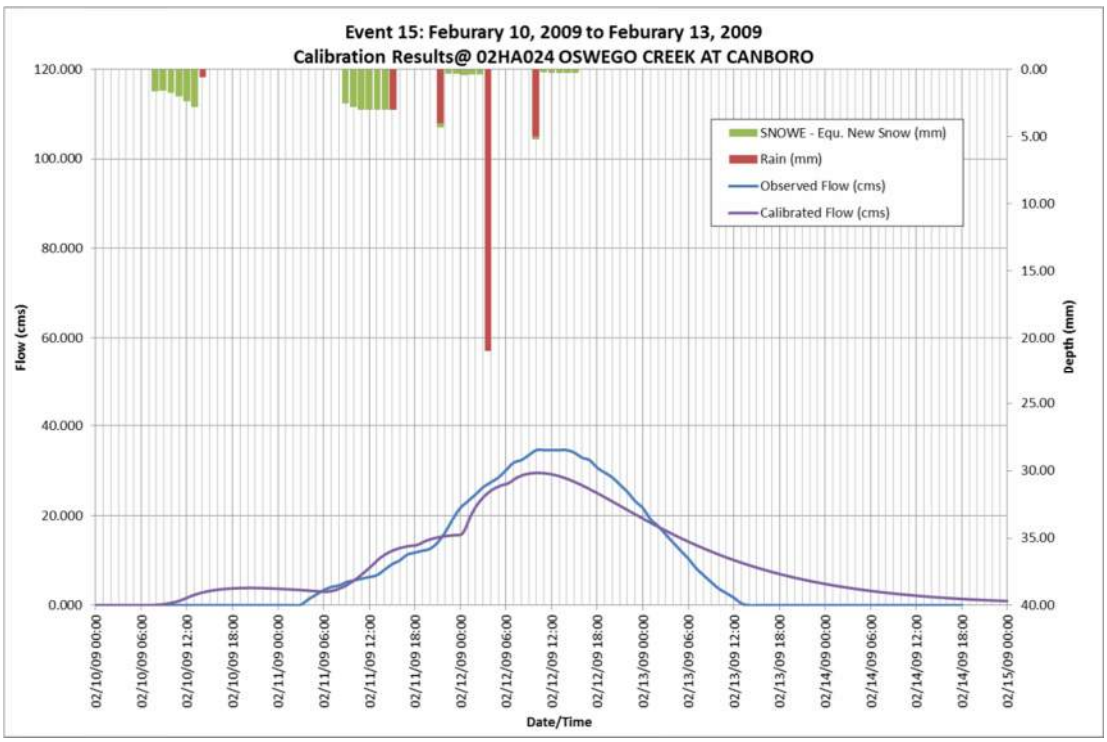

Figure 4.8 Hydrograph Comparison – Event ID 15 (Feb 2009) at Oswego Creek Streamflow Gauge

5.0 DETERMINATION OF THE 100-YEAR EVENT FOR REGULATORY FLOODPLAIN MAPPING

5.1 Methodology

As noted earlier, based on the evaluation of the historical records at the EC-WSC streamflow gauge on the Welland River below Caistor Corners (ID 02HA007), 54 out of a total of 57 maximum annual peak flows were recorded at the gauge during winter and spring seasons, when snow melts contribute an extensive amount of the runoff from catchments to the receiving watercourse. Therefore, due to the characteristics of the watershed, the corresponding flows from the hydrological model obtained by simulating a typical 100-year design rainfall are not necessarily the same as the peak 1 in 100 year return period flows observed for the Welland River. Thus the design storm approach is not appropriate for the study area.

In order to determine the 100-year flows along Welland River for the purposes of regulatory floodplain mapping, a synthetic rainfall/snowmelt-runoff simulation was established based on an actual event. The following describes the procedure used to develop the synthetic 100-year event for the study.

1. Perform frequency analysis based on a 57-years of continuous flow data collected at EC-WSC streamflow gauge of Welland River below Caistor Corners (ID 02HA007 from 1958-2014) to statistically calculate the 100-Year peak runoff rate at this location.

2. Select the most representative calibrated rainfall-runoff hydrological simulation from a total of 15 calibrated events described in Section 3.2.2 as a basis for the 100-Year simulation for the watershed.

3. Adjust rainfall/snowmelt hyetographs to ensure that the resulting peak runoff rate at Welland River below Caistor streamflow gauge is equivalent to the calculated 100-Year peak runoff rate from frequency analysis (Task 1). The adjusted rainfall/snowmelt hyetograph is designated as the synthetic 100-Year event for the Welland River watershed.

4. Run the synthetic 100-Year rainfall/snowmelt-runoff hydrological simulation to determine flows at other flow points along Welland River.

5.2 Determination of 100-Year Peak Runoff Rate at the Flow Gauge

Frequency analysis of the recorded data at Environmental Canada WSC streamflow gauge at Welland River below Caistor Corners (ID 02HA007) was performed. The gauge has 57-years of continuous flow data collected from 1958 to 2014. The analysis was carried out by using Environmental Canada's Consolidated Frequency Analysis (CFA) Package and was based on a variety of considerations, which is described as follows.

- Data Time Series Interval
  - Annual Extreme Daily Data (Maximum)
  - Instantaneous Data with Gap Filled based on Annual Extreme Daily Data
  - Hourly Data
- Data (Sample) Selection Approach
  - All Data (57 Years of Record)
  - Randomly Selected Events
  - Distributed Events
  - Combination of Top Ranked Events and Randomly Selected Events
- Statistical Distribution
  - Generalized Extreme Value (GEV)
  - Gumbel EV
  - Three-Parameter Lognormal (3LN)
  - Log Pearson Type III (LP3)
  - Wakeby
  - Weibull

The results of the frequency analysis is summarized in **Table 5.1**. Detailed information on data analysis is included in **Appendix H**.

As indicated in Table 5.1, a value of **114.0 m^3/s** (#23 of **Table 5.1**), which was determined based on instantaneous data of all 57 years of record with Generalized Extreme Value distribution, is considered as the most appropriate value to be used as the 100-Year peak runoff rate at this gauge location.

Table 5.1 Summary of Frequency Analysis to Determine 100-Year Flows

#	Analysis on # Years of Data	Data Set	Data (Sample) Selection Approach	Distribution	Q100 (CMS)
1	57	Daily Max.	Use All Years Data	GEV	101.0
2	57		Use All Years Data	3LN	98.3
3	57		Use All Years Data	LP3	96.9
4	57		Use All Years Data	WAKEBY	101.0
5	57		Use All Years Data	Gumbel	100.4
6	16		Randomly Selected from All Years - Test 1	Gumbel	106.3
7	16		Randomly Selected from All Years - Test 2	Gumbel	103.5
8	16		Randomly Selected from All Years - Test 3	Gumbel	105.4
9	16		Top 10 Events plus 6 Randomly Selected from the Rest	Gumbel	105.5
10	16		Evenly Distributed 16 Events from All Years	Gumbel	105.6
11	16		Randomly Selected 2 Events from Divided 8 Groups of All Years	Gumbel	102.3
12	16		Top 9 Events[3] plus 7 Randomly Selected from Divided 7 Groups of the Rest	Gumbel	104.1
13	16		Top 9 Events[3] plus 7 Randomly Selected from Divided 7 Groups of the Rest	GEV	98.4
14	16		Top 9 Events[3] plus 7 Randomly Selected from Divided 7 Groups of the Rest	3LN	90.8
15	16		Top 9 Events[3] plus 7 Randomly Selected from Divided 7 Groups of the Rest	LP3	101.0
16	16		Top 9 Events[3] plus 7 Randomly Selected from Divided 7 Groups of the Rest	WAKEBY	101.0
17	16		Top 9 Events[3] plus 7 Randomly Selected from Divided 7 Groups of the Rest	WEIBULL	93.8
18	15		Final Selected 15 Events	GEV	98.6
19	15		Final Selected 15 Events	3LN	91.0
20	15		Final Selected 15 Events	LP3	97.1
21	15		Final Selected 15 Events	WAKEBY	99.9
22	16		Final Selected 15 Events	WEIBULL	93.3
23	57	Instan-taneous [1]	Use All Years Data	GEV	114.0
24	57		Use All Years Data	3LN	110.0
25	57		Use All Years Data	LP3	109.0
26	57		Use All Years Data	WAKEBY	117.0
27	15		Final Selected 15 Events	GEV	115.0
28	15		Final Selected 15 Events	3LN	109.0
29	15		Final Selected 15 Events	LP3	113.0
30	15		Final Selected 15 Events	WAKEBY	114.0
31	15	Hourly [2]	Final Selected 15 Events	GEV	123.0
32	15		Final Selected 15 Events	3LN	112.0
33	15		Final Selected 15 Events	LP3	126.0
34	15		Final Selected 15 Events	WAKEBY	118.0
35	15		Final Selected 15 Events	WEIBULL	115.0

Note:
1) Gap filled for non-instantaneous data. Fitted curve used.
2) Revised based on the available data for the selected approach (top 9 plus 7 randomly) to provide statistically equivalent
3) Excluding data with SYM of A: partical day; B: ice conditions; E: Estimated

5.3 Synthetic 100-Year Events for Welland River Watershed

The calibrated simulation of the February 2009 event (Event ID 15) was selected to be the most representative calibrated rainfall/snowmelt-runoff hydrological simulation to establish the synthetic 100-Year Storm Event for the study. The selection was based on the following evaluation criteria.

- February 2009 Event is one of the most significant events (**Tables 3.2 and 3.3**);
- Minimized error associated with February 2009 event by comparing with the regression curve during flow frequency analysis (**Figure 3.2**); and
- The rainfall/snowmelt input of the February 2009 Event for the simulation is a combination of rainfall precipitation and equivalent amount of snow water content. This reflects the observed characteristics for critical events in the Welland River watershed.

The rainfall/snowmelt hyetograph of the selected February 2009 event was then adjusted by trial and error process to ensure that the resulting peak runoff rate at Welland River below Caistor streamflow gauge is equivalent to the determined 100-Year peak runoff rate from frequency analysis (i.e., 114.0 m^3/s). The trial and error exercise concluded that the adjusted rainfall distribution has a total depth of 100.19 mm, maximum intensity of 31.4 mm/hr and a duration of 54-hours. This event was designated as the synthetic 100-Year event for the Welland River watershed. The event hyetograph is shown in **Figure 5.1**. All related information including calculations and simulation results are included in **Appendix I**.

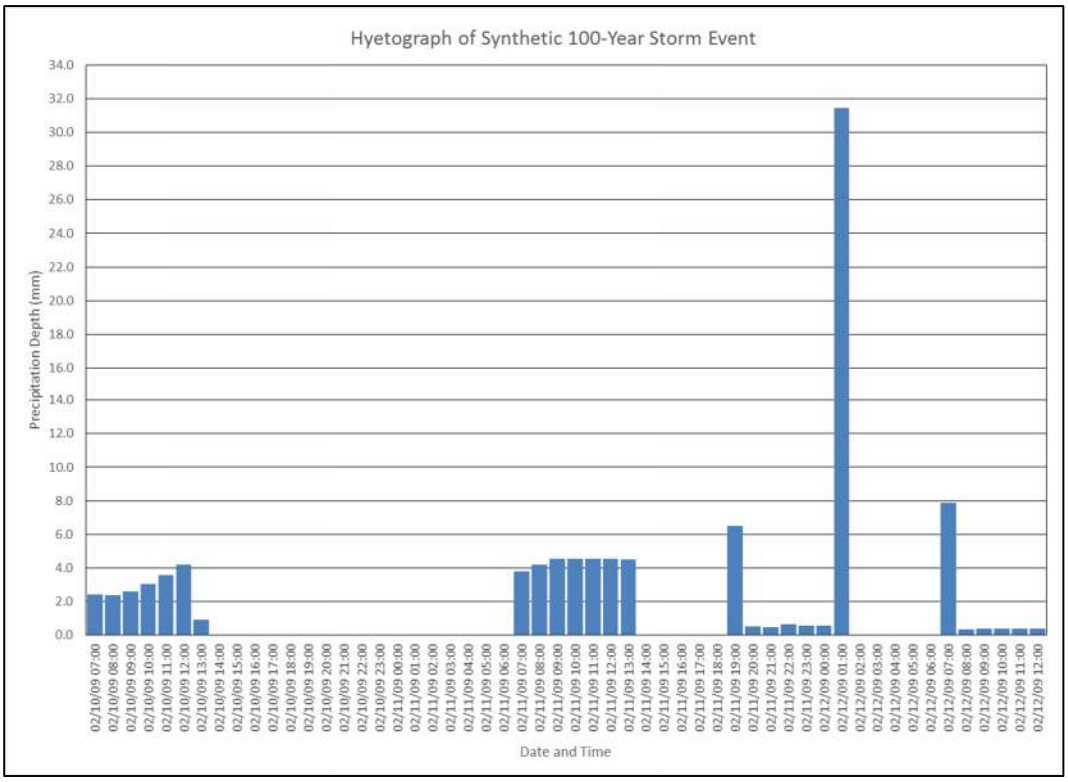

Figure 5.1 Hyetograph of Synthetic 100-Year Rainfall/Snowmelt Event

5.4 Simulation of Synthetic 100-Year Storm Events

With an established 100-Year Rainfall/Snowmelt Event for the Welland River watershed, the hydrological simulation was performed by using the calibrated parameters based on the February 2009 event (Event ID 15). **Table 5.2** summarizes the resulting 100-Year peak runoff rate from each sub-watersheds (catchments) of the Welland River watershed. All related information is included in **Appendix J**.

Table 5.2 Resulting 100-Year Peak Flows from Each Catchments of Welland Watershed

Subwatershed Name	Catchment ID	Area (km^2)	Peak Runoff Rate (m^3/s)	Peak Runoff Unit Rate (L/ha)
Beaver Creek	1020	72.75	41.50	5.70
Buckhorn Creek	1005	24.35	17.28	7.10
Coyle	1027	40.70	35.35	8.69
Draper	2036	8.86	47.66	53.77
Elsie Creek	1007	25.59	17.86	6.98
Grassy Brook	1032	13.15	8.11	6.17
Little Forks Creeks	1024	13.48	7.83	5.81
Lower Forks Creek	1035	105.66	42.72	4.04
Lower Oswego Creek	1034	103.37	45.73	4.42
Lyons Creek	1033	80.30	37.35	4.65
Moore's Creek	1012	33.28	22.01	6.61
Sucker Creek	1022	11.16	8.68	7.78
Thompson Creek	1030	14.59	10.94	7.50
Upper Forks Creek	1026	65.66	23.11	3.52
Upper Oswego Creek (u/s of Oswego Gauge)	1017	81.21	46.65	5.74
West Wolf Creek	1002	13.86	10.31	7.44
Wilson Creek	1014	6.44	5.39	8.37
Wolf Creek	1009	23.54	16.78	7.13
Local Drainage to Main Branch	1001	43.11	25.36	5.88
Local Drainage to Main Branch	1003	26.87	20.31	7.56
Local Drainage to Main Branch	1004	5.85	4.68	8.00
Local Drainage to Main Branch	1006	5.39	4.32	8.02
Local Drainage to Main Branch	1008	3.69	3.42	9.26
Local Drainage to Main Branch	1010	8.02	8.01	9.98
Local Drainage to Main Branch	1011	9.00	5.16	5.73
Local Drainage to Main Branch	1013	17.21	12.21	7.09
Local Drainage to Main Branch	1015	10.53	8.16	7.75
Local Drainage to Main Branch	1016	22.89	12.61	5.51
Local Drainage to Main Branch	1018	11.61	7.16	6.16
Local Drainage to Main Branch	1019	2.18	1.24	5.70
Local Drainage to Main Branch	1021	3.93	3.77	9.61
Local Drainage to Main Branch	1023	19.58	14.12	7.21
Local Drainage to Main Branch	1025	13.78	9.20	6.67
Local Drainage to Main Branch	1029	9.47	5.63	5.94
Local Drainage to Main Branch	1037	25.21	11.25	4.46
Local Drainage to Main Branch	2028	5.18	14.47	27.92
Local Drainage to Main Branch	2031	11.26	28.31	25.15

According to the “Technical Guide River and Stream Systems: Flooding Hazard Limit”, MNR, 2002, areal reduction factors are required for the Hazel and Timmins storms, which have known areal distributions. Although it is possible that the actual February 2009 storm event has a non-uniform areal distributions, without detailed study on such event, the distribution remains unknown. In addition, the established 100-Year rainfall/snowmelt hyetograph is a synthetic event based on an actual event which has been shown to match observed flows. Therefore, it is appropriate not to apply an areal reduction factor for the hydrological model of 100-Year event.

Flows at Flow Nodes along Water Courses

Note that the resulting hydrographs from each sub-watershed (catchment) of the 100-Year event model will be provided as input to the dynamic hydraulic model (MIKE 11) for the purposes of updating the Regulatory floodplain for the Welland River. MIKE 11 hydraulic model will calculate the flows at each flow nodes along the water courses by incorporating the effects of channel routing and providing with the required boundary conditions (i.e., water elevations at Niagara River, Chippawa Power Canal, Welland Canal and Siphons, etc.). Please refer to the Hydraulics report for more details.

6.0 CONCLUSIONS OF THE HYDROLOGICAL MODEL FOR WELLAND RIVER WATERSHED

A calibrated hydrological model to simulate an established 100-year rainfall/snowmelt event was developed. The resulting hydrographs from each sub-watershed (catchment) of the model were plugged into the dynamic hydraulic model (MIKE 11) for the purposes of updating the Regulatory flood lines of the Welland River.

The following summarizes the methodology, describe the modelling tasks and presents key findings of the subject study.

- A hydrological model was developed for the Welland River watershed by using the latest VO4.0 hydrological model. The model includes a total of 37 Catchments (i.e., 34 NASHYDs and 3 STANDHYDs), 20 Channels and 1 Reservoir (i.e., Binbrook Dam).
- A total of 15 annual extreme daily flow events were selected for the model calibration. These selected 15 events could provide equivalent statistical results with those based on all available data from Environmental Canada WSC's streamflow gauge at Welland River below Caistor Corners (ID 02HA007) for a period of 57 years from 1958 to 2014.
- The calculated equivalent snow water contents were added to the recorded rainfall depths to complete the input data for the rainfall-runoff calibration events.
- The calibration results confirm that the criteria as described in the Wastewater Planning Users Group (WaPUG) Modelling Code of Practice (2002) were fully achieved. The observed hydrograph shapes were very well reproduced for all calibration events, and the average simulated peak flows for calibration events were within 3% of their respective observed values.
- A synthetic 100-Year Rainfall/Snowmelt Event was established based on the actual February 2009 event. Such 100-Year storm has a total depth of 100.19 mm, maximum rainfall intensity of 31.4 mm/hr and a duration of 54-hours.
- A hydrological model based on the calibrated February 2009 event was used to simulate the established synthetic 100-Year rainfall/snowmelt event. The model produces a peak runoff rate (i.e., 114.0 m^3/s) at Environmental Canada WSC's Welland River below Caistor streamflow gauge equivalent to the 100-Year peak runoff rate determined based on a comprehensive frequency analysis. The resulting hydrographs from each sub-watershed (catchment) of the 100-Year event model will be provided as input to the dynamic hydraulic model for the purposes of updating the Regulatory floodplain for the Welland River.

7.0 LIMITATIONS OF THE HYDROLOGICAL MODEL FOR WELLAND RIVER WATERSHED

Although a successful calibration was achieved and a reliable hydrological model was developed for the Welland River watershed, limitations associated with the model development are inevitable. These are listed below. By understanding the model limitations, the results of the model application can be justified and provides explanations if discrepancies occur.

- The developed hydrological model was successfully calibrated at a single streamflow gauge at Welland River below Caistor Corners (ID 02HA007). This gauge is located upstream in the watershed and is the only available gauge to avoid any backwater effects from the Niagara River. Consequently, no calibration was performed for the catchment (sub-watersheds) located downstream of the flow gauge. A validation of the hydrology for areas downstream of the streamflow gauge will be achieved by comparing the resulting water levels from the developed hydraulic model with those observed at downstream water level gauges.
- Environmental Canada's precipitation gauge at Hamilton Airport (ID 6153194) is the only station to provide continuous historical weather data for the calibration of the subject hydrological model. All actual storm events have their own areal distributions. However, without detailed study on each event, the distributions remains unknown and thus a uniform precipitation input was applied for the entire watershed. Since the calibration events occurred in the winter/spring period when rainfall distributions tend to be relatively uniform, this is thought not to be a serious limitation.
- Although the effects of snowmelt were considered during the development of the hydrological model, the equivalent snow water contents were calculated based on an empirical formula. Again, as the simulated runoff volumes were close to those observed and the antecedent conditions required were intuitively what one would expect (i.e. close to saturation), this does not appear to be a serious limitation.
- Parameters for channel routing (e.g., Manning's N) were not included in the hydrological model calibration process. Therefore, the resulting flows along the Welland River from the developed hydrological model, especially at flow nodes located in the downstream areas of the watershed, are for reference purposes only. Reliable flows at these locations will be generated by the calibrated/validated fully dynamic hydraulic model for the Welland River.

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APPENDIX A – Hydrological Model Parameters

Welland River Hydrology - Catchment Parameters

Multiplier for 2009 Event (ID 15) → 1.18 | 0.01 | 0.6 | 1.25

		ha	m	m	m	%			%				hr	hr		mm						m	m		mm		
Catch_ID	Subwatershed	Area	Length	Top_Elev	Bot_Elev	Slope	Weighted CN	Runoff Coefficient	Imperviousness	TIMP / XIMP	VO Command	VO ID	Tc - Airport Method	Tp - Airport Method	Soil Storage, S	Ia	n, Roughness - Pervious	Number of Linear Reservoir N	n, Roughness - Imp.	Initial K - Pervious	Initial K - Imp.	LGP	LGI	Adjusted CN	Adjusted Ia	Adjusted N	Adjusted Tp
1	Local	4311.07	25987.68	244.57	198.12	0.18	82.5	0.29	13.37	0.00	NASHYD	1001	12.5	8.35	53.98	8.10	0.25	3.00	0.013	251.59	42.69	40	5361	97.3	0.08	1.80	10.44
2	West Wolf Creek	1386.25	11899.82	210.94	183.88	0.23	82.2	0.27	10.64	0.00	NASHYD	1002	8.0	5.34	54.98	8.25	0.25	3.00	0.013	146.48	24.85	40	3040	97.0	0.08	1.80	6.68
3	Local	2686.92	13228.50	221.01	185.21	0.27	82.7	0.29	13.04	0.00	NASHYD	1003	7.8	5.21	53.15	7.97	0.25	3.00	0.013	148.16	25.14	40	4232	97.6	0.08	1.80	6.52
4	Local	585.08	7756.75	196.46	181.04	0.20	82.1	0.28	10.80	0.00	NASHYD	1004	6.7	4.50	55.40	8.31	0.25	3.00	0.013	117.96	20.01	40	1975	96.9	0.08	1.80	5.63
5	Buckhorn Creek	2434.69	13810.50	210.28	181.04	0.21	81.3	0.29	13.27	0.00	NASHYD	1005	8.6	5.76	58.24	8.74	0.25	3.00	0.013	163.64	27.76	40	4029	96.0	0.09	1.80	7.20
6	Local	538.99	6952.70	193.96	181.08	0.19	81.3	0.27	9.92	0.00	NASHYD	1006	6.6	4.40	58.28	8.74	0.25	3.00	0.013	112.86	19.15	40	1896	96.0	0.09	1.80	5.50
7	Elsie Creek	2559.44	13522.41	206.91	181.08	0.19	81.2	0.29	12.71	0.00	NASHYD	1007	8.8	5.93	58.73	8.81	0.25	3.00	0.013	166.65	28.28	40	4131	95.8	0.09	1.80	7.41
8	Local	369.42	5623.42	193.94	179.20	0.26	80.9	0.30	14.01	0.00	NASHYD	1008	5.1	3.41	60.16	9.02	0.25	3.00	0.013	89.52	15.19	40	1569	95.4	0.09	1.80	4.26
9	Wolf Creek	2354.08	13774.89	210.62	179.20	0.23	81.4	0.28	11.14	0.00	NASHYD	1009	8.5	5.72	57.94	8.69	0.25	3.00	0.013	159.78	27.11	40	3962	96.1	0.09	1.80	7.15
10	Local	802.02	3937.49	188.78	178.12	0.27	79.4	0.27	10.26	0.00	NASHYD	1010	4.3	2.91	66.02	6.60	0.25	3.00	0.013	71.59	12.15	40	2312	93.7	0.07	1.80	3.64
11	Local	900.00	9942.56	180.61	175.47	0.05	79.3	0.28	11.58	0.00	NASHYD	1011	11.8	7.90	66.42	6.64	0.25	3.00	0.013	205.10	34.80	40	2449	93.5	0.07	1.80	9.88
12	Moore's Creek	3327.68	15375.20	205.42	174.18	0.20	80.0	0.27	10.16	0.00	NASHYD	1012	9.4	6.33	63.38	9.51	0.25	3.00	0.013	176.70	29.98	40	4710	94.4	0.10	1.80	7.91
13	Local	1721.41	11334.55	197.43	177.69	0.17	81.0	0.28	10.79	0.00	NASHYD	1013	8.5	5.69	59.68	8.95	0.25	3.00	0.013	154.12	26.15	40	3388	95.5	0.09	1.80	7.11
14	Wilson Creek	643.60	5756.74	184.89	172.65	0.21	79.1	0.26	9.13	0.00	NASHYD	1014	5.7	3.85	67.26	6.73	0.25	3.00	0.013	96.69	16.41	40	2071	93.3	0.07	1.80	4.81
15	Local	1052.77	6401.81	180.53	171.83	0.14	80.4	0.29	12.18	0.00	NASHYD	1015	6.8	4.59	61.88	9.28	0.25	3.00	0.013	117.88	20.00	40	2649	94.9	0.09	1.80	5.73
16	Local	2288.76	11652.47	178.64	171.83	0.06	78.7	0.28	11.16	0.00	NASHYD	1016	12.3	8.25	68.83	6.88	0.25	3.00	0.013	217.46	36.90	40	3906	92.8	0.07	1.80	10.31
17	swego Creek - Osweg	8120.87	19921.63	205.33	174.39	0.16	79.2	0.27	10.59	0.00	NASHYD	1017	11.7	7.85	66.82	6.68	0.25	3.00	0.013	223.75	37.96	40	7358	93.4	0.07	1.80	9.81
18	Local	1161.45	10976.94	179.73	171.32	0.08	80.1	0.29	12.99	0.00	NASHYD	1018	10.8	7.20	63.09	9.46	0.25	3.00	0.013	193.42	32.82	40	2783	94.5	0.09	1.80	9.00
19	Local	218.28	3103.14	171.32	171.09	0.01	79.7	0.31	15.57	0.00	NASHYD	1019	12.1	8.09	64.88	6.49	0.25	3.00	0.013	182.48	30.96	40	1206	94.0	0.06	1.80	10.11
20	Beaver Creek	7275.31	20267.67	196.13	171.09	0.12	81.0	0.29	12.15	0.00	NASHYD	1020	12.6	8.42	59.54	8.93	0.25	3.00	0.013	242.10	41.08	40	6964	95.6	0.09	1.80	10.53
21	Local	392.54	4711.80	183.97	171.08	0.27	79.6	0.29	12.57	0.00	NASHYD	1021	4.6	3.11	64.91	6.49	0.25	3.00	0.013	79.48	13.49	40	1618	94.0	0.06	1.80	3.89
22	Sucker Creek	1115.90	8179.74	188.35	171.08	0.21	80.2	0.28	11.68	0.00	NASHYD	1022	6.7	4.50	62.60	9.39	0.25	3.00	0.013	119.61	20.29	40	2728	94.7	0.09	1.80	5.63
23	Local	1958.42	8517.68	182.56	171.20	0.13	80.0	0.28	12.08	0.00	NASHYD	1023	8.0	5.33	63.43	9.51	0.25	3.00	0.013	140.69	23.87	40	3613	94.4	0.10	1.80	6.66
24	Little Forks Creeks	1347.66	11790.29	178.94	171.15	0.07	80.2	0.28	11.19	0.00	NASHYD	1024	11.9	7.96	62.86	9.43	0.25	3.00	0.013	211.10	35.82	40	2997	94.6	0.09	1.80	9.95
25	Local	1378.37	9209.53	178.91	170.99	0.09	80.7	0.29	12.85	0.00	NASHYD	1025	9.5	6.36	60.80	9.12	0.25	3.00	0.013	168.17	28.53	40	3031	95.2	0.09	1.80	7.95
26	Upper Forks Creek	6566.04	16378.78	177.70	174.15	0.02	74.8	0.28	11.76	0.00	NASHYD	1026	20.1	13.49	85.37	8.54	0.25	3.00	0.013	359.18	60.94	40	6616	88.3	0.09	1.80	16.86
27	Coyle	4069.85	11224.48	257.07	170.99	0.77	76.2	0.31	15.93	0.00	NASHYD	1027	5.0	3.32	79.21	7.92	0.25	3.00	0.013	98.22	16.66	40	5209	89.9	0.08	1.80	4.15
29	Local	946.78	9263.81	174.92	170.82	0.04	79.9	0.32	17.64	0.00	NASHYD	1029	11.4	7.61	63.73	6.37	0.25	3.00	0.013	206.03	34.96	40	2512	94.3	0.06	1.80	9.52
30	Thompson Creek	1458.54	7044.95	181.28	170.46	0.15	78.8	0.28	11.34	0.00	NASHYD	1030	6.9	4.65	68.18	6.82	0.25	3.00	0.013	120.32	20.42	40	3118	93.0	0.07	1.80	5.82
32	Grassy Brook	1315.28	12791.21	184.36	171.30	0.10	79.9	0.28	11.64	0.00	NASHYD	1032	10.7	7.16	63.84	6.38	0.25	3.00	0.013	194.50	33.00	40	2961	94.3	0.06	1.80	8.94
33	Lyons Creek	8029.53	18300.01	179.76	171.35	0.05	80.3	0.28	11.53	0.00	NASHYD	1033	16.6	11.15	62.41	9.36	0.25	3.00	0.013	306.42	51.99	40	7316	94.7	0.09	1.80	13.94
34	Lower Oswego Creek	10337.19	31279.10	200.06	171.19	0.09	79.1	0.28	11.88	0.00	NASHYD	1034	17.2	11.55	67.06	6.71	0.25	3.00	0.013	342.87	58.17	40	8301	93.4	0.07	1.80	14.43
35	Lower Forks Creek	10566.05	17538.10	175.26	170.99	0.02	80.5	0.28	10.91	0.00	NASHYD	1035	20.2	13.54	61.35	9.20	0.25	3.00	0.013	361.60	61.35	40	8393	95.0	0.09	1.80	16.93
37	Local	2521.39	8032.05	170.99	170.59	0.00	84.4	0.39	27.83	0.00	NASHYD	1037	19.8	13.24	46.92	7.04	0.25	3.00	0.013	364.11	61.78	40	4100	99.6	0.07	1.80	16.55
28	Local	518.04	5627.38	177.32	173.20	0.07	81.9	0.37	24.27	0.24	STANDHYD	2028	N/A	N/A	56.07	8.41	0.25	0.00	0.013	131.33	22.28	40	1858	96.7	0.08		
31	Local	1125.76	7158.51	176.22	171.00	0.07	82.3	0.40	28.30	0.28	STANDHYD	2031	N/A	N/A	54.61	8.19	0.25	0.00	0.013	151.86	25.77	40	2740	97.1	0.08		
36	Draper	886.29	7340.12	237.89	170.99	0.91	87.0	0.50	43.04	0.43	STANDHYD	2036	N/A	N/A	38.07	5.71	0.25	0.00	0.013	72.28	12.26	40	2431	102.6	0.06		

APPENDIX B – Channel Routing for Welland River Hydrology

Catch_ID	VO ID	Subwatershed	Area (ha)	Stream_Nam	Stream_L (m)	Top_Elev	Bot_Elev	Slope (%)	Slope (%) in Model	Channel ID	VSN	HEC-RAS Project	Reach Code	Cross Section #
3	41003	Local	2686.92	003-Welland	7791.11	198.12	185.21	0.166	0.166	41003	1.03	UpperWelland	WWC-1	1053.34
4	41004	Local	585.08	004-Welland	3790.54	185.21	181.04	0.110	0.110	41004	1.04	UpperWelland	WR-53	4190.369
6	41006	Local	538.99	006-Welland	6204.69	182.22	181.63	0.010	0.010	41006	1.06	UpperWelland	WR-52	627.6702
8	41008	Local	369.42	008-Welland	4745.84	181.63	181.27	0.008	0.008	41008	1.08	UpperWelland	WR-51	2806.166
10	41010	Local	802.02	010-Welland	3695.53	181.27	180.61	0.018	0.018	41010	1.10	UpperWelland	WR-50	2691.177
11	41011	Local	900.00	011-Welland	9942.56	180.61	175.47	0.052	0.052	41011	1.11	UpperWelland	WR-94_95	3953.78
13	41013	Local	1721.41	013-Welland	7156.36	178.09	177.59	0.007	0.007	41013	1.13	UpperWelland	WR-39	3909.702
15	41015	Local	1052.77	015-Welland	5733.70	177.68	176.61	0.019	0.019	41015	1.15	UpperWelland	WR-36	6681.1
16	41016	Local	2288.76	016-Welland	3642.91	176.61	172.07	0.125	0.125	41016	1.16	UpperWelland	WR-36	4299.4
18	41018	Local	1161.45	018-Welland	8528.66	172.07	171.28	0.009	0.009	41018	1.18	WellandRiver	UWR-01	8894.899
19	41019	Local	218.28	019-Welland	3103.14	171.32	171.09	0.007	0.007	41019	1.19	WellandRiver	UWR-01	2419.885
21	41021	Local	392.54	021-Welland	2641.18	171.09	171.08	0.000	0.001	41021	1.21	WellandRiver	CRW-10	1768.021
23	41023	Local	1958.42	023-Welland	9253.35	171.08	171.15	-0.001	0.001	41023	1.23	WellandRiver	CRW-08	1497.361
25	41025	Local	1378.37	025-Welland	6310.25	171.15	170.99	0.003	0.003	41025	1.25	WellandRiver	CRW-05	1326.548
29	41029	Local	946.78	029-Welland	9263.81	174.92	170.82	0.044	0.044	41029	1.29		N/A	55497
34	41034	Lower Oswego Creek	10337.19	Lower Oswego	20328.50	174.39	171.19	0.016	0.016	41034	1.34	Lower Oswego Creek	DEM-5M-2002	GIS Cut
35	41035	Lower Forks Creek	10566.05	002 Forks	7831.15	174.14	170.99	0.040	0.040	41035	1.35	Lower Forks Creek	DEM-5M-2002	GIS Cut
37	41037	Local	2521.39	027-Welland	8032.05	170.99	170.59	0.005	0.005	41037	1.37	WellandRiver	CRW-04	1247.277
28	42028	Local	518.04	028-Welland	5627.38	177.32	173.20	0.073	0.073	42028	1.28	WellandRiver	CRW-01	2253.451
31	42031	Local	1125.76	031-Welland	7228.17	173.36	171.00	0.033	0.033	42031	1.31		N/A	61882

APPENDIX C – Reservoir Routing for Welland River Hydrology

Spillway (Emergency and Morning Glory)

Level (m)	Flow (cms)	Abs Level (m)	Fitted Flow (cms)	Difference
198.8	0	0	0	
199.3	8	0.5	11	39%
199.8	25	1	21	-15%
200.1	38	1.3	32	-15%
200.4	50	1.6	51	2%
200.56	60	1.76	65	8%
200.7	72	1.9	80	11%
201.13	150	2.33	145	-4%
201.37	200	2.57	196	-2%
201.75	300	2.95	303	1%

Level (m)	Inc. Level (m)	Flow (cms)
198.8	0	0
198.9	0.1	3
199	0.2	5
199.1	0.3	7
199.2	0.4	9
199.3	0.5	11
199.4	0.6	13
199.5	0.7	15
199.6	0.8	17
199.7	0.9	19
199.8	1	21
199.9	1.1	24
200	1.2	28
200.1	1.3	32
200.2	1.4	38
200.3	1.5	44
200.4	1.6	51
200.5	1.7	59
200.6	1.8	69
200.7	1.9	80
200.8	2	92
200.9	2.1	106
201	2.2	122
201.1	2.3	139
201.2	2.4	158
201.3	2.5	180
201.4	2.6	203
201.5	2.7	229
201.6	2.8	256
201.7	2.9	287
201.8	3	320

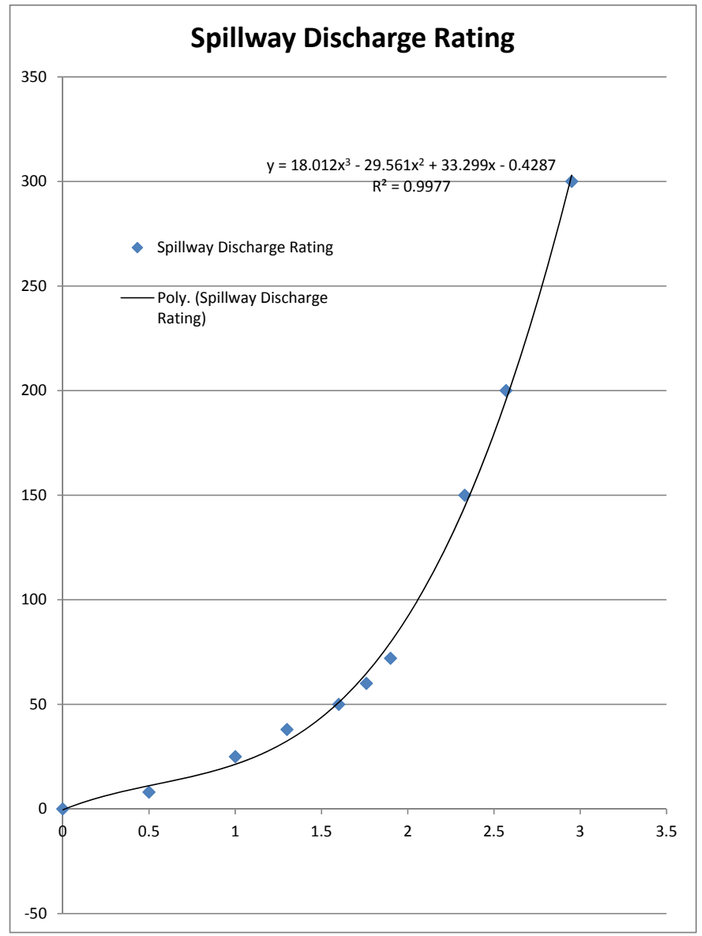
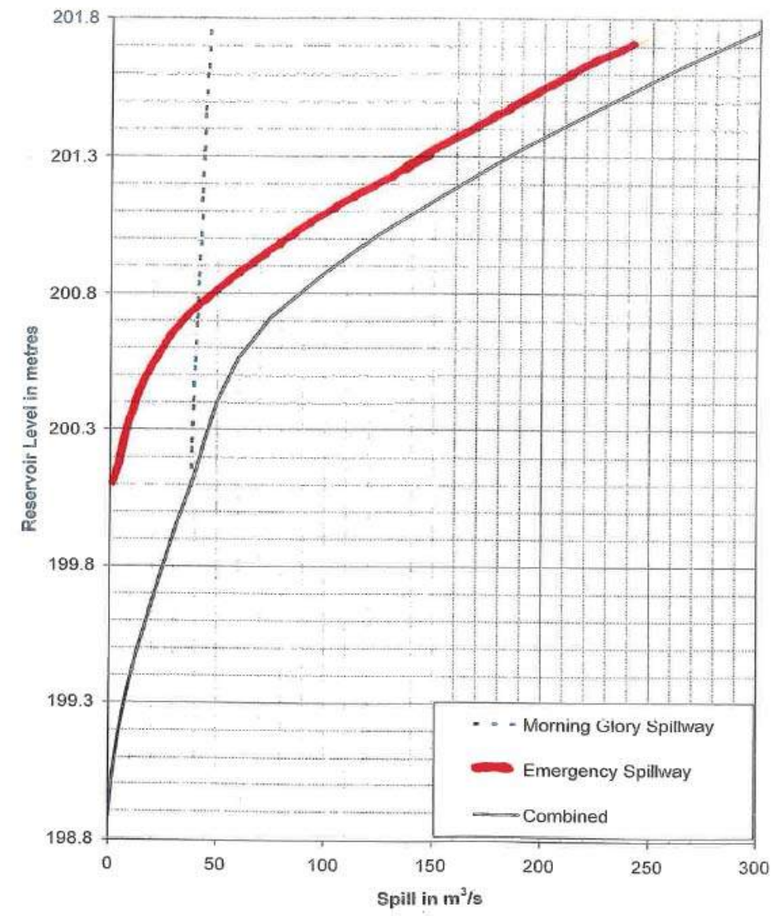


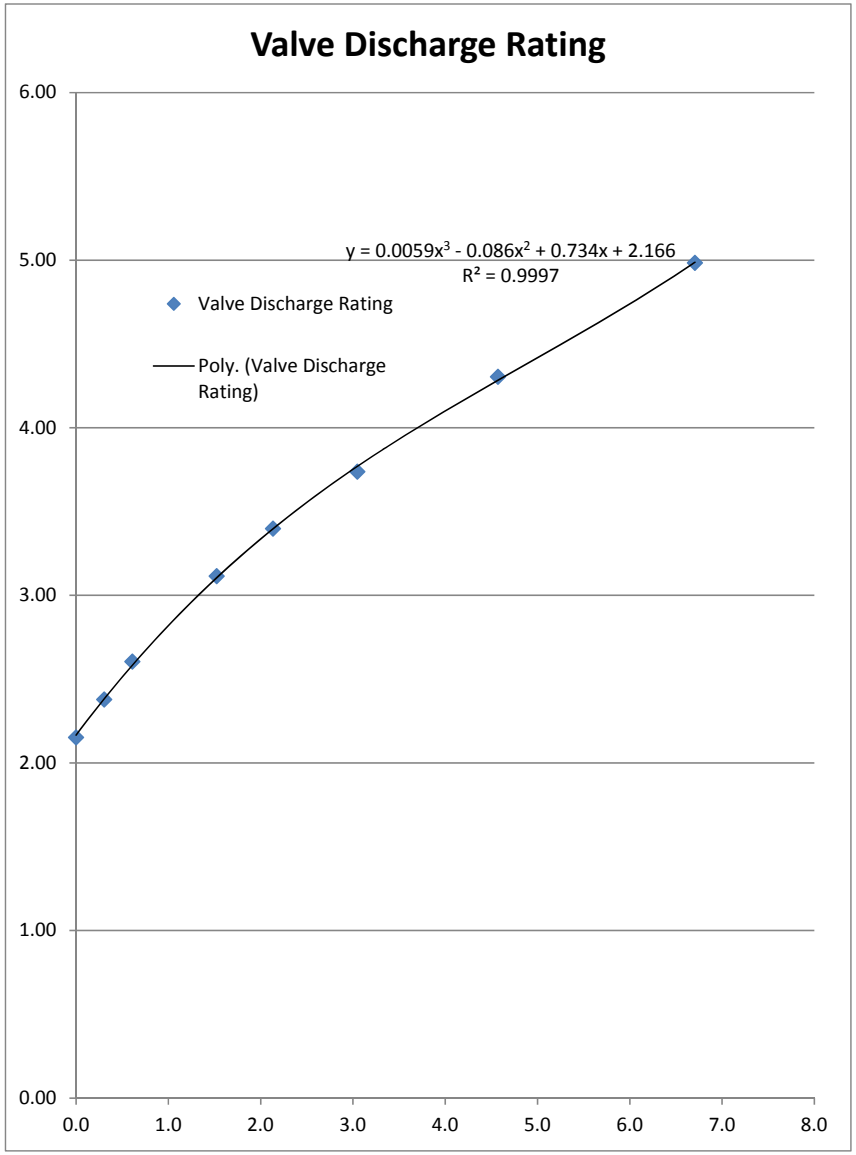
Figure 11
Binbrook Spillway Discharge Rating



Valve Rating Curve (combine 30 and 16 inch)

Level (ft)	Flow (cfs)	Level (m)	Flow (cms)	Abs Level (	Fitted Flow	Difference
635	76	193.5	2.15	0.0	2.17	1%
636	84	193.9	2.38	0.3	2.38	0%
637	92	194.2	2.61	0.6	2.58	-1%
640	110	195.1	3.11	1.5	3.11	0%
642	120	195.7	3.40	2.1	3.40	0%
645	132	196.6	3.74	3.0	3.77	1%
650	152	198.1	4.30	4.6	4.29	0%
657	176	200.3	4.98	6.7	5.00	0%

Level (m)	Inc. Level (	Flow (cms)
193.5	0	2.17
193.6	0.1	2.24
193.7	0.2	2.31
193.8	0.3	2.38
193.9	0.4	2.45
194.0	0.5	2.51
194.1	0.6	2.58
194.2	0.7	2.64
194.3	0.8	2.70
194.4	0.9	2.76
194.5	1	2.82
194.6	1.1	2.88
194.7	1.2	2.93
194.8	1.3	2.99
194.9	1.4	3.04
195.0	1.5	3.09
195.1	1.6	3.14
195.2	1.7	3.19
195.3	1.8	3.24
195.4	1.9	3.29
195.5	2	3.34
195.6	2.1	3.38
195.7	2.2	3.43
195.8	2.3	3.47
195.9	2.4	3.51
196.0	2.5	3.56
196.1	2.6	3.60
196.2	2.7	3.64
196.3	2.8	3.68
196.4	2.9	3.72
196.5	3	3.75



Elevation (m)	Storage (mil c.m.)	Storage (c.m.)	Storage (ha.m)	Abs Level (m)	Fitted Storage (ha.m)	Difference
191	0	0	0	0	-1.9	
193	0.3	300000	30	2	34.2	14%
194	0.7	700000	70	3	70.8	1%
195	1.2	1200000	120	4	124.8	4%
196	2.1	2100000	210	5	200.2	-5%
197	3.1	3100000	310	6	300.7	-3%
198	4.2	4200000	420	7	430.4	2%
199	5.9	5900000	590	8	592.9	0%
200	7.9	7900000	790	9	792.3	0%
201	10.4	10400000	1040	10	1032.4	-1%
201.48	11.6	11600000	1160	10.48	1163.2	0%

Elevation (m)	Abs Level (m)	Storage (ha.m)
191	0	-1.9
192	1	34.2
193	2	70.8
194	3	124.8
195	4	200.2
196	5	300.7
197	6	430.4
198	7	592.9
199	8	792.3
200	9	1032.4
201	10	1163.2

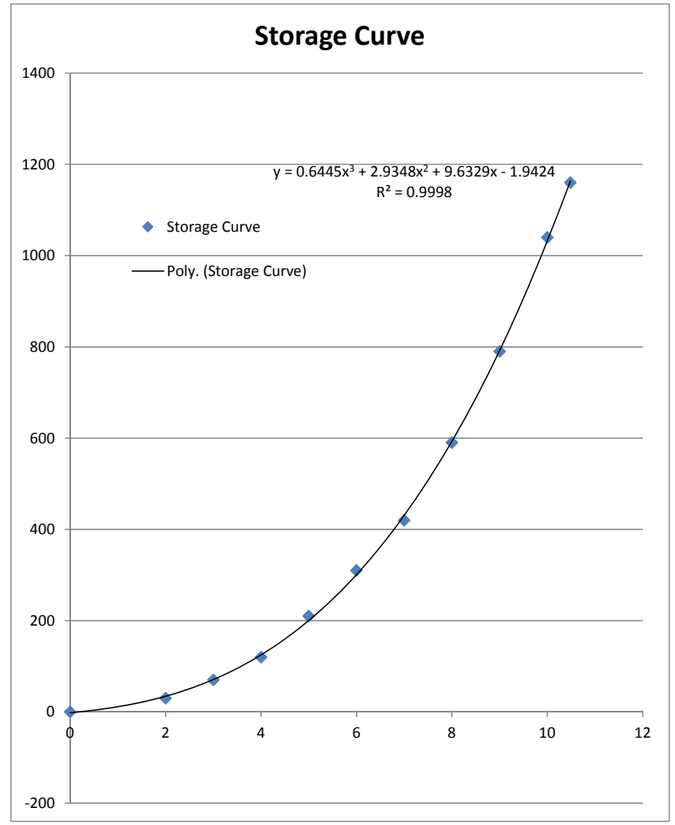
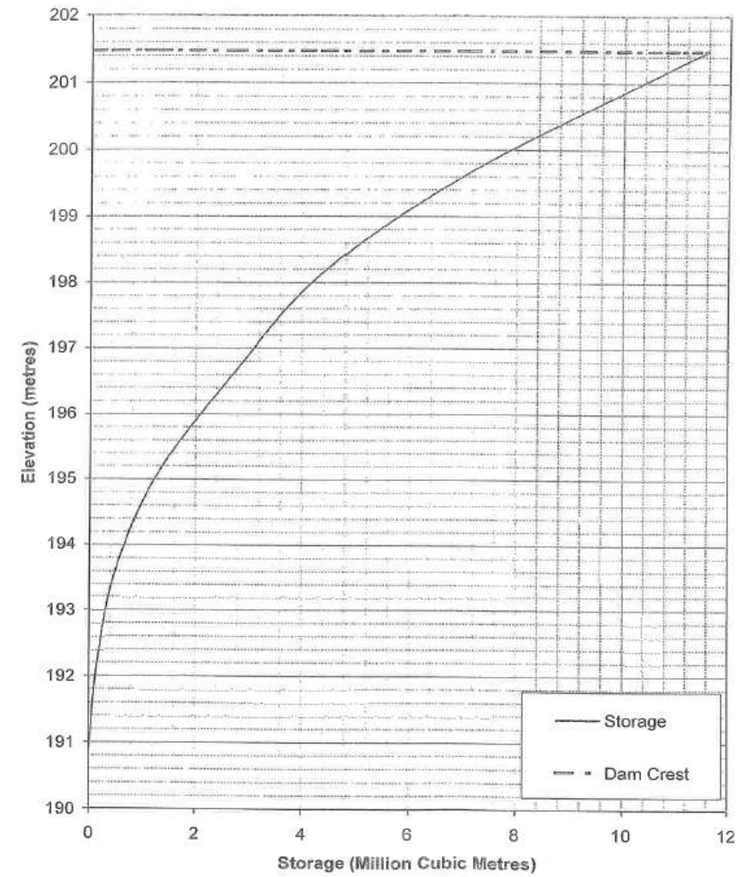


Figure 10
Lake Niapenco Storage Curve



Valve			Spill			Storage			Active Level Combined		Active Storage
Level (m)	Inc. Level (m)	Flow (cms)	Level (m)	Inc. Level (m)	Flow (cms)	Level (m)	Inc. Level (m)	Storage (ha.m)	Level (m)	Flow (cms)	ha.m
193.5	0.0	2.17				193.5	2.5	52.3			
195.5	2.0	3.34				195.5	4.5	163.2			
197.5	4.0	4.10				197.5	6.5	367.9			
198.8	5.3	4.50	198.8	0.0	0	198.8	7.8	557.6	198.8	**4.1**	**0**
199.0	5.5	4.57	199.0	0.2	5	199.0	8.0	592.9	199.0	**9.8**	**35**
199.2	5.7	4.63	199.2	0.4	9	199.2	8.2	629.7	199.2	**13.9**	**72**
199.4	5.9	4.70	199.4	0.6	13	199.4	8.4	668.1	199.4	**17.5**	**110**
199.6	6.1	4.77	199.6	0.8	17	199.6	8.6	707.9	199.6	**21.3**	**150**
199.8	6.3	4.84	199.8	1.0	21	199.8	8.8	749.3	199.8	**26.2**	**192**
200.0	6.5	4.91	200.0	1.2	28	200.0	9.0	792.3	200.0	**33.0**	**235**
200.2	6.7	4.98	200.2	1.4	38	200.2	9.2	836.9	200.2	**42.7**	**279**
200.4	6.9	5.06	200.4	1.6	51	200.4	9.4	883.2	200.4	**56.0**	**326**
200.6	7.1	5.13	200.6	1.8	69	200.6	9.6	931.2	200.6	**73.9**	**374**
200.8	7.3	5.22	200.8	2.0	92	200.8	9.8	980.9	200.8	**97.2**	**423**
201.0	7.5	5.30	201.0	2.2	122	201.0	10.0	1032.4	201.0	**126.8**	**475**
201.2	7.7	5.39	201.2	2.4	158	201.2	10.2	1085.6	201.2	**163.6**	**528**
201.4	7.9	5.48	201.4	2.6	203	201.4	10.4	1140.6	201.4	**208.4**	**583**
201.6	8.1	5.58	201.6	2.8	256	201.6	10.6	1197.5	201.6	**262.0**	**640**
201.8	8.3	5.68	201.8	3.0	320	201.8	10.8	1256.3	201.8	**325.4**	**699**

Sources:

NIAGARA PENINSULA CONSERVATION AUTHORITY

BINBROOK DAM OPERATIONS AND MAINTENANCE MANUAL

2013

NIAGARA PENINSULA CONSERVATION AUTHORITY
250 THOROLD ROAD WEST, 3RD FLOOR
WELLAND ONTARIO L3C 3W2

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REVISED DECEMBER 2013

APPENDIX D – Frequency Analysis of Precipitation Data

Gauge Summary

ID	StationID	Parameter	LocationName	Easting	Northing	From	To	Time Step_min	Region	Municipality	Owner	Note	Data Source
		PRECIP	Welland River at Wellandport	623679.926	4762487.293	5/6/2010 7:45	12/3/2015 11:00	15					NPCA
		PRECIP	Welland River at Caistors	612615.477	4764158.211	1/19/2012 6:00	12/3/2015 10:00	15					NPCA
		PRECIP	Oswego Creek	607751.173	4760694.611	6/23/2009 0:00	12/3/2015 10:00	60					NPCA
		PRECIP	Welland River at Binbrook	595545.031	4772920.275	7/7/2009 0:00	12/3/2015 11:00	15					NPCA
		PRECIP	Big Forks Creek	631427.623	4756427.328	1/5/2012 16:45	11/5/2015 18:30	15					NPCA
		PRECIP	Niagara Falls	658567.93	4769588.245	1/25/2012 6:25	12/3/2015 11:05	5					NPCA
		PRECIP	WellandWWTP	643613.985	4763167.621	3/15/2011 6:10	10/31/2015 22:15	5					NPCA
		PRECIP	Hamilton	585924.364	4780889.813	3/15/2012 15:45	10/23/2015 11:45	15					NPCA
		PRECIP	Ruigrok	605093.72	4763867.661	1/1/2012 16:45	12/3/2015 10:00	15				Missing Data	NPCA
		PRECIP	EC Brown	637186.03	4759083.753	5/28/2012 21:15	12/3/2015 10:00	15					NPCA
		Flow at Dam	Brinbrook Discharge			12/5/2012 9:30	10/17/2014 11:30	15					NPCA
		LEVEL	BIG FORKS	631427.62	4756427.33	11/3/2011 15:45	12/7/2015 13:45	15					NPCA
		LEVEL	Welland River at EC BROWN	637186.03	4759083.75	9/4/2014 8:35	11/26/2015 10:35	15				15 min Time Step - Time needs Revision	NPCA
		LEVEL	SIPHON EAST	642891.93	4761648.42								NPCA
		LEVEL	NIAGARA RIVER AT FORT ERIE	670247.94	4755191.30								NPCA
		LEVEL / FLOW	Welland River at CAISTORS	612615.48	4764158.21	10/12/2009 6:00	10/13/2009 13:00	60					NPCA
		LEVEL / FLOW	Welland River at CAISTORS	612615.48	4764158.21	10/13/2009 13:15	7/27/2011 7:45	15					NPCA
		LEVEL / FLOW	Welland River at CAISTORS	612615.48	4764158.21	7/27/2011 8:00	1/10/2012 12:00	60				Data Unusable	NPCA
		LEVEL / FLOW	Welland River at CAISTORS	612615.48	4764158.21	1/10/2012 12:15	12/7/2015 11:00	5				Rating Curve, 2015	NPCA
		LEVEL / FLOW	Welland River at WELLANDPORT	623679.93	4762487.29	3/3/2010 11:15	12/6/2015 12:30	15				Rating Curve, 1988	NPCA
		LEVEL	OSWEGO	607751.17	4760694.61	6/23/2009 0:00	10/13/2009 13:00	60					NPCA
		LEVEL	OSWEGO	607751.17	4760694.61	10/13/2009 13:00	9/11/2015 7:45	15					NPCA
		LEVEL / FLOW	SIPHON WEST	642479.82	4761594.48							Rating Curve, 1988 and Difficult to Use	NPCA
		LEVEL / FLOW	Welland River at SOUTHBROOK	596767.83	4771987.16	7/1/2009 0:00	7/14/2009 9:45	60				Rating Curve, 2012	NPCA
		LEVEL / FLOW	Welland River at SOUTHBROOK	596767.83	4771987.16	7/14/2009 9:45	10/23/2015 11:00	15				Rating Curve, 2012	NPCA
		LEVEL	Welland River at BINBROOK	595545.03	4772920.28	7/7/2009 0:00	12/4/2015 4:00	15					NPCA

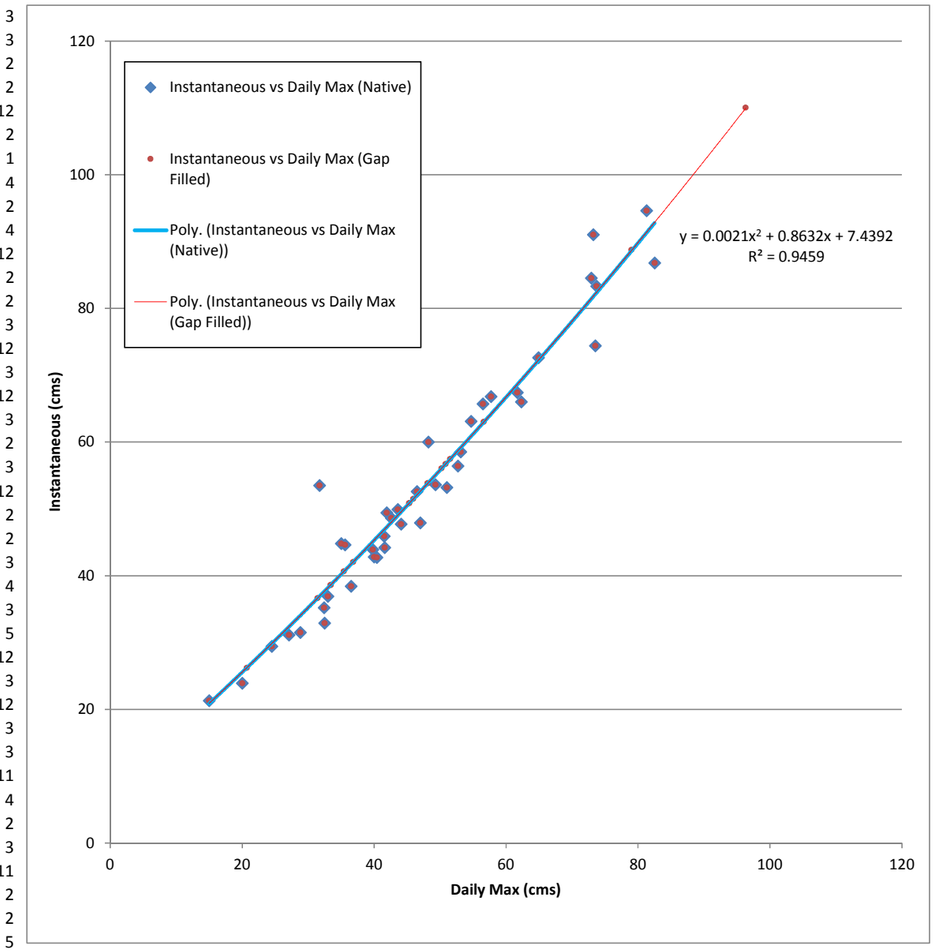
	6153194	EC WEATHER STATION	HAMILTON A	43°10'18.072" N	79°56'03.036" W	1959	2011	DAILY					EC
	6139445	EC WEATHER STATION	WELLAND	42°59'33.096" N	79°15'40.098" W	1872	2014	DAILY					EC
	02HA007	EC-WSC STREAMFLOW GAUGE	WELLAND RIVER BELOW CAISTOR CORNERS	43°1'18.4¨ N	79°37'4.9¨ W	1957	2010	DAILY					EC - WSC

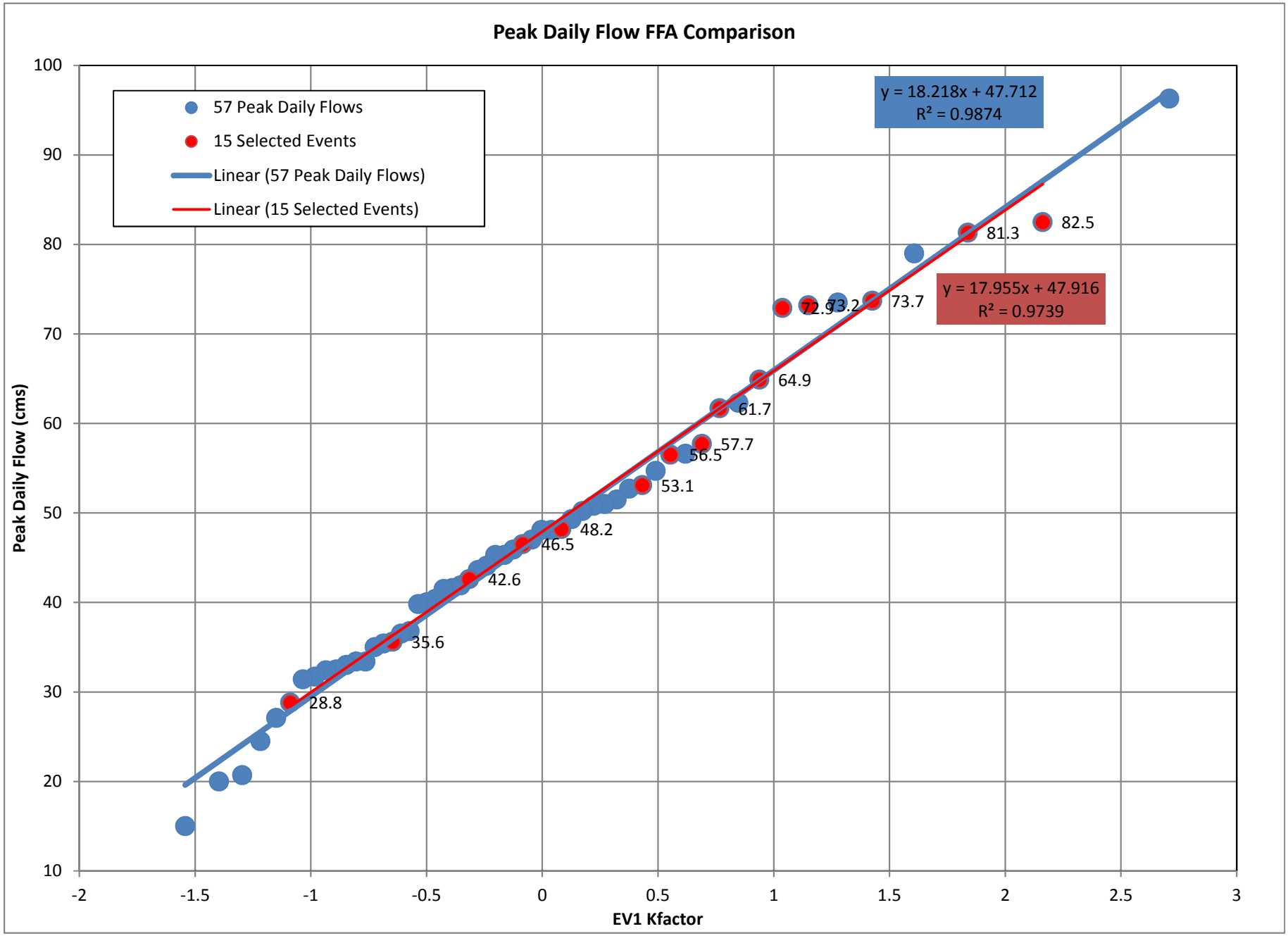
Year	MM--DD	MAX	SYM	LN(Max)	Rank	Empirical T	EV1 Kfactor	Selected
1959	03--21	96.3	E	4.567468	1	58.0	2.7091031	
2008	12--28	82.5		4.412798	2	29.0	2.1617885	x
2009	02--12	81.3		4.398146	3	19.3	1.8386758	x
1960	04--01	79	B	4.369448	4	14.5	1.6072919	
1990	12--30	73.7		4.300003	5	11.6	1.4261186	x
1984	02--14	73.5	A	4.297285	6	9.7	1.2766605	
2007	03--15	73.2		4.293195	7	8.3	1.1490496	x
2001	02--11	72.9		4.289089	8	7.3	1.0373937	x
2006	12--02	64.9		4.172848	9	6.4	0.9378907	x
2005	04--05	62.3		4.131961	10	5.8	0.8479426	
1976	03--06	61.7		4.122284	11	5.3	0.765695	x
2013	01--14	57.7		4.055257	12	4.8	0.689777	x
1965	02--11	56.6	B	4.036009	13	4.5	0.6191459	
2012	10--31	56.5		4.034241	14	4.1	0.5529897	x
2010	03--14	54.7		4.001864	15	3.9	0.4906629	
1995	11--12	53.1		3.972177	16	3.6	0.4316439	x
1969	01--31	52.7		3.964615	17	3.4	0.3755039	
1962	11--11	51.5	E	3.941582	18	3.2	0.3218864	
1973	12--28	51		3.931826	19	3.1	0.2704908	
1985	02--25	50.8	B	3.927896	20	2.9	0.2210609	
2011	03--06	50.2	B	3.916015	21	2.8	0.1733762	
1979	12--26	49.3		3.897924	22	2.6	0.1272449	
1996	04--14	48.2		3.875359	23	2.5	0.0824988	x
1971	02--28	48.1	B	3.873282	24	2.4	0.0389887	
1978	03--22	48.1	B	3.873282	25	2.3	-0.003419	
1977	12--16	47		3.850148	26	2.2	-0.044843	
1991	03--28	46.5		3.839452	27	2.1	-0.085395	x
1961	02--26	45.9		3.826465	28	2.1	-0.125173	
1963	03--18	45.3	B	3.813307	29	2.0	-0.164272	
1968	02--03	45.3	B	3.813307	30	1.9	-0.202778	
1986	03--11	44.1		3.78646	31	1.9	-0.240775	
1980	03--22	43.6		3.775057	32	1.8	-0.27834	
2014	05--16	42.6		3.751854	33	1.8	-0.315552	x
1998	03--27	41.9		3.735286	34	1.7	-0.352484	
1974	02--23	41.6		3.7281	35	1.7	-0.389211	
2000	02--26	41.5		3.725693	36	1.6	-0.42581	
1987	04--06	40.4		3.69883	37	1.6	-0.462356	
1982	03--15	40	B	3.688879	38	1.5	-0.49893	
1993	03--29	39.8	B	3.683867	39	1.5	-0.535616	
1994	03--23	36.8	B	3.605498	40	1.5	-0.572504	
1983	12--13	36.5		3.597312	41	1.4	-0.609691	
1999	11--03	35.6		3.572346	42	1.4	-0.647287	x
1975	02--25	35.4	B	3.566712	43	1.3	-0.685412	
1997	02--22	35		3.555348	44	1.3	-0.724208	
1966	02--12	33.4	B	3.508556	45	1.3	-0.763835	
1967	12--22	33.4		3.508556	46	1.3	-0.804488	
1981	02--18	33	B	3.496508	47	1.2	-0.846401	
2003	03--19	32.5	B	3.48124	48	1.2	-0.889865	
1992	12--31	32.4		3.478158	49	1.2	-0.93525	
2004	03--06	31.7		3.456317	50	1.2	-0.983044	
1964	03--15	31.4		3.446808	51	1.1	-1.033904	
2002	05--14	28.8		3.360375	52	1.1	-1.088768	x
1972	04--17	27.1		3.299534	53	1.1	-1.149038	
1970	04--03	24.5		3.198673	54	1.1	-1.216975	
1958	03--02	20.7		3.030134	55	1.1	-1.296642	
1988	03--26	20		2.995732	56	1.0	-1.396679	
1989	05--12	15		2.70805	57	1.0	-1.542624	

$$K = -\left[\frac{(6)^{1/2}\,(0.5772 + \ln\ln T/T - 1)}{\pi}\right]$$

ID	PARAM	Year	PeakFlowMax	SYM	HH:MM	CODE	MM--DD	MaxAnnualFlow	SYM	MM--DD	MinAnnual	SYM	MM--DD	MM
02HA007	1	1958	26.2					20.7		03--02	0		07--18	3
02HA007	1	1959	110.0					96.3	E	03--21	0		06--19	3
02HA007	1	1960	88.7					79	B	04--01	0	B	03--09	4
02HA007	1	1961	51.5					45.9		02--26	0	B	01--21	2
02HA007	1	1962	57.5					51.5	E	11--11				11
02HA007	1	1963	50.9					45.3	B	03--18	0		07--07	3
02HA007	1	1964	36.6					31.4		03--15	0		06--23	3
02HA007	1	1965	63.0					56.6	B	02--11	0		06--28	2
02HA007	1	1966	38.6					33.4	B	02--12	0		07--09	2
02HA007	1	1967	38.6					33.4		12--22	0		06--26	12
02HA007	1	1968	50.9					45.3	B	02--03	0	B	01--15	2
02HA007	1	1969	56.4		17:00	EST	01--31	52.7		01--31	0		08--16	1
02HA007	1	1970	29.4		18:46	EST	12--04	24.5		04--03	0.006	B	01--26	4
02HA007	1	1971	53.8					48.1	B	02--28	0		07--15	2
02HA007	1	1972	31.1		1:05	EST	12--07	27.1		04--17	0.023	B	02--13	4
02HA007	1	1973	53.2		10:31	EST	12--28	51		12--28	0.093		06--21	12
02HA007	1	1974	44.2		5:52	EST	02--23	41.6		02--23	0.027		07--17	2
02HA007	1	1975	40.6					35.4	B	02--25	0.014		07--07	2
02HA007	1	1976	67.4		2:30	EST	03--06	61.7		03--06	0.022		06--14	3
02HA007	1	1977	47.9		9:02	EST	12--16	47		12--16	0.011		05--30	12
02HA007	1	1978	53.8					48.1	B	03--22	0.031		06--06	3
02HA007	1	1979	53.6		1:46	EST	12--26	49.3		12--26	0.039		07--24	12
02HA007	1	1980	49.9		0:33	EST	03--22	43.6		03--22	0.016		07--21	3
02HA007	1	1981	36.9		23:30	EST	02--17	33	B	02--18	0.02		07--18	2
02HA007	1	1982	42.8		0:16	EST	12--26	40	B	03--15	0.034		05--22	3
02HA007	1	1983	38.4		6:15	EST	12--13	36.5		12--13	0.067		07--14	12
02HA007	1	1984	74.4		14:30	EST	02--14	73.5	A	02--14	0.071		08--21	2
02HA007	1	1985	56.7					50.8	B	02--25	0.001		08--03	2
02HA007	1	1986	47.7		2:44	EST	03--12	44.1		03--11	0.041		08--26	3
02HA007	1	1987	42.7		17:44	EST	04--05	40.4		04--06	0.079		05--29	4
02HA007	1	1988	23.9		11:37	EST	03--26	20		03--26	0		06--17	3
02HA007	1	1989	21.3		19:23	EST	05--12	15		05--12	0.065		07--19	5
02HA007	1	1990	83.3		17:47	EST	12--30	73.7		12--30	0.041		07--07	12
02HA007	1	1991	52.6		7:59	EST	03--28	46.5		03--28	0.009		07--03	3
02HA007	1	1992	35.2		11:26	EST	12--31	32.4		12--31	0.039	A	06--17	12
02HA007	1	1993	43.9		23:22	EST	03--29	39.8	B	03--29	0.033		08--13	3
02HA007	1	1994	42.0					36.8	B	03--23	0.027		07--27	3
02HA007	1	1995	58.5		6:25	EST	11--12	53.1		11--12	0.006		06--21	11
02HA007	1	1996	60		0:55	EST	04--14	48.2		04--14	0.027	E	07--09	4
02HA007	1	1997	44.8		20:00	EST	02--27	35		02--22	0.03		10--03	2
02HA007	1	1998	49.4		4:00	EST	03--27	41.9		03--27	0.009		08--29	3
02HA007	1	1999	44.6		13:49	EST	11--03	35.6		11--03	0.001		09--20	11
02HA007	1	2000	45.9		13:40	EST	06--15	41.5		02--26	0.007		09--18	2
02HA007	1	2001	84.5		2:35	EST	02--11	72.9		02--11	0.005		08--15	2
02HA007	1	2002	31.5		9:40	EST	05--14	28.8		05--14	0.003		07--13	5
02HA007	1	2003	32.9		11:01	EST	11--29	32.5	B	03--19	0.004		08--31	3
02HA007	1	2004	53.5		23:59	EST	12--31	31.7		03--06	0.006		10--11	3
02HA007	1	2005	66		1:10	EST	04--06	62.3		04--05	0		07--20	4
02HA007	1	2006	72.6		3:20	EST	12--02	64.9		12--02	0.003		07--08	12
02HA007	1	2007	91		23:51	EST	03--14	73.2		03--15	0		07--03	3
02HA007	1	2008	86.8		10:48	EST	12--28	82.5		12--28	0.013		07--18	12
02HA007	1	2009	94.6		20:55	EST	02--12	81.3		02--12	0.02		06--27	2
02HA007	1	2010	63.1		21:15	EST	03--14	54.7		03--14	0.006		07--08	3
02HA007	1	2011	56.1			EST		50.20	B	03--06				3
02HA007	1	2012	65.7		23:45	EST	10--30	56.50		10--31				10
02HA007	1	2013	66.8		22:35	EST	01--13	57.70		01--14				1
02HA007	1	2014	48.6		18:15	EST	05--13	42.60		05--16				5

Data Gap filled




Peak Daily Flow FFA Comparison
57 Peak Daily Flows
15 Selected Events
Linear (57 Peak Daily Flows)
Linear (15 Selected Events)
y = 18.218x + 47.712
R² = 0.9874
y = 17.955x + 47.916
R² = 0.9739
82.5
81.3
73.7
73.2
72.9
64.9
61.7
57.7
56.5
53.1
48.2
46.5
42.6
35.6
28.8
Peak Daily Flow (cms)
EV1 Kfactor
100
90
80
70
60
50
40
30
20
10
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3

APPENDIX E – Rainfall Runoff Events

WELLAND RIVER HYDROLOGY

August 22, 2016

September 12, 2016

Events #	Year	Period		Hourly Peak Discharge Rate - Baseflow Substracted	Total Runoff Volume - Baseflow Substracted	Peak Rainfall Intensity	Peak Equ. Precip. Intensity	Total Rain Depth	Total Equivalent Snowwater Depth	Total Precipitation Depth	Runoff / Total Precipitation	Hourly Peak Baseflow	Hourly Peak Discharge Rate	Daily Peak Discharge Rate from EC Station	NOTE
		From	To	cms	mm	mm/hr	mm/hr	mm	mm	mm	%	cms	cms	cms	
1	1961	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	45.9	Data Record N/A
2	1967	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	33.4	Data Record N/A
3	1973	12/27/73 1:00 AM	12/30/73 11:00 PM	9.6	3.7	0.8	0.8	4.6	0.0	4.6	80%	43.5	53.1	51	All Rain, Insignificant Amount Runoff Direclty from Rainfall. Most Baseflow from Snowmelt before events
4	1976	3/3/76 7:00 PM	3/8/76 11:00 PM	55.1	44.0	12.5	12.7	34.8	16.6	51.4	86%	11.7	66.8	61.7	Mixed Snow Rain - Majority Snow; Precipitation: Daily Data Three (3) Days before Hourly Data, Hourly Data Used.
5	1983	12/11/83 12:00 PM	12/15/83 11:00 PM	21.8	10.4	2.9	2.9	13.4	0.0	13.4	78%	16.6	38.4	36.5	All Rain, Most Baseflow from Snowmelt before events
6	1990	12/28/90 1:00 AM	12/31/90 11:00 PM	80.8	48.7	6.4	6.8	67.9	9.7	77.6	63%	2.6	83.4	73.7	Mixed Snow Rain - Majority Rain; Precipitation: Daily Data One (1) Day before Hourly Data, Hourly Data Used.
7	1995	11/10/95 1:00 AM	11/14/95 11:00 PM	45.3	36.0	4.6	4.6	47.6	0.0	47.6	76%	1.0	46.3	53.1	All Rain
8	2000	2/24/00 1:00 AM	2/28/00 11:00 PM	14.4	9.2	1.8	1.8	11.2	0.0	11.2	82%	28.3	42.7	41.5	All Rain, Most Baseflow from Snowmelt before events
9	2001	2/8/01 1:00 AM	2/14/01 6:00 PM	63.4	45.9	10.5	10.8	41.1	17.5	58.6	78%	21.0	84.4	72.9	Mixed Snow Rain - Majority Rain
10	2002	5/11/02 12:00 PM	5/16/02 11:00 PM	30.1	19.8	3.0	3.0	34.8	0.0	34.8	57%	1.3	31.4	28.8	All Rain
11	2005	4/1/05 1:00 AM	4/7/05 11:00 PM	37.8	38.7	2.1	2.2	18.9	28.5	47.4	82%	21.0	58.7	62.3	Precipitation: Total Daily Depth ≠ Total Hourly Depth; Hourly Data Used.
12	2006	11/30/06 12:00 AM	12/4/06 11:00 PM	71.9	50.7	7.9	7.9	57.0	0.0	57.0	89%	21.0	92.9	64.9	All Rain
13	2007	3/13/07 12:00 AM	3/17/07 11:00 PM	73.7	49.5	0.0	7.7	0.0	53.7	53.7	92%	21.0	94.7	73.2	All Snow
14	2008	12/24/08 1:00 AM	12/30/08 10:00 PM	27.0	9.9	8.0	8.7	10.8	11.3	22.1	45%	59.8	86.7	82.5	Mixed Snow Rain - Majority Snow / Adjust Hyetograph for Calibration
15	2009	2/10/09 12:00 AM	2/14/09 6:00 PM	78.2	57.3	21.0	21.0	33.6	33.3	66.9	86%	21.0	99.2	81.3	Mixed Snow Rain
16	2013	1/12/13 12:00 AM	1/16/13 11:00 PM	56.8	36.7	38.0	38.0	44.5	0.0	44.5	83%	10.0	66.8	57.7	All Rain - Isolated Sigificant Peak Intensity during an hour
17	1984	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	73.5	Data Record Incompleted
18	1991	3/27/91 12:00 AM	3/31/91 11:00 PM	50.0	30.7	10.9	10.9	36.1	0.0	36.1	85%	2.6	52.6	46.5	New Events - All Rain
19	1996	4/12/96 12:00 AM	4/16/96 11:00 PM	57.9	42.2	6.1	6.1	67.3	0.0	67.3	63%	1.7	59.6	48.2	New Events - All Rain
20	1997	2/21/97 12:00 AM	2/25/97 11:00 PM	9.9	3.1	1.8	1.8	6.0	0.0	6.0	51%	28.7	38.6	35	Large amount of snow melt before events - Sigificant high base flow - Calibration not applicable
21	1999	11/2/99 12:00 AM	11/6/99 11:00 PM	44.6	30.9	7.9	7.9	58.8	0.0	58.8	53%	0.0	44.6	35.6	New Events - All Rain
22	2012	10/29/12 12:00 AM	11/2/12 11:00 PM	53.8	36.4	4.7	4.7	48.0	0.0	48.0	76%	11.6	65.4	56.5	New Events - All Rain
23	2014	5/13/14 12:00 AM	5/15/14 5:00 AM	30.4	12.7	19.0	19.0	20.9	0.0	20.9	61%	10.0	40.4	42.6	New Events - All Rain - Observed Two Peaks, the First (Highest) is Used

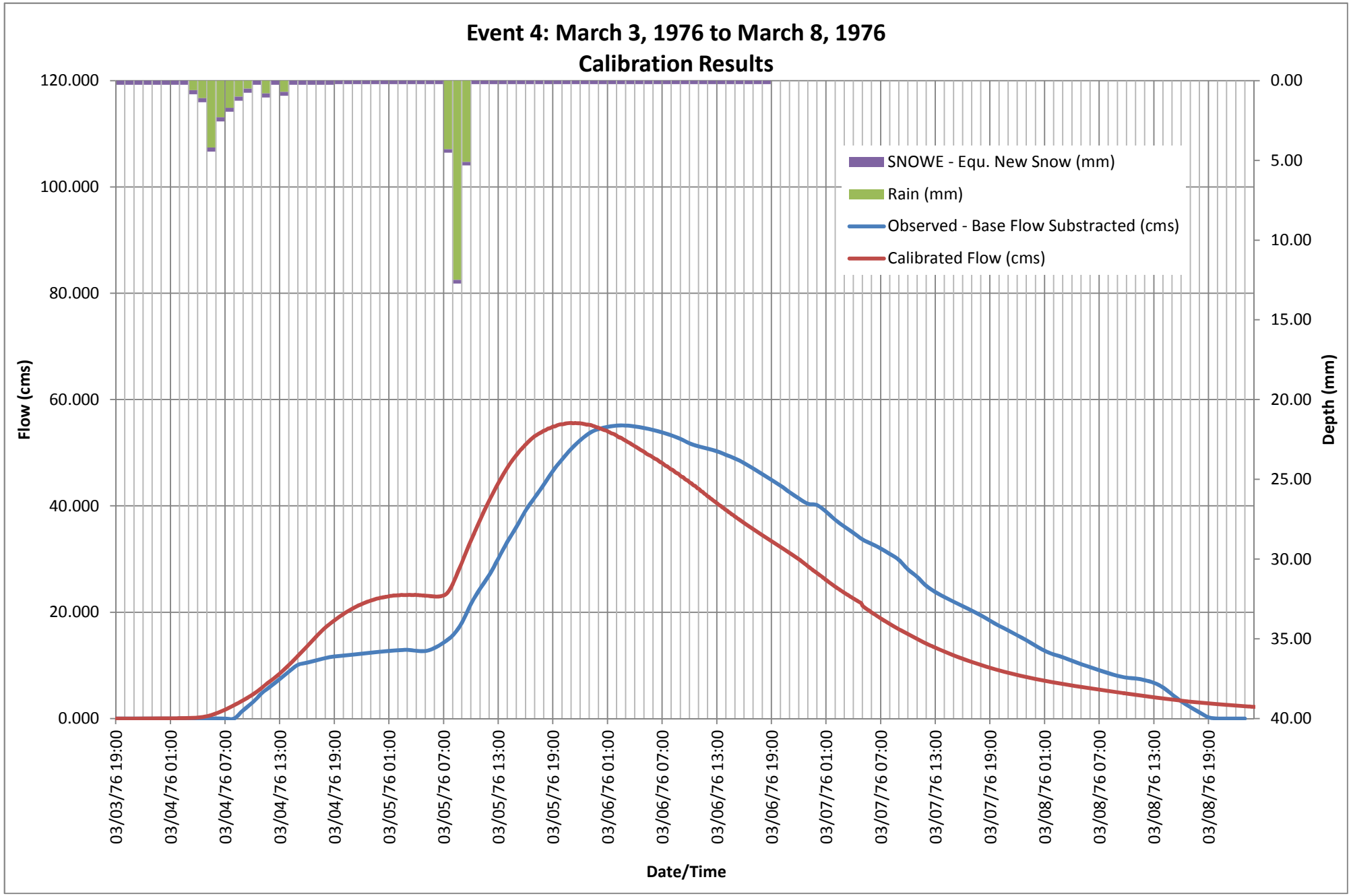
Calbrated Events

APPENDIX F – Calibration Results

Welland Hydrology, MMM
22-Aug-16
27-Sep-16
Hydrological Model Calibration Results

#	Events	Year	CALIBRATION #	Multiplier - CN - NASHYD	Multiplier - N - NASHYD	Multiplier - Tp - NASHYD	Channel Roughness	Runoff Volume - cu. M. (Observed)	Runoff Volume - cu.m. (Simulated)	Runoff Volume Difference	Peak Flow * - cms (Observed)	Peak Flow * - cms (Simulated)	Peak Flow Difference
1	4	1976	4.05.REV	1.185	0.7	1.35	1	10126026	9649071.41	-4.7%	55.125	53.612	-2.7%
2	6	1990	6.04.REV	1.1	0.9	1.2	1	11200579.2	12289688.24	9.7%	80.774	77.519	-4.0%
3	7	1995	7.04.REV	1.17	0.55	1.7	1	8286307.2	8129910.468	-1.9%	45.323	44.231	-2.4%
4	9	2001	9.03.REV	1.3	0.7	1.3	1	10566054	10153988.07	-3.9%	63.402	62.081	-2.1%
5	10	2002	10.04.REV	1.13	1	1.3	1	4553686.8	4556641.965	0.1%	30.084	29.697	-1.3%
6	12	2006	12.04.REV	1.18	0.75	1.3	1	11661044.4	10670154.64	-8.5%	71.945	69.948	-2.8%
7	13	2007	13.04.REV	1.185	0.7	1.35	1	11376230.4	10172511.7	-10.6%	73.739	71.484	-3.1%
8	14	2008	14.02.REV	1.185	0.8	1.2	1	2286630	3388143.665	48.2%	26.952	27.173	0.8%
9	15	2009	15.04.REV	1.18	0.6	1.25	1	13181490	12791501.62	-3.0%	78.218	73.953	-5.5%
10	16	2013	16.03.REV	1.18	0.7	1.5	1	8448400.8	7991509.015	-5.4%	56.76	54.625	-3.8%
11	18	1991	18.03.REV	1.185	0.9	1.1	1	7062111	6409874.247	-9.2%	50.045	48.32	-3.4%
12	19	1996	19.03.REV	1.05	0.7	1.5	1	9704966.4	8913142.505	-8.2%	57.939	56.78	-2.0%
13	21	1999	21.03.REV	1.05	0.57	1.5	1	7110527.58	7119066.802	0.1%	44.557	43.643	-2.1%
14	22	2012	22.03.REV	1.17	0.8	1.3	1	8370963	8264720.802	-1.3%	53.775	52.192	-2.9%
15	23	2014	23.01.REV	1.185	1	1	1	2910978	3251990.524	11.7%	30.383	30.049	-1.1%
SUMMARY				**1.162**	**0.758**	**1.323**				**0.9%**			**-2.6%**

* Baseflow substracted


Event 4: March 3, 1976 to March 8, 1976
Calibration Results
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
Flow (cms)
Depth (mm)
Date/Time
120.000
100.000
80.000
60.000
40.000
20.000
0.000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
03/03/76 19:00
03/04/76 01:00
03/04/76 07:00
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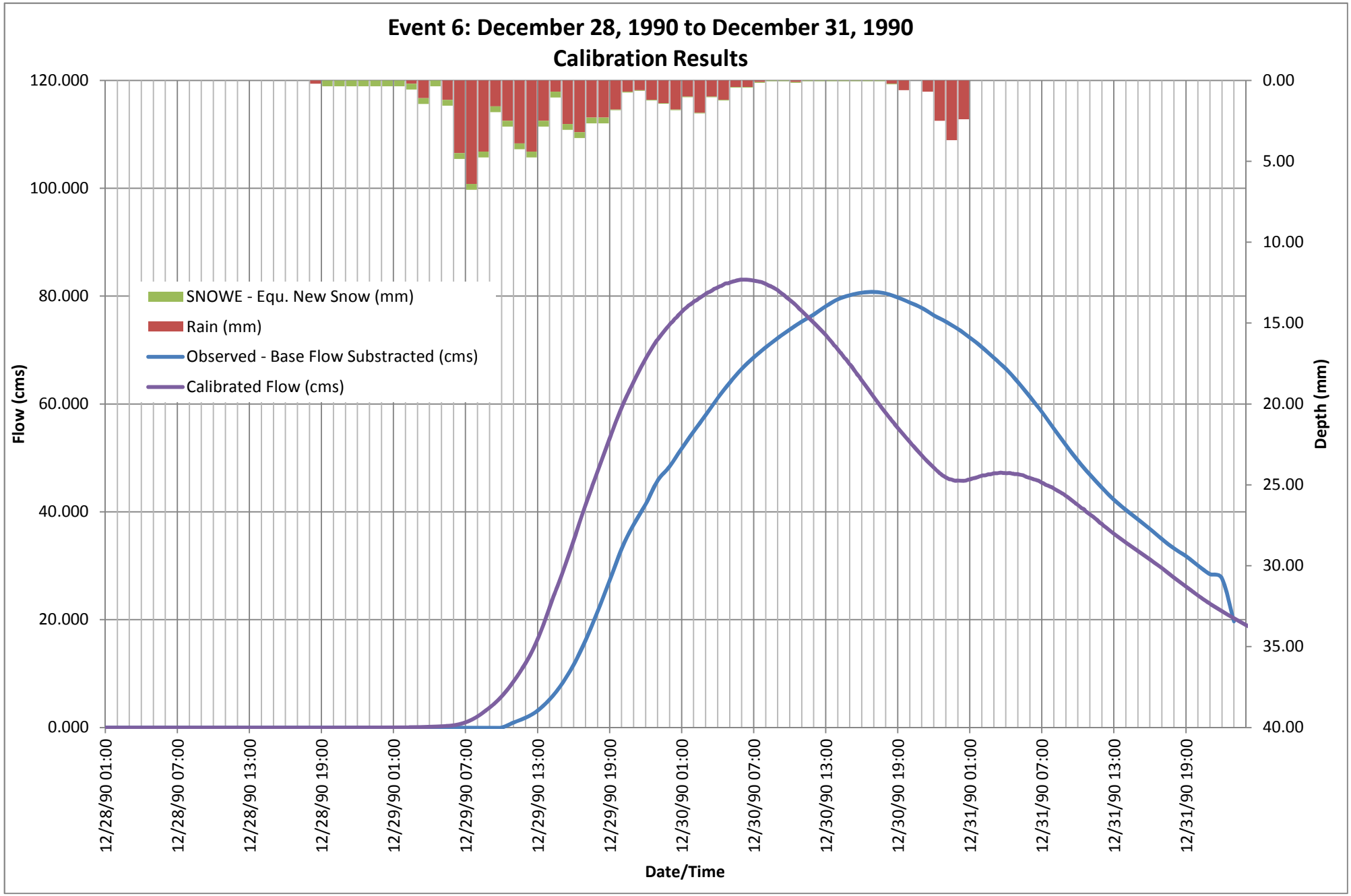
Event 6: December 28, 1990 to December 31, 1990
Calibration Results
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
Flow (cms)
Depth (mm)
Date/Time
120.000
100.000
80.000
60.000
40.000
20.000
0.000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
12/28/90 01:00
12/28/90 07:00
12/28/90 13:00
12/28/90 19:00
12/29/90 01:00
12/29/90 07:00
12/29/90 13:00
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12/30/90 07:00
12/30/90 13:00
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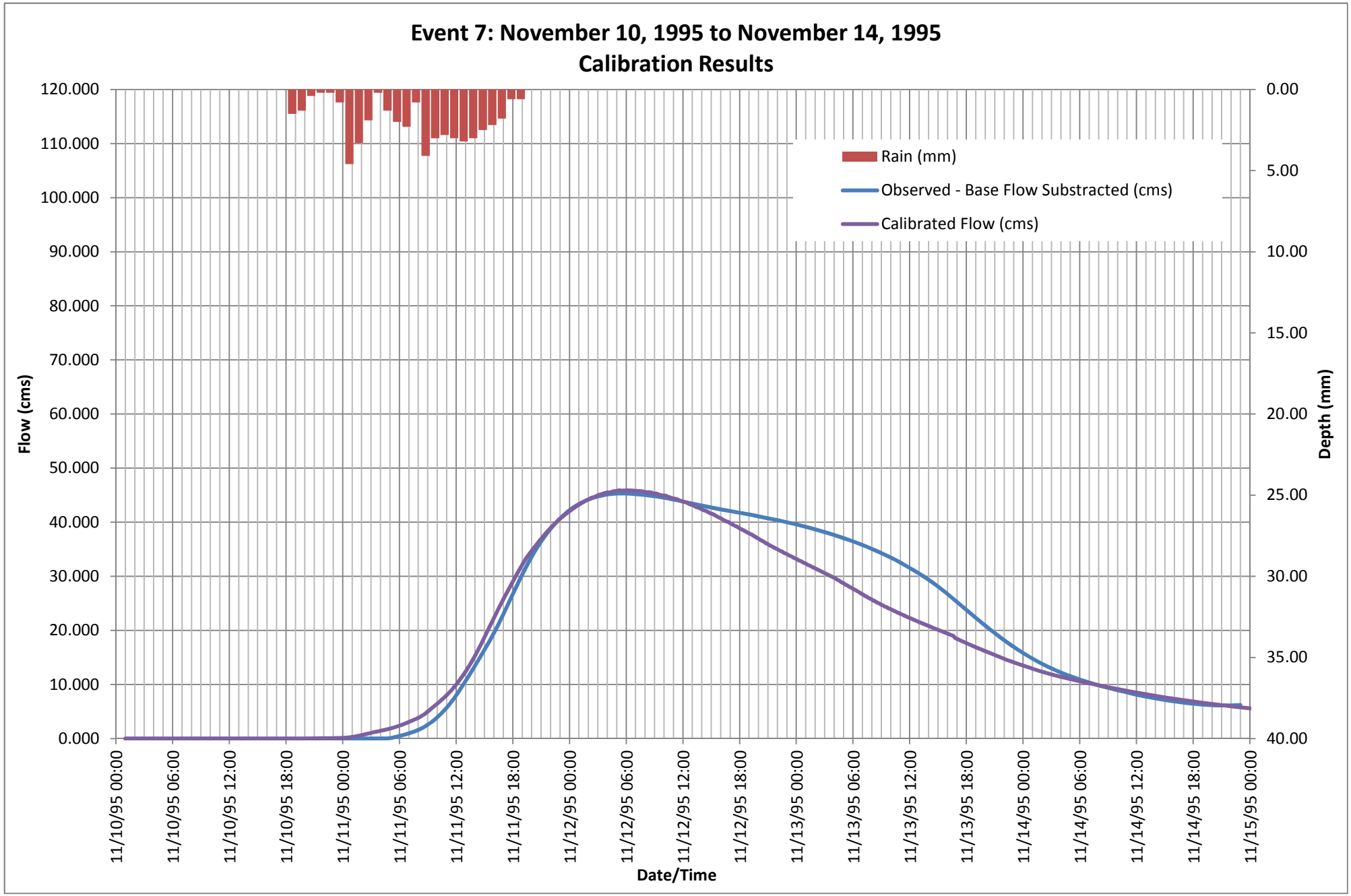
12/31/90 07:00
12/31/90 13:00
12/31/90 19:00


Event 7: November 10, 1995 to November 14, 1995
Calibration Results
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
Flow (cms)
Depth (mm)
Date/Time
120.000
110.000
100.000
90.000
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
11/10/95 00:00
11/10/95 06:00
11/10/95 12:00
11/10/95 18:00
11/11/95 00:00
11/11/95 06:00
11/11/95 12:00
11/11/95 18:00
11/12/95 00:00
11/12/95 06:00
11/12/95 12:00
11/12/95 18:00
11/13/95 00:00
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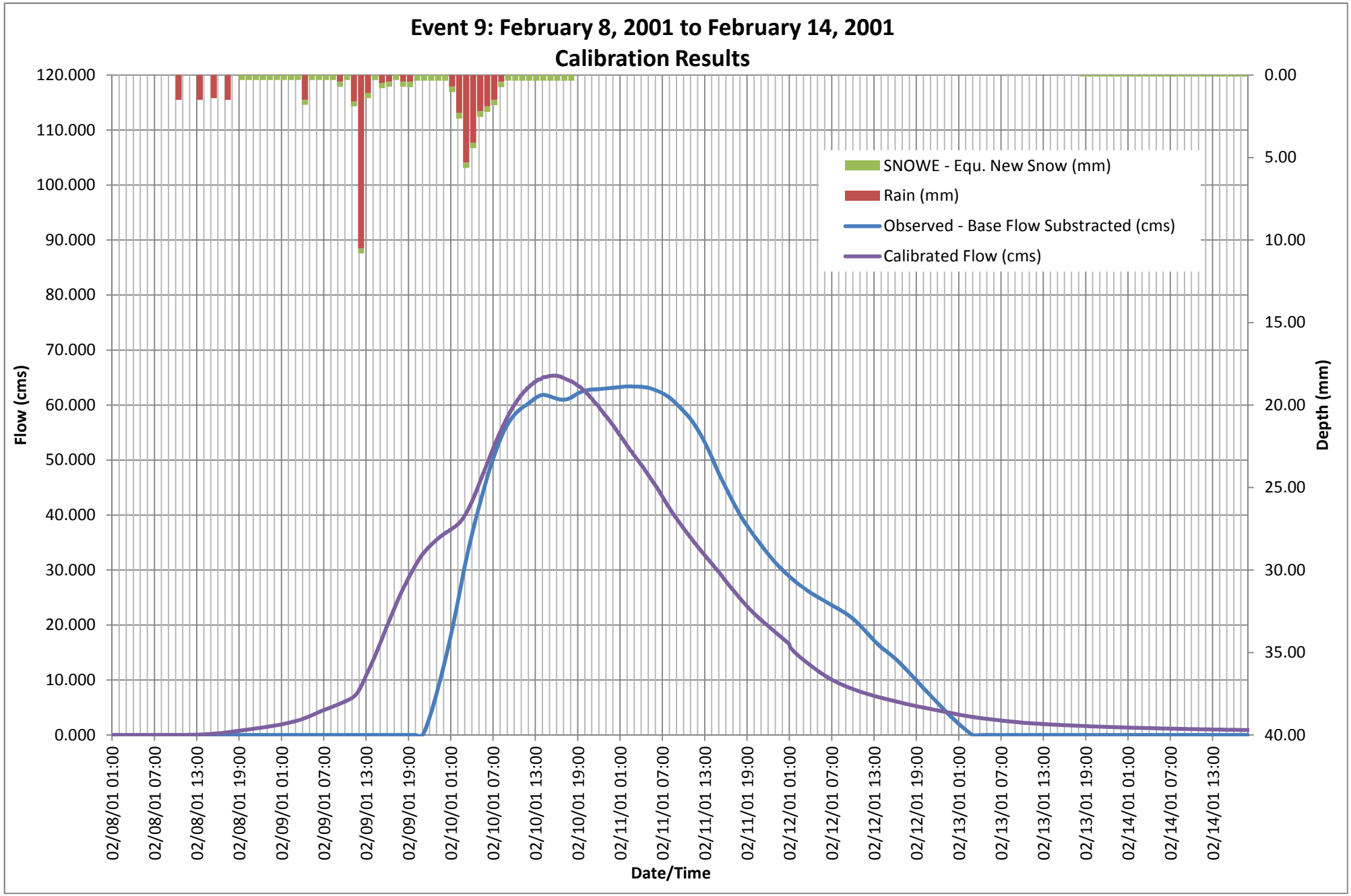
Event 9: February 8, 2001 to February 14, 2001
Calibration Results
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
Flow (cms)
Depth (mm)
Date/Time
120.000
110.000
100.000
90.000
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
02/08/01 01:00
02/08/01 07:00
02/08/01 13:00
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02/09/01 07:00
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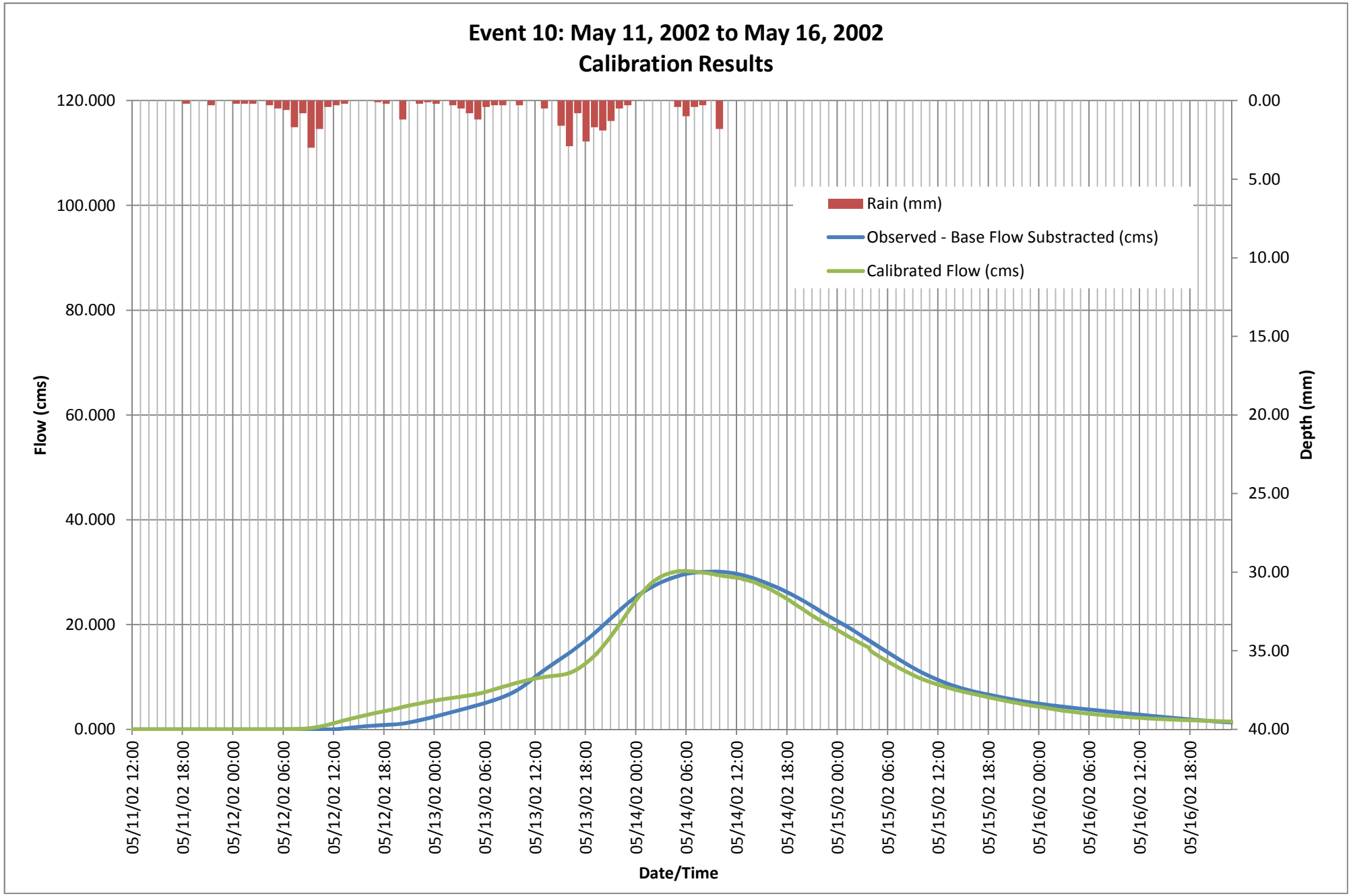
02/14/01 07:00
02/14/01 13:00


Event 10: May 11, 2002 to May 16, 2002
Calibration Results
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
Flow (cms)
Depth (mm)
Date/Time
120.000
100.000
80.000
60.000
40.000
20.000
0.000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
05/11/02 12:00
05/11/02 18:00
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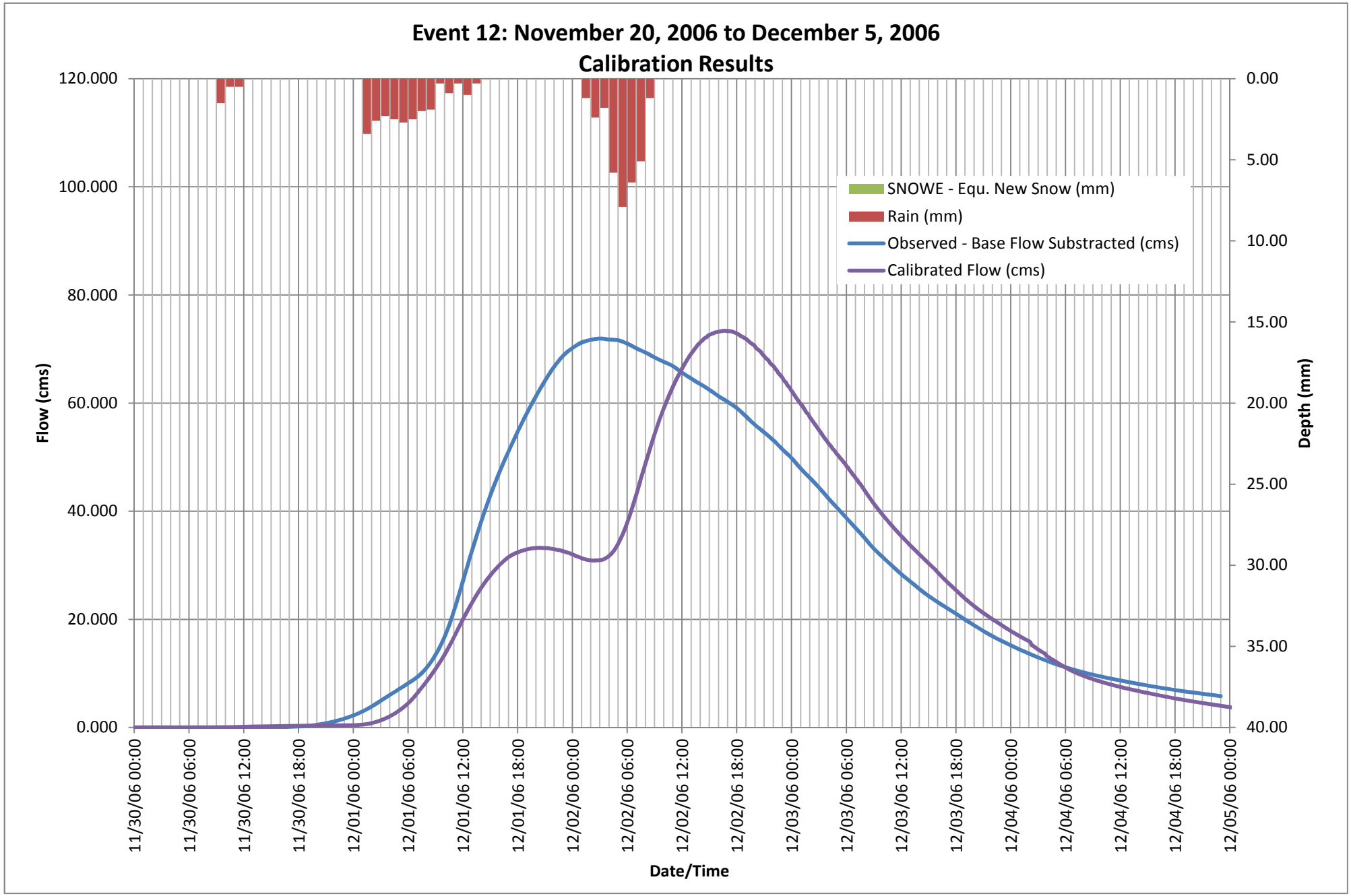
05/16/02 18:00


Event 12: November 20, 2006 to December 5, 2006
Calibration Results
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
Flow (cms)
Depth (mm)
Date/Time
120.000
100.000
80.000
60.000
40.000
20.000
0.000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
11/30/06 00:00
11/30/06 06:00
11/30/06 12:00
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12/01/06 06:00
12/01/06 12:00
12/01/06 18:00
12/02/06 00:00
12/02/06 06:00
12/02/06 12:00
12/02/06 18:00
12/03/06 00:00
12/03/06 06:00
12/03/06 12:00
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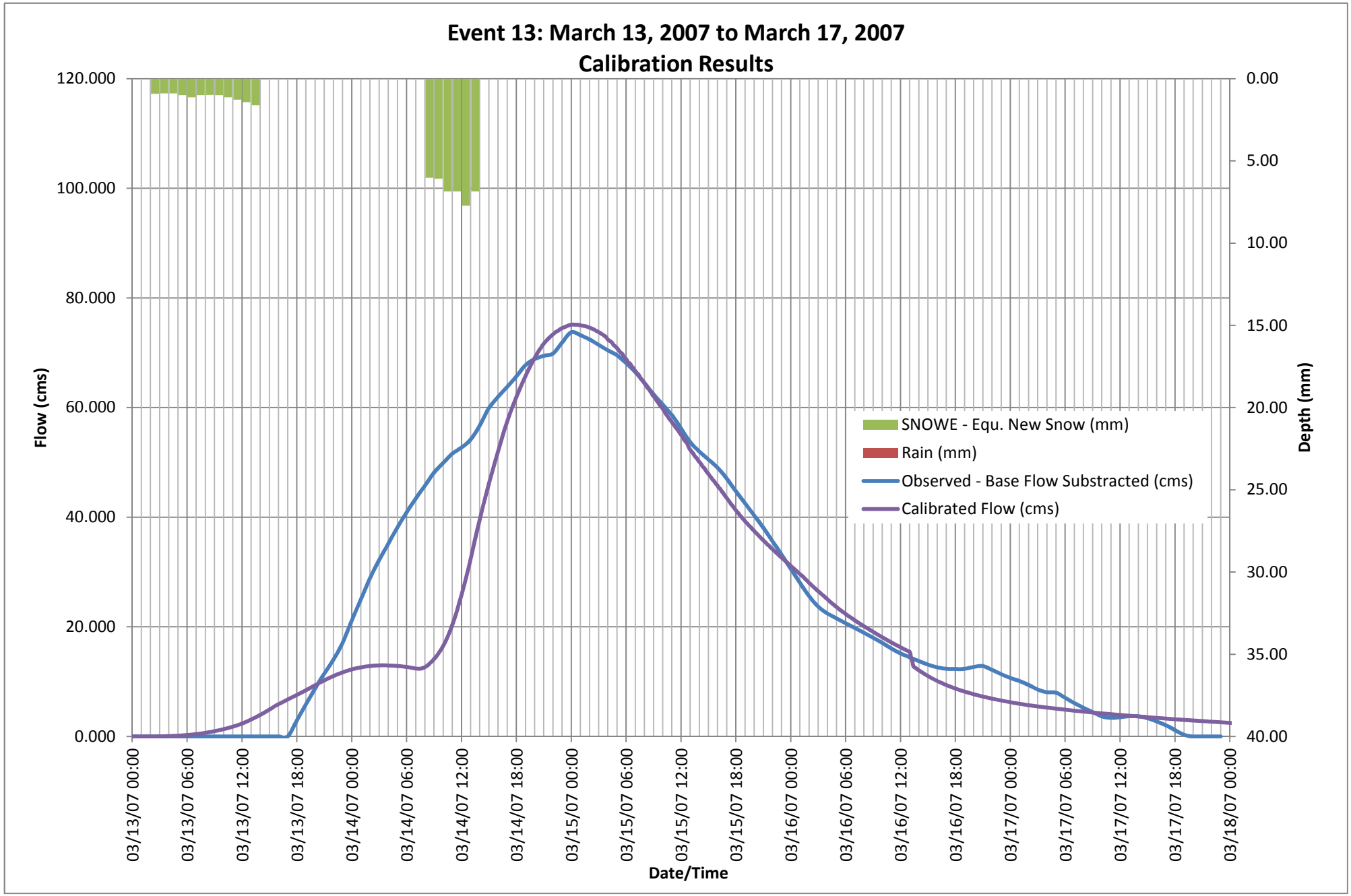
12/04/06 18:00
12/05/06 00:00


Event 13: March 13, 2007 to March 17, 2007
Calibration Results
Flow (cms)
Depth (mm)
Date/Time
120.000
100.000
80.000
60.000
40.000
20.000
0.000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
03/13/07 00:00
03/13/07 06:00
03/13/07 12:00
03/13/07 18:00
03/14/07 00:00
03/14/07 06:00
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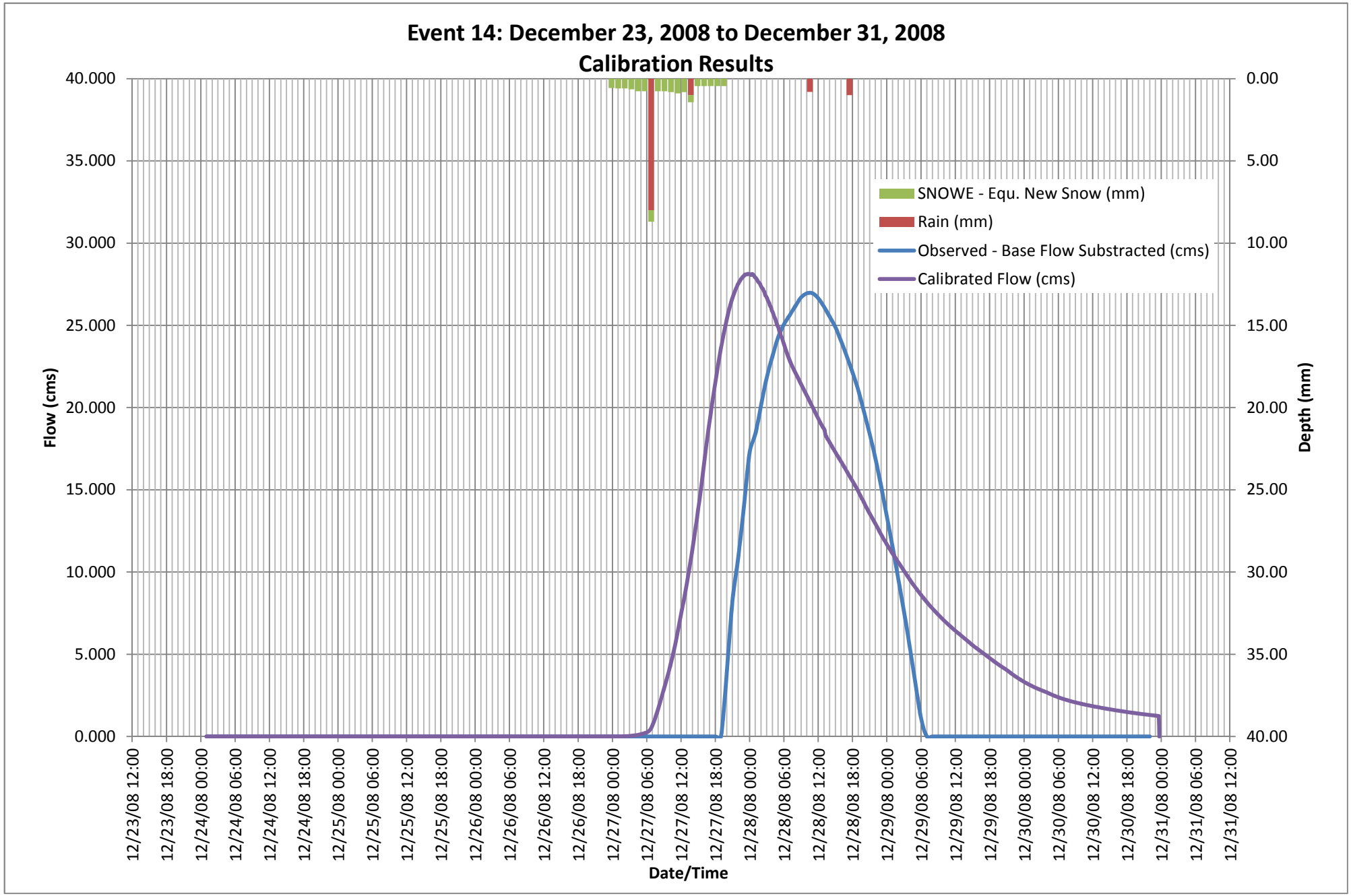
03/16/07 06:00
03/16/07 12:00
03/16/07 18:00
03/17/07 00:00
03/17/07 06:00
03/17/07 12:00
03/17/07 18:00
03/18/07 00:00
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)


Event 14: December 23, 2008 to December 31, 2008
Calibration Results
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
Flow (cms)
Depth (mm)
Date/Time
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
0.00
5.00
10.00
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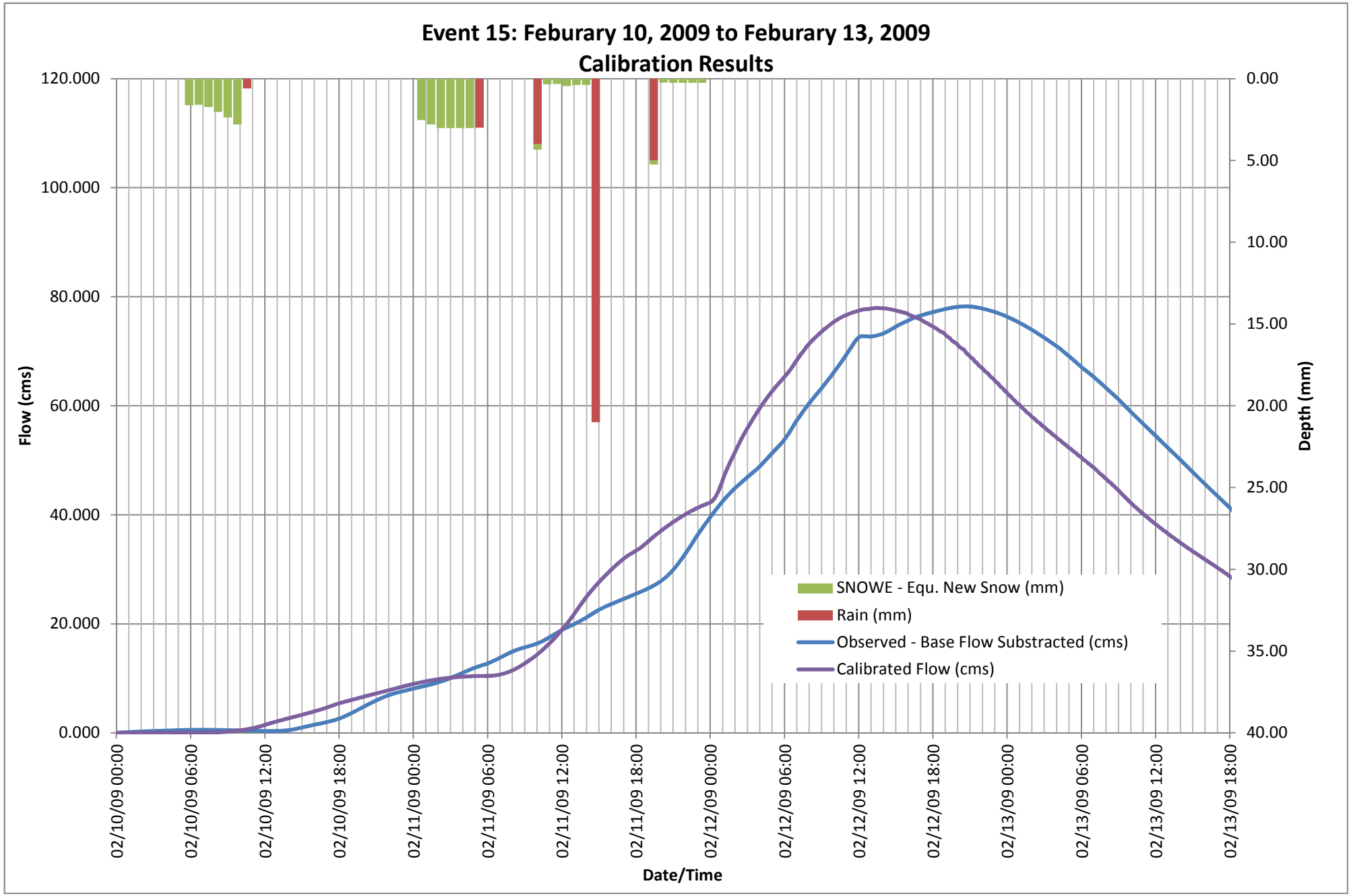
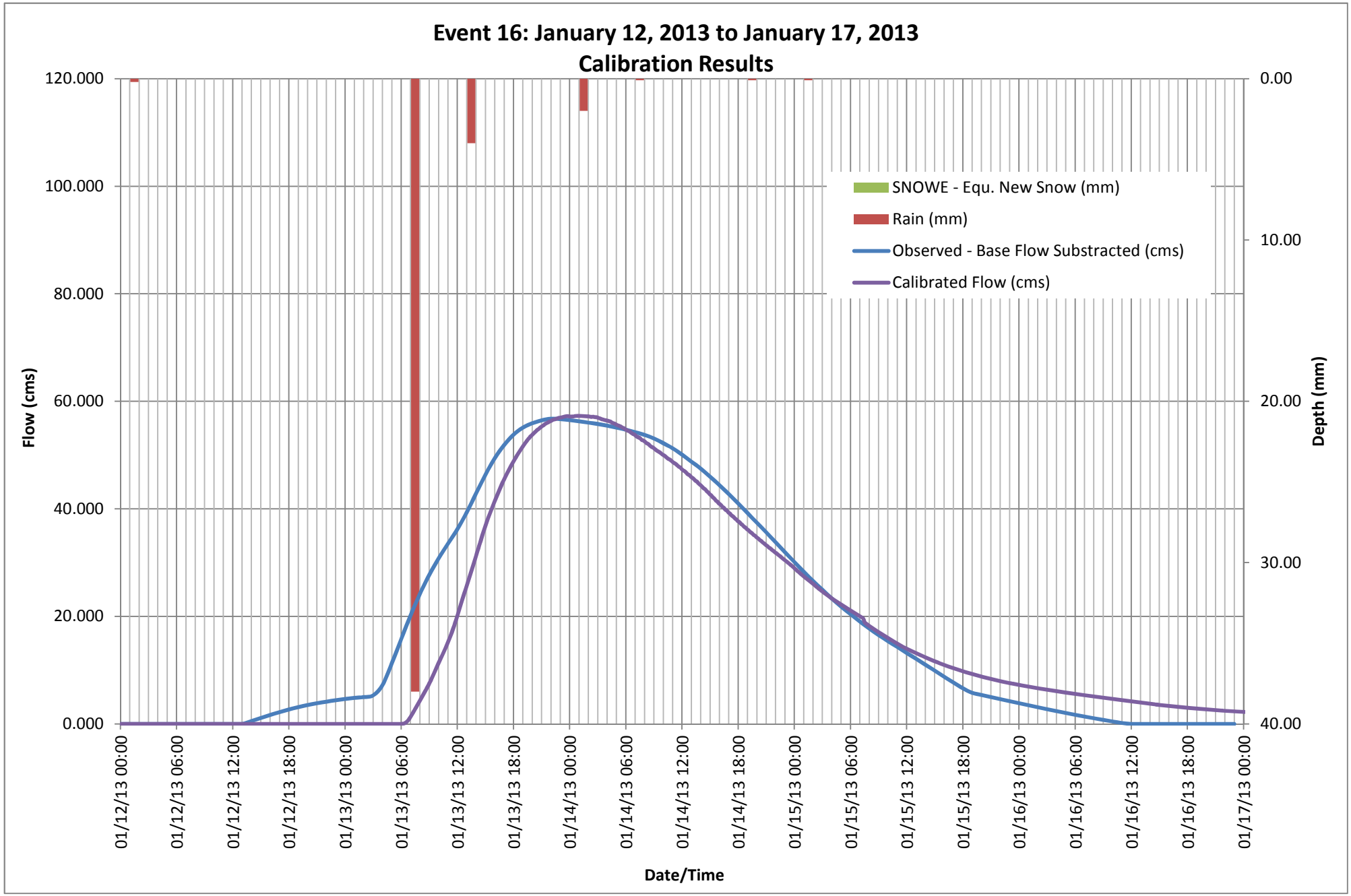
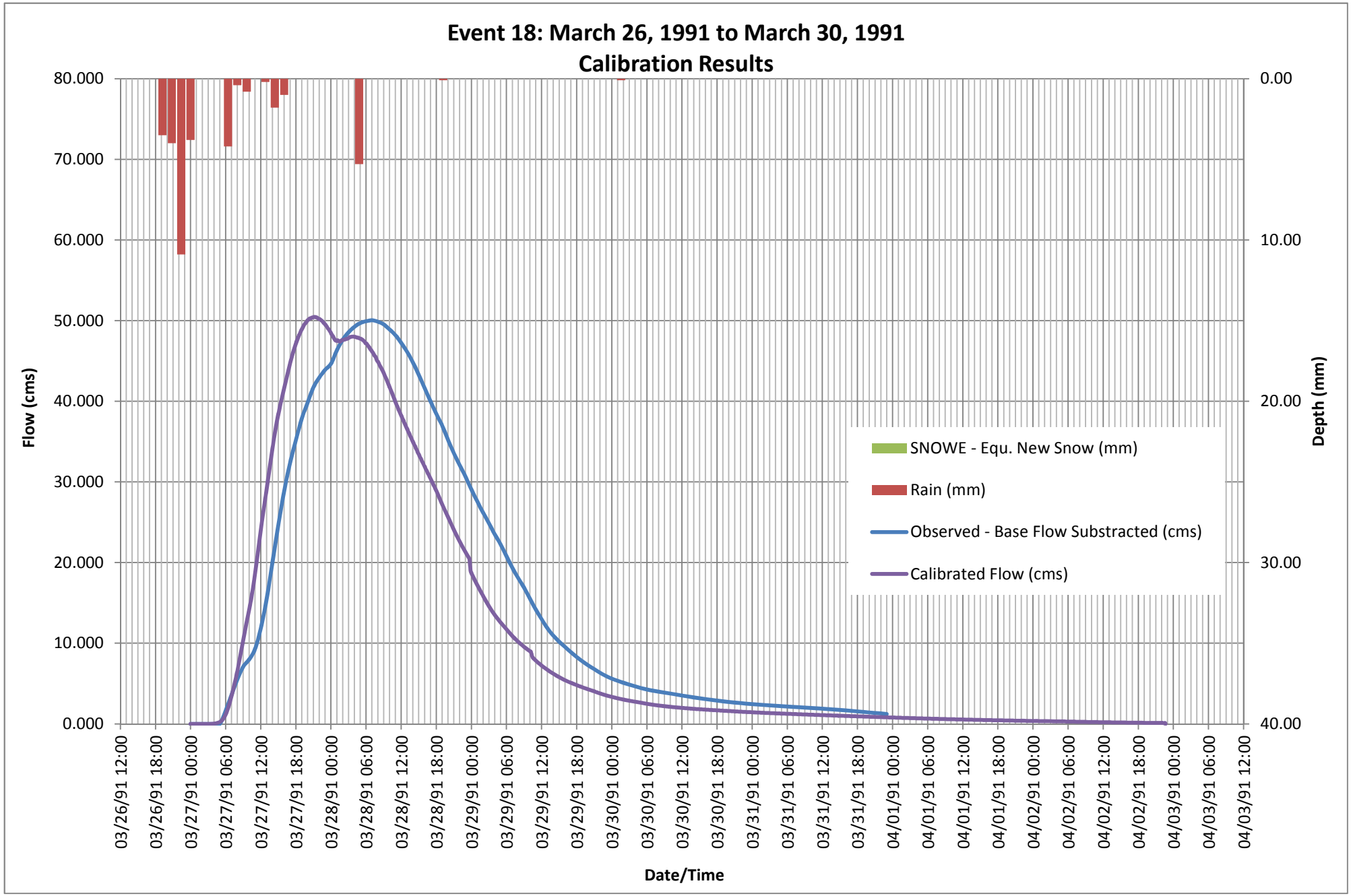
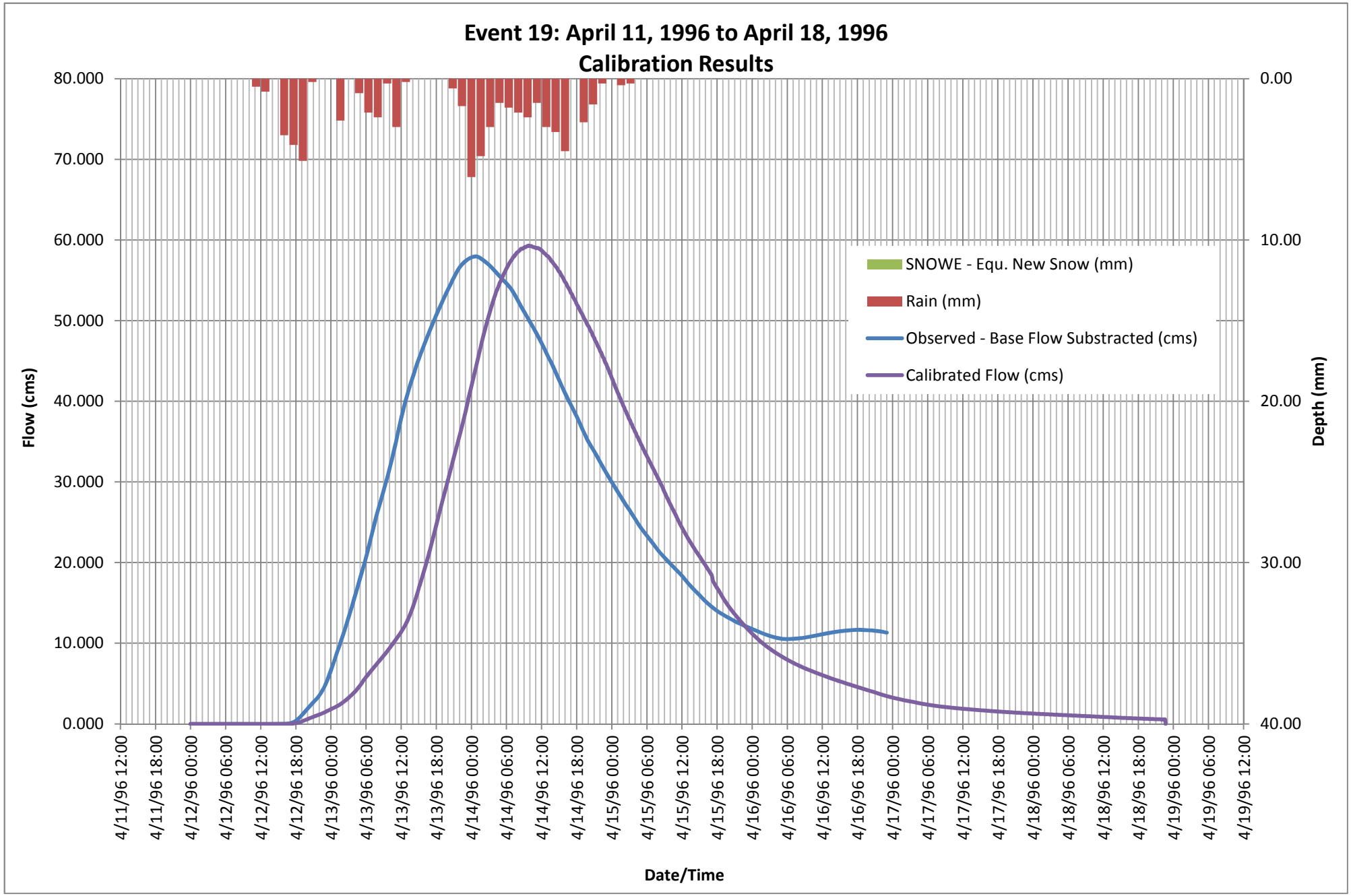
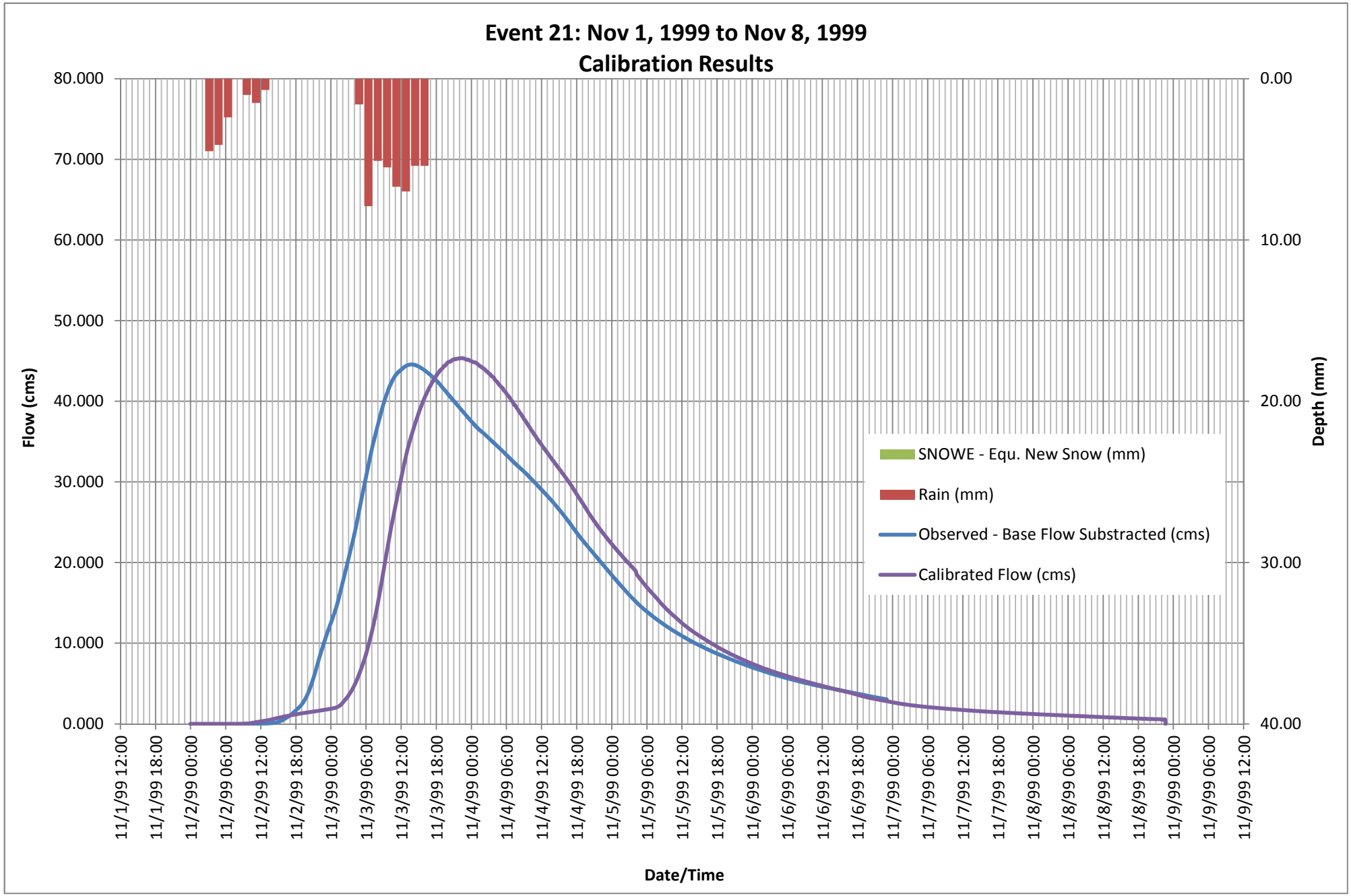
12/30/08 12:00
12/30/08 18:00
12/31/08 00:00
12/31/08 06:00
12/31/08 12:00

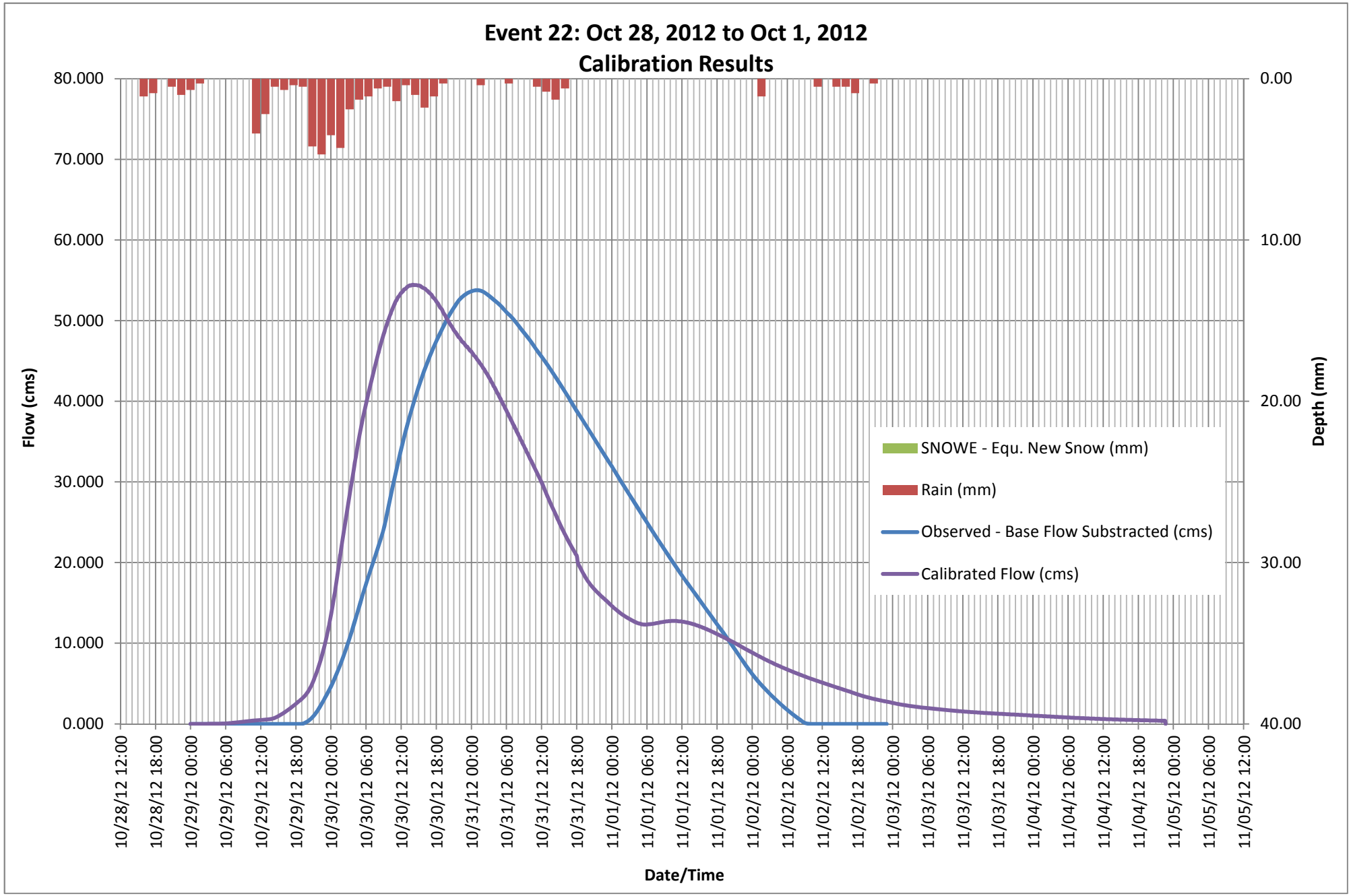

Event 15: Feburary 10, 2009 to Feburary 13, 2009
Calibration Results
Flow (cms)
Depth (mm)
Date/Time
120.000
100.000
80.000
60.000
40.000
20.000
0.000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
02/10/09 00:00
02/10/09 06:00
02/10/09 12:00
02/10/09 18:00
02/11/09 00:00
02/11/09 06:00
02/11/09 12:00
02/11/09 18:00
02/12/09 00:00
02/12/09 06:00
02/12/09 12:00
02/12/09 18:00
02/13/09 00:00
02/13/09 06:00
02/13/09 12:00
02/13/09 18:00
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)

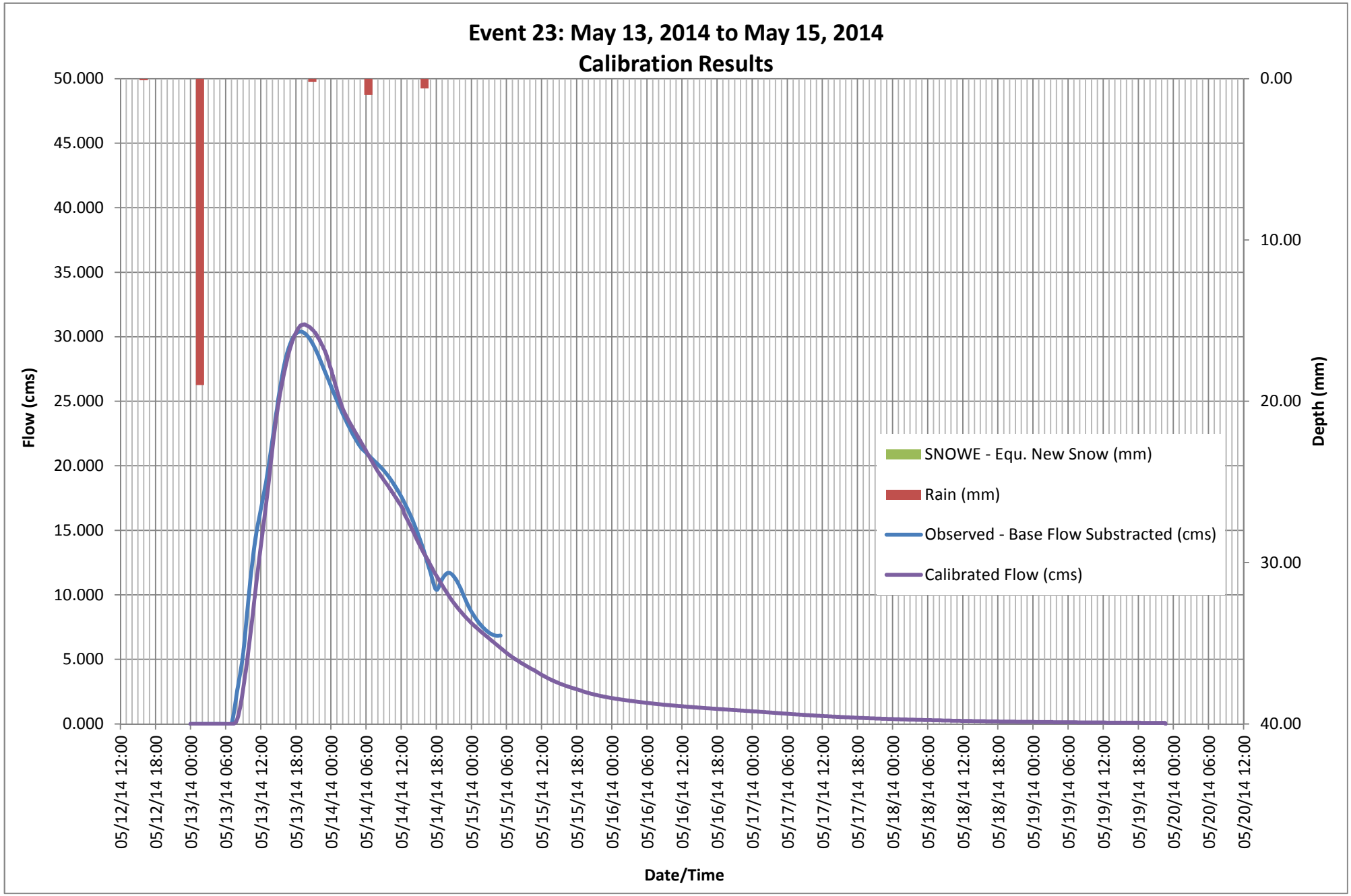

Event 16: January 12, 2013 to January 17, 2013
Calibration Results
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
Flow (cms)
Depth (mm)
Date/Time
120.000
100.000
80.000
60.000
40.000
20.000
0.000
0.00
10.00
20.00
30.00
40.00
01/12/13 00:00
01/12/13 06:00
01/12/13 12:00
01/12/13 18:00
01/13/13 00:00
01/13/13 06:00
01/13/13 12:00
01/13/13 18:00
01/14/13 00:00
01/14/13 06:00
01/14/13 12:00
01/14/13 18:00
01/15/13 00:00
01/15/13 06:00
01/15/13 12:00
01/15/13 18:00
01/16/13 00:00
01/16/13 06:00
01/16/13 12:00
01/16/13 18:00
01/17/13 00:00


Event 18: March 26, 1991 to March 30, 1991
Calibration Results
Flow (cms)
Depth (mm)
Date/Time
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
0.00
10.00
20.00
30.00
40.00
03/26/91 12:00
03/26/91 18:00
03/27/91 00:00
03/27/91 06:00
03/27/91 12:00
03/27/91 18:00
03/28/91 00:00
03/28/91 06:00
03/28/91 12:00
03/28/91 18:00
03/29/91 00:00
03/29/91 06:00
03/29/91 12:00
03/29/91 18:00
03/30/91 00:00
03/30/91 06:00
03/30/91 12:00
03/30/91 18:00
03/31/91 00:00
03/31/91 06:00
03/31/91 12:00
03/31/91 18:00
04/01/91 00:00
04/01/91 06:00
04/01/91 12:00
04/01/91 18:00
04/02/91 00:00
04/02/91 06:00
04/02/91 12:00
04/02/91 18:00
04/03/91 00:00
04/03/91 06:00
04/03/91 12:00


Event 19: April 11, 1996 to April 18, 1996
Calibration Results
Flow (cms)
Depth (mm)
Date/Time
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
0.00
10.00
20.00
30.00
40.00
4/11/96 12:00
4/11/96 18:00
4/12/96 00:00
4/12/96 06:00
4/12/96 12:00
4/12/96 18:00
4/13/96 00:00
4/13/96 06:00
4/13/96 12:00
4/13/96 18:00
4/14/96 00:00
4/14/96 06:00
4/14/96 12:00
4/14/96 18:00
4/15/96 00:00
4/15/96 06:00
4/15/96 12:00
4/15/96 18:00
4/16/96 00:00
4/16/96 06:00
4/16/96 12:00
4/16/96 18:00
4/17/96 00:00
4/17/96 06:00
4/17/96 12:00
4/17/96 18:00
4/18/96 00:00
4/18/96 06:00
4/18/96 12:00
4/18/96 18:00
4/19/96 00:00
4/19/96 06:00
4/19/96 12:00


Event 21: Nov 1, 1999 to Nov 8, 1999
Calibration Results
Flow (cms)
Depth (mm)
Date/Time
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
0.00
10.00
20.00
30.00
40.00
11/1/99 12:00
11/1/99 18:00
11/2/99 00:00
11/2/99 06:00
11/2/99 12:00
11/2/99 18:00
11/3/99 00:00
11/3/99 06:00
11/3/99 12:00
11/3/99 18:00
11/4/99 00:00
11/4/99 06:00
11/4/99 12:00
11/4/99 18:00
11/5/99 00:00
11/5/99 06:00
11/5/99 12:00
11/5/99 18:00
11/6/99 00:00
11/6/99 06:00
11/6/99 12:00
11/6/99 18:00
11/7/99 00:00
11/7/99 06:00
11/7/99 12:00
11/7/99 18:00
11/8/99 00:00
11/8/99 06:00
11/8/99 12:00
11/8/99 18:00
11/9/99 00:00
11/9/99 06:00
11/9/99 12:00
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)


Event 22: Oct 28, 2012 to Oct 1, 2012
Calibration Results
Flow (cms)
Depth (mm)
Date/Time
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
0.00
10.00
20.00
30.00
40.00
10/28/12 12:00
10/28/12 18:00
10/29/12 00:00
10/29/12 06:00
10/29/12 12:00
10/29/12 18:00
10/30/12 00:00
10/30/12 06:00
10/30/12 12:00
10/30/12 18:00
10/31/12 00:00
10/31/12 06:00
10/31/12 12:00
10/31/12 18:00
11/01/12 00:00
11/01/12 06:00
11/01/12 12:00
11/01/12 18:00
11/02/12 00:00
11/02/12 06:00
11/02/12 12:00
11/02/12 18:00
11/03/12 00:00
11/03/12 06:00
11/03/12 12:00
11/03/12 18:00
11/04/12 00:00
11/04/12 06:00
11/04/12 12:00
11/04/12 18:00
11/05/12 00:00
11/05/12 06:00
11/05/12 12:00
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)


Event 23: May 13, 2014 to May 15, 2014
Calibration Results
Flow (cms)
Depth (mm)
Date/Time
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed - Base Flow Substracted (cms)
Calibrated Flow (cms)
50.000
45.000
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
0.00
10.00
20.00
30.00
40.00
05/12/14 12:00
05/12/14 18:00
05/13/14 00:00
05/13/14 06:00
05/13/14 12:00
05/13/14 18:00
05/14/14 00:00
05/14/14 06:00
05/14/14 12:00
05/14/14 18:00
05/15/14 00:00
05/15/14 06:00
05/15/14 12:00
05/15/14 18:00
05/16/14 00:00
05/16/14 06:00
05/16/14 12:00
05/16/14 18:00
05/17/14 00:00
05/17/14 06:00
05/17/14 12:00
05/17/14 18:00
05/18/14 00:00
05/18/14 06:00
05/18/14 12:00
05/18/14 18:00
05/19/14 00:00
05/19/14 06:00
05/19/14 12:00
05/19/14 18:00
05/20/14 00:00
05/20/14 06:00
05/20/14 12:00

APPENDIX G – Further Validation at Oswego Creek Flow Gauge

Real-time Data - Subject to Revision
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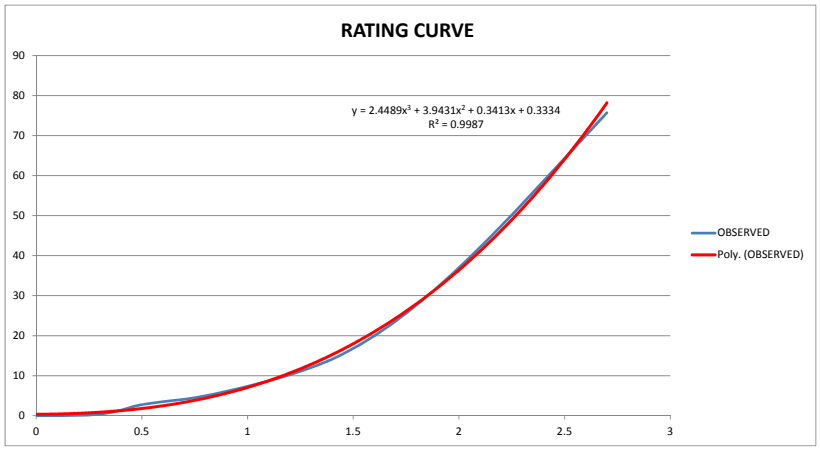
Stage/Discharge Curve for: 02HA024 OSWEGO CREEK AT CANBORO
Rating Table: 9 Valid Period: 2009-10-03 21:00:00 To 2010-04-01 00:00:00

Description of Parameters:
Stage Discharge

2	0	0	0.3334	#DIV/0!
2.01	0.001	0.01	0.33721	33621%
2.02	0.001	0.02	0.341823	34082%
2.03	0.002	0.03	0.347254	17263%
2.04	0.002	0.04	0.353518	17576%
2.05	0.003	0.05	0.360629	11921%
2.06	0.004	0.06	0.368602	9115%
2.07	0.005	0.07	0.377452	7449%
2.08	0.007	0.08	0.387194	5431%
2.09	0.009	0.09	0.397841	4320%
2.1	0.011	0.1	0.40941	3622%
2.11	0.013	0.11	0.421914	3145%
2.12	0.016	0.12	0.435368	2621%
2.13	0.02	0.13	0.449788	2149%
2.14	0.023	0.14	0.465187	1923%
2.15	0.028	0.15	0.48158	1620%
2.16	0.033	0.16	0.498982	1412%
2.17	0.039	0.17	0.517408	1227%
2.18	0.047	0.18	0.536872	1042%
2.19	0.056	0.19	0.55739	895%
2.2	0.066	0.2	0.578975	777%
2.21	0.079	0.21	0.601643	662%
2.22	0.094	0.22	0.625408	565%
2.23	0.115	0.23	0.650285	465%
2.24	0.14	0.24	0.676288	383%
2.25	0.17	0.25	0.703433	314%
2.26	0.206	0.26	0.731733	255%
2.27	0.245	0.27	0.761205	211%
2.28	0.285	0.28	0.791861	178%
2.29	0.327	0.29	0.823718	152%
2.3	0.377	0.3	0.856789	127%
2.31	0.44	0.31	0.89109	103%
2.32	0.513	0.32	0.926635	81%
2.33	0.595	0.33	0.963439	62%
2.34	0.685	0.34	1.001516	46%
2.35	0.78	0.35	1.040881	33%
2.36	0.875	0.36	1.08155	24%
2.37	0.98	0.37	1.123536	15%
2.38	1.1	0.38	1.166854	6%
2.39	1.22	0.39	1.211519	-1%
2.4	1.36	0.4	1.257546	-8%
2.41	1.5	0.41	1.304949	-13%
2.42	1.65	0.42	1.353743	-18%
2.43	1.8	0.43	1.403943	-22%
2.44	1.98	0.44	1.455563	-26%
2.45	2.16	0.45	1.508619	-30%
2.46	2.32	0.46	1.563124	-33%
2.47	2.44	0.47	1.619094	-34%
2.48	2.54	0.48	1.676543	-34%
2.49	2.64	0.49	1.735486	-34%
2.5	2.74	0.5	1.795938	-34%
2.51	2.83	0.51	1.857912	-34%
2.52	2.92	0.52	1.921425	-34%
2.53	3	0.53	1.986491	-34%
2.54	3.08	0.54	2.053124	-33%
2.55	3.16	0.55	2.121338	-33%
2.56	3.23	0.56	2.19115	-32%
2.57	3.3	0.57	2.262573	-31%
2.58	3.37	0.58	2.335623	-31%
2.59	3.44	0.59	2.410313	-30%
2.6	3.5	0.6	2.486658	-29%
2.61	3.56	0.61	2.564674	-28%
2.62	3.62	0.62	2.644375	-27%
2.63	3.68	0.63	2.725775	-26%
2.64	3.74	0.64	2.80889	-25%
2.65	3.8	0.65	2.893734	-24%
2.66	3.86	0.66	2.980321	-23%
2.67	3.92	0.67	3.068667	-22%
2.68	3.98	0.68	3.158786	-21%
2.69	4.04	0.69	3.250693	-20%
2.7	4.1	0.7	3.344402	-18%
2.71	4.175	0.71	3.439928	-18%
2.72	4.25	0.72	3.537286	-17%
2.73	4.33	0.73	3.636491	-16%
2.74	4.41	0.74	3.737557	-15%
2.75	4.49	0.75	3.840498	-14%
2.76	4.57	0.76	3.945331	-14%
2.77	4.66	0.77	4.052069	-13%
2.78	4.75	0.78	4.160726	-12%
2.79	4.85	0.79	4.271319	-12%
2.8	4.95	0.8	4.383861	-11%
2.81	5.06	0.81	4.498367	-11%
2.82	5.17	0.82	4.614852	-11%
2.83	5.28	0.83	4.73333	-10%
2.84	5.39	0.84	4.853816	-10%
2.85	5.505	0.85	4.976325	-10%
2.86	5.62	0.86	5.100872	-9%
2.87	5.74	0.87	5.227471	-9%
2.88	5.86	0.88	5.356137	-9%
2.89	5.98	0.89	5.486885	-8%
2.9	6.1	0.9	5.619729	-8%
2.91	6.22	0.91	5.754684	-7%
2.92	6.34	0.92	5.891765	-7%
2.93	6.46	0.93	6.030986	-7%



1 Hour

SIMULATED DATA

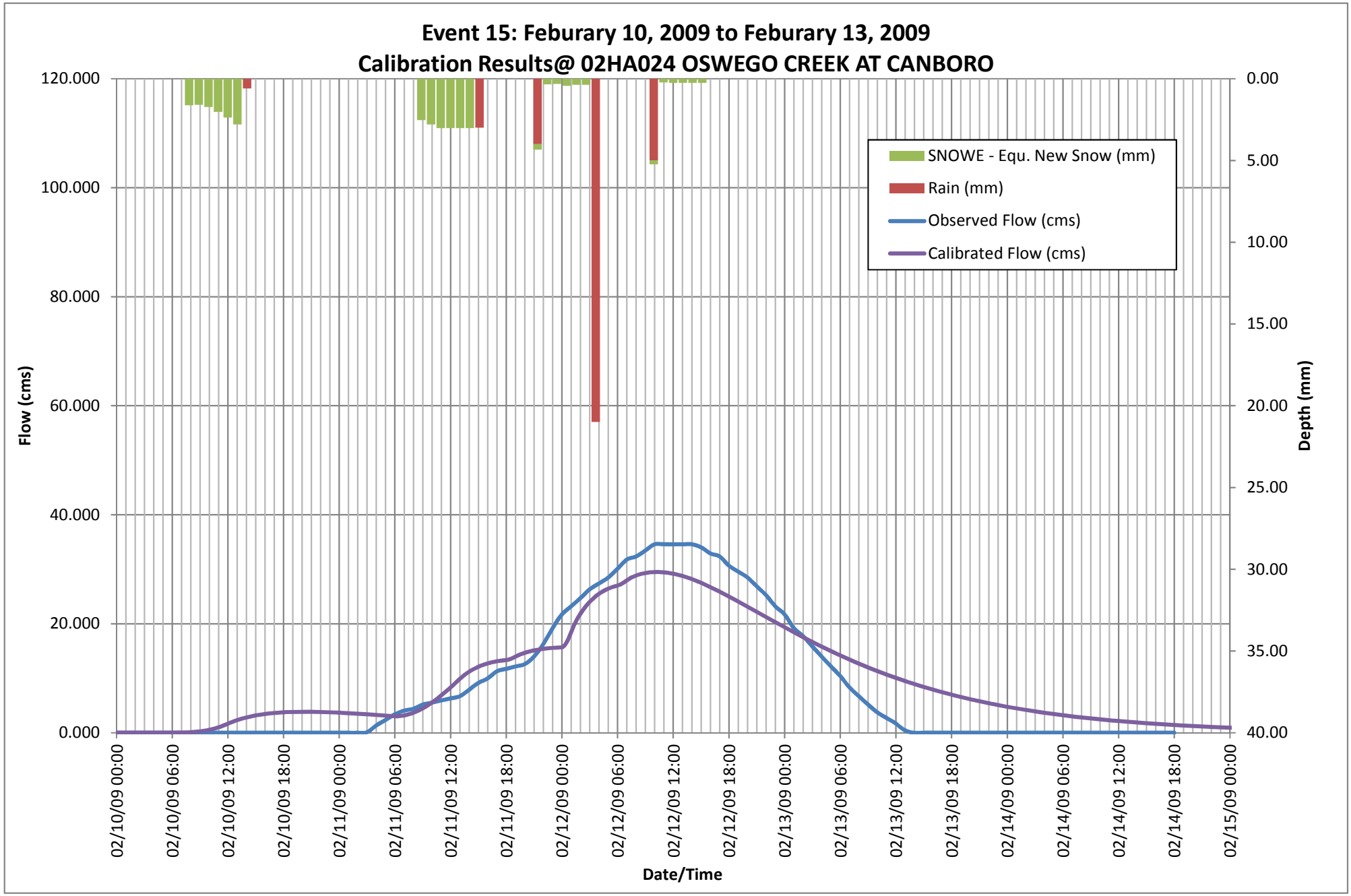
Oswego

Run	NHYD	DT [hr]	AREA [ha]	PKFW [m³/s]	TP [hr]	RV [mm]	DWF [m³/s]
Run 13	1017	0.083	8120.870	29.503	58.167	45.443	0.000

Run 13	1017	0.083	8120.87	29.503	58.167	45.443	0

Runoff Volume for observed and calibrated was adjusted to be matched

Date/Time	Observed Flow (cms)	Observed Flow (cms)	Rain (mm)	SNOWE - Equ. New Snow (mm)	Equ. Total Precip. (mm)	Time (hrs)	Date/Time	Calibrated Flow (cms)	Time	FLOW (CMS)		
Runoff Volume	114.99	45.443										
Peak Discharge (cms)	51.880	34.586	21.00	66.92	21.00							
Baseflow (cms)	17.294			86%								
02/10/09 00:00	9.900	0.000	0.00	0.00	0.00	0.000	02/10/09 00:00	0.000	2/10/2009 12:00:00 AM	9.9	0	0
02/10/09 01:00	9.900	0.000	0.00	0	0.00	0.083	02/10/09 00:04	0.000	2/10/2009 1:00:00 AM	9.9	0.083	0
02/10/09 02:00	9.750	0.000	0.00	0	0.00	0.167	02/10/09 00:10	0.000	2/10/2009 2:00:00 AM	9.75	0.167	0
02/10/09 03:00	9.600	0.000	0.00	0	0.00	0.250	02/10/09 00:15	0.000	2/10/2009 3:00:00 AM	9.6	0.25	0
02/10/09 04:00	9.450	0.000	0.00	0	0.00	0.333	02/10/09 00:19	0.000	2/10/2009 4:00:00 AM	9.45	0.333	0
02/10/09 05:00	9.300	0.000	0.00	0	0.00	0.417	02/10/09 00:25	0.000	2/10/2009 5:00:00 AM	9.3	0.417	0
02/10/09 06:00	9.000	0.000	0.00	0	0.00	0.500	02/10/09 00:30	0.000	2/10/2009 6:00:00 AM	9	0.5	0
02/10/09 07:00	8.560	0.000	0.00	1.621741	1.62	0.583	02/10/09 00:34	0.000	2/10/2009 7:00:00 AM	8.56	0.583	0
02/10/09 08:00	8.280	0.000	0.00	1.596	1.60	0.667	02/10/09 00:40	0.000	2/10/2009 8:00:00 AM	8.28	0.667	0
02/10/09 09:00	8.700	0.000	0.00	1.728926	1.73	0.750	02/10/09 00:45	0.000	2/10/2009 9:00:00 AM	8.7	0.75	0
02/10/09 10:00	8.700	0.000	0.00	2.028914	2.03	0.833	02/10/09 00:49	0.000	2/10/2009 10:00:00 AM	8.7	0.833	0
02/10/09 11:00	8.700	0.000	0.00	2.380952	2.38	0.917	02/10/09 00:55	0.000	2/10/2009 11:00:00 AM	8.7	0.917	0
02/10/09 12:00	8.560	0.000	0.00	2.794073	2.79	1.000	02/10/09 01:00	0.000	2/10/2009 12:00:00 PM	8.56	1	0
02/10/09 13:00	8.700	0.000	0.60	0	0.60	1.083	02/10/09 01:04	0.000	2/10/2009 1:00:00 PM	8.7	1.083	0
02/10/09 14:00	8.850	0.000	0.00	0	0.00	1.167	02/10/09 01:10	0.000	2/10/2009 2:00:00 PM	8.85	1.167	0
02/10/09 15:00	9.300	0.000	0.00	0	0.00	1.250	02/10/09 01:15	0.000	2/10/2009 3:00:00 PM	9.3	1.25	0
02/10/09 16:00	9.900	0.000	0.00	0	0.00	1.333	02/10/09 01:19	0.000	2/10/2009 4:00:00 PM	9.9	1.333	0
02/10/09 17:00	10.560	0.000	0.00	0	0.00	1.417	02/10/09 01:25	0.000	2/10/2009 5:00:00 PM	10.56	1.417	0
02/10/09 18:00	11.280	0.000	0.00	0	0.00	1.500	02/10/09 01:30	0.000	2/10/2009 6:00:00 PM	11.28	1.5	0
02/10/09 19:00	11.820	0.000	0.00	0	0.00	1.583	02/10/09 01:34	0.000	2/10/2009 7:00:00 PM	11.82	1.583	0
02/10/09 20:00	12.400	0.000	0.00	0	0.00	1.667	02/10/09 01:40	0.000	2/10/2009 8:00:00 PM	12.4	1.667	0
02/10/09 21:00	13.000	0.000	0.00	0	0.00	1.750	02/10/09 01:45	0.000	2/10/2009 9:00:00 PM	13	1.75	0
02/10/09 22:00	13.660	0.000	0.00	0	0.00	1.833	02/10/09 01:49	0.000	2/10/2009 10:00:00 PM	13.66	1.833	0
02/10/09 23:00	14.100	0.000	0.00	0	0.00	1.917	02/10/09 01:55	0.000	2/10/2009 11:00:00 PM	14.1	1.917	0
02/11/09 00:00	14.880	0.000	0.00	0	0.00	2.000	02/10/09 02:00	0.000	2/11/2009 12:00:00 AM	14.88	2	0
02/11/09 01:00	15.680	0.000	0.00	0	0.00	2.083	02/10/09 02:04	0.000	2/11/2009 1:00:00 AM	15.68	2.083	0
02/11/09 02:00	16.520	0.000	0.00	0	0.00	2.167	02/10/09 02:10	0.000	2/11/2009 2:00:00 AM	16.52	2.167	0
02/11/09 03:00	17.400	0.106	0.00	0	0.00	2.250	02/10/09 02:15	0.000	2/11/2009 3:00:00 AM	17.4	2.25	0
02/11/09 04:00	18.640	1.346	0.00	0	0.00	2.333	02/10/09 02:19	0.000	2/11/2009 4:00:00 AM	18.64	2.333	0
02/11/09 05:00	19.660	2.366	0.00	0	0.00	2.417	02/10/09 02:25	0.000	2/11/2009 5:00:00 AM	19.66	2.417	0
02/11/09 06:00	20.680	3.386	0.00	0	0.00	2.500	02/10/09 02:30	0.000	2/11/2009 6:00:00 AM	20.68	2.5	0
02/11/09 07:00	21.360	4.066	0.00	2.538315	2.54	2.583	02/10/09 02:34	0.000	2/11/2009 7:00:00 AM	21.36	2.583	0
02/11/09 08:00	21.700	4.406	0.00	2.794073	2.79	2.667	02/10/09 02:40	0.000	2/11/2009 8:00:00 AM	21.7	2.667	0
02/11/09 09:00	22.460	5.166	0.00	3.026783	3.03	2.750	02/10/09 02:45	0.000	2/11/2009 9:00:00 AM	22.46	2.75	0
02/11/09 10:00	22.840	5.546	0.00	3.026783	3.03	2.833	02/10/09 02:49	0.000	2/11/2009 10:00:00 AM	22.84	2.833	0
02/11/09 11:00	23.220	5.926	0.00	3.026783	3.03	2.917	02/10/09 02:55	0.000	2/11/2009 11:00:00 AM	23.22	2.917	0
02/11/09 12:00	23.600	6.306	0.00	3.026783	3.03	3.000	02/10/09 03:00	0.000	2/11/2009 12:00:00 PM	23.6	3	0
02/11/09 13:00	24.000	6.706	3.00	0	3.00	3.083	02/10/09 03:04	0.000	2/11/2009 1:00:00 PM	24	3.083	0
02/11/09 14:00	25.200	7.906	0.00	0	0.00	3.167	02/10/09 03:10	0.000	2/11/2009 2:00:00 PM	25.2	3.167	0
02/11/09 15:00	26.440	9.146	0.00	0	0.00	3.250	02/10/09 03:15	0.000	2/11/2009 3:00:00 PM	26.44	3.25	0
02/11/09 16:00	27.280	9.986	0.00	0	0.00	3.333	02/10/09 03:19	0.000	2/11/2009 4:00:00 PM	27.28	3.333	0
02/11/09 17:00	28.580	11.286	0.00	0	0.00	3.417	02/10/09 03:25	0.000	2/11/2009 5:00:00 PM	28.58	3.417	0
02/11/09 18:00	29.020	11.726	0.00	0	0.00	3.500	02/10/09 03:30	0.000	2/11/2009 6:00:00 PM	29.02	3.5	0
02/11/09 19:00	29.460	12.166	4.00	0.345266	4.35	3.583	02/10/09 03:34	0.000	2/11/2009 7:00:00 PM	29.46	3.583	0
02/11/09 20:00	29.900	12.606	0.00	0.350835	0.35	3.667	02/10/09 03:40	0.000	2/11/2009 8:00:00 PM	29.9	3.667	0
02/11/09 21:00	31.280	13.986	0.00	0.323861	0.32	3.750	02/10/09 03:45	0.000	2/11/2009 9:00:00 PM	31.28	3.75	0
02/11/09 22:00	33.580	16.286	0.00	0.445998	0.45	3.833	02/10/09 03:49	0.000	2/11/2009 10:00:00 PM	33.58	3.833	0
02/11/09 23:00	36.500	19.206	0.00	0.380055	0.38	3.917	02/10/09 03:55	0.000	2/11/2009 11:00:00 PM	36.5	3.917	0
02/12/09 00:00	39.000	21.706	0.00	0.380055	0.38	4.000	02/10/09 04:00	0.000	2/12/2009 12:00:00 AM	39	4	0
02/12/09 01:00	40.500	23.206	21.00	0	21.00	4.083	02/10/09 04:04	0.000	2/12/2009 1:00:00 AM	40.5	4.083	0
02/12/09 02:00	42.000	24.706	0.00	0	0.00	4.167	02/10/09 04:10	0.000	2/12/2009 2:00:00 AM	42	4.167	0
02/12/09 03:00	43.620	26.326	0.00	0	0.00	4.250	02/10/09 04:15	0.000	2/12/2009 3:00:00 AM	43.62	4.25	0
02/12/09 04:00	44.700	27.406	0.00	0	0.00	4.333	02/10/09 04:19	0.000	2/12/2009 4:00:00 AM	44.7	4.333	0
02/12/09 05:00	45.780	28.486	0.00	0	0.00	4.417	02/10/09 04:25	0.000	2/12/2009 5:00:00 AM	45.78	4.417	0
02/12/09 06:00	47.400	30.106	0.00	0	0.00	4.500	02/10/09 04:30	0.000	2/12/2009 6:00:00 AM	47.4	4.5	0
02/12/09 07:00	49.080	31.786	5.00	0.244769	5.24	4.583	02/10/09 04:34	0.000	2/12/2009 7:00:00 AM	49.08	4.583	0
02/12/09 08:00	49.640	32.346	0.00	0.235172	0.24	4.667	02/10/09 04:40	0.000	2/12/2009 8:00:00 AM	49.64	4.667	0
02/12/09 09:00	50.760	33.466	0.00	0.254758	0.25	4.750	02/10/09 04:45	0.000	2/12/2009 9:00:00 AM	50.76	4.75	0
02/12/09 10:00	51.880	34.586	0.00	0.254758	0.25	4.833	02/10/09 04:49	0.000	2/12/2009 10:00:00 AM	51.88	4.833	0
02/12/09 11:00	51.880	34.586	0.00	0.254758	0.25	4.917	02/10/09 04:55	0.000	2/12/2009 11:00:00 AM	51.88	4.917	0
02/12/09 12:00	51.880	34.586	0.00	0.254758	0.25	5.000	02/10/09 05:00	0.000	2/12/2009 12:00:00 PM	51.88	5	0
02/12/09 13:00	51.880	34.586	0.00	0	0.00	5.083	02/10/09 05:04	0.000	2/12/2009 1:00:00 PM	51.88	5.083	0
02/12/09 14:00	51.880	34.586	0.00	0	0.00	5.167	02/10/09 05:10	0.000	2/12/2009 2:00:00 PM	51.88	5.167	0
02/12/09 15:00	51.320	34.026	0.00	0	0.00	5.250	02/10/09 05:15	0.000	2/12/2009 3:00:00 PM	51.32	5.25	0
02/12/09 16:00	50.200	32.906	0.00	0	0.00	5.333	02/10/09 05:19	0.000	2/12/2009 4:00:00 PM	50.2	5.333	0
02/12/09 17:00	49.640	32.346	0.00	0	0.00	5.417	02/10/09 05:25	0.000	2/12/2009 5:00:00 PM	49.64	5.417	0
02/12/09 18:00	47.960	30.666	0.00	0	0.00	5.500	02/10/09 05:30	0.000	2/12/2009 6:00:00 PM	47.96	5.5	0
02/12/09 19:00	46.860	29.566	0.00	0	0.00	5.583	02/10/09 05:34	0.000	2/12/2009 7:00:00 PM	46.86	5.583	0
02/12/09 20:00	45.780	28.486	0.00	0	0.00	5.667	02/10/09 05:40	0.000	2/12/2009 8:00:00 PM	45.78	5.667	0
02/12/09 21:00	44.160	26.866	0.00	0	0.00	5.750	02/10/09 05:45	0.000	2/12/2009 9:00:00 PM	44.16	5.75	0
02/12/09 22:00	42.540	25.246	0.00	0	0.00	5.833	02/10/09 05:49	0.000	2/12/2009 10:00:00 PM	42.54	5.833	0
02/12/09 23:00	40.500	23.206	0.00	0	0.00	5.917	02/10/09 05:55	0.000	2/12/2009 11:00:00 PM	40.5	5.917	0
02/13/09 00:00	39.000	21.706	0.00	0	0.00	6.000	02/10/09 06:00	0.000	2/13/2009 12:00:00 AM	39	6	0
02/13/09 01:00	36.500	19.206	0.00	0	0.00	6.083	02/10/09 06:04	0.000	2/13/2009 1:00:00 AM	36.5	6.083	0
02/13/09 02:00	35.000	17.706	0.00	0	0.00	6.167	02/10/09 06:10	0.000	2/13/2009 2:00:00 AM	35	6.167	0
02/13/09 03:00	33.120	15.826	0.00	0	0.00	6.250	02/10/09 06:15	0.000	2/13/2009 3:00:00 AM	33.12	6.25	0
02/13/09 04:00	31.280	13.986	0.00	0	0.00	6.333	02/10/09 06:19	0.001	2/13/2009 4:00:00 AM	31.28	6.333	0.001
02/13/09 05:00	29.460	12.166	0.00	0	0.00	6.417	02/10/09 06:25	0.001	2/13/2009 5:00:00 AM	29.46	6.417	0.001
02/13/09 06:00	27.700	10.406	0.00	0	0.00	6.500	02/10/09 06:30	0.002	2/13/2009 6:00:00 AM	27.7	6.5	0.002
02/13/09 07:00	25.600	8.306	0.00	0	0.00	6.583	02/10/09 06:34	0.003	2/13/2009 7:00:00 AM	25.6	6.583	0.003
02/13/09 08:00	24.000	6.706	0.00	0	0.00	6.667	02/10/09 06:40	0.005	2/13/2009 8:00:00 AM	24	6.667	0.005
02/13/09 09:00	22.460	5.166	0.00	0	0.00	6.750	02/10/09 06:45	0.006	2/13/2009 9:00:00 AM	22.46	6.75	0.006
02/13/09 10:00	21.020	3.726	0.00	0	0.00	6.833	02/10/09 06:49	0.008	2/13/2009 10:00:00 AM	21.02	6.833	0.008
02/13/09 11:00	20.000	2.706	0.00	0	0.00	6.917	02/10/09 06:55	0.011	2/13/2009 11:00:00 AM	20	6.917	0.011
02/13/09 12:00	18.980	1.686	0.00	0	0.00	7.000	02/10/09 07:00	0.014	2/13/2009 12:00:00 PM	18.98	7	0.014
02/13/09 13:00	17.700	0.406	0.00	0	0.00	7.083	02/10/09 07:04	0.017	2/13/2009 1:00:00 PM	17.7	7.083	0.017
02/13/09 14:00	16.800	0.000	0.00	0	0.00	7.167	02/10/09 07:10	0.021	2/13/2009 2:00:00 PM	16.8	7.167	0.021
02/13/09 15:00	15.960	0.000	0.00	0	0.00	7.250	02/10/09 07:15	0.025	2/13/2009 3:00:00 PM	15.96	7.25	0.025
02/13/09 16:00	15.140	0.000	0.00	0	0.00	7.333	02/10/09 07:19	0.030	2/13/2009 4:00:00 PM	15.14	7.333	0.03
02/13/09 17:00	14.360	0.000	0.00	0	0.00	7.417	02/10/09 07:25	0.035	2/13/2009 5:00:00 PM	14.36	7.417	0.035
02/13/09 18:00	13.660	0.000	0.00	0	0.00	7.500	02/10/09 07:30	0.041	2/13/2009 6:00:00 PM	13.66	7.5	0.041
02/13/09 19:00	13.000	0.000	0.00	0	0.00	7.583	02/10/09 07:34	0.047	2/13/2009 7:00:00 PM	13	7.583	0.047
02/13/09 20:00	12.400	0.000	0.00	0	0.00	7.667	02/10/09 07:40	0.053	2/13/2009 8:00:00 PM	12.4	7.667	0.053
02/13/09 21:00	11.640	0.000	0.00	0	0.00	7.750	02/10/09 07:45	0.061	2/13/2009 9:00:00 PM	11.64	7.75	0.061
02/13/09 22:00	11.100	0.000	0.00	0	0.00	7.833	02/10/09 07:49	0.069	2/13/2009 10:00:00 PM	11.1	7.833	0.069
02/13/09 23:00	10.380	0.000	0.00	0	0.00	7.917	02/10/09 07:55	0.077	2/13/2009 11:00:00 PM	10.38	7.917	0.077
02/14/09 00:00	9.900	0.000	0.00	0	0.00	8.000	02/10/09 08:00	0.086	2/14/2009 12:00:00 AM	9.9	8	0.086
02/14/09 01:00	9.450	0.000	0.00	0	0.00	8.083	02/10/09 08:04	0.096	2/14/2009 1:00:00 AM	9.45	8.083	0.096
02/14/09 02:00	8.850	0.000	0.00	0	0.00	8.167	02/10/09 08:10	0.106	2/14/2009 2:00:00 AM	8.85	8.167	0.106
02/14/09 03:00	8.420	0.000	0.00	0	0.00	8.250	02/10/09 08:15	0.117	2/14/2009 3:00:00 AM	8.42	8.25	0.117
02/14/09 04:00	8.000	0.000	0.00	0	0.00	8.333	02/10/09 08:19	0.129	2/14/2009 4:00:00 AM	8	8.333	0.129
02/14/09 05:00	7.592	0.000	0.00	0	0.00	8.417	02/10/09 08:25	0.141	2/14/2009 5:00:00 AM	7.592	8.417	0.141
02/14/09 06:00	6.940	0.000	0.00	0	0.00	8.500	02/10/09 08:30	0.154	2/14/2009 6:00:00 AM	6.94	8.5	0.154
02/14/09 07:00	6.340	0.000	0.00	0	0.00	8.583	02/10/09 08:34	0.168	2/14/2009 7:00:00 AM	6.34	8.583	0.168
02/14/09 08:00	5.740	0.000	0.00	0	0.00	8.667	02/10/09 08:40	0.183	2/14/2009 8:00:00 AM	5.74	8.667	0.183
02/14/09 09:00	5.390	0.000	0.00	0	0.00	8.750	02/10/09 08:45	0.198	2/14/2009 9:00:00 AM	5.39	8.75	0.198
02/14/09 10:00	5.060	0.000	0.00	0	0.00	8.833	02/10/09 08:49	0.214	2/14/2009 10:00:00 AM	5.06	8.833	0.214
02/14/09 11:00	5.060	0.000	0.00	0	0.00	8.917	02/10/09 08:55	0.231	2/14/2009 11:00:00 AM	5.06	8.917	0.231
02/14/09 12:00	5.170	0.000	0.00	0	0.00	9.000	02/10/09 09:00	0.248	2/14/2009 12:00:00 PM	5.17	9	0.248
02/14/09 13:00	5.280	0.000	0.00	0	0.00	9.083	02/10/09 09:04	0.267	2/14/2009 1:00:00 PM	5.28	9.083	0.267
02/14/09 14:00	5.390	0.000	0.00	0	0.00	9.167	02/10/09 09:10	0.287	2/14/2009 2:00:00 PM	5.39	9.167	0.287
02/14/09 15:00	5.505	0.000	0.00	0	0.00	9.250	02/10/09 09:15	0.307	2/14/2009 3:00:00 PM	5.505	9.25	0.307
02/14/09 16:00	5.620	0.000	0.00	0	0.00	9.333	02/10/09 09:19	0.329	2/14/2009 4:00:00 PM	5.62	9.333	0.329
02/14/09 17:00	5.620	0.000	0.00	0	0.00	9.417	02/10/09 09:25	0.351	2/14/2009 5:00:00 PM	5.62	9.417	0.351
02/14/09 18:00	5.620	0.000	0.00	0	0.00	9.500	02/10/09 09:30	0.375	2/14/2009 6:00:00 PM	5.62	9.5	0.375


Event 15: Feburary 10, 2009 to Feburary 13, 2009
Calibration Results@ 02HA024 OSWEGO CREEK AT CANBORO
SNOWE - Equ. New Snow (mm)
Rain (mm)
Observed Flow (cms)
Calibrated Flow (cms)
Flow (cms)
Depth (mm)
Date/Time
120.000
100.000
80.000
60.000
40.000
20.000
0.000
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
02/10/09 00:00
02/10/09 06:00
02/10/09 12:00
02/10/09 18:00
02/11/09 00:00
02/11/09 06:00
02/11/09 12:00
02/11/09 18:00
02/12/09 00:00
02/12/09 06:00
02/12/09 12:00
02/12/09 18:00
02/13/09 00:00
02/13/09 06:00
02/13/09 12:00
02/13/09 18:00
02/14/09 00:00
02/14/09 06:00
02/14/09 12:00
02/14/09 18:00
02/15/09 00:00

APPENDIX H – Frequency Analysis of Streamflow Data

#	Analysis on # Years of Data	Data Set	Approach	Methodology	Q100 (CMS)
1	57	Daily Max.	Use All Years Data	Frequency Analysis (CFA) - GEV	101.0
2	57		Use All Years Data	Frequency Analysis (CFA) - 3LN	98.3
3	57		Use All Years Data	Frequency Analysis (CFA) - LP3	96.9
4	57		Use All Years Data	Frequency Analysis (CFA) - WAKEBY	101.0
5	57		Use All Years Data	Extreme Value (Gumbel)	100.4
6	16		Randomly Selected from All Years - Test 1	Extreme Value (Gumbel)	106.3
7	16		Randomly Selected from All Years - Test 2	Extreme Value (Gumbel)	103.5
8	16		Randomly Selected from All Years - Test 3	Extreme Value (Gumbel)	105.4
9	16		Top 10 Events plus 6 Randomly Selected from the Rest	Extreme Value (Gumbel)	105.5
10	16		Evenly Distributed 16 Events from All Years	Extreme Value (Gumbel)	105.6
11	16		Randomly Selected 2 Events from Divided 8 Groups of All Years	Extreme Value (Gumbel)	102.3
12	16		Top 9 Events* plus 7 Randomly Selected from Divided 7 Groups of the Rest	Extreme Value (Gumbel)	104.1
13	16		Top 9 Events* plus 7 Randomly Selected from Divided 7 Groups of the Rest	Frequency Analysis (CFA) - GEV	98.4
14	16		Top 9 Events* plus 7 Randomly Selected from Divided 7 Groups of the Rest	Frequency Analysis (CFA) - 3LN	90.8
15	16		Top 9 Events* plus 7 Randomly Selected from Divided 7 Groups of the Rest	Frequency Analysis (CFA) - LP3	101.0
16	16		Top 9 Events* plus 7 Randomly Selected from Divided 7 Groups of the Rest	Frequency Analysis (CFA) - WAKEBY	101.0
17	16		Top 9 Events* plus 7 Randomly Selected from Divided 7 Groups of the Rest	Frequency Analysis (CFA) - WEIBULL	93.8
18	15		Revised Selected 15 Events	Frequency Analysis (CFA) - GEV	98.6
19	15		Revised Selected 15 Events	Frequency Analysis (CFA) - 3LN	91.0
20	15		Revised Selected 15 Events	Frequency Analysis (CFA) - LP3	97.1
21	15		Revised Selected 15 Events	Frequency Analysis (CFA) - WAKEBY	99.9
22	16		Revised Selected 15 Events	Frequency Analysis (CFA) - WEIBULL	93.3
23	57	Instantaneous [1]	Use All Years Data	Frequency Analysis (CFA) - GEV	**114.0**
24	57		Use All Years Data	Frequency Analysis (CFA) - 3LN	110.0
25	57		Use All Years Data	Frequency Analysis (CFA) - LP3	109.0
26	57		Use All Years Data	Frequency Analysis (CFA) - WAKEBY	117.0
27	15		Revised Selected 15 Events	Frequency Analysis (CFA) - GEV	115.0
28	15		Revised Selected 15 Events	Frequency Analysis (CFA) - 3LN	109.0
29	15		Revised Selected 15 Events	Frequency Analysis (CFA) - LP3	113.0
30	15		Revised Selected 15 Events	Frequency Analysis (CFA) - WAKEBY	114.0
31	15	Hourly [2]	Revised Selected 15 Events	Frequency Analysis (CFA) - GEV	123.0
32	15		Revised Selected 15 Events	Frequency Analysis (CFA) - 3LN	112.0
33	15		Revised Selected 15 Events	Frequency Analysis (CFA) - LP3	126.0
34	15		Revised Selected 15 Events	Frequency Analysis (CFA) - WAKEBY	118.0
35	15		Revised Selected 15 Events	Frequency Analysis (CFA) - WEIBULL	115.0

Note:

* Exclude data with SYM of A: partical day; B: ice conditions; E: Estimated

Selected Approach: Top 9 Events plus 7 Randomly Selected from Divided 7 Groups of the Rest

1) Gap filled for non-instantaneous data. Fitted curve used.

2) Revised based on the available data for the selected approach (top 9 plus 7 randomly) to provide statistically equivalent

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
3	1958	20.700	96.300	1	1.05	95.333
3	1959	96.300	82.500	2	2.80	35.750
4	1960	79.000	81.300	3	4.55	22.000
2	1961	45.900	79.000	4	6.29	15.889
11	1962	51.500	73.700	5	8.04	12.435
3	1963	45.300	73.500	6	9.79	10.214
3	1964	31.400	73.200	7	11.54	8.667
2	1965	56.600	72.900	8	13.29	7.526
2	1966	33.400	64.900	9	15.03	6.651
12	1967	33.400	62.300	10	16.78	5.958
2	1968	45.300	61.700	11	18.53	5.396
1	1969	52.700	57.700	12	20.28	4.931
4	1970	24.500	56.600	13	22.03	4.540

Press <RETURN> to continue

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
2	1971	48.100	56.500	14	23.78	4.206
4	1972	27.100	54.700	15	25.52	3.918
12	1973	51.000	53.100	16	27.27	3.667
2	1974	41.600	52.700	17	29.02	3.446
2	1975	35.400	51.500	18	30.77	3.250
3	1976	61.700	51.000	19	32.52	3.075
12	1977	47.000	50.800	20	34.27	2.918
3	1978	48.100	50.200	21	36.01	2.777
12	1979	49.300	49.300	22	37.76	2.648
3	1980	43.600	48.200	23	39.51	2.531
2	1981	33.000	48.100	24	41.26	2.424
3	1982	40.000	48.100	25	43.01	2.325
12	1983	36.500	47.000	26	44.76	2.234

Press <RETURN> to continue

All Years _ Daily

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
2	1984	73.500	46.500	27	46.50	2.150
2	1985	50.800	45.900	28	48.25	2.072
3	1986	44.100	45.300	29	50.00	2.000
4	1987	40.400	45.300	30	51.75	1.932
3	1988	20.000	44.100	31	53.50	1.869
5	1989	15.000	43.600	32	55.24	1.810
12	1990	73.700	42.600	33	56.99	1.755
3	1991	46.500	41.900	34	58.74	1.702
12	1992	32.400	41.600	35	60.49	1.653
3	1993	39.800	41.500	36	62.24	1.607
3	1994	36.800	40.400	37	63.99	1.563
11	1995	53.100	40.000	38	65.73	1.521
4	1996	48.200	39.800	39	67.48	1.482

Press <RETURN> to continue

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
2	1997	35.000	36.800	40	69.23	1.444
3	1998	41.900	36.500	41	70.98	1.409
11	1999	35.600	35.600	42	72.73	1.375
2	2000	41.500	35.400	43	74.48	1.343
2	2001	72.900	35.000	44	76.22	1.312
5	2002	28.800	33.400	45	77.97	1.283
3	2003	32.500	33.400	46	79.72	1.254
3	2004	31.700	33.000	47	81.47	1.227
4	2005	62.300	32.500	48	83.22	1.202
12	2006	64.900	32.400	49	84.97	1.177
3	2007	73.200	31.700	50	86.71	1.153
12	2008	82.500	31.400	51	88.46	1.130
2	2009	81.300	28.800	52	90.21	1.109

Press <RETURN> to continue

All Years _ Daily

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
3	2010	54.700	27.100	53	91.96	1.087
3	2011	50.200	24.500	54	93.71	1.067
10	2012	56.500	20.700	55	95.45	1.048
1	2013	57.700	20.000	56	97.20	1.029
5	2014	42.600	15.000*	57	98.95	1.011

Press <RETURN> to continue

All Years _ Daily

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

        FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
        02HA007     WELLAND RIVER BELOW CAISTOR CORNERS

                              SAMPLE STATISTICS
                     MEAN       S.D.        C.V       C.S.       C.K.
   X SERIES        47.342     16.886       .357       .711      3.620
LN X SERIES         3.794       .368       .097      -.404      3.779
L-MOM RATIO        47.342      9.384       .198       .142       .166

X(MIN)=      15.000                          TOTAL SAMPLE SIZE=  57
X(MAX)=      96.300                        NO. OF LOW OUTLIERS=   1
LOWER OUTLIER LIMIT OF X=   15.740           NO. OF ZERO FLOWS=   0

               AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                     MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES        47.920     16.461       .344       .816      3.656
LN X SERIES         3.813       .341       .089      -.087      3.162
L-MOM RATIO        47.920      9.127       .190       .165       .157

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
            DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)=  .7273E+04
     PARAMETERS OF THE GEV WHICH DUPLICATES THE CONDITIONAL FUNCTION:
                U=     39.83    A=   13.401    K=     .002

                         FLOOD FREQUENCY REGIME

                RETURN        EXCEEDANCE        FLOOD
                PERIOD        PROBABILITY

                 1.003           .997            16.2
                 1.050           .952            24.9
                 1.250           .800            33.5
                 2.000           .500            44.7
                 5.000           .200            59.9
                10.000           .100            69.9
                20.000           .050            79.5
                50.000           .020            91.9
               100.000           .010           101
               200.000           .005           110
               500.000           .002           123

Press <RETURN> to continue , <CTRL> P to obtain hard copy
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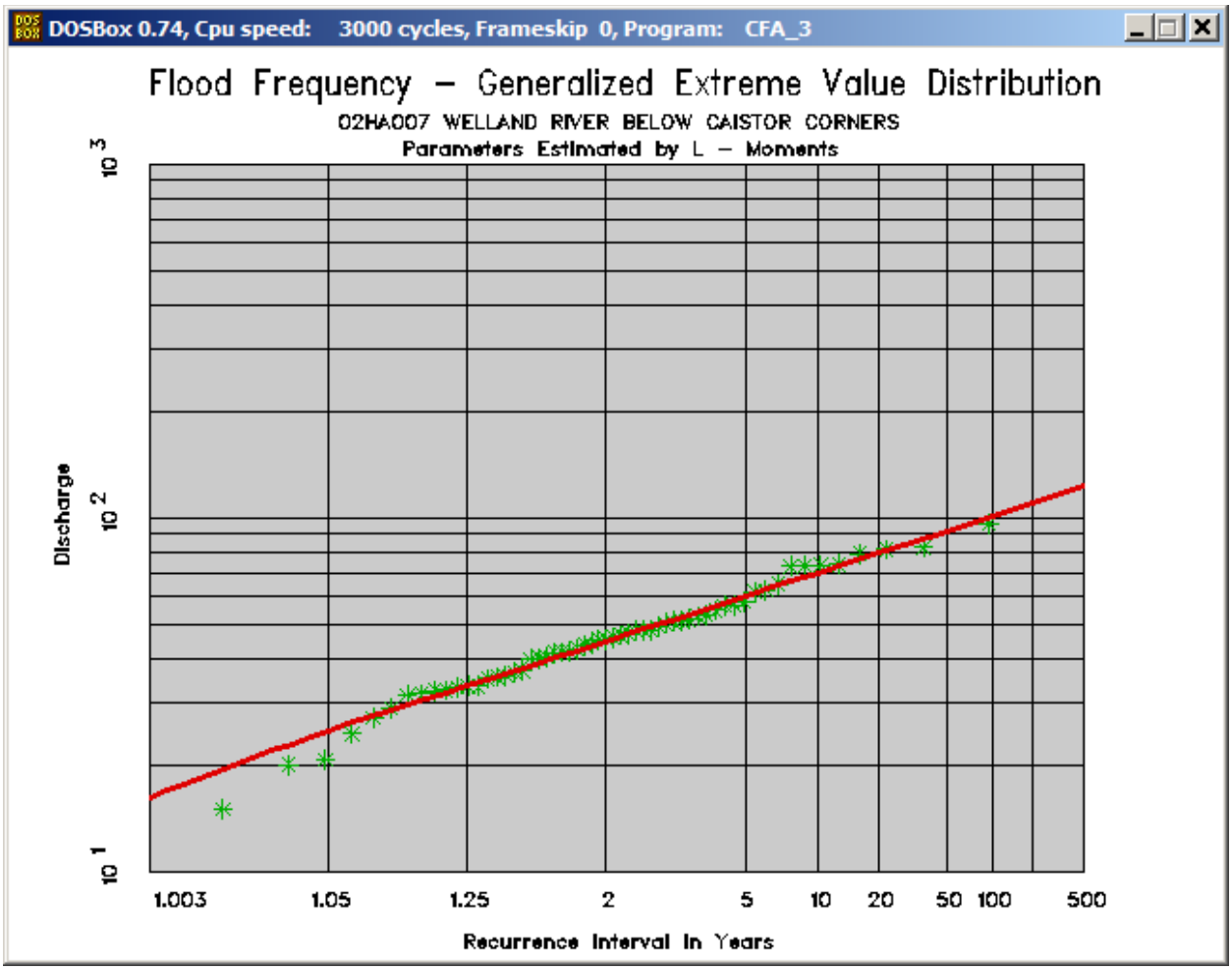
All Years _ Daily



All Years _ Daily

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

```
FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS

                         SAMPLE STATISTICS
                  MEAN       S.D.        C.V       C.S.       C.K.
     X SERIES    47.342     16.886       .357       .711      3.620
  LN X SERIES     3.794       .368       .097      -.404      3.779

  X(MIN)=     15.000                        TOTAL SAMPLE SIZE=  57
  X(MAX)=     96.300                      NO. OF LOW OUTLIERS=   1
  LOWER OUTLIER LIMIT OF X=   15.740        NO. OF ZERO FLOWS=   0


               AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                  MEAN       S.D.        C.V.       C.S.       C.K.
     X SERIES    47.920     16.461       .344       .816      3.656
  LN X SERIES     3.813       .341       .089      -.087      3.162
LN(X-A) SERIES    3.913       .308       .079       .007      3.096

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=    -4.539   M= 3.905   S=  .313

                        FLOOD FREQUENCY REGIME

               RETURN        EXCEEDANCE        FLOOD
               PERIOD        PROBABILITY

                1.003          .997            16.5
                1.050          .952            24.9
                1.250          .800            33.6
                2.000          .500            45.1
                5.000          .200            60.1
               10.000          .100            69.6
               20.000          .050            78.6
               50.000          .020            89.9
              100.000          .010            98.3
              200.000          .005           107
              500.000          .002           118

Press <RETURN> to continue , <CTRL> P to obtain hard copy_
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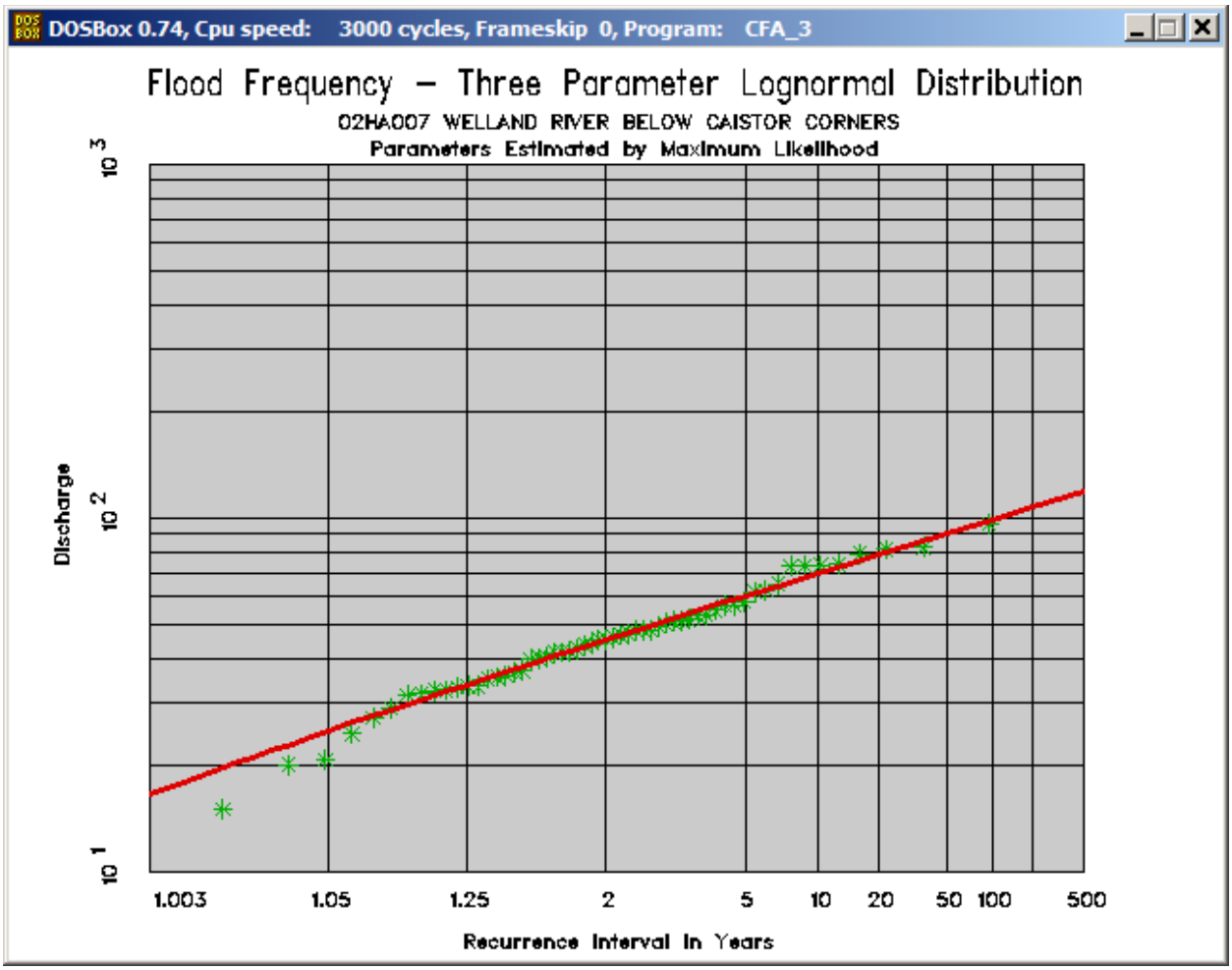
All Years _ Daily



All Years _ Daily

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

```
FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS

                         SAMPLE STATISTICS
                  MEAN       S.D.        C.V       C.S.       C.K.
   X SERIES     47.342     16.886       .357       .711      3.620
LN X SERIES      3.794       .368       .097      -.404      3.779

X(MIN)=     15.000                        TOTAL SAMPLE SIZE=  57
X(MAX)=     96.300                      NO. OF LOW OUTLIERS=   1
LOWER OUTLIER LIMIT OF X=   15.740        NO. OF ZERO FLOWS=   0


              AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                  MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     47.920     16.461       .344       .816      3.656
LN X SERIES      3.813       .341       .089      -.087      3.162

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
          DISTRIBUTION IS UPPER BOUNDED AT M=  .1224E+07
   PARAMETERS OF THE LP3 WHICH DUPLICATES THE CONDITIONAL FUNCTION:
    A= -.1109E-01 B=  920.5     LOG(M)=  14.02     M =  .1224E+07
    SYNTHETIC STATISTICS: MEAN=   3.807  S.D.=   .337  C.S.= -.066

                        FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003           .997            -
               1.050           .952           25.5
               1.250           .800           34.0
               2.000           .500           45.2
               5.000           .200           59.8
              10.000           .100           69.1
              20.000           .050           77.8
              50.000           .020           88.8
             100.000           .010           96.9
             200.000           .005          105
             500.000           .002          115

Press <RETURN> to continue , <CTRL> P to obtain hard copy
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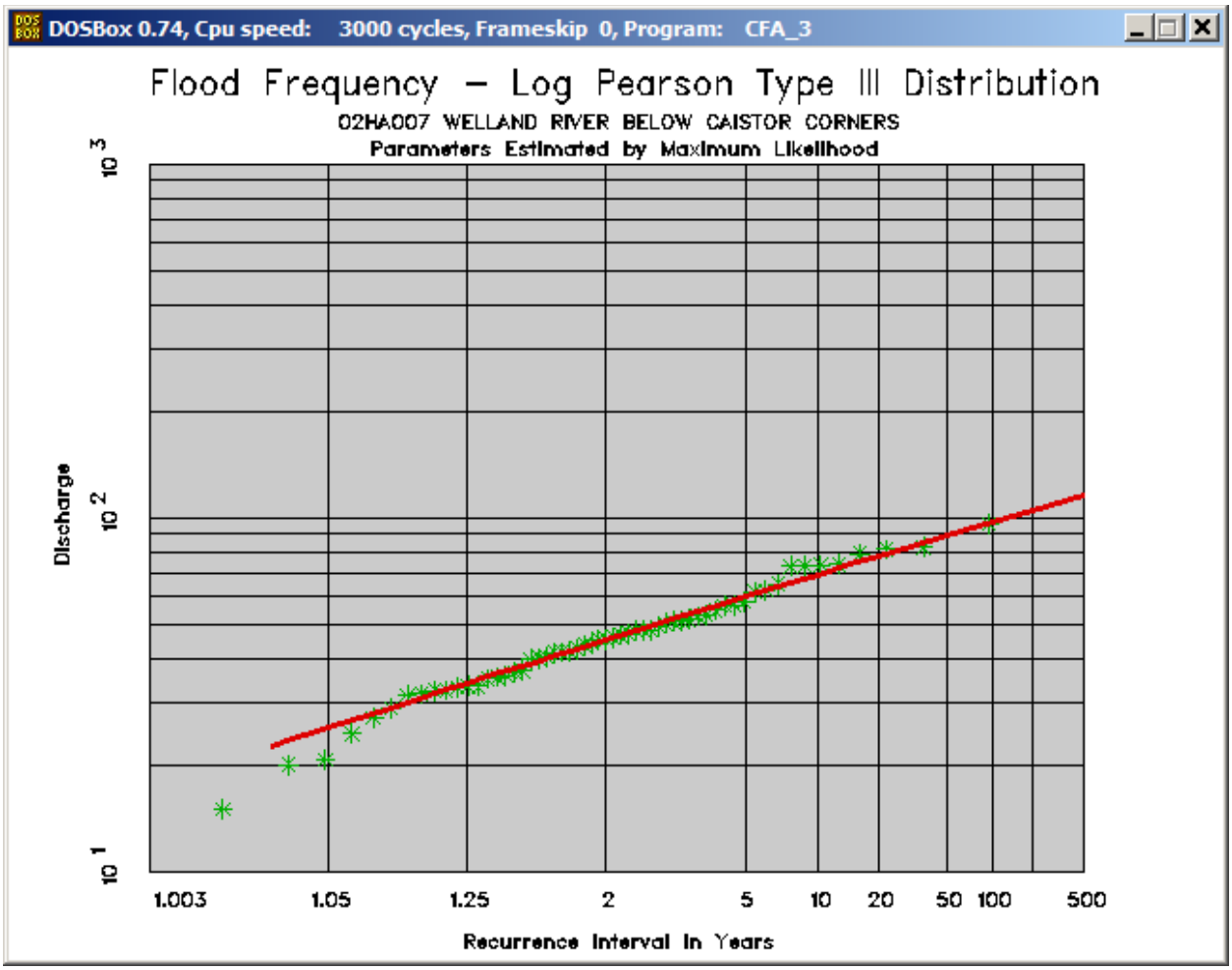
All Years _ Daily



All Years _ Daily

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

```
FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS

                        SAMPLE STATISTICS
                 MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     47.342     16.886       .357       .711      3.620
LN X SERIES      3.794       .368       .097      -.404      3.779
L-MOM RATIO     47.342      9.384       .198       .142       .166

X(MIN)=     15.000                        TOTAL SAMPLE SIZE=  57
X(MAX)=     96.300                      NO. OF LOW OUTLIERS=   1
LOWER OUTLIER LIMIT OF X=   15.740        NO. OF ZERO FLOWS=   0

             AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                 MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     47.920     16.461       .344       .816      3.656
LN X SERIES      3.813       .341       .089      -.087      3.162
L-MOM RATIO     47.920      9.127       .190       .165       .157

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

```
THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M=   16.834   A=     15.514   B= 10.45   C=   -197.118   D= -.094
          DISTRIBUTION IS UPPER BOUNDED AT E=  .2295E+03

                        FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003          .997             -
               1.050          .952            21.7
               1.250          .800            34.3
               2.000          .500            44.5
               5.000          .200            59.7
              10.000          .100            70.4
              20.000          .050            80.4
              50.000          .020            92.7
             100.000          .010           101
             200.000          .005           109
             500.000          .002           119

Press <RETURN> to continue , <CTRL> P to obtain hard copy
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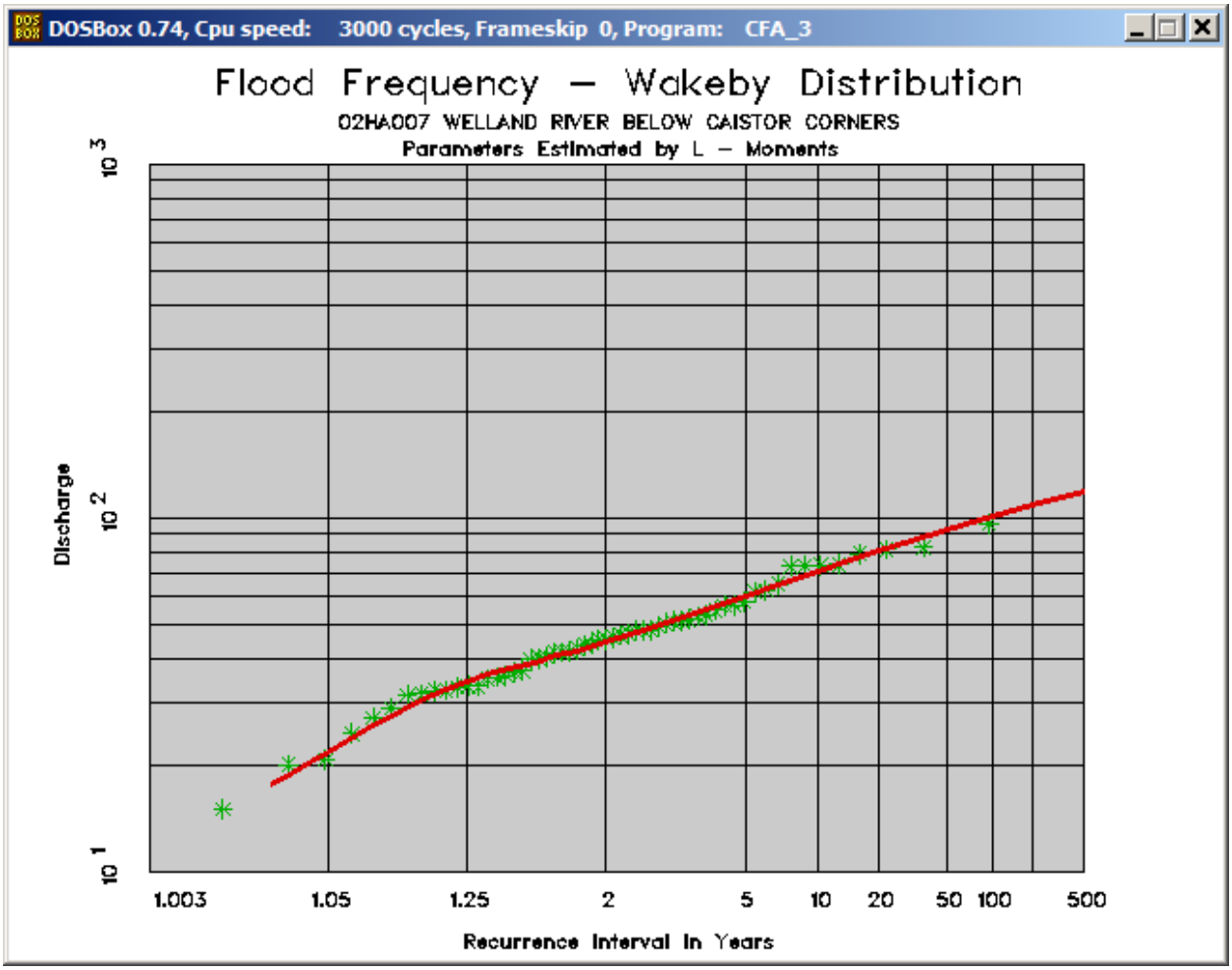
All Years _ Daily



All Years _ Daily

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (INS.)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
0	1958	26.210	110.040	1	1.05	95.333
0	1959	110.040	94.600	2	2.80	35.750
0	1960	88.740	91.000	3	4.55	22.000
0	1961	51.480	88.740	4	6.29	15.889
0	1962	57.460	86.800	5	8.04	12.435
0	1963	50.850	84.500	6	9.79	10.214
0	1964	36.610	83.300	7	11.54	8.667
0	1965	63.020	74.400	8	13.29	7.526
0	1966	38.610	72.600	9	15.03	6.651
0	1967	38.610	67.400	10	16.78	5.958
0	1968	50.850	66.800	11	18.53	5.396
1	1969	56.400	66.000	12	20.28	4.931
12	1970	29.400	65.700	13	22.03	4.540

Press <RETURN> to continue

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (INS.)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
0	1971	53.820	52.600	27	46.50	2.150
12	1972	31.100	51.480	28	48.25	2.072
12	1973	53.200	50.850	29	50.00	2.000
2	1974	44.200	50.850	30	51.75	1.932
0	1975	40.630	49.900	31	53.50	1.869
3	1976	67.400	49.400	32	55.24	1.810
12	1977	47.900	48.600	33	56.99	1.755
0	1978	53.820	47.900	34	58.74	1.702
12	1979	53.600	47.700	35	60.49	1.653
3	1980	49.900	45.900	36	62.24	1.607
2	1981	36.900	44.800	37	63.99	1.563
12	1982	42.800	44.600	38	65.73	1.521
12	1983	38.400	44.200	39	67.48	1.482

Press <RETURN> to continue

All Years _ Instantaneous

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (INS.)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
2	1984	74.400	52.600	27	46.50	2.150
0	1985	56.710	51.480	28	48.25	2.072
3	1986	47.700	50.850	29	50.00	2.000
4	1987	42.700	50.850	30	51.75	1.932
3	1988	23.900	49.900	31	53.50	1.869
5	1989	21.300	49.400	32	55.24	1.810
12	1990	83.300	48.600	33	56.99	1.755
3	1991	52.600	47.900	34	58.74	1.702
12	1992	35.200	47.700	35	60.49	1.653
3	1993	43.900	45.900	36	62.24	1.607
0	1994	42.050	44.800	37	63.99	1.563
11	1995	58.500	44.600	38	65.73	1.521
4	1996	60.000	44.200	39	67.48	1.482

Press <RETURN> to continue

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (INS.)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
2	1997	44.800	43.900	40	69.23	1.444
3	1998	49.400	42.800	41	70.98	1.409
11	1999	44.600	42.700	42	72.73	1.375
6	2000	45.900	42.050	43	74.48	1.343
2	2001	84.500	40.630	44	76.22	1.312
5	2002	31.500	38.610	45	77.97	1.283
11	2003	32.900	38.610	46	79.72	1.254
12	2004	53.500	38.400	47	81.47	1.227
4	2005	66.000	36.900	48	83.22	1.202
12	2006	72.600	36.610	49	84.97	1.177
3	2007	91.000	35.200	50	86.71	1.153
12	2008	86.800	32.900	51	88.46	1.130
2	2009	94.600	31.500	52	90.21	1.109

Press <RETURN> to continue

All Years _ Instantaneous

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (INS.)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
3	2010	63.100	31.100	53	91.96	1.087
0	2011	56.060	29.400	54	93.71	1.067
10	2012	65.700	26.210	55	95.45	1.048
1	2013	66.800	23.900	56	97.20	1.029
5	2014	48.600	21.300	57	98.95	1.011

Press <RETURN> to continue

All Years _ Instantaneous

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

        FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
        02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (INS.)

                              SAMPLE STATISTICS
                     MEAN       S.D.        C.V       C.S.       C.K.
      X SERIES      53.554     18.676       .349       .863      3.897
   LN X SERIES       3.923       .346       .088      -.118      3.271
   L-MOM RATIO      53.554     10.295       .192       .164       .179

   X(MIN)=     21.300                          TOTAL SAMPLE SIZE=  57
   X(MAX)=    110.040                        NO. OF LOW OUTLIERS=   0
   LOWER OUTLIER LIMIT OF X=   19.039          NO. OF ZERO FLOWS=   0

 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
            DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)=  .8577E+04
        GEV PARAMETERS:     U=     44.91   A=   15.023   K=     .002

                         FLOOD FREQUENCY REGIME

                RETURN        EXCEEDANCE        FLOOD
                PERIOD        PROBABILITY

                 1.003          .997            18.4
                 1.050          .952            28.2
                 1.250          .800            37.8
                 2.000          .500            50.4
                 5.000          .200            67.4
                10.000          .100            78.6
                20.000          .050            89.4
                50.000          .020           103
               100.000          .010           114
               200.000          .005           124
               500.000          .002           138

 Press <RETURN> to continue , <CTRL> P to obtain hard copy
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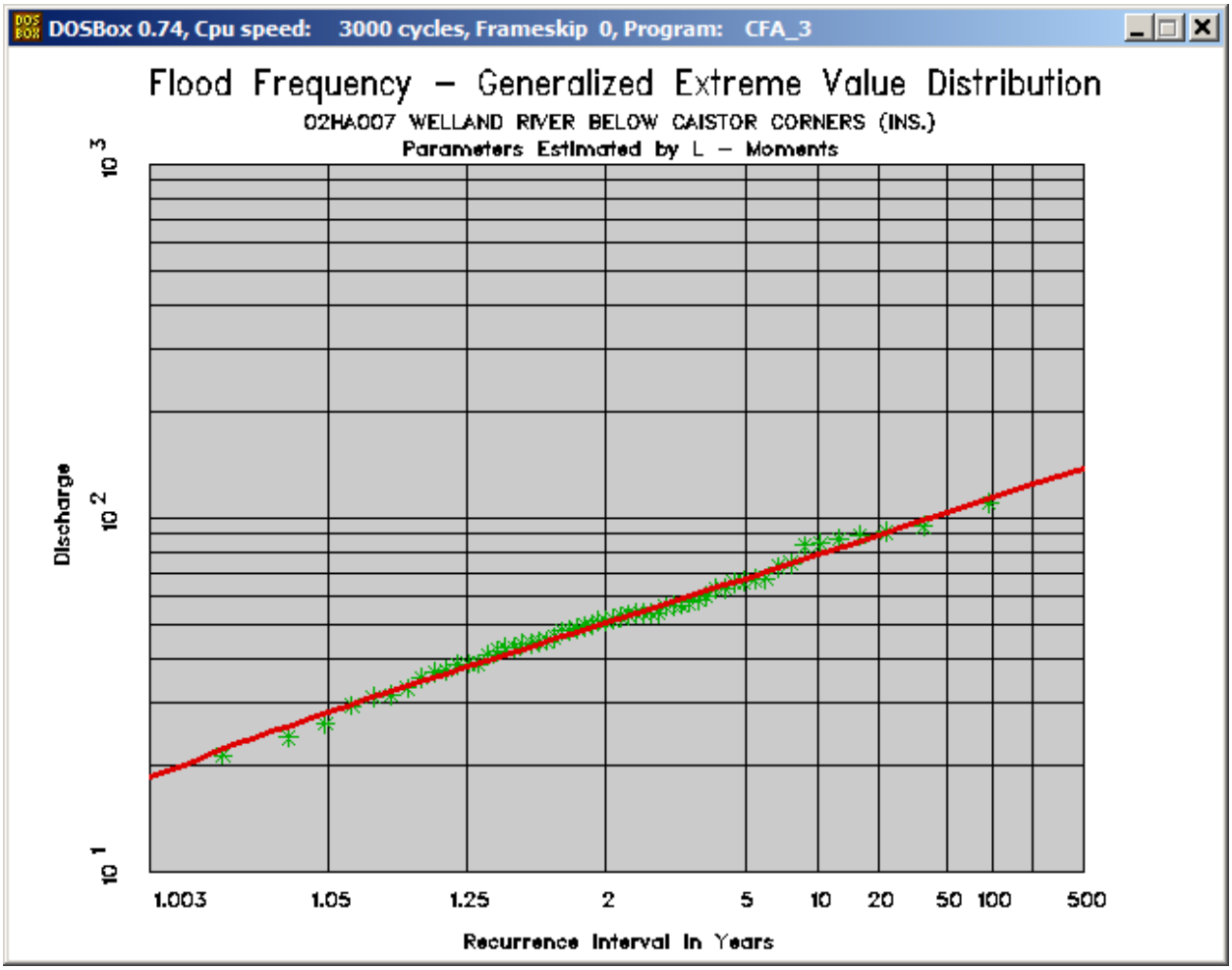
All Years _ Instantaneous



All Years _ Instantaneous

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

        FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
        02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (INS.)

                              SAMPLE STATISTICS
                     MEAN       S.D.        C.V       C.S.       C.K.
      X SERIES     53.554     18.676       .349       .863      3.897
   LN X SERIES      3.923       .346       .088      -.118      3.271
LN(X-A) SERIES      4.035       .309       .077      -.007      3.202

   X(MIN)=     21.300                        TOTAL SAMPLE SIZE=  57
   X(MAX)=    110.040                      NO. OF LOW OUTLIERS=   0
   LOWER OUTLIER LIMIT OF X=   19.039        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

            SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD
        3LN PARAMETERS:     A=    -5.730   M= 4.035   S=  .309

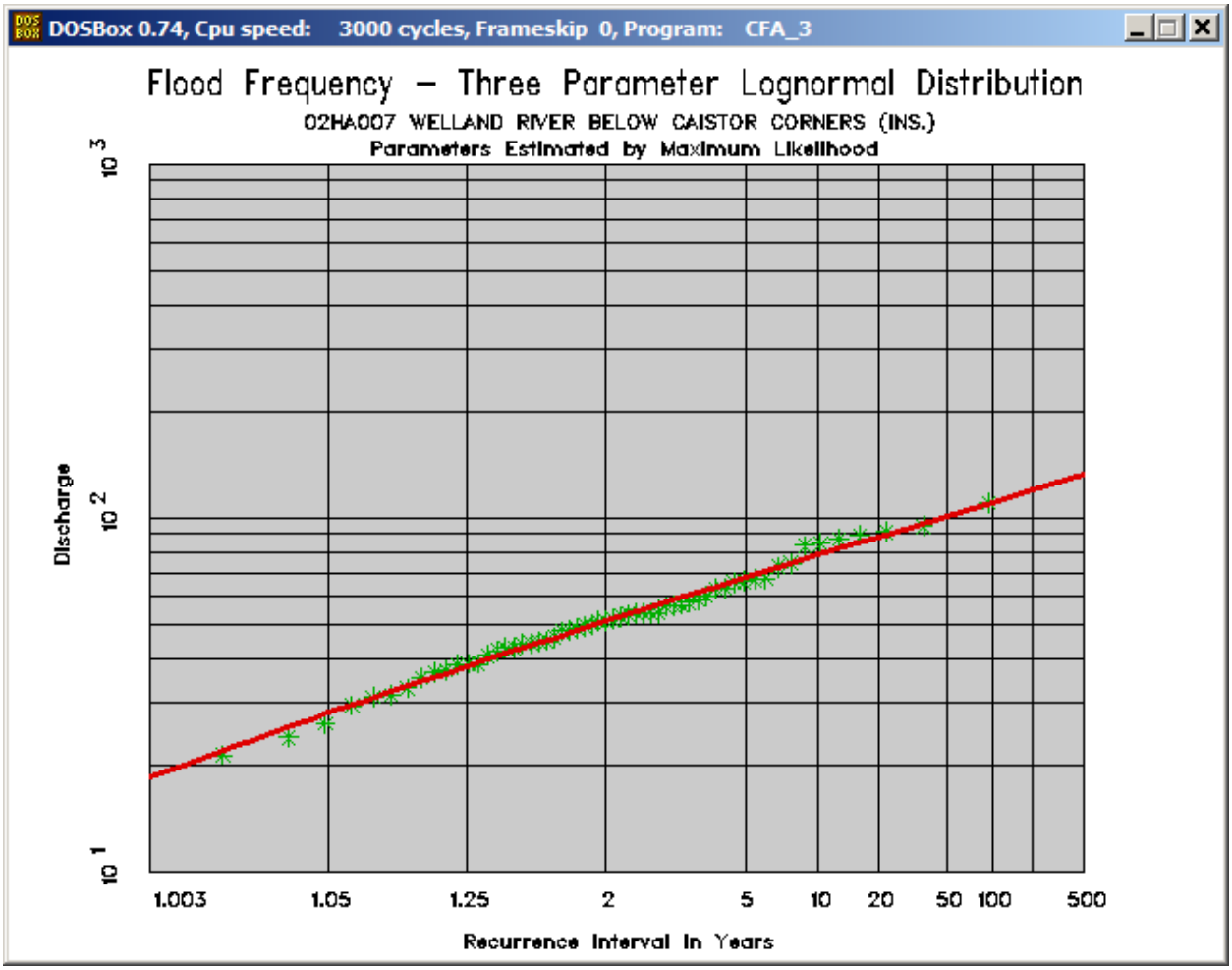
                         FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003          .997            18.5
               1.050          .952            28.0
               1.250          .800            37.9
               2.000          .500            50.8
               5.000          .200            67.6
              10.000          .100            78.3
              20.000          .050            88.3
              50.000          .020           101
             100.000          .010           110
             200.000          .005           120
             500.000          .002           132

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

All Years _ Instantaneous



All Years _ Instantaneous

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

        FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
        02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (INS.)

                              SAMPLE STATISTICS
                     MEAN        S.D.        C.V        C.S.       C.K.
     X SERIES      53.554      18.676       .349        .863      3.897
  LN X SERIES       3.923        .346       .088       -.118      3.271

  X(MIN)=     21.300                          TOTAL SAMPLE SIZE=  57
  X(MAX)=    110.040                        NO. OF LOW OUTLIERS=   0
  LOWER OUTLIER LIMIT OF X=   19.039          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

            SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD
            DISTRIBUTION IS UPPER BOUNDED AT M=  .1598E+05
    LP3 PARAMETERS: A= -.2049E-01 B=  281.0     LOG(M)=  9.679
                                                   M =  .1598E+05

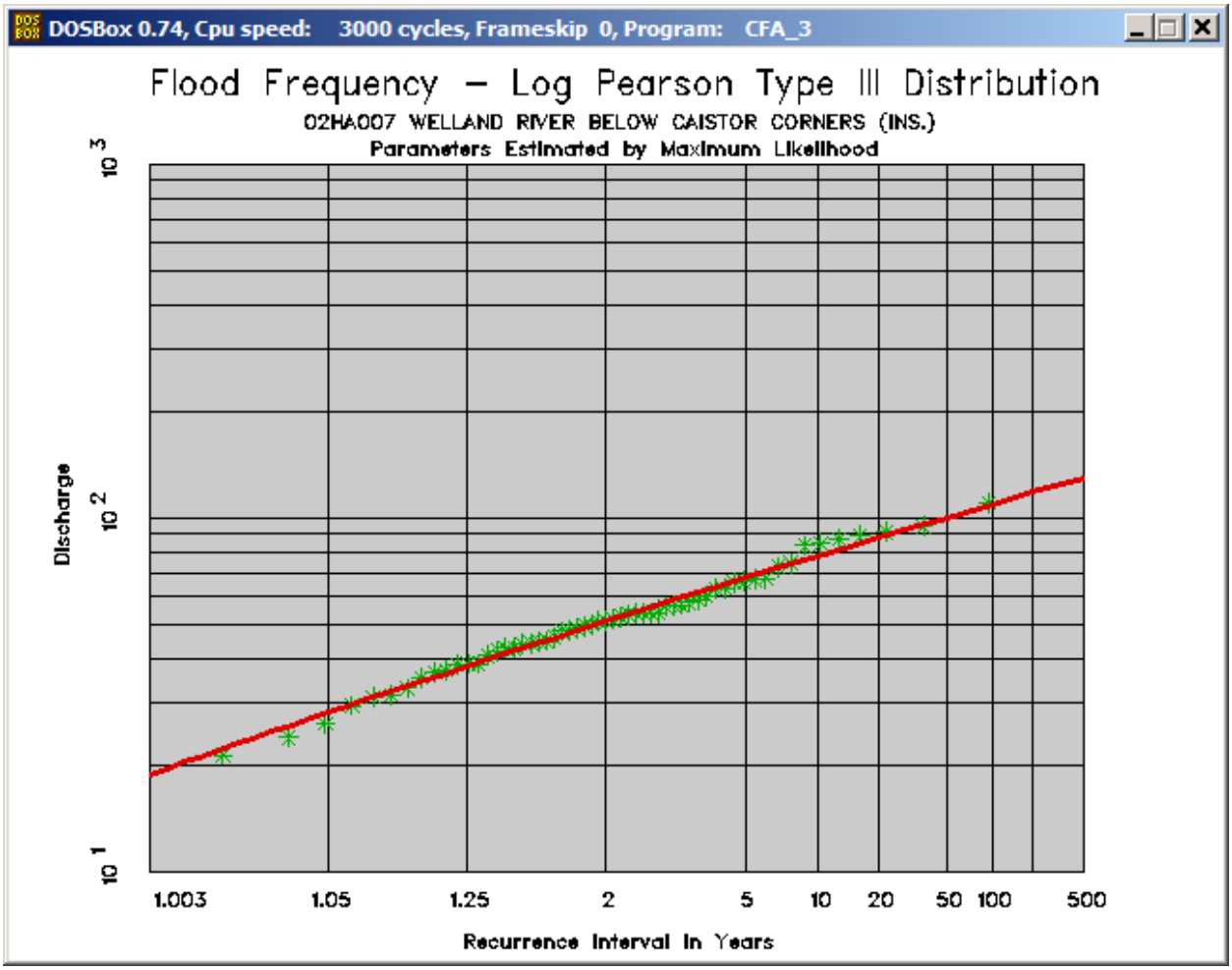
                         FLOOD FREQUENCY REGIME

                RETURN        EXCEEDANCE        FLOOD
                PERIOD        PROBABILITY

                 1.003          .997            18.8
                 1.050          .952            28.1
                 1.250          .800            37.9
                 2.000          .500            50.9
                 5.000          .200            67.6
                10.000          .100            78.1
                20.000          .050            87.9
                50.000          .020           100
               100.000          .010           109
               200.000          .005           118
               500.000          .002           129

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

All Years _ Instantaneous



All Years _ Instantaneous

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

```
FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (INS.)

                         SAMPLE STATISTICS
                 MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     53.554     18.676       .349       .863      3.897
LN X SERIES      3.923       .346       .088      -.118      3.271
L-MOM RATIO     53.554     10.295       .192       .164       .179

X(MIN)=     21.300                        TOTAL SAMPLE SIZE=  57
X(MAX)=    110.040                      NO. OF LOW OUTLIERS=   0
LOWER OUTLIER LIMIT OF X=   19.039        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

```
THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M=   17.204   A=     20.148   B=  9.94   C=   -519.751   D= -.036
          DISTRIBUTION IS UPPER BOUNDED AT E=  .5571E+03

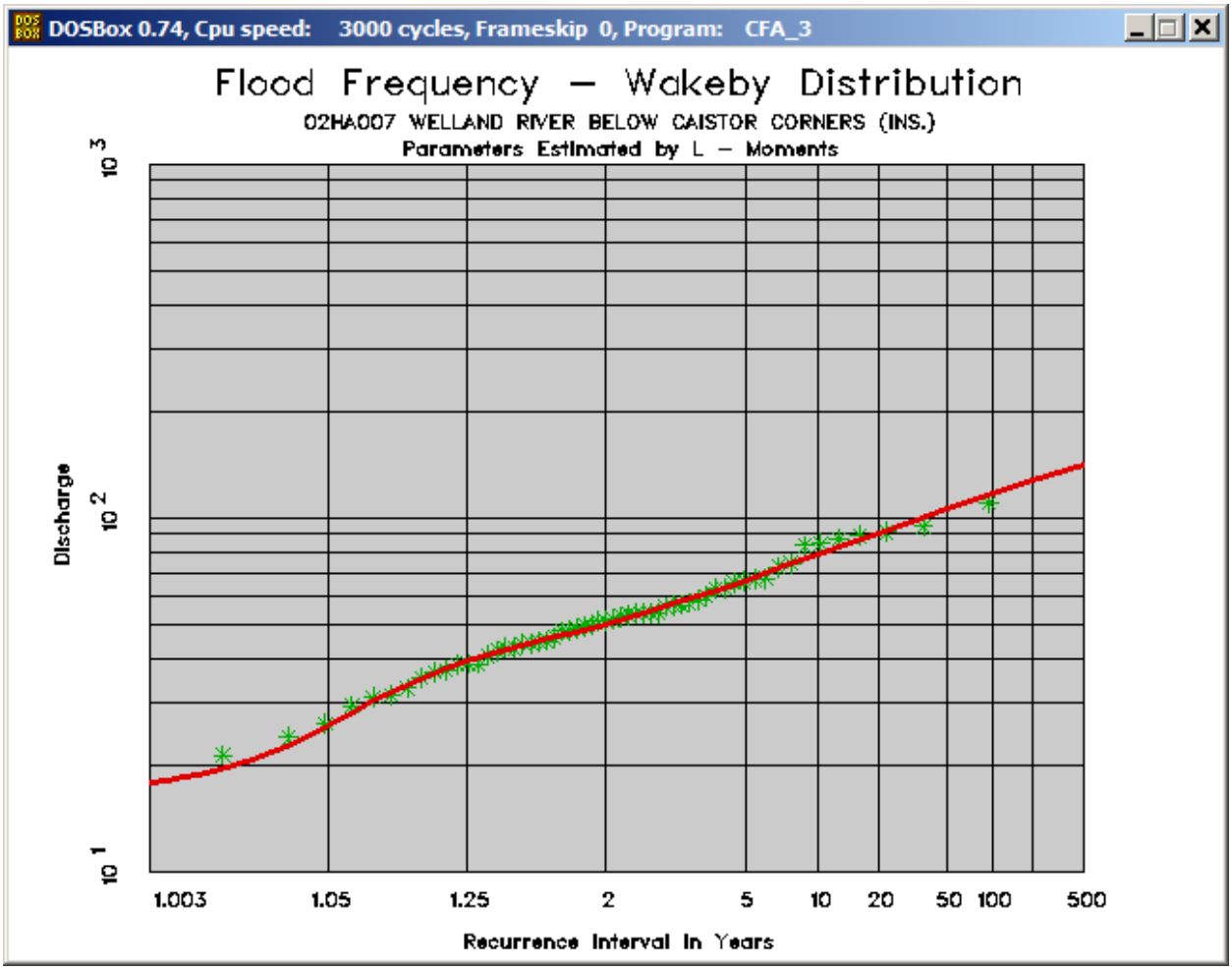
                        FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003           .997            17.9
               1.050           .952            25.9
               1.250           .800            39.3
               2.000           .500            50.1
               5.000           .200            66.6
              10.000           .100            78.7
              20.000           .050            90.4
              50.000           .020           106
             100.000           .010           117
             200.000           .005           128
             500.000           .002           141

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

All Years _ Instantaneous



All Years _ Instantaneous

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

WSC STATION NO=02HA007
WSC STATION NAME=9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
2	1961	45.900	82.500	1	3.70	27.000
12	1967	33.400	81.300	2	9.88	10.125
12	1973	51.000	73.700	3	16.05	6.231
3	1976	61.700	73.200	4	22.22	4.500
12	1983	36.500	72.900	5	28.40	3.522
12	1990	73.700	64.900	6	34.57	2.893
11	1995	53.100	62.300	7	40.74	2.455
2	2000	41.500	61.700	8	46.91	2.132
2	2001	72.900	57.700	9	53.09	1.884
52	2002	28.800	53.100	10	59.26	1.688
4	2005	62.300	51.000	11	65.43	1.528
12	2006	64.900	45.900	12	71.60	1.397
3	2007	73.200	41.500	13	77.78	1.286

Press <RETURN> to continue

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

WSC STATION NO=02HA007
WSC STATION NAME=9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
12	2008	82.500	36.500	14	83.95	1.191
2	2009	81.300	33.400	15	90.12	1.110
12	2013	57.700	28.800	16	96.30	1.038

Press <RETURN> to continue

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

```
FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
02HA007     9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS

                        SAMPLE STATISTICS
                 MEAN       S.D.        C.V       C.S.       C.K.
   X SERIES     57.525     16.992       .295      -.183      2.628
LN X SERIES      4.006       .324       .081      -.629      3.095
L-MOM RATIO     57.525     10.053       .175      -.058       .018

X(MIN)=     28.800                        TOTAL SAMPLE SIZE=  16
X(MAX)=     82.500                      NO. OF LOW OUTLIERS=   0
LOWER OUTLIER LIMIT OF X=   26.247        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

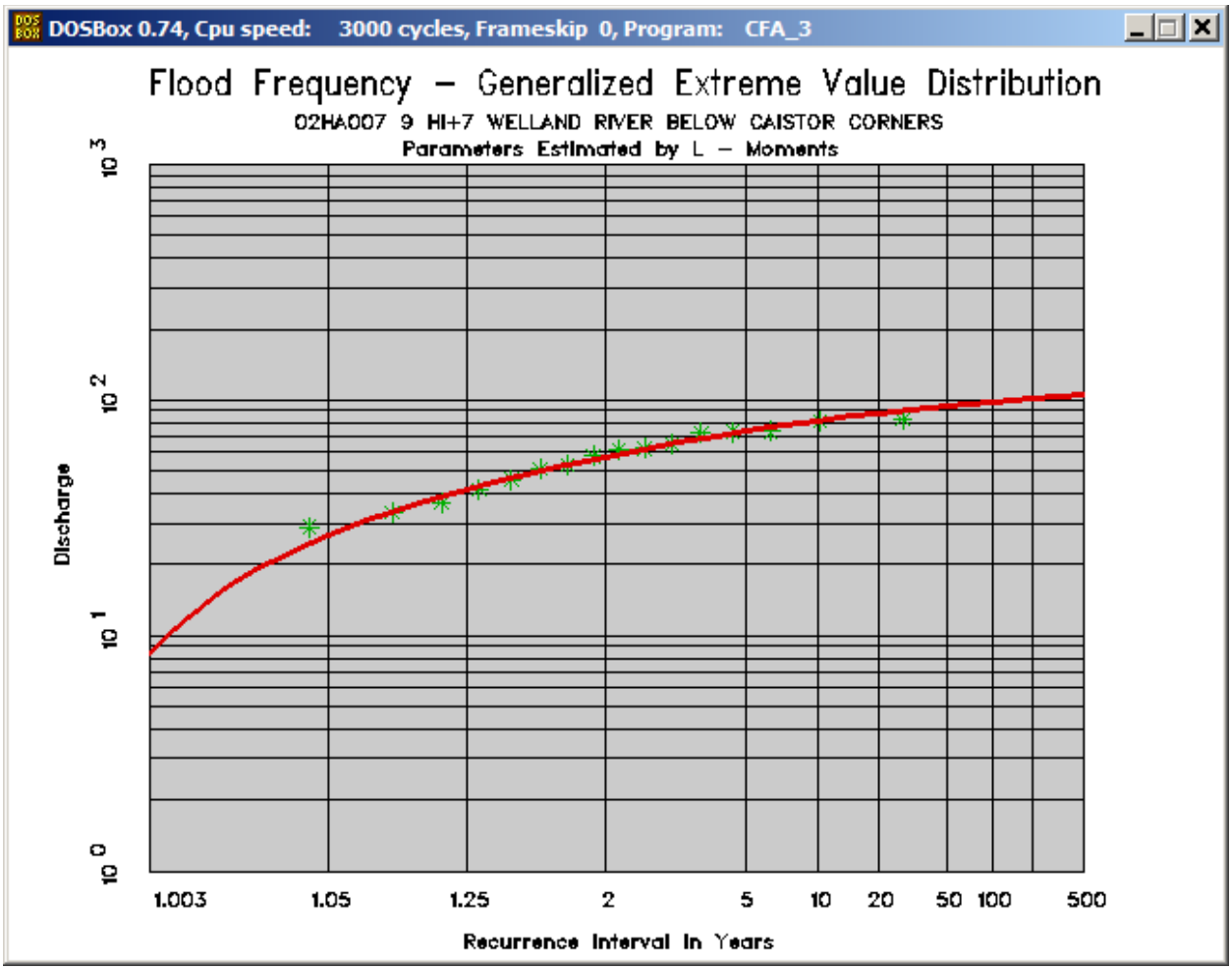
```
SOLUTION OBTAINED VIA L - MOMENTS
DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)=  .1154E+03
GEV PARAMETERS:     U=     51.04   A=   18.595   K=     .289

                    FLOOD FREQUENCY REGIME

          RETURN        EXCEEDANCE        FLOOD
          PERIOD        PROBABILITY

           1.003           .997             8.38
           1.050           .952            26.6
           1.250           .800            41.6
           2.000           .500            57.5
           5.000           .200            73.7
          10.000           .100            81.8
          20.000           .050            88.1
          50.000           .020            94.6
         100.000           .010            98.4
         200.000           .005           101
         500.000           .002           105

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
02HA007 9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS
Parameters Estimated by L – Moments
Discharge
10 3
10 2
10 1
10 0
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

9+7_Daily

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

```
FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
02HA007     9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS

                         SAMPLE STATISTICS
                  MEAN       S.D.        C.V       C.S.       C.K.
      X SERIES    57.525     16.992      .295      -.183      2.628
   LN X SERIES     4.006       .324      .081      -.629      3.095
LN(A-X) SERIES     4.496       .188      .042      -.076      2.625

   X(MIN)=     28.800                        TOTAL SAMPLE SIZE=  16
   X(MAX)=     82.500                      NO. OF LOW OUTLIERS=   0
   LOWER OUTLIER LIMIT OF X=   26.247        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

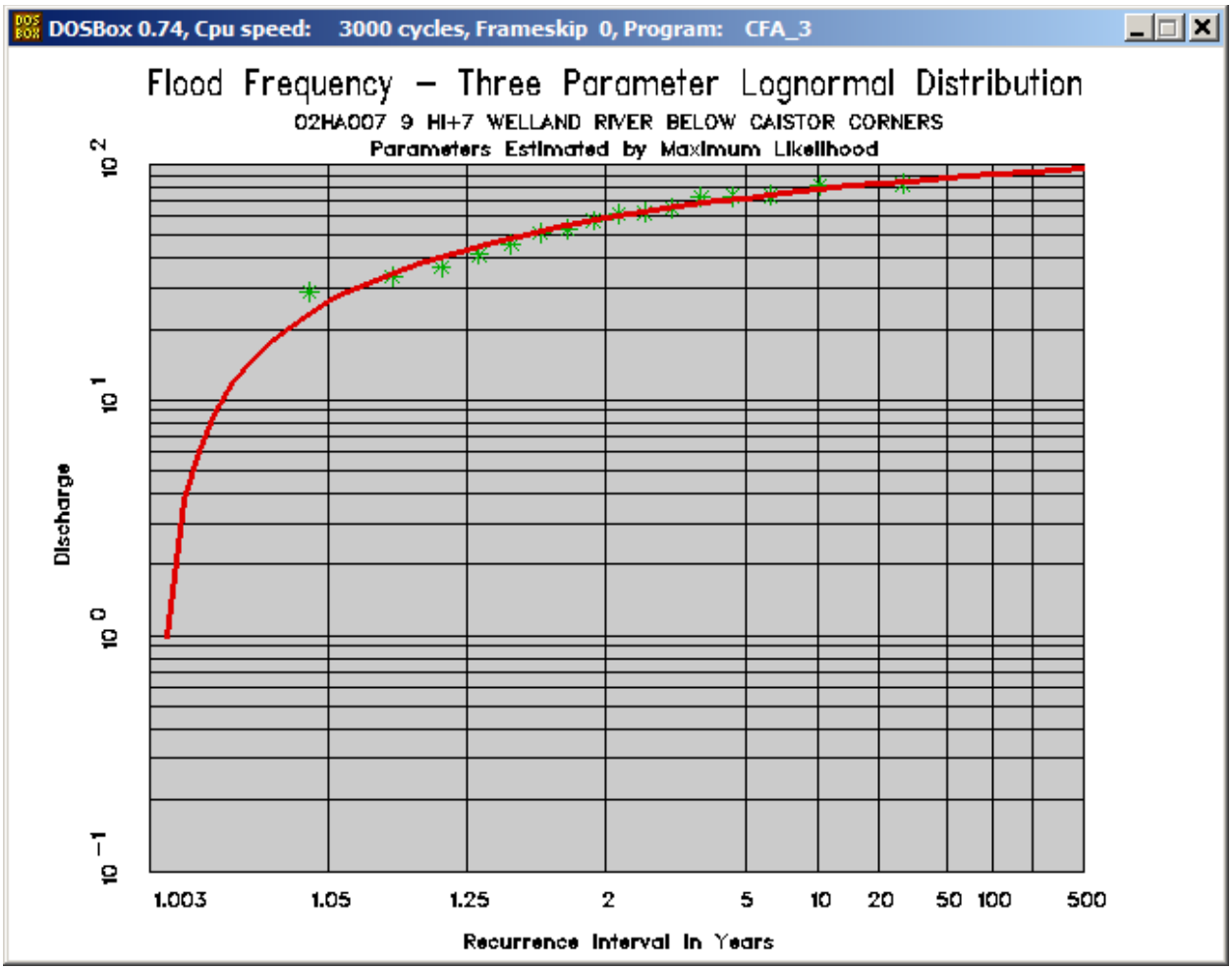
```
SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD
DISTRIBUTION IS UPPER BOUNDED AT A=  .1487E+03
3LN PARAMETERS:     A=   148.686   M= 4.496   S=  .188

                    FLOOD FREQUENCY REGIME

          RETURN        EXCEEDANCE        FLOOD
          PERIOD        PROBABILITY

           1.003          .997             -
           1.050          .952            26.0
           1.250          .800            43.6
           2.000          .500            59.0
           5.000          .200            72.1
          10.000          .100            78.2
          20.000          .050            82.9
          50.000          .020            87.7
         100.000          .010            90.8
         200.000          .005            93.4
         500.000          .002            96.5

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


DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Three Parameter Lognormal Distribution
02HA007 9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS
Parameters Estimated by Maximum Likelihood
Discharge
10 2
10 1
10 0
10 −1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

9+7_Daily

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

```
FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02HA007     9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS

                    SAMPLE STATISTICS
                MEAN       S.D.       C.V       C.S.       C.K.
   X SERIES    57.525     16.992      .295      -.183      2.628
LN X SERIES     4.006       .324      .081      -.629      3.095

X(MIN)=     28.800                    TOTAL SAMPLE SIZE=  16
X(MAX)=     82.500                  NO. OF LOW OUTLIERS=   0
LOWER OUTLIER LIMIT OF X=   26.247    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

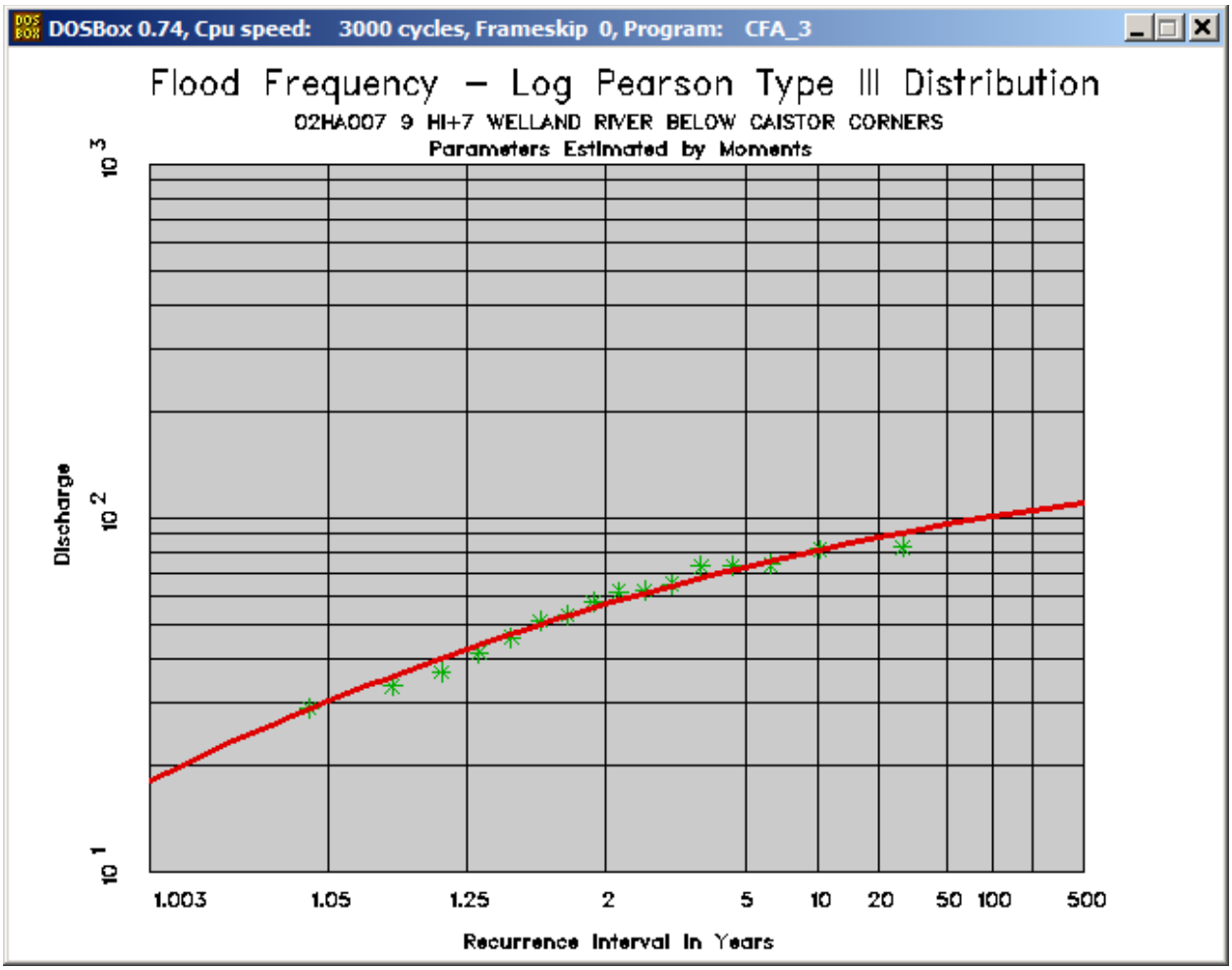
```
SOLUTION OBTAINED VIA MOMENTS
DISTRIBUTION IS UPPER BOUNDED AT M=  153.9
LP3 PARAMETERS: A= -.1020     B=  10.09     LOG(M)=  5.036
                                                M =  153.9

                    FLOOD FREQUENCY REGIME

            RETURN        EXCEEDANCE        FLOOD
            PERIOD        PROBABILITY

             1.003          .997            18.0
             1.050          .952            30.3
             1.250          .800            42.5
             2.000          .500            56.8
             5.000          .200            72.5
            10.000          .100            80.9
            20.000          .050            87.9
            50.000          .020            95.5
           100.000          .010           101
           200.000          .005           105
           500.000          .002           110

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


DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Log Pearson Type III Distribution
02HA007 9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS
Parameters Estimated by Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

9+7_Daily

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

```
FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02HA007     9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS

                        SAMPLE STATISTICS
                 MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     57.525     16.992       .295      -.183      2.628
LN X SERIES      4.006       .324       .081      -.629      3.095
L-MOM RATIO     57.525     10.053       .175      -.058       .018

X(MIN)=     28.800                        TOTAL SAMPLE SIZE=  16
X(MAX)=     82.500                      NO. OF LOW OUTLIERS=   0
LOWER OUTLIER LIMIT OF X=   26.247        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

```
THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M=   20.326   A=     29.717   B=  3.61   C=    -86.339   D= -.192
          DISTRIBUTION IS UPPER BOUNDED AT E=  .1364E+03

                        FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003           .997            20.7
               1.050           .952            25.9
               1.250           .800            40.4
               2.000           .500            58.4
               5.000           .200            72.9
              10.000           .100            80.9
              20.000           .050            87.9
              50.000           .020            95.7
             100.000           .010           101
             200.000           .005           105
             500.000           .002           110

Press <RETURN> to continue , <CTRL> P to obtain hard copy
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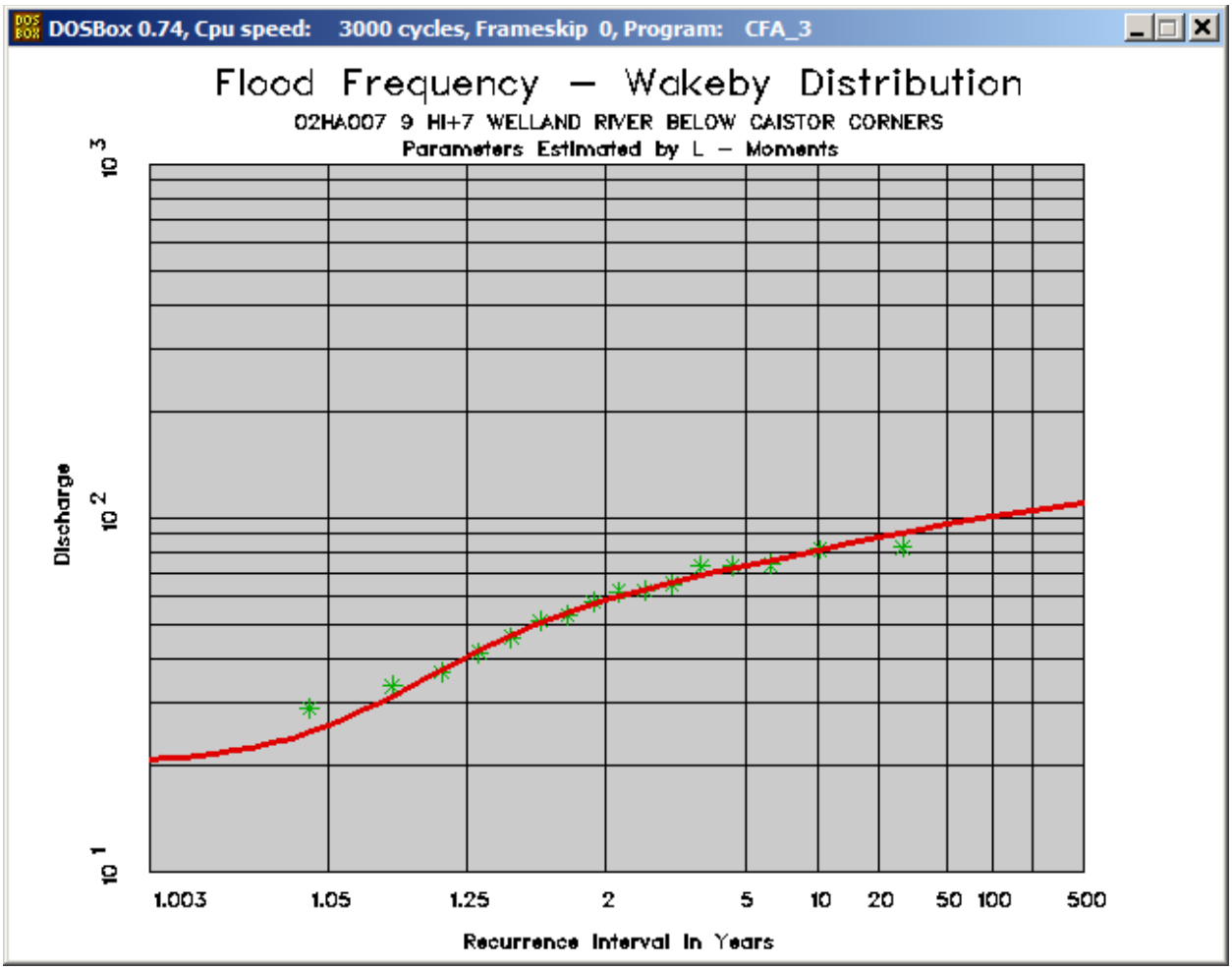
DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Wakeby Distribution
02HA007 9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS
Parameters Estimated by L – Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

9+7_Daily

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

```
          FREQUENCY ANALYSIS - WEIBULL DISTRIBUTION
          02HA007     9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS
                          SAMPLE STATISTICS
                MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     57.525     16.992       .295      -.183      2.628
LN X SERIES      4.006       .324       .081      -.629      3.095

X(MIN)=     28.800                        TOTAL SAMPLE SIZE=  16
X(MAX)=     82.500                      NO. OF LOW OUTLIERS=   0
                                          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

```
                      WEIBULL PARAMETERS

         1/A = .22038     E =   -10.38     U =    63.99

                      FLOOD FREQUENCY REGIME

            RETURN        EXCEEDANCE        FLOOD
            PERIOD        PROBABILITY

             1.003           .997            10.3
             1.050           .952            27.8
             1.250           .800            43.1
             2.000           .500            58.2
             5.000           .200            72.2
            10.000           .100            79.0
            20.000           .050            84.3
            50.000           .020            90.1
           100.000           .010            93.8
           200.000           .005            97.0
           500.000           .002           101

  Press <RETURN> to continue , <CTRL> P to obtain hard copy_
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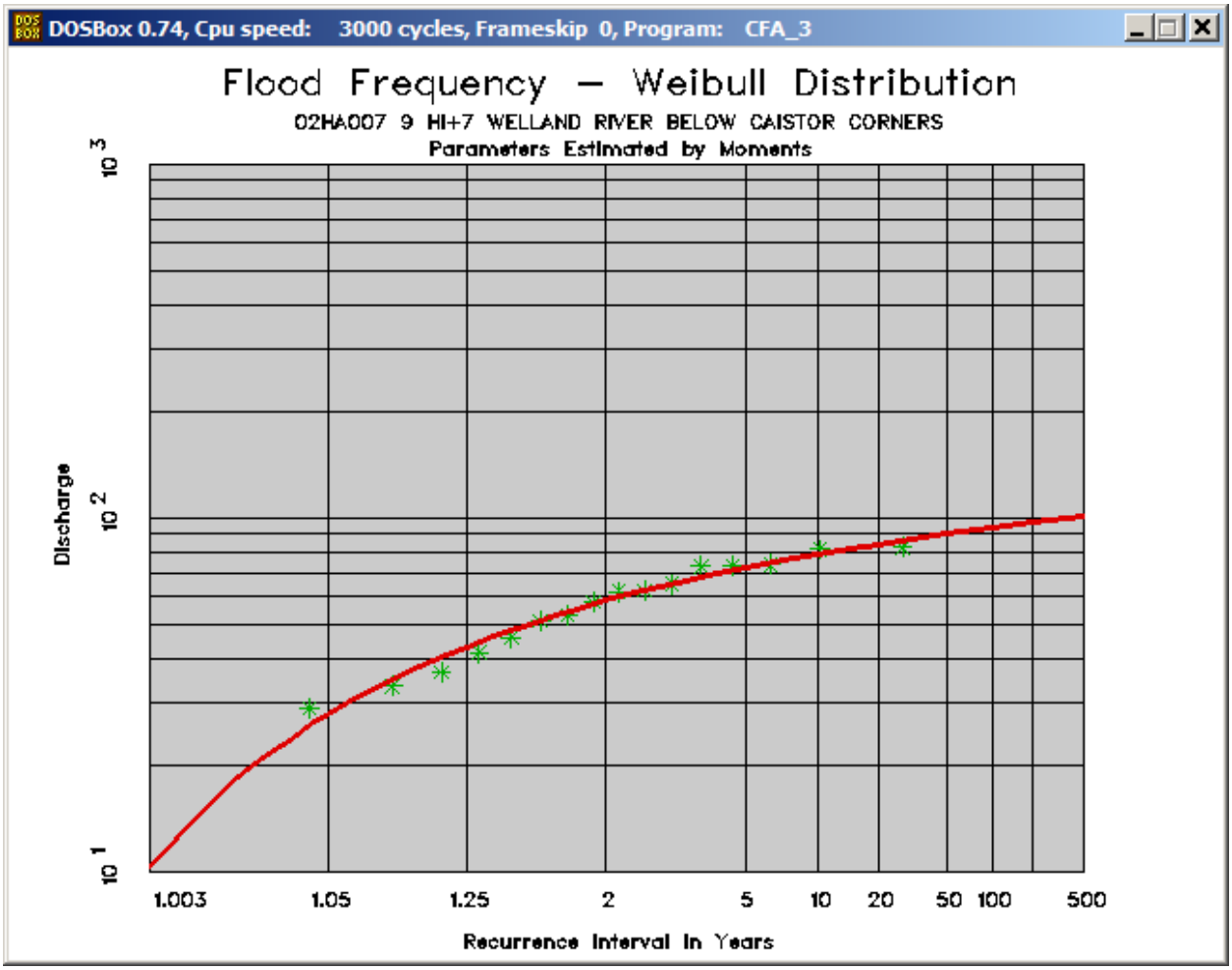
DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Weibull Distribution
02HA007 9 HI+7 WELLAND RIVER BELOW CAISTOR CORNERS
Parameters Estimated by Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

9+7_Daily

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
3	1976	61.700	82.500	1	3.95	25.333
12	1990	73.700	81.300	2	10.53	9.500
3	1991	46.500	73.700	3	17.11	5.846
11	1995	53.100	73.200	4	23.68	4.222
4	1996	48.200	72.900	5	30.26	3.304
11	1999	35.600	64.900	6	36.84	2.714
2	2001	72.900	61.700	7	43.42	2.303
5	2002	28.800	57.700	8	50.00	2.000
11	2006	64.900	56.500	9	56.58	1.767
3	2007	73.200	53.100	10	63.16	1.583
12	2008	82.500	48.200	11	69.74	1.434
2	2009	81.300	46.500	12	76.32	1.310
10	2012	56.500	42.600	13	82.89	1.206

Press <RETURN> to continue

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
1	2013	57.700	35.600	14	89.47	1.118
5	2014	42.600	28.800	15	96.05	1.041

Press <RETURN> to continue

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

```
FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)

                         SAMPLE STATISTICS
                  MEAN       S.D.        C.V       C.S.       C.K.
   X SERIES     58.613     16.354       .279      -.204      2.921
LN X SERIES      4.030       .307       .076      -.750      3.806
L-MOM RATIO     58.613      9.670       .165      -.056       .047

X(MIN)=     28.800                        TOTAL SAMPLE SIZE=  15
X(MAX)=     82.500                      NO. OF LOW OUTLIERS=   0
LOWER OUTLIER LIMIT OF X=   28.230        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

```
SOLUTION OBTAINED VIA L - MOMENTS
DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)=  .1160E+03
GEV PARAMETERS:     U=     52.26   A=   17.992   K=     .282

                    FLOOD FREQUENCY REGIME

          RETURN        EXCEEDANCE        FLOOD
          PERIOD        PROBABILITY

           1.003           .997            11.2
           1.050           .952            28.7
           1.250           .800            43.1
           2.000           .500            58.5
           5.000           .200            74.3
          10.000           .100            82.2
          20.000           .050            88.4
          50.000           .020            94.8
         100.000           .010            98.6
         200.000           .005           102
         500.000           .002           105

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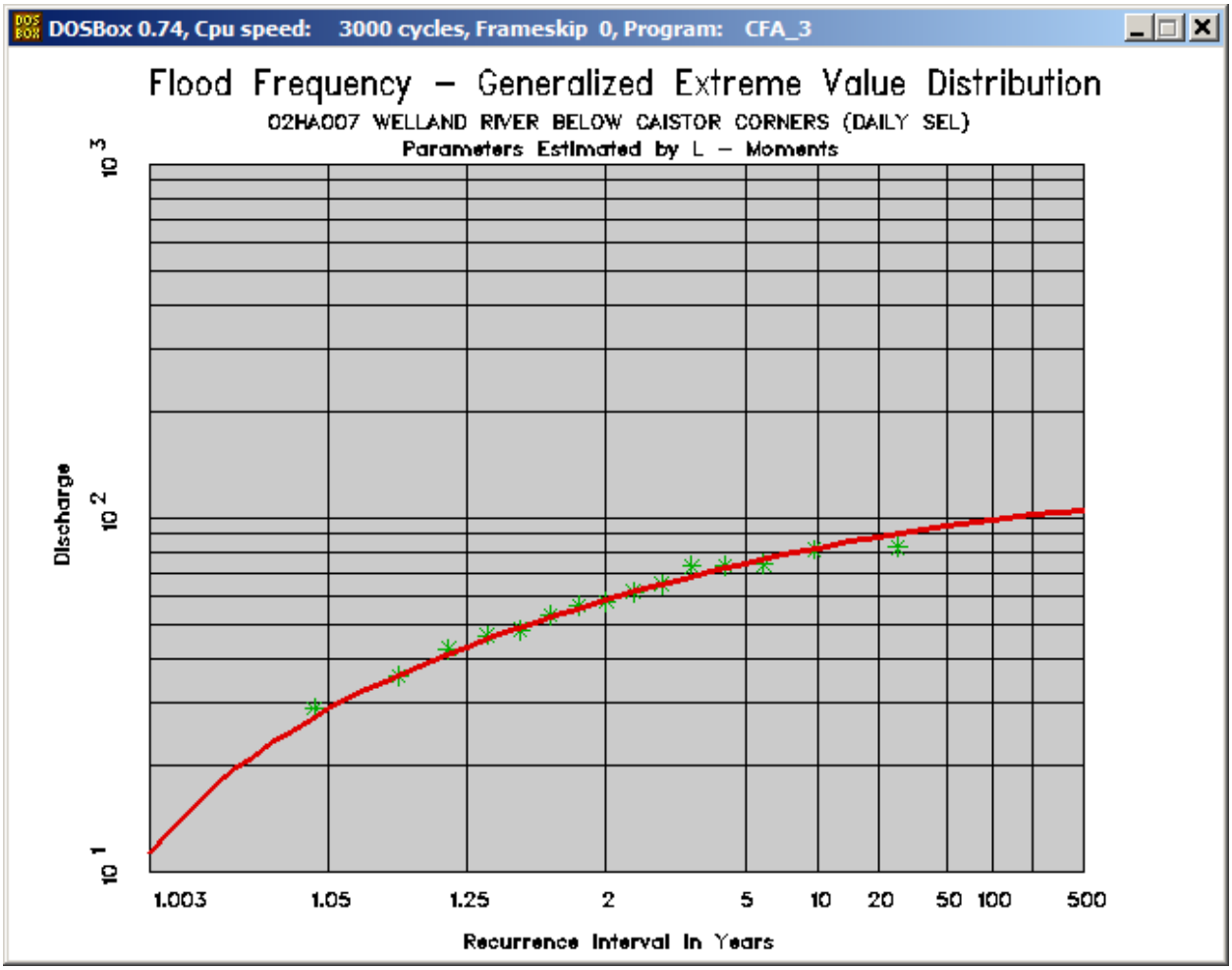

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Generalized Extreme Value Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)
Parameters Estimated by L – Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

        FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
        02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)

                              SAMPLE STATISTICS
                     MEAN       S.D.        C.V       C.S.       C.K.
      X SERIES     58.613     16.354       .279      -.204      2.921
   LN X SERIES      4.030       .307       .076      -.750      3.806
LN(A-X) SERIES      4.536       .174       .038      -.066      2.798

   X(MIN)=     28.800                        TOTAL SAMPLE SIZE=  15
   X(MAX)=     82.500                      NO. OF LOW OUTLIERS=   0
   LOWER OUTLIER LIMIT OF X=   28.230        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

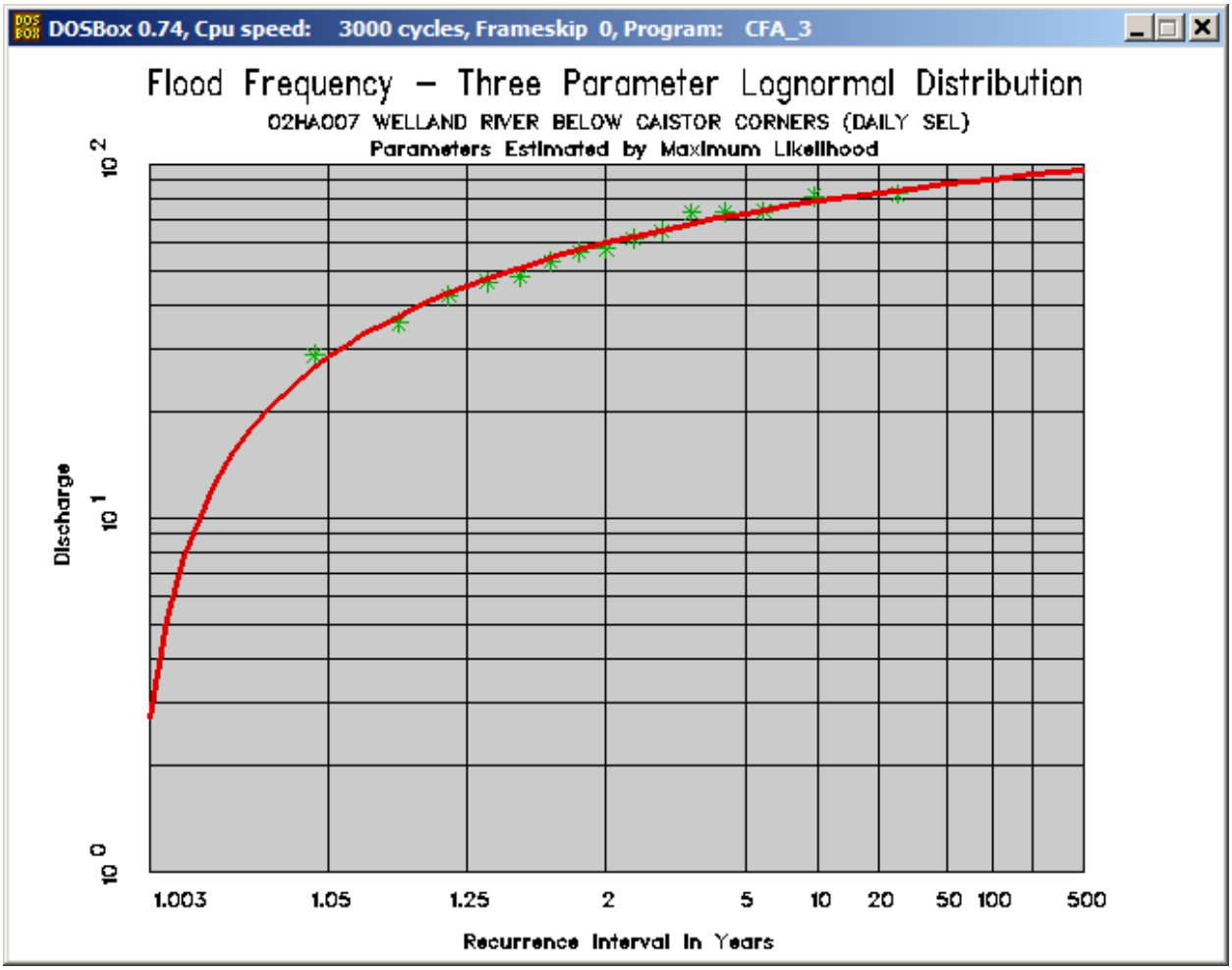
           SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD
           DISTRIBUTION IS UPPER BOUNDED AT A=  .1533E+03
        3LN PARAMETERS:     A=   153.258   M= 4.536   S=  .174

                         FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003          .997             2.72
               1.050          .952            28.5
               1.250          .800            45.2
               2.000          .500            59.9
               5.000          .200            72.6
              10.000          .100            78.6
              20.000          .050            83.2
              50.000          .020            88.0
             100.000          .010            91.0
             200.000          .005            93.6
             500.000          .002            96.7

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


DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Three Parameter Lognormal Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)
Parameters Estimated by Maximum Likelihood
Discharge
10 2
10 1
10 0
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

```
FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)

                         SAMPLE STATISTICS
                 MEAN       S.D.        C.V       C.S.       C.K.
   X SERIES     58.613     16.354       .279      -.204      2.921
LN X SERIES      4.030       .307       .076      -.750      3.806

X(MIN)=     28.800                        TOTAL SAMPLE SIZE=  15
X(MAX)=     82.500                      NO. OF LOW OUTLIERS=   0
LOWER OUTLIER LIMIT OF X=   28.230        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

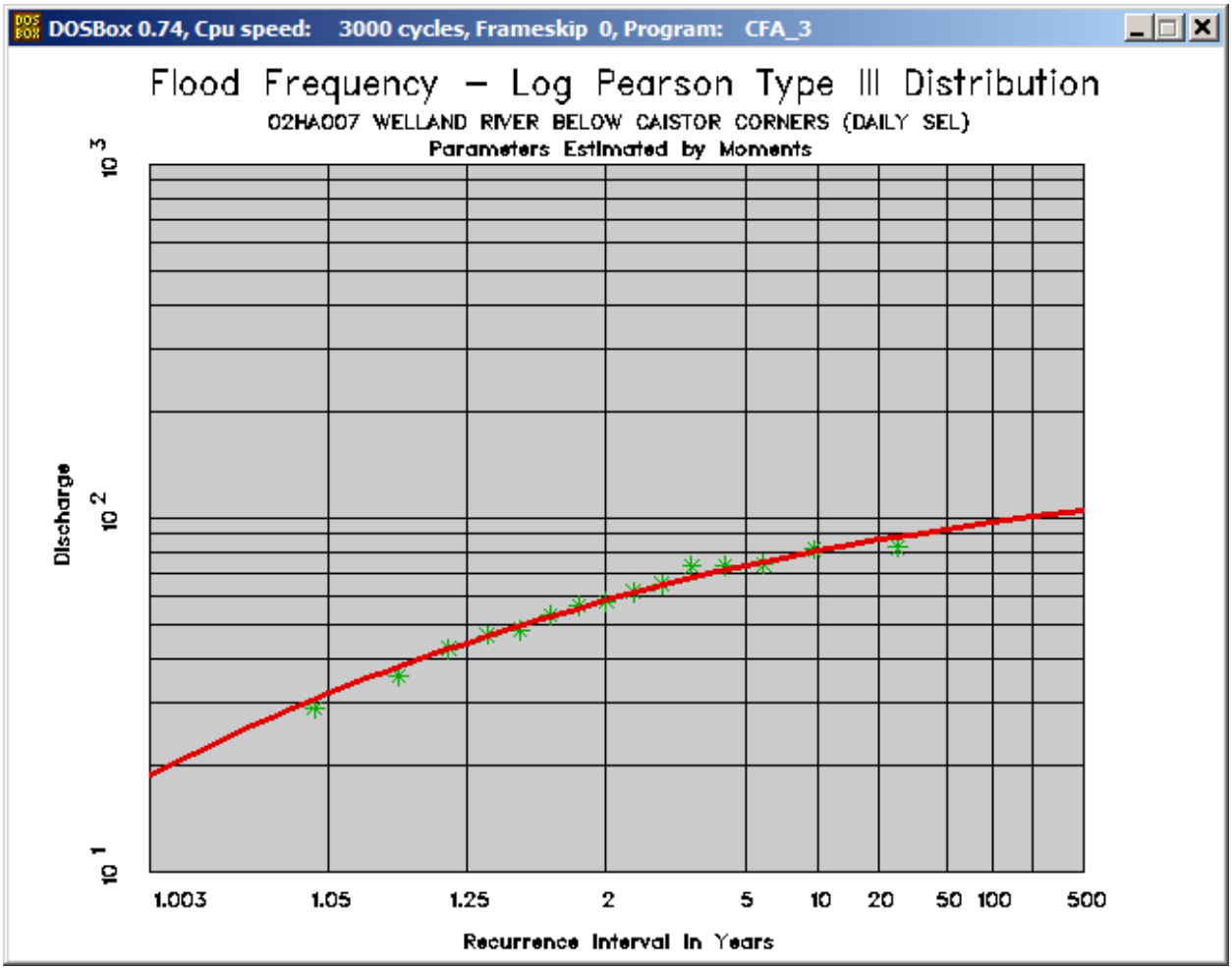
```
                SOLUTION OBTAINED VIA MOMENTS
          DISTRIBUTION IS UPPER BOUNDED AT M=  127.6
   LP3 PARAMETERS: A= -.1151     B=  7.116     LOG(M)=  4.849
                                                  M =  127.6

                        FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003          .997            18.8
               1.050          .952            31.8
               1.250          .800            44.2
               2.000          .500            58.4
               5.000          .200            73.1
              10.000          .100            80.7
              20.000          .050            86.7
              50.000          .020            93.1
             100.000          .010            97.1
             200.000          .005           101
             500.000          .002           105

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


DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Log Pearson Type III Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)
Parameters Estimated by Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

```
FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)

                         SAMPLE STATISTICS
                  MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     58.613     16.354       .279      -.204      2.921
LN X SERIES      4.030       .307       .076      -.750      3.806
L-MOM RATIO     58.613      9.670       .165      -.056       .047

X(MIN)=     28.800                        TOTAL SAMPLE SIZE=  15
X(MAX)=     82.500                      NO. OF LOW OUTLIERS=   0
LOWER OUTLIER LIMIT OF X=   28.230        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

```
THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

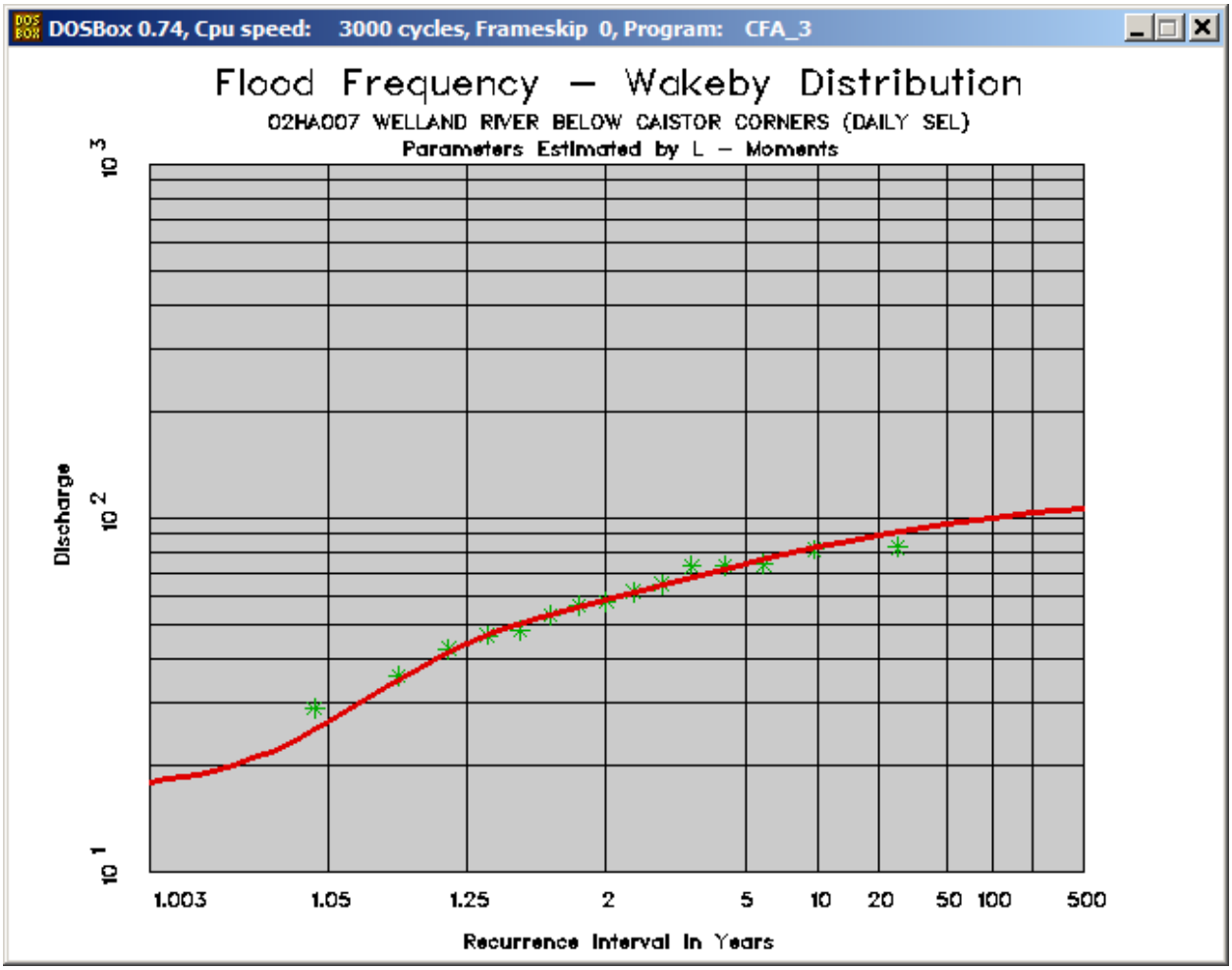
M=   17.280   A=     26.207   B=  7.49   C=    -70.740   D= -.347
          DISTRIBUTION IS UPPER BOUNDED AT E=  .1142E+03

                        FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003           .997            17.9
               1.050           .952            26.5
               1.250           .800            43.8
               2.000           .500            58.5
               5.000           .200            73.7
              10.000           .100            82.4
              20.000           .050            89.2
              50.000           .020            96.0
             100.000           .010            99.9
             200.000           .005           103
             500.000           .002           106

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
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)
Parameters Estimated by L – Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

```
          FREQUENCY ANALYSIS - WEIBULL DISTRIBUTION
          02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)
                          SAMPLE STATISTICS
                MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES    58.613     16.354       .279      -.204      2.921
LN X SERIES     4.030       .307       .076      -.750      3.806

X(MIN)=     28.800                        TOTAL SAMPLE SIZE=  15
X(MAX)=     82.500                      NO. OF LOW OUTLIERS=   0
                                          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

```
                      WEIBULL PARAMETERS

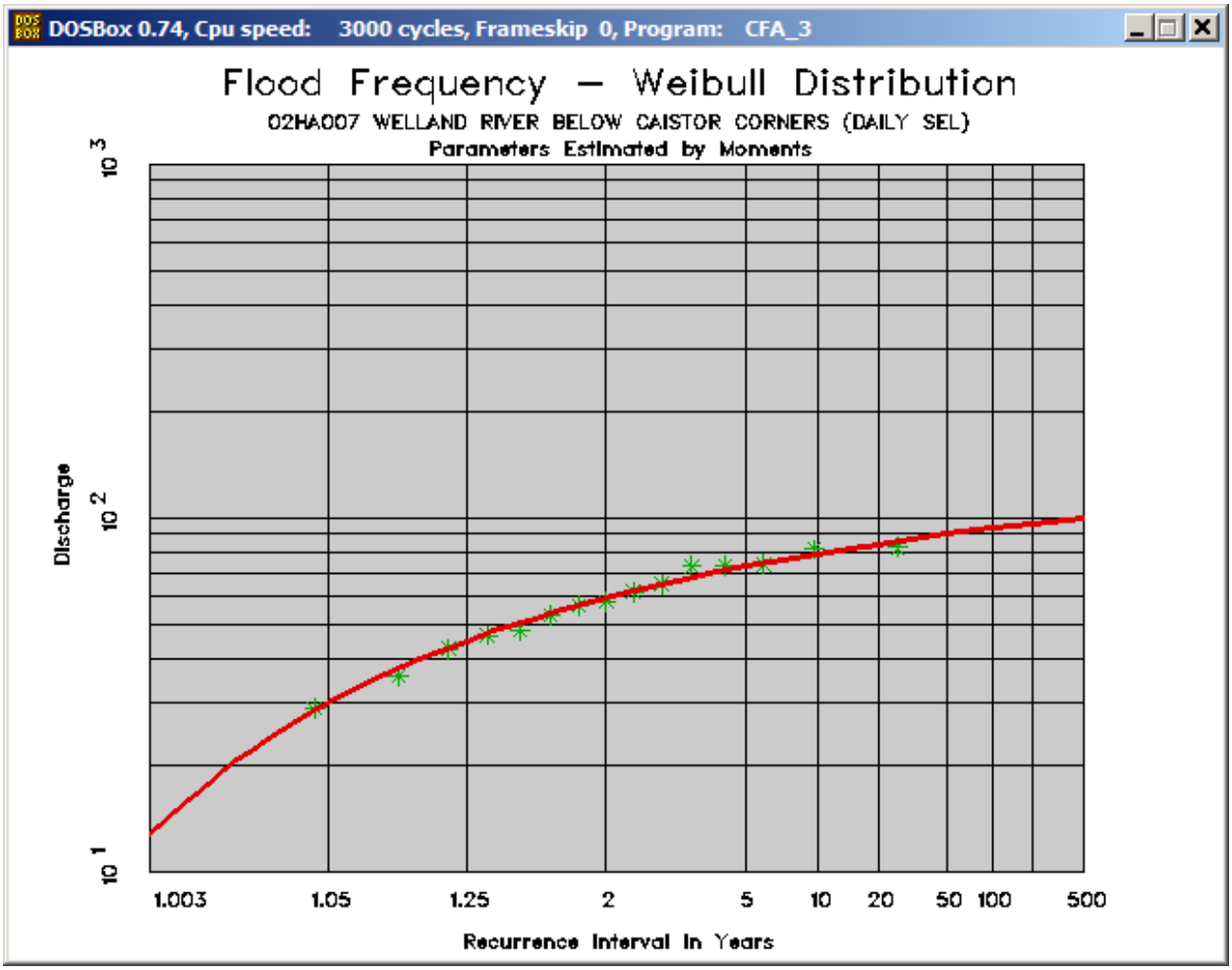
         1/A = .21403     E =    -8.51     U =    64.88

                      FLOOD FREQUENCY REGIME

            RETURN        EXCEEDANCE        FLOOD
            PERIOD        PROBABILITY

             1.003           .997            12.7
             1.050           .952            29.9
             1.250           .800            44.7
             2.000           .500            59.3
             5.000           .200            72.8
            10.000           .100            79.2
            20.000           .050            84.3
            50.000           .020            89.8
           100.000           .010            93.3
           200.000           .005            96.4
           500.000           .002            100

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


DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Weibull Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (DAILY SEL)
Parameters Estimated by Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (HR)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
3	1976	66.800	99.200	1	3.95	25.333
12	1990	83.370	94.720	2	10.53	9.500
3	1991	52.600	92.930	3	17.11	5.846
11	1995	46.320	86.730	4	23.68	4.222
4	1996	59.610	84.380	5	30.26	3.304
11	1999	44.590	83.370	6	36.84	2.714
2	2001	84.380	66.800	7	43.42	2.303
5	2002	31.420	66.760	8	50.00	2.000
11	2006	92.930	65.400	9	56.58	1.767
3	2007	94.720	59.610	10	63.16	1.583
12	2008	86.730	52.600	11	69.74	1.434
2	2009	99.200	46.320	12	76.32	1.310
10	2012	65.400	44.590	13	82.89	1.206

Press <RETURN> to continue

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (HR)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
1	2013	66.760	40.380	14	89.47	1.118
5	2014	40.380	31.420	15	96.05	1.041

Press <RETURN> to continue

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

```
FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (HR)

                         SAMPLE STATISTICS
                  MEAN       S.D.        C.V       C.S.       C.K.
     X SERIES    67.681     21.711       .321      -.092      2.488
  LN X SERIES     4.161       .351       .084      -.559      3.130
  L-MOM RATIO    67.681     12.839       .190      -.031      -.017

  X(MIN)=     31.420                        TOTAL SAMPLE SIZE=  15
  X(MAX)=     99.200                      NO. OF LOW OUTLIERS=   0
  LOWER OUTLIER LIMIT OF X=   29.156        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

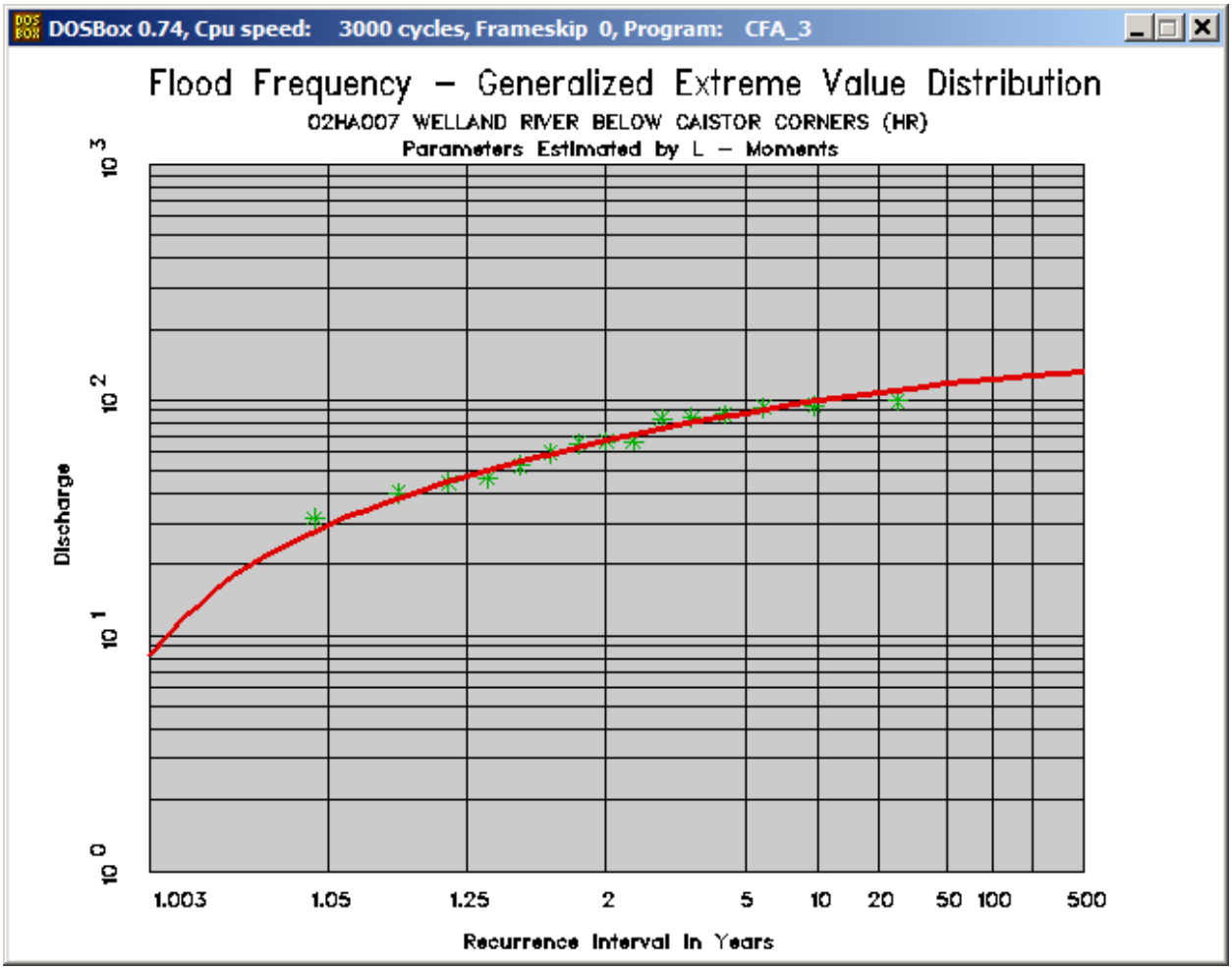
```
SOLUTION OBTAINED VIA L - MOMENTS
DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)=  .1528E+03
GEV PARAMETERS:     U=     58.98   A=   23.066   K=     .246

                    FLOOD FREQUENCY REGIME

          RETURN        EXCEEDANCE        FLOOD
          PERIOD        PROBABILITY

           1.003           .997             8.19
           1.050           .952            29.4
           1.250           .800            47.3
           2.000           .500            67.1
           5.000           .200            87.9
          10.000           .100            98.8
          20.000           .050           108
          50.000           .020           117
         100.000           .010           123
         200.000           .005           127
         500.000           .002           132

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
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (HR)
Parameters Estimated by L – Moments
Discharge
10 3
10 2
10 1
10 0
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

```
FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (HR)

                         SAMPLE STATISTICS
                  MEAN       S.D.        C.V       C.S.       C.K.
      X SERIES   67.681     21.711       .321      -.092      2.488
   LN X SERIES    4.161       .351       .084      -.559      3.130
LN(A-X) SERIES    5.057       .138       .027      -.065      2.437

   X(MIN)=     31.420                      TOTAL SAMPLE SIZE=  15
   X(MAX)=     99.200                    NO. OF LOW OUTLIERS=   0
   LOWER OUTLIER LIMIT OF X=   29.156      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

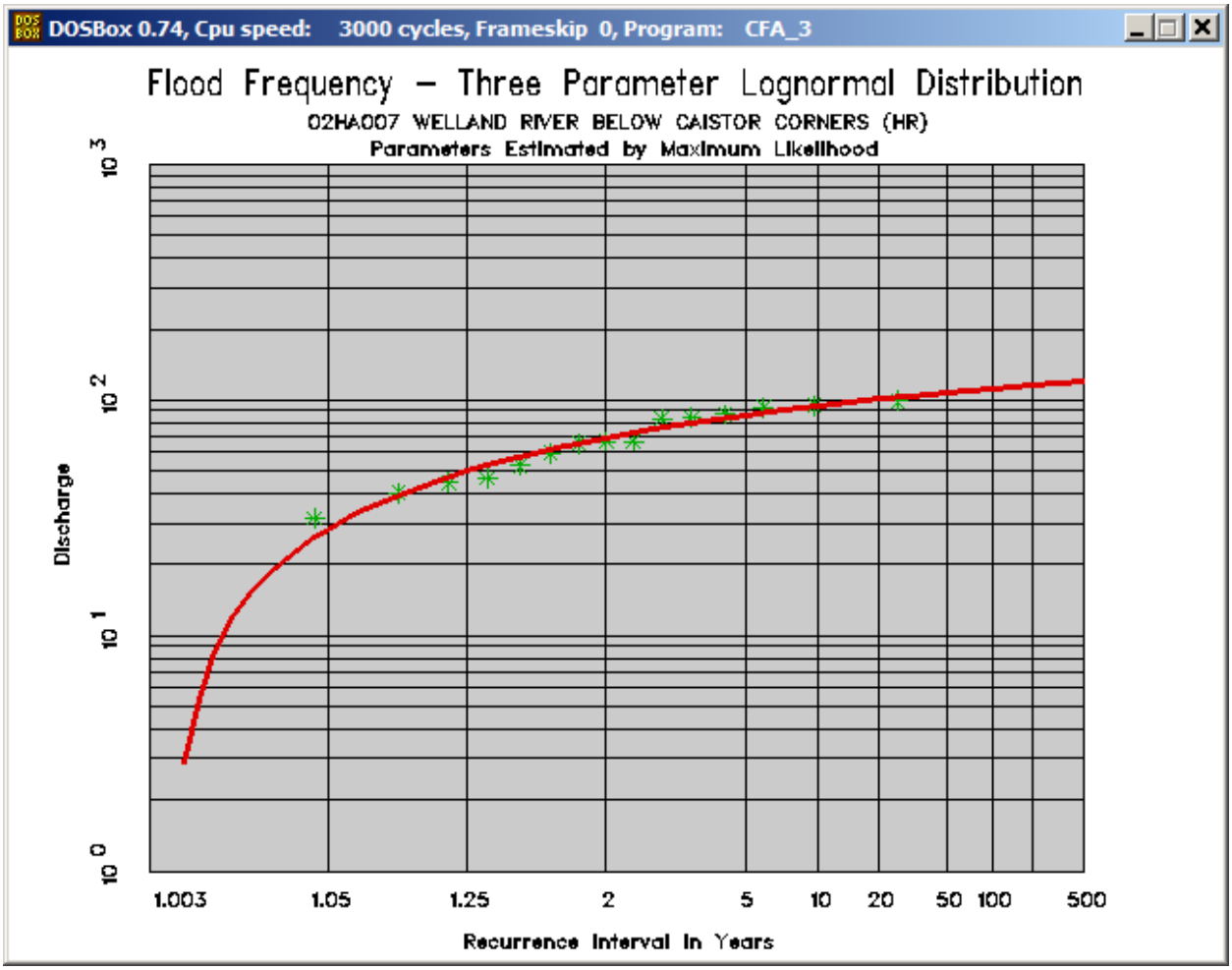
```
SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD
DISTRIBUTION IS UPPER BOUNDED AT A=  .2262E+03
3LN PARAMETERS:     A=   226.179   M= 5.057   S=  .138

                    FLOOD FREQUENCY REGIME

          RETURN        EXCEEDANCE        FLOOD
          PERIOD        PROBABILITY

           1.003           .997            -
           1.050           .952           28.4
           1.250           .800           49.8
           2.000           .500           69.1
           5.000           .200           86.3
          10.000           .100           94.5
          20.000           .050          101
          50.000           .020          108
         100.000           .010          112
         200.000           .005          116
         500.000           .002          121

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


DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Three Parameter Lognormal Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (HR)
Parameters Estimated by Maximum Likelihood
Discharge
10 3
10 2
10 1
10 0
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

```
FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (HR)

                    SAMPLE STATISTICS
                MEAN       S.D.        C.V       C.S.       C.K.
   X SERIES    67.681     21.711       .321      -.092      2.488
LN X SERIES     4.161       .351       .084      -.559      3.130

X(MIN)=     31.420                      TOTAL SAMPLE SIZE=  15
X(MAX)=     99.200                    NO. OF LOW OUTLIERS=   0
LOWER OUTLIER LIMIT OF X=   29.156      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

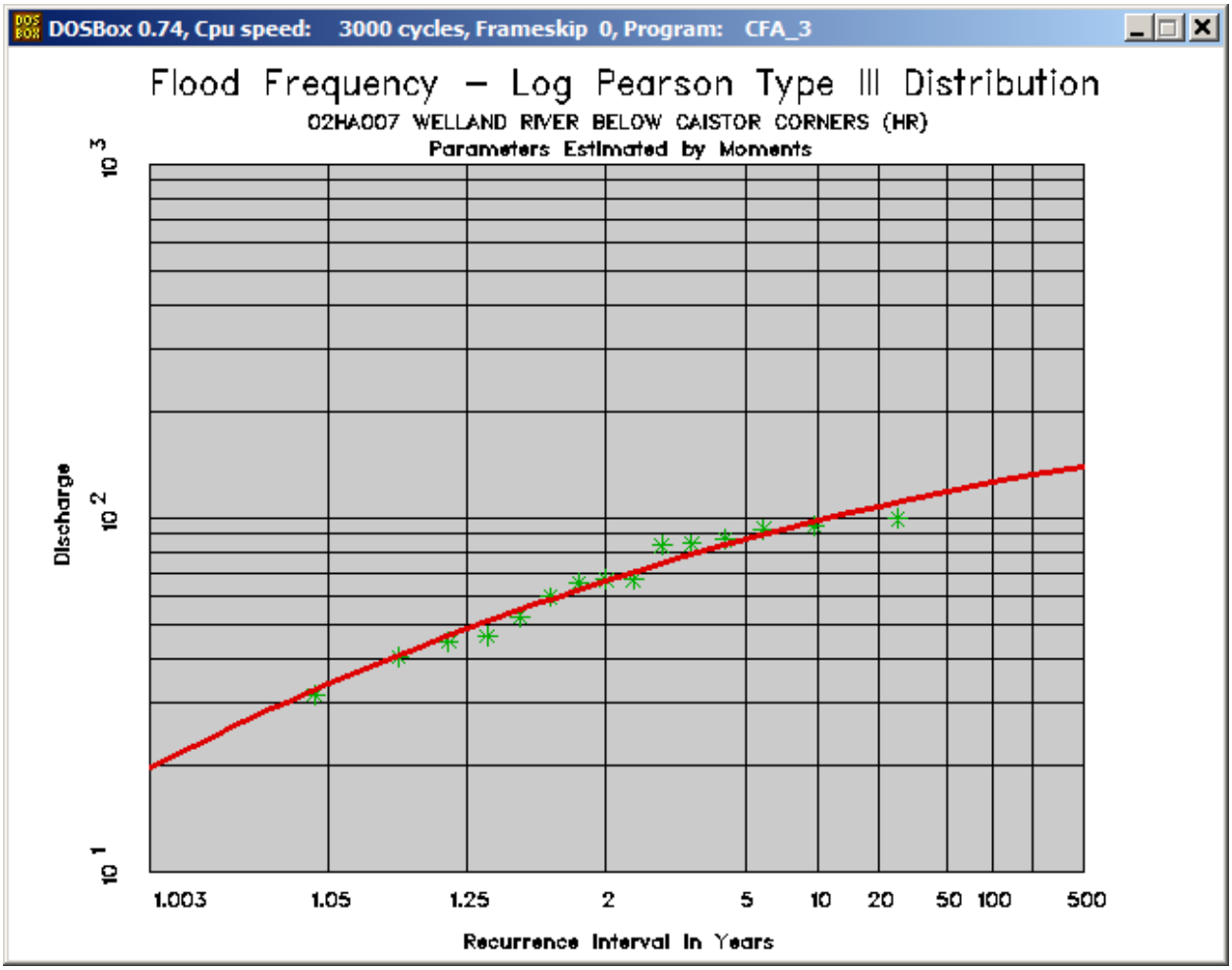
```
              SOLUTION OBTAINED VIA MOMENTS
         DISTRIBUTION IS UPPER BOUNDED AT M=  225.2
LP3 PARAMETERS: A= -.9807E-01 B=  12.81     LOG(M)=  5.417
                                                M =  225.2

                    FLOOD FREQUENCY REGIME

            RETURN        EXCEEDANCE        FLOOD
            PERIOD        PROBABILITY

             1.003          .997             19.7
             1.050          .952             33.9
             1.250          .800             48.4
             2.000          .500             66.2
             5.000          .200             86.6
            10.000          .100             97.9
            20.000          .050            108
            50.000          .020            118
           100.000          .010            126
           200.000          .005            132
           500.000          .002            140

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


DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Log Pearson Type III Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (HR)
Parameters Estimated by Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

```
FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (HR)

                    SAMPLE STATISTICS
                MEAN       S.D.       C.V.       C.S.       C.K.
   X SERIES    67.681     21.711      .321      -.092      2.488
LN X SERIES     4.161       .351      .084      -.559      3.130
L-MOM RATIO    67.681     12.839      .190      -.031      -.017

X(MIN)=     31.420                    TOTAL SAMPLE SIZE=  15
X(MAX)=     99.200                  NO. OF LOW OUTLIERS=   0
LOWER OUTLIER LIMIT OF X=   29.156    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

```
THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

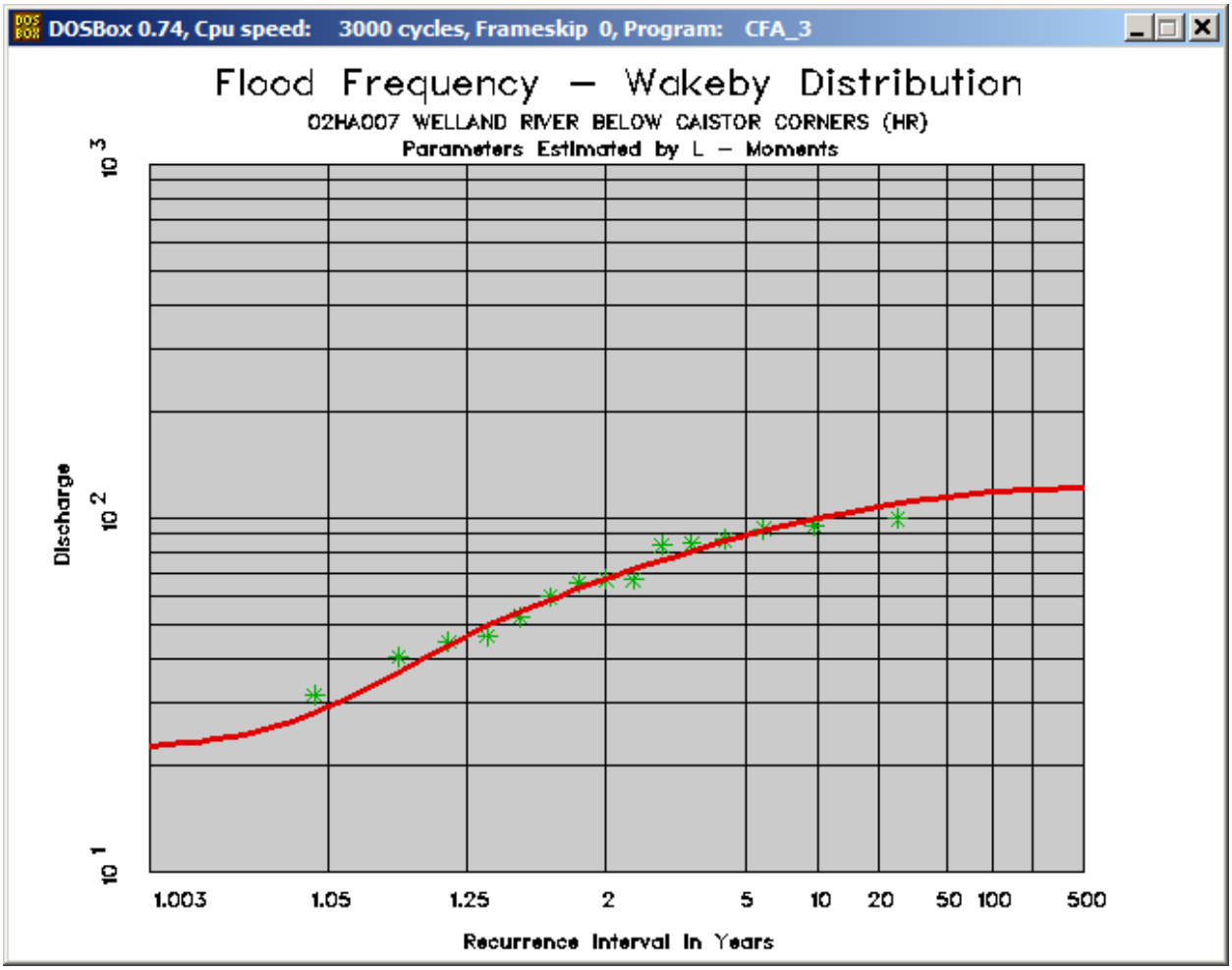
M=   22.166   A=     21.891   B=  5.46   C=    -82.312   D= -.489
          DISTRIBUTION IS UPPER BOUNDED AT E=  .1264E+03

                    FLOOD FREQUENCY REGIME

            RETURN        EXCEEDANCE        FLOOD
            PERIOD        PROBABILITY

             1.003           .997            22.6
             1.050           .952            29.2
             1.250           .800            46.1
             2.000           .500            67.2
             5.000           .200            88.9
            10.000           .100            99.6
            20.000           .050           107
            50.000           .020           114
           100.000           .010           118
           200.000           .005           120
           500.000           .002           122

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
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (HR)
Parameters Estimated by L – Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

```
          FREQUENCY ANALYSIS - WEIBULL DISTRIBUTION
          02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (HR)
                          SAMPLE STATISTICS
                MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     67.681     21.711       .321      -.092      2.488
LN X SERIES      4.161       .351       .084      -.559      3.130

X(MIN)=     31.420                        TOTAL SAMPLE SIZE=  15
X(MAX)=     99.200                      NO. OF LOW OUTLIERS=   0
                                          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

```
                      WEIBULL PARAMETERS

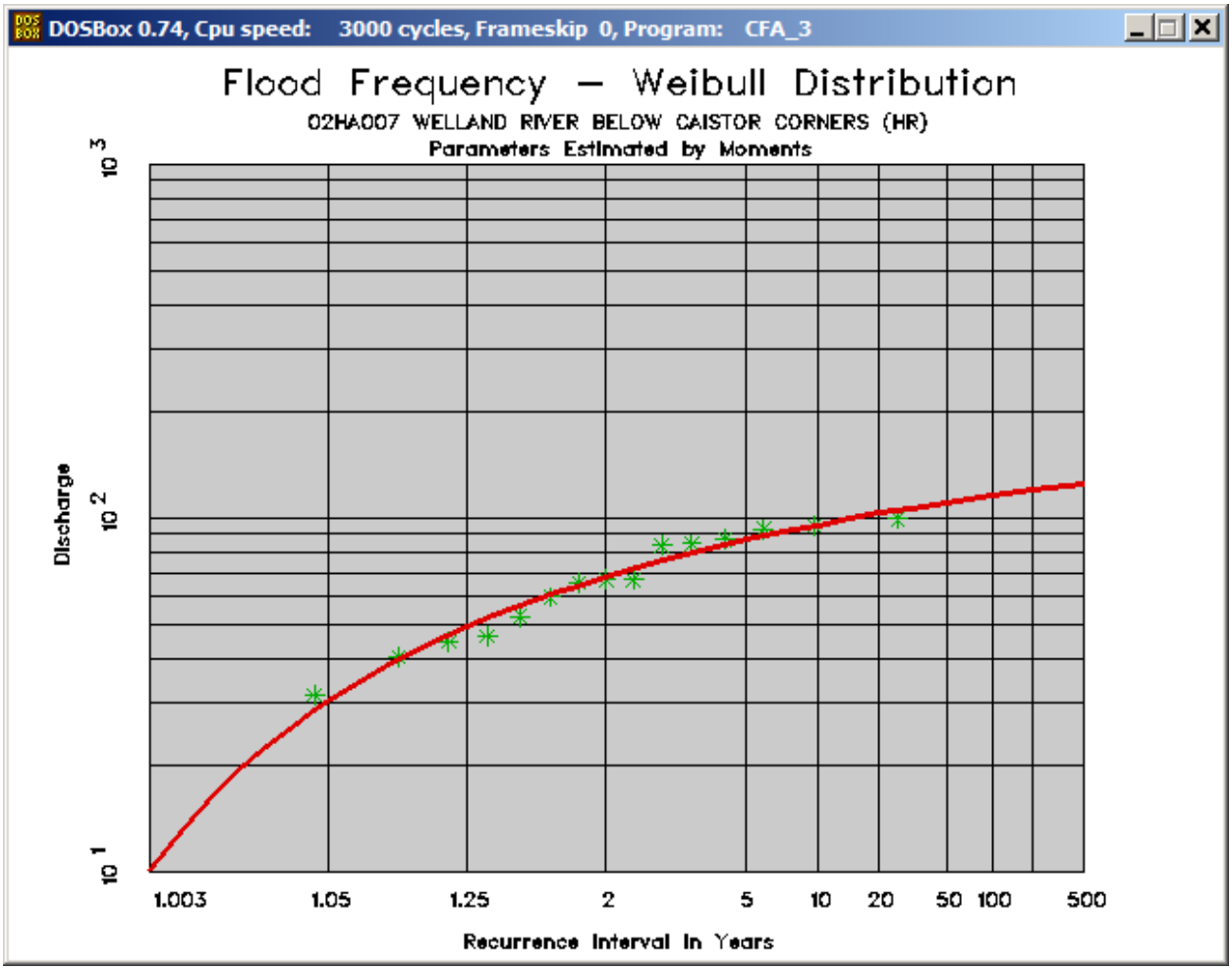
         1/A = .24798     E =   -10.28     U =    75.69

                      FLOOD FREQUENCY REGIME

            RETURN        EXCEEDANCE        FLOOD
            PERIOD        PROBABILITY

             1.003           .997            10.1
             1.050           .952            30.4
             1.250           .800            49.0
             2.000           .500            68.2
             5.000           .200            86.5
            10.000           .100            95.4
            20.000           .050           103
            50.000           .020           110
           100.000           .010           115
           200.000           .005           120
           500.000           .002           125

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


DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Weibull Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (HR)
Parameters Estimated by Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
3	1976	67.400	94.600	1	3.95	25.333
12	1990	83.300	91.000	2	10.53	9.500
3	1991	52.600	86.800	3	17.11	5.846
11	1995	58.500	84.500	4	23.68	4.222
4	1996	60.000	83.300	5	30.26	3.304
11	1999	44.600	72.600	6	36.84	2.714
2	2001	84.500	67.400	7	43.42	2.303
5	2002	31.500	66.800	8	50.00	2.000
11	2006	72.600	65.700	9	56.58	1.767
3	2007	91.000	60.000	10	63.16	1.583
12	2008	86.800	58.500	11	69.74	1.434
2	2009	94.600	52.600	12	76.32	1.310
10	2012	65.700	48.600	13	82.89	1.206

Press <RETURN> to continue

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

WSC STATION NO=02HA007
WSC STATION NAME=WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
1	2013	66.800	44.600	14	89.47	1.118
5	2014	48.600	31.500*	15	96.05	1.041

Press <RETURN> to continue

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

```
FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED

                        SAMPLE STATISTICS
                 MEAN       S.D.        C.V       C.S.       C.K.
   X SERIES     67.233     18.446       .274      -.223      3.086
LN X SERIES      4.168       .304       .073      -.865      4.435
L-MOM RATIO     67.233     10.857       .161      -.050       .066

X(MIN)=     31.500                        TOTAL SAMPLE SIZE=  15
X(MAX)=     94.600                      NO. OF LOW OUTLIERS=   1
LOWER OUTLIER LIMIT OF X=   32.623        NO. OF ZERO FLOWS=   0

             AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                 MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     69.786     16.161       .232       .051      2.624
LN X SERIES      4.220       .239       .057      -.270      2.852
L-MOM RATIO     69.786      9.582       .137       .012       .006

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 L - MOMENTS
          DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)=  .1502E+03
   PARAMETERS OF THE GEV WHICH DUPLICATES THE CONDITIONAL FUNCTION:
              U=     60.41   A=   18.359   K=     .204

                      FLOOD FREQUENCY REGIME

             RETURN        EXCEEDANCE        FLOOD
             PERIOD        PROBABILITY

              1.003          .997            21.5
              1.050          .952            37.5
              1.250          .800            51.2
              2.000          .500            66.9
              5.000          .200            84.1
             10.000          .100            93.5
             20.000          .050           101
             50.000          .020           110
            100.000          .010           115
            200.000          .005           120
            500.000          .002           125

Press <RETURN> to continue , <CTRL> P to obtain hard copy
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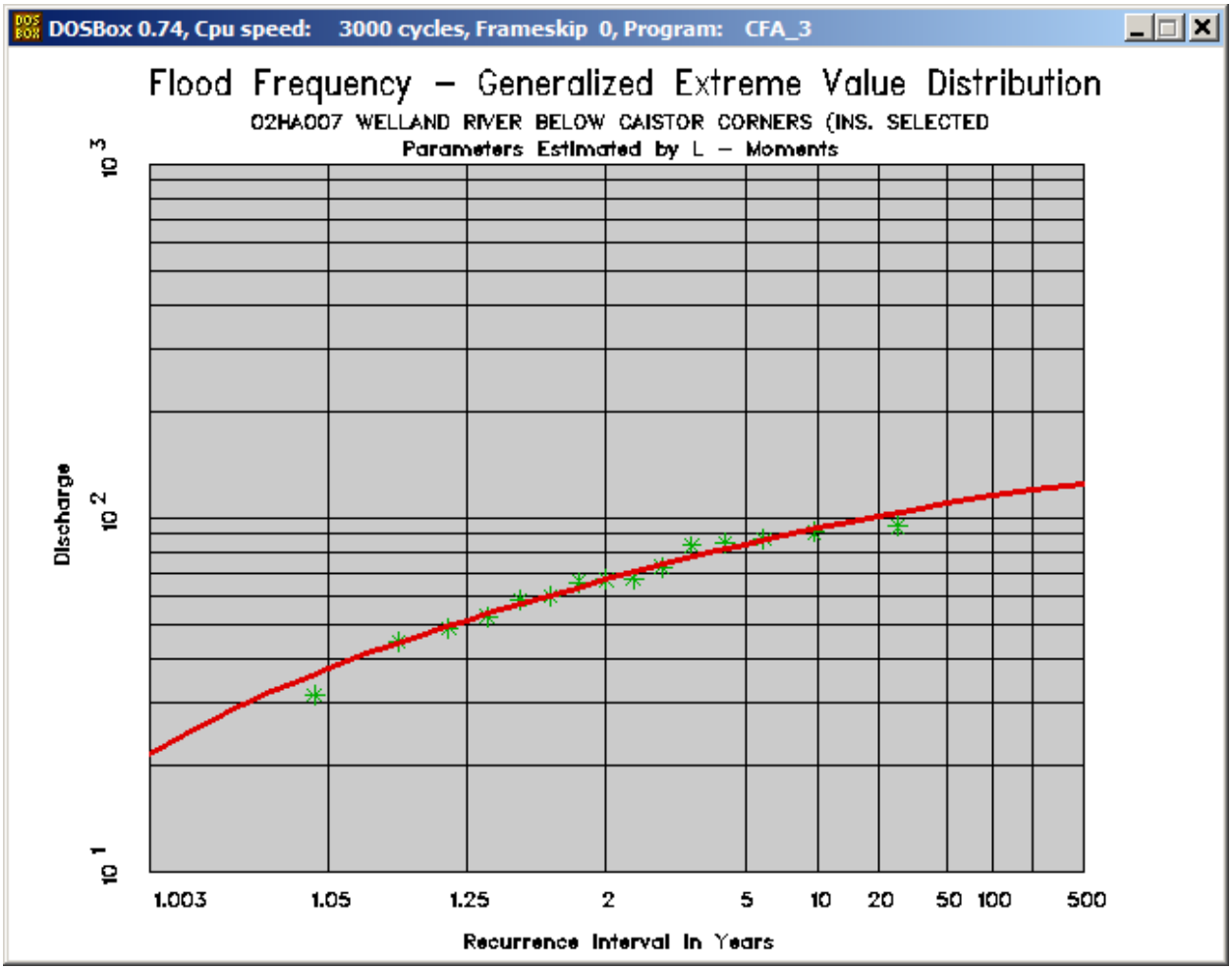
DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Generalized Extreme Value Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED
Parameters Estimated by L – Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

        FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
        02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED

                              SAMPLE STATISTICS
                     MEAN        S.D.        C.V        C.S.       C.K.
      X SERIES      67.233      18.446       .274      -.223      3.086
   LN X SERIES       4.168        .304       .073      -.865      4.435

   X(MIN)=     31.500                          TOTAL SAMPLE SIZE=  15
   X(MAX)=     94.600                        NO. OF LOW OUTLIERS=   1
   LOWER OUTLIER LIMIT OF X=   32.623          NO. OF ZERO FLOWS=   0


                AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                     MEAN        S.D.        C.V.       C.S.       C.K.
      X SERIES      69.786      16.161       .232       .051      2.624
   LN X SERIES       4.220        .239       .057      -.270      2.852
LN(X-A) SERIES       6.060        .038       .006       .003      2.640

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
     PARAMETERS OF THE 3LN WHICH DUPLICATES THE CONDITIONAL FUNCTION:
                A=  -359.001   M= 6.057   S=  .040

                         FLOOD FREQUENCY REGIME

                RETURN        EXCEEDANCE        FLOOD
                PERIOD        PROBABILITY

                 1.003          .997            23.8
                 1.050          .952            40.5
                 1.250          .800            53.9
                 2.000          .500            67.9
                 5.000          .200            82.4
                10.000          .100            90.2
                20.000          .050            96.7
                50.000          .020           104
               100.000          .010           109
               200.000          .005           114
               500.000          .002           120

Press <RETURN> to continue , <CTRL> P to obtain hard copy_
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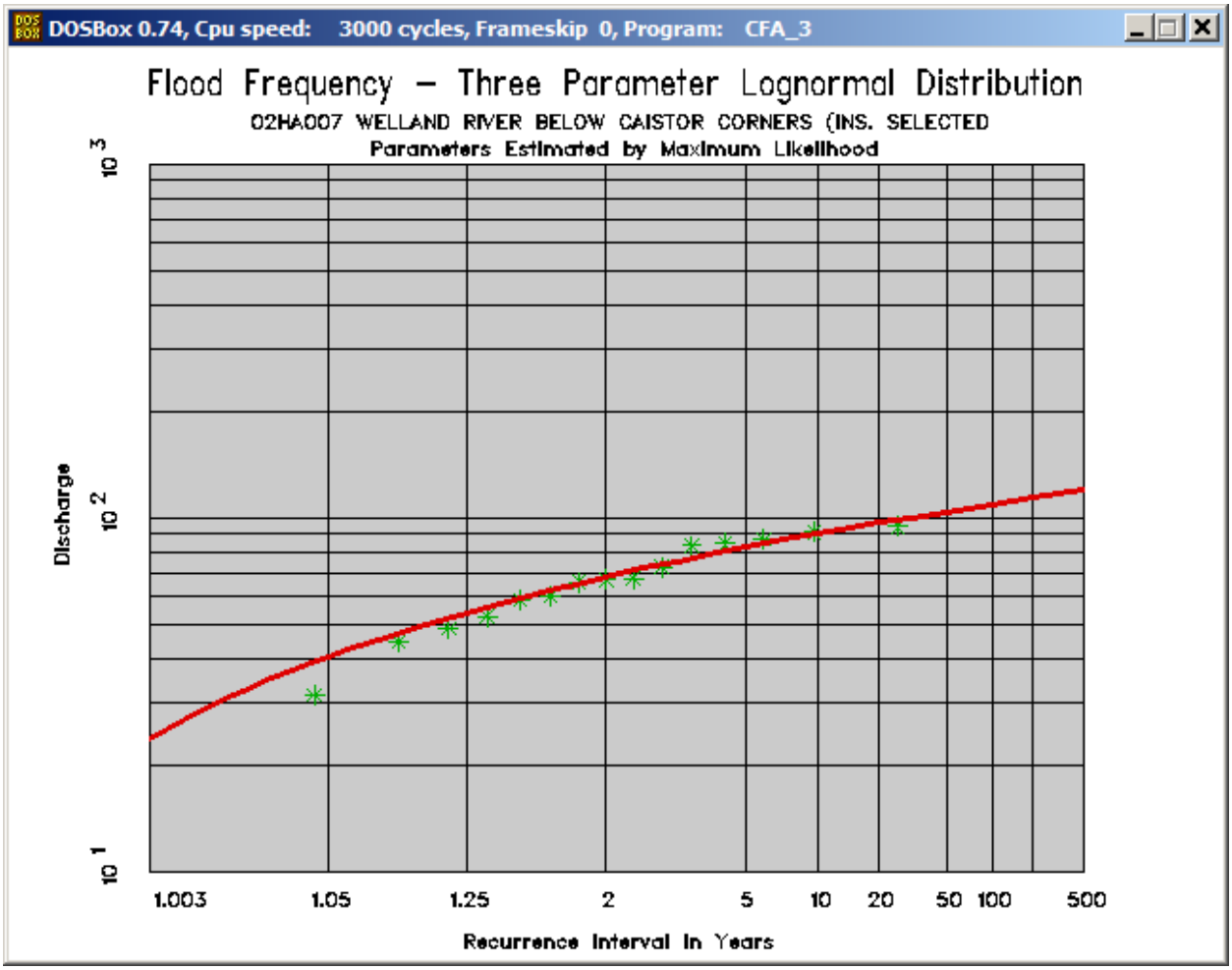
DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Three Parameter Lognormal Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED
Parameters Estimated by Maximum Likelihood
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

```
FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED

                         SAMPLE STATISTICS
                  MEAN       S.D.        C.V       C.S.       C.K.
   X SERIES     67.233     18.446       .274      -.223      3.086
LN X SERIES      4.168       .304       .073      -.865      4.435

X(MIN)=     31.500                        TOTAL SAMPLE SIZE=  15
X(MAX)=     94.600                      NO. OF LOW OUTLIERS=   1
LOWER OUTLIER LIMIT OF X=   32.623        NO. OF ZERO FLOWS=   0


              AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                  MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     69.786     16.161       .232       .051      2.624
LN X SERIES      4.220       .239       .057      -.270      2.852

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 MOMENTS
          DISTRIBUTION IS UPPER BOUNDED AT M=  377.5
    PARAMETERS OF THE LP3 WHICH DUPLICATES THE CONDITIONAL FUNCTION:
     A= -.3562E-01 B=  48.75     LOG(M)=  5.934     M =  377.5
     SYNTHETIC STATISTICS: MEAN=   4.197  S.D.=   .249  C.S.= -.286

                         FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003          .997             -
               1.050          .952             -
               1.250          .800            54.2
               2.000          .500            67.3
               5.000          .200            82.2
              10.000          .100            90.7
              20.000          .050            98.0
              50.000          .020           107
             100.000          .010           113
             200.000          .005           118
             500.000          .002           125

Press <RETURN> to continue , <CTRL> P to obtain hard copy_
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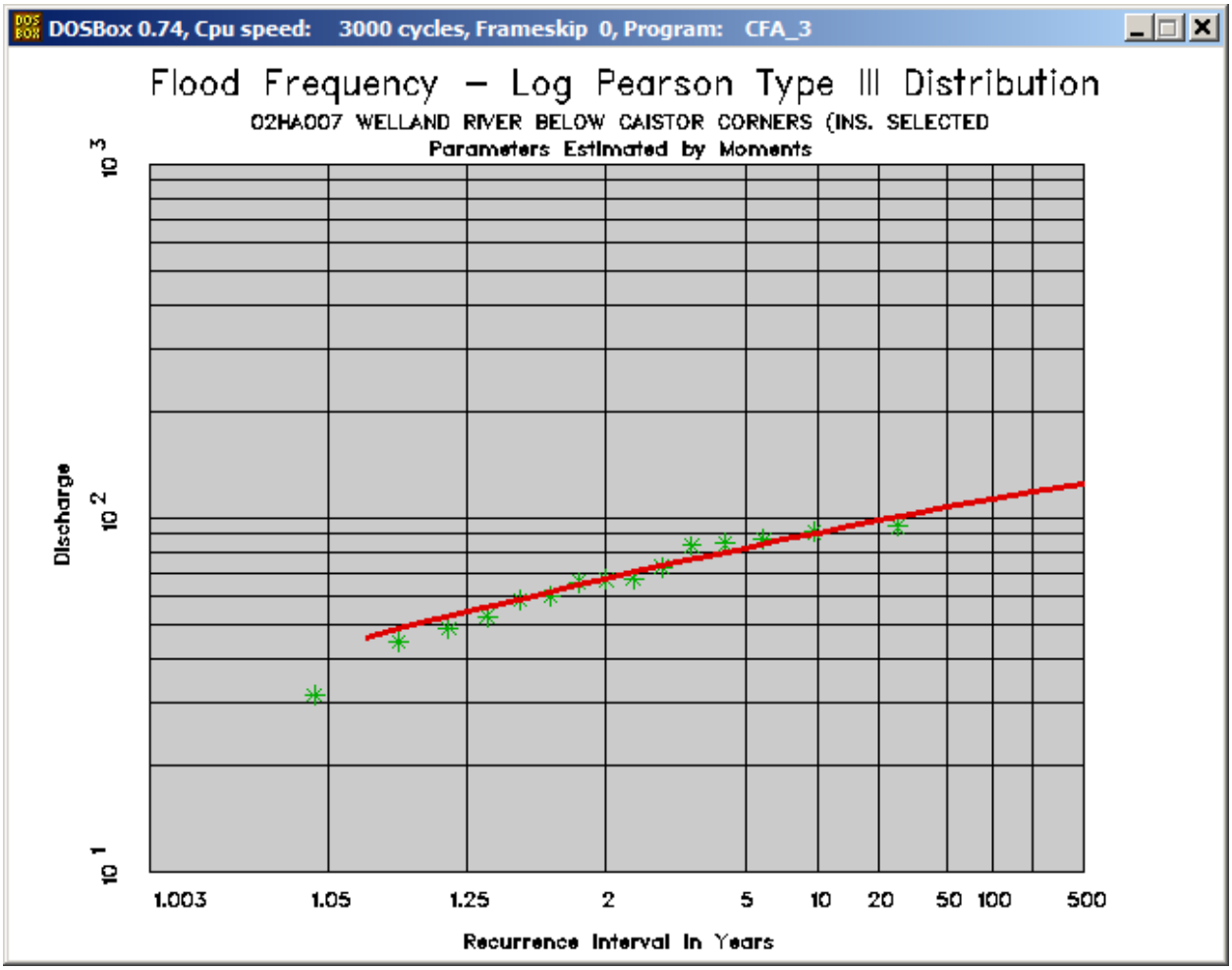
DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Log Pearson Type III Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED
Parameters Estimated by Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

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

```
FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02HA007     WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED

                        SAMPLE STATISTICS
                 MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     67.233     18.446       .274      -.223      3.086
LN X SERIES      4.168       .304       .073      -.865      4.435
L-MOM RATIO     67.233     10.857       .161      -.050       .066

X(MIN)=     31.500                        TOTAL SAMPLE SIZE=  15
X(MAX)=     94.600                      NO. OF LOW OUTLIERS=   1
LOWER OUTLIER LIMIT OF X=   32.623        NO. OF ZERO FLOWS=   0

              AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS
                 MEAN       S.D.        C.V.       C.S.       C.K.
   X SERIES     69.786     16.161       .232       .051      2.624
LN X SERIES      4.220       .239       .057      -.270      2.852
L-MOM RATIO     69.786      9.582       .137       .012       .006

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

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

```
THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M=   25.251   A=     25.391   B= 13.45   C=    -79.239   D= -.358
          DISTRIBUTION IS UPPER BOUNDED AT E=  .1299E+03

                        FLOOD FREQUENCY REGIME

              RETURN        EXCEEDANCE        FLOOD
              PERIOD        PROBABILITY

               1.003           .997             -
               1.050           .952             -
               1.250           .800            51.7
               2.000           .500            66.5
               5.000           .200            84.3
              10.000           .100            94.3
              20.000           .050           102
              50.000           .020           110
             100.000           .010           114
             200.000           .005           118
             500.000           .002           121

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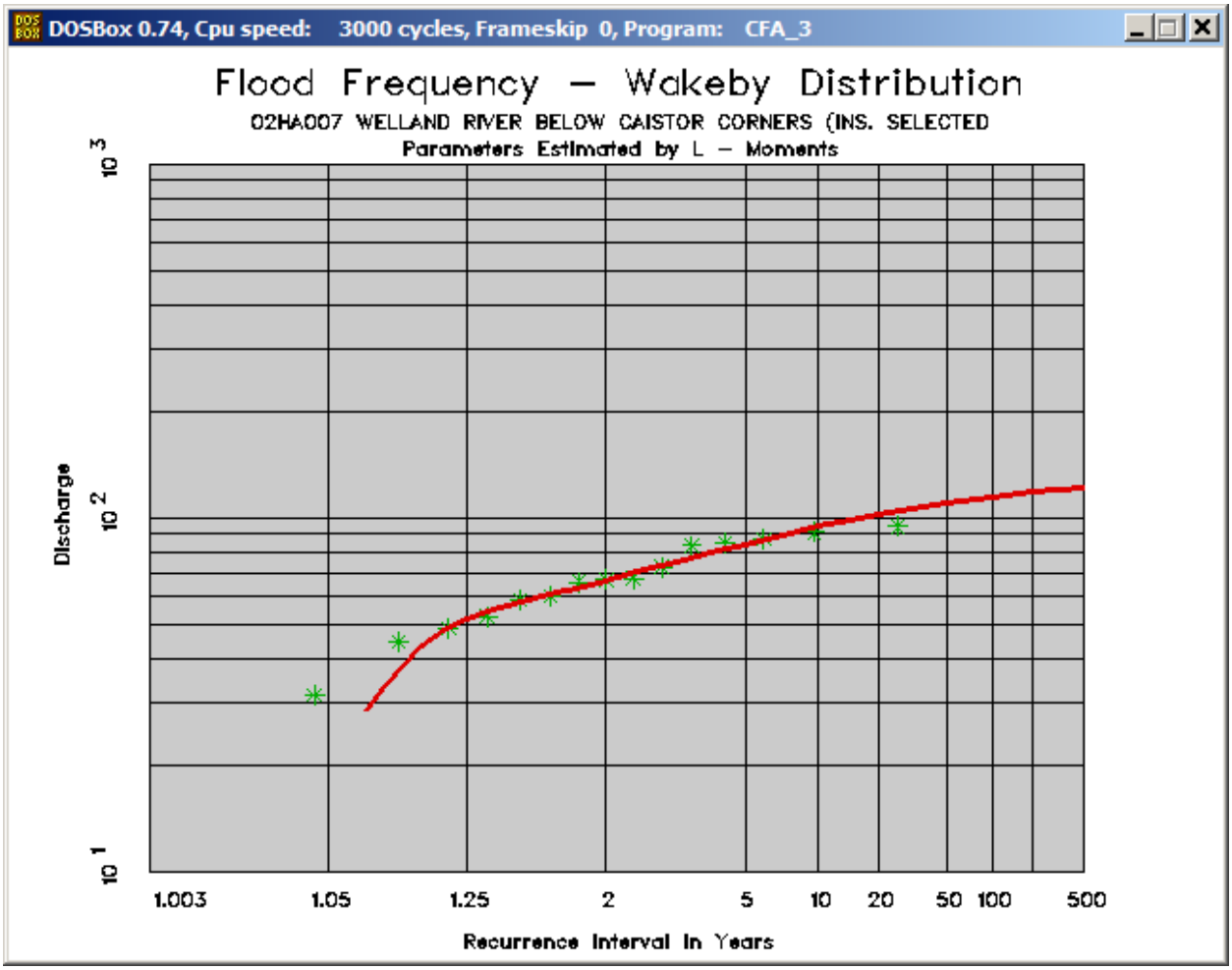
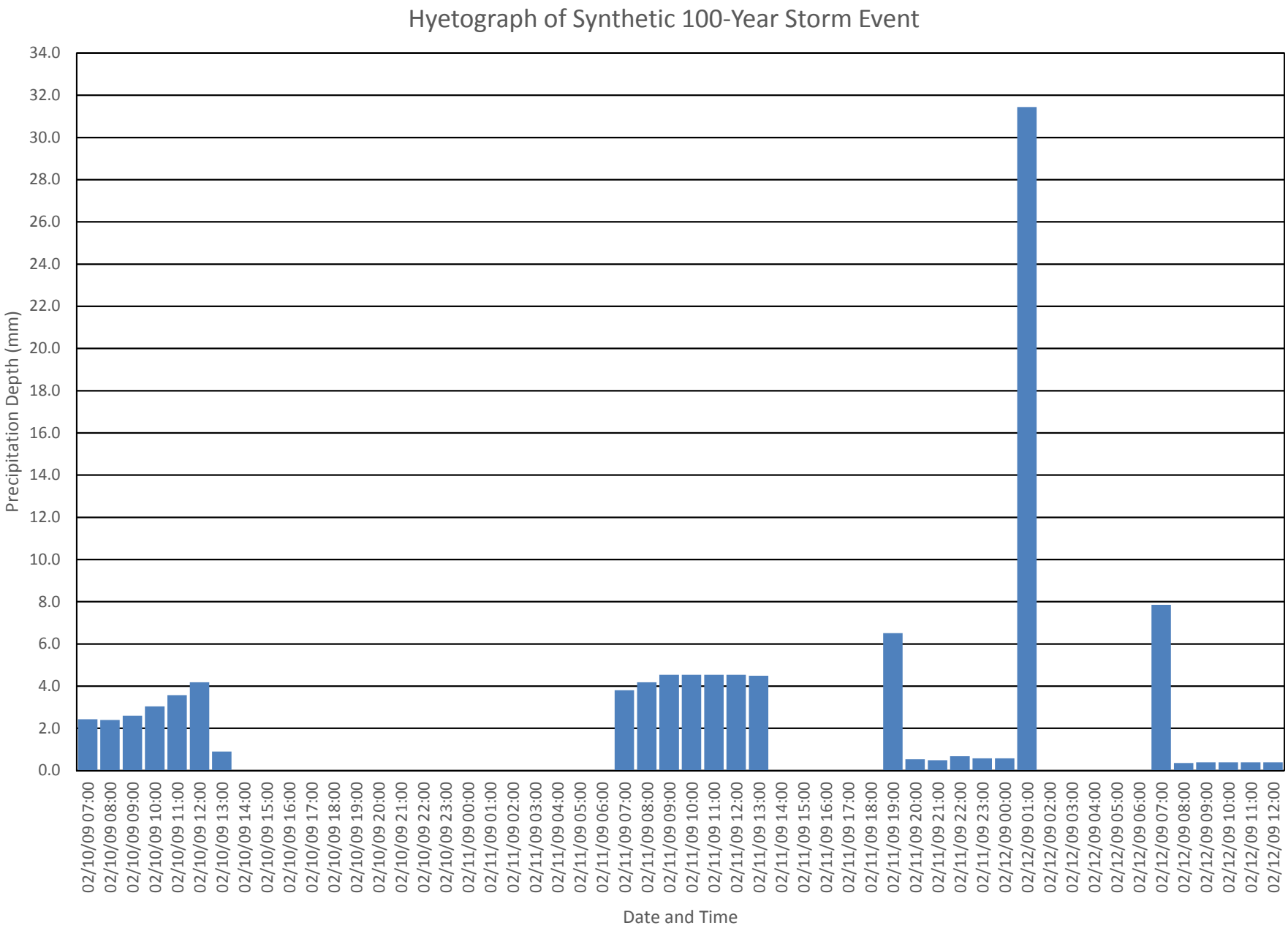

DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: CFA_3
Flood Frequency – Wakeby Distribution
02HA007 WELLAND RIVER BELOW CAISTOR CORNERS (INS. SELECTED
Parameters Estimated by L – Moments
Discharge
10 3
10 2
10 1
1.003
1.05
1.25
2
5
10
20
50
100
500
Recurrence Interval in Years

APPENDIX I – Synthetic 100-Year Events for Welland River Watershed


Hyetograph of Synthetic 100-Year Storm Event
Precipitation Depth (mm)
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
02/10/09 07:00
02/10/09 08:00
02/10/09 09:00
02/10/09 10:00
02/10/09 11:00
02/10/09 12:00
02/10/09 13:00
02/10/09 14:00
02/10/09 15:00
02/10/09 16:00
02/10/09 17:00
02/10/09 18:00
02/10/09 19:00
02/10/09 20:00
02/10/09 21:00
02/10/09 22:00
02/10/09 23:00
02/11/09 00:00
02/11/09 01:00
02/11/09 02:00
02/11/09 03:00
02/11/09 04:00
02/11/09 05:00
02/11/09 06:00
02/11/09 07:00
02/11/09 08:00
02/11/09 09:00
02/11/09 10:00
02/11/09 11:00
02/11/09 12:00
02/11/09 13:00
02/11/09 14:00
02/11/09 15:00
02/11/09 16:00
02/11/09 17:00
02/11/09 18:00
02/11/09 19:00
02/11/09 20:00
02/11/09 21:00
02/11/09 22:00
02/11/09 23:00
02/12/09 00:00
02/12/09 01:00
02/12/09 02:00
02/12/09 03:00
02/12/09 04:00
02/12/09 05:00
02/12/09 06:00
02/12/09 07:00
02/12/09 08:00
02/12/09 09:00
02/12/09 10:00
02/12/09 11:00
02/12/09 12:00
Date and Time

Multiplier		1	1.5	1.496	1.497
Simulated Peak Flow (cms)		73.953	114.304	113.895	114.087
Date/Time		SNOWE - Equ. New Snow (mm)	#1	#2	#3 (FINAL)
Total Depth in mm		66.92	100.37	100.12	100.19
TS (hr)	TS (min)	21.00	31.50	31.42	31.44
02/10/09 00:00	60	0.00	0.000	0.000	0.000
02/10/09 01:00	120	0.00	0.000	0.000	0.000
02/10/09 02:00	180	0.00	0.000	0.000	0.000
02/10/09 03:00	240	0.00	0.000	0.000	0.000
02/10/09 04:00	300	0.00	0.000	0.000	0.000
02/10/09 05:00	360	0.00	0.000	0.000	0.000
02/10/09 06:00	420	0.00	0.000	0.000	0.000
02/10/09 07:00	480	1.62	2.433	2.427	2.428
02/10/09 08:00	540	1.60	2.394	2.388	2.390
02/10/09 09:00	600	1.73	2.593	2.587	2.589
02/10/09 10:00	660	2.03	3.043	3.036	3.038
02/10/09 11:00	720	2.38	3.571	3.562	3.565
02/10/09 12:00	780	2.79	4.191	4.181	4.183
02/10/09 13:00	840	0.60	0.900	0.898	0.898
02/10/09 14:00	900	0.00	0.000	0.000	0.000
02/10/09 15:00	960	0.00	0.000	0.000	0.000
02/10/09 16:00	1020	0.00	0.000	0.000	0.000
02/10/09 17:00	1080	0.00	0.000	0.000	0.000
02/10/09 18:00	1140	0.00	0.000	0.000	0.000
02/10/09 19:00	1200	0.00	0.000	0.000	0.000
02/10/09 20:00	1260	0.00	0.000	0.000	0.000
02/10/09 21:00	1320	0.00	0.000	0.000	0.000
02/10/09 22:00	1380	0.00	0.000	0.000	0.000
02/10/09 23:00	1440	0.00	0.000	0.000	0.000
02/11/09 00:00	1500	0.00	0.000	0.000	0.000
02/11/09 01:00	1560	0.00	0.000	0.000	0.000
02/11/09 02:00	1620	0.00	0.000	0.000	0.000
02/11/09 03:00	1680	0.00	0.000	0.000	0.000
02/11/09 04:00	1740	0.00	0.000	0.000	0.000
02/11/09 05:00	1800	0.00	0.000	0.000	0.000
02/11/09 06:00	1860	0.00	0.000	0.000	0.000
02/11/09 07:00	1920	2.54	3.807	3.798	3.800
02/11/09 08:00	1980	2.79	4.191	4.181	4.183
02/11/09 09:00	2040	3.03	4.540	4.529	4.532
02/11/09 10:00	2100	3.03	4.540	4.529	4.532
02/11/09 11:00	2160	3.03	4.540	4.529	4.532
02/11/09 12:00	2220	3.03	4.540	4.529	4.532
02/11/09 13:00	2280	3.00	4.500	4.489	4.492
02/11/09 14:00	2340	0.00	0.000	0.000	0.000
02/11/09 15:00	2400	0.00	0.000	0.000	0.000
02/11/09 16:00	2460	0.00	0.000	0.000	0.000
02/11/09 17:00	2520	0.00	0.000	0.000	0.000
02/11/09 18:00	2580	0.00	0.000	0.000	0.000
02/11/09 19:00	2640	4.35	6.518	6.502	6.506
02/11/09 20:00	2700	0.35	0.526	0.525	0.525
02/11/09 21:00	2760	0.32	0.486	0.485	0.485
02/11/09 22:00	2820	0.45	0.669	0.667	0.668
02/11/09 23:00	2880	0.38	0.570	0.569	0.569
02/12/09 00:00	2940	0.38	0.570	0.569	0.569
02/12/09 01:00	3000	21.00	31.500	31.421	31.441
02/12/09 02:00	3060	0.00	0.000	0.000	0.000
02/12/09 03:00	3120	0.00	0.000	0.000	0.000
02/12/09 04:00	3180	0.00	0.000	0.000	0.000
02/12/09 05:00	3240	0.00	0.000	0.000	0.000
02/12/09 06:00	3300	0.00	0.000	0.000	0.000
02/12/09 07:00	3360	5.24	7.867	7.847	7.852
02/12/09 08:00	3420	0.24	0.353	0.352	0.352
02/12/09 09:00	3480	0.25	0.382	0.381	0.381
02/12/09 10:00	3540	0.25	0.382	0.381	0.381
02/12/09 11:00	3600	0.25	0.382	0.381	0.381
02/12/09 12:00	3660	0.25	0.382	0.381	0.381

APPENDIX J – Simulation of Synthetic 100-Year Storm Events

Run	Node	Location	Drainage Area (ha)	FLOW (cms)
Final_Syn100Yr	6010	Abingdon Road	18027.96	91.54
Final_Syn100Yr	6011	Welland at Caistor / Church Road	22255.64	114.09
Final_Syn100Yr	6015	Brooks Bridge	25673.42	119.37
Final_Syn100Yr	6018	Welland Aat Wellandport	47581.69	197.37
Final_Syn100Yr	6023	Becketts Bridge	59889.8	203.08
Final_Syn100Yr	6025	EC Brown / O'Reillys Bridge	78400.27	241.29
Final_Syn100Yr	6037	Welland at Siphon	85877.79	241.65
Final_Syn100Yr	6029	Montrose Road	88801.15	231.70
Final_Syn100Yr	6031	Outlet to Chippawa Power Canal (OPG)	99271.72	272.03

Note: The reduced flows from upstream node at 6037 to downstream node at 6029 are due to the channel routing in the hydrological model.

Run	Node	Location	Drainage Area (ha)	FLOW (cms) - Baseflow Substracted	Calculated Unit Baseflow (cms/ha)	TOTAL FLOW (cms)
Event 15 _ 2009	6010	Abingdon Road	18027.96	59.16	0.000943	76.16
Event 15 _ 2009	6011	Welland at Caistor / Church Road	22255.64	73.95	0.000943	94.94
Event 15 _ 2009	6015	Brooks Bridge	25673.42	77.38	0.000943	101.58
Event 15 _ 2009	6018	Welland Aat Wellandport	47581.69	123.75	0.000943	168.61
Event 15 _ 2009	6023	Becketts Bridge	59889.8	112.95	0.000943	169.41
Event 15 _ 2009	6025	EC Brown / O'Reillys Bridge	78400.27	137.93	0.000943	211.84
Event 15 _ 2009	6037	Welland at Siphon	85877.79	139.67	0.000943	220.64
Event 15 _ 2009	6029	Montrose Road	88801.15	142.04	0.000943	225.76
Event 15 _ 2009	6031	Outlet to Chippawa Power Canal (OPG)	99271.72	169.68	0.000943	263.27

Note: the flows at flow nodes from hydrological model don't reflect the effects on channel routing. Therefore, the flows in above tables are for reference purposes only.

Hydrographs from each sub-watershed (catchment) resulted from hydrological model will be provided as input to the dynamic hydraulic model (MIKE 11) for the purposes of updating the Regulatory floodplain for the Welland River. MIKE 11 hydraulic model will calculate the flows at each flow nodes along the water courses by incorporating the effects of channel routing and providing with the required boundary conditions (i.e., water elevations at Niagara River, Chippawa Power Canal, Welland Canal and Siphons, etc.).

Subwatershed Name	Catchment ID *	Area (km^2)	Peak Runoff Rate (m3/s)	Peak Runoff Unit Rate (L/ha)
Beaver Creek	1020	72.75	41.50	5.70
Buckhorn Creek	1005	24.35	17.28	7.10
Coyle	1027	40.70	35.35	8.69
Draper	2036	8.86	47.66	53.77
Elsie Creek	1007	25.59	17.86	6.98
Grassy Brook	1032	13.15	8.11	6.17
Little Forks Creeks	1024	13.48	7.83	5.81
Lower Forks Creek	1035	105.66	42.72	4.04
Lower Oswego Creek	1034	103.37	45.73	4.42
Lyons Creek	1033	80.30	37.35	4.65
Moore's Creek	1012	33.28	22.01	6.61
Sucker Creek	1022	11.16	8.68	7.78
Thompson Creek	1030	14.59	10.94	7.50
Upper Forks Creek	1026	65.66	23.11	3.52
Upper Oswego Creek (u/s of Oswego Gauge)	1017	81.21	46.65	5.74
West Wolf Creek	1002	13.86	10.31	7.44
Wilson Creek	1014	6.44	5.39	8.37
Wolf Creek	1009	23.54	16.78	7.13
Local Drainage to Main Branch	1001	43.11	25.36	5.88
Local Drainage to Main Branch	1003	26.87	20.31	7.56
Local Drainage to Main Branch	1004	5.85	4.68	8.00
Local Drainage to Main Branch	1006	5.39	4.32	8.02
Local Drainage to Main Branch	1008	3.69	3.42	9.26
Local Drainage to Main Branch	1010	8.02	8.01	9.98
Local Drainage to Main Branch	1011	9.00	5.16	5.73
Local Drainage to Main Branch	1013	17.21	12.21	7.09
Local Drainage to Main Branch	1015	10.53	8.16	7.75
Local Drainage to Main Branch	1016	22.89	12.61	5.51
Local Drainage to Main Branch	1018	11.61	7.16	6.16
Local Drainage to Main Branch	1019	2.18	1.24	5.70
Local Drainage to Main Branch	1021	3.93	3.77	9.61
Local Drainage to Main Branch	1023	19.58	14.12	7.21
Local Drainage to Main Branch	1025	13.78	9.20	6.67
Local Drainage to Main Branch	1029	9.47	5.63	5.94
Local Drainage to Main Branch	1037	25.21	11.25	4.46
Local Drainage to Main Branch	2028	5.18	14.47	27.92
Local Drainage to Main Branch	2031	11.26	28.31	25.15