HYDROLOGY & HYDRAULICS REPORT

Quinte Conservation Authority
And
The Township of South and Central Frontenac

FHIMP ON22-46

For the

Napanee River Upper Lakes
Flood Hazard Mapping

June 10, 2024

1-71 Millennium Parkway
Belleville, ON, K8N 4Z5

Phone: (613) 969-1111
Fax: (613) 969-8988

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1 Introduction

Quinte Conservation Authority (QC) has partnered with the Townships of South and Central Frontenac (the Townships) along with federal and provincial partners to lead the Napanee River Upper Lakes Flood Hazard Mapping.

With acquired funding through the federal Flood Hazard Identification Mapping Program (FHIMP), QC has undertaken a leadership role in the production of updated mapping for the Napanee River Upper Lakes. The objective is to provide a floodplain mapping update that will allow QC and the Township staff to make informed planning and regulation decisions. Jewell Engineering Inc. (Jewell) is pleased to support this initiative through the technical analysis and reporting described herein.

The driving forces for this project include climate change, improved modelling techniques and software programs, improved data acquisition tools, land use changes, and updated infrastructure that can dramatically influence flood behaviour and floodplain extents.

The need for accurate, detailed floodplain mapping that factors in climate change forecasting has become increasingly evident as flood damages become the largest cost to the Canadian economy out of any other natural hazard. Updated floodplain maps are needed to protect human life, property, and infrastructure from the damaging effects of flooding that is occurring with increased frequency.

The funds deployed by the federal and local governments to complete this updated floodplain mapping provide a dual benefit; it protects the local community from potential flood hazards *and* reduces the dependence on provincial and federal funds associated with the Disaster Financial Assistance Arrangements (DFAA) administered by Public Safety Canada.

This report is intended to describe the hydrologic and hydraulic analysis that was completed to produce the 2024 floodplain mapping set.

2 Background

The following background documents were reviewed in preparation of this Hydrology & Hydraulics Report.

The ***1981 Napanee Salmon Upstream Lakes Watershed Study*** prepared by Crysler & Lathem Limited was issued to establish fill line mapping for several lakes of interest in the upper reaches of the Salmon and Napanee watersheds. The 1981 study offers insight into previous hydrologic modeling and mapping methods. It includes hydrologic calculations for rainfall and snowmelt conditions, with outlet descriptions for particular lakes of interest, including those controlled by the Hardwood Dam. Additional controls, such as the storage-discharge for the Cameron Swamp and old Thirteen Island Lake Dam were also included. The hydrologic model in the 1981 study used TR20 software that is no longer of standard use among practioners. The 1981 report served a useful purpose to the conservation authority and the 2024 floodplain mapping includes additional lakes within the Napanee River Upper Lakes system as well as updated outlet surveys, crossing surveys, and the application of current modeling software and technical guidance.

The ***1978 Napanee River Basin Study*** prepared by Crysler & Lathem Limited includes a "structural, economic, and environmental analysis of each dam and its headpond." The report notes that the Cameron Swamp is a wetland that has significant impacts on the flows in the Napanee River (this was further confirmed with information in the 1981 study as well as the current hydrology review at the Camden East flow gauge). A fill line was included for the Cameron Swamp with the intent to ensure its environmental features and natural flood hazard controls receive maximum protection.

The ***13 Island Lake Dam Hazard Potential Classification and Structural Design Report*** was prepared by Jewell Engineering in September of 2022. This document was reviewed since the information describes the changes in the old dam at 13 Island Lake to the new dam. It describes that the old dam was constructed in 1975 to control summer lake levels for recreational purposes. The old dam was comprised of four (4) 1200mm steel culverts that were adapted to permit installation of four 8" high logs. Due to a loss of road granular materials and observations of failure of the steel culverts, three (3) 1.8m x 0.9m concrete box culverts were selected as the replacement structure after going through the public process. The normal operating water level behind the dam is 150.43m with 2 - 0.15m (6") logs in place.

The ***Dam Safety Review Report for the Colebrook Dam*** was prepared by Hatch Ltd. in February of 2022. While outside of the subject study area for the Napanee River Upper Lakes floodplain mapping, the Dam Safety Review was investigated to determine the potential impacts it has on the local flow gauge at the Napanee River at Camden East station. The 1% AEP inflows and outflows for the Colebrook Dam are unchanged based on Table 3-1 of the Hatch report, indicating the Colebrook Dam would provide no appreciable flow attenuation in a regulatory level flood event. Therefore, flow attenuation impacts on the Camden East gauge are expected to be driven by the Cameron Swamp, Hardwood Dam, and several other outlet controls within the watershed that contributes to the Camden East gauge.

3 Study Area

The study area for the Napanee River Upper Lakes was outlined by QC at the beginning of the project and is reproduced in Appendix A-1.

The study area focuses on the major lakes within the watershed; this includes Potspoon Lake, White Lake, St. Andrew Lakes, Cole Lake, Thirty Island Lake, Thirteen Island Lake, Fourteen Island Lake, Little John Lake, Sigsworth Lake, Hambly Lake, Van Luven Lake, Howes Lake, and Verona Lake.

The study area also includes four (4) river branches that connect the Napanee River Upper Lakes to their confluence at Verona Lake. Runoff from the four river branches and thirteen (13) lakes are subject to flow controls from the Hardwood Dam immediately downstream of County Road 38 in Verona for low flow conditions, and the Cameron Swamp for moderate and high flow conditions.

The northwest branch includes the tributary that connects St. Andrew Lakes and Cole Lake before draining as Cole Creek through Godfrey towards Howes Lake and Verona Lake.

The north branch includes White Lake that outlets to White Creek. White Creek crosses north of Glendower before meeting the northeast branch at Thirteen Island Lake.

The northeast branch includes Potspoon Lake that drains in series to Thirty Island Lake and then Thirteen Island Lake. The north/northeast branches outlet from Thirteen Island Lake into Howes Lake, where it meets the runoff from the northwest branches of Cole Creek.

The east branch has relatively short channel sections as it includes Little John Lake, Sigworth Lake, and Fourteen Island Lake, each of which are in close proximity to one another. The outlet of Fourteen Island Lake drains through two smaller lakes (Little Mud Lake and Spring Lake) before meeting the confluence with the other three main branches of the Napanee River Upper Lakes at Verona Lake.

The study area is evidently dominated by the thirteen lakes identified above. Each lake has an outlet control, whether man-made or natural, which encourages these lakes to act as a system of reservoirs and connector channels. The study area focuses on the water levels and flood hazard limits produced by the regulatory peak flows that contribute to these lake reservoirs and river channels.

4 Hydrology

The hydrology assessment was prepared for the lake outlets and several nodes of interest throughout study area. Various methodologies were applied and compared to determine representative peak flows. Each methodology was carefully considered prior to the selection of the peak flows for use in the hydraulic model, including potential increases in flows due to spring-melt conditions.

The Napanee River Upper Lakes watershed is within *Zone 2* of *Flood Hazard Criteria Zones for Ontario Conservation Authorities*. Therefore, the flood standard is the 1% annual exceedance probability (AEP).

The detailed hydrologic analysis for the purpose of quantifying the peak flow rates is described below.

4.1 Data Sources

Data collection is an integral component of the hydrologic assessment. A description of each primary data source applied in the analysis is provided below.

4.1.1 LiDAR, Catchment Areas & Terrain

The subject watershed for the Upper Lakes has a total area of 148.5km^2.

The watershed is discretized into sixteen (16) sub-catchments based on confluence points, lake outlets, and dam locations. The catchment boundaries are identified in Appendix A-2.

External catchments beyond the subject watershed were included for calibration purposes to allow the hydrologic model results to be compared to flow gauge observations of the Napanee River at the Camden East station (see further discussion in Section 4.3).

Catchment areas were delineated using topographic information from the following sources.

1) Provincial LiDAR developed and published by *Land Information Ontario* was reviewed in combination with ESRI server data information to assist in delineation of the sub-catchment boundaries. The sub-catchment configurations are similar to those delineated in the 1981 Crysler and Lathem study, however Jewell's assessment is more localized (i.e. more sub-catchments) and with updated LiDAR data. The 2023 catchment delineations included a detailed review of the contour information with GIS software extents set as dense as 0.5m contours in select locations areas to ensure the accuracy of the sub-catchment boundaries.

2) A site-specific topographic survey for lake outlets and hydraulic structures was completed to assist in the stage-storage-discharge relationship supplied to the hydrologic and hydraulic models.

4.1.2 Soils and Land Cover

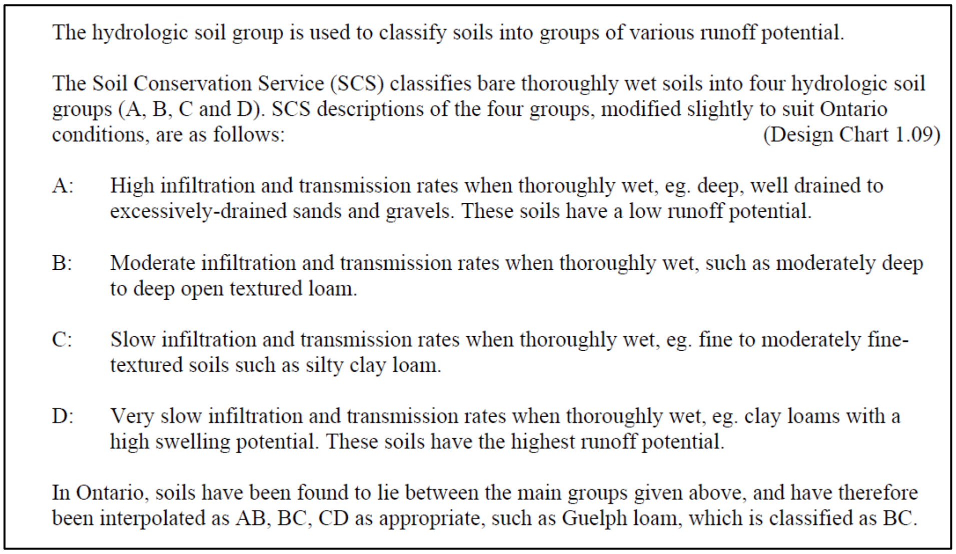
A soils map is provided in Appendix B. Soils information was obtained from the Soil Survey Complex database produced by the *Ontario Ministry of Agriculture, Food and Rural Affairs* in cooperation with the *Ontario Ministry of Natural Resources and Forestry*.

The HSG classification for soils is used to identify drainage characteristics for various soil types. An excerpt from Chapter 8 of the *1997 MTO Drainage Management Manual* that describes drainage characteristics for each HSG is provided below.

The soils in the Napanee River Upper Lakes watershed are predominantly Hydrologic Soils Groups (HSG) B, as shown in Appendix B and Table 4-1.

Table 4-1: Napanee River Upper Lakes Overall Watershed Hydrologic Soils Group Summary

HSG Soils Group	Area (km²)	Land coverage (%)
A	1.2	1
B	117.1	79
C	24.3	16
D	5.9	4



The hydrologic soil group is used to classify soils into groups of various runoff potential.

The Soil Conservation Service (SCS) classifies bare thoroughly wet soils into four hydrologic soil groups (A, B, C and D). SCS descriptions of the four groups, modified slightly to suit Ontario conditions, are as follows: (Design Chart 1.09)

A: High infiltration and transmission rates when thoroughly wet, eg. deep, well drained to excessively-drained sands and gravels. These soils have a low runoff potential.

B: Moderate infiltration and transmission rates when thoroughly wet, such as moderately deep to deep open textured loam.

C: Slow infiltration and transmission rates when thoroughly wet, eg. fine to moderately fine-textured soils such as silty clay loam.

D: Very slow infiltration and transmission rates when thoroughly wet, eg. clay loams with a high swelling potential. These soils have the highest runoff potential.

In Ontario, soils have been found to lie between the main groups given above, and have therefore been interpolated as AB, BC, CD as appropriate, such as Guelph loam, which is classified as BC.

Figure 4-1: Excerpt from 1997 MTO DMM Describing Hydrologic Soils Group Classifications

The soils data is used to develop curve numbers (CNs) that are a key modelling parameter used in the Soil Conservation Service (now known as the *National Resources Conservation Service*) methodology for estimating the proportion of precipitation that will runoff the lands and the portion that will infiltrate. CNs are a function of soil type, land cover, slope, and land use. The higher the CN – the greater the proportion of precipitation that is expected to runoff the lands. CNs are representative of the pervious portion of the watershed. Jewell followed the guidance in *MTO Design Chart 1.09* to determine curve numbers for the discretized catchments.

Land cover information was obtained from the Ontario Land Cover Compilation (OLCC), a database owned by *Land Information Ontario,* and provided by the *Ontario Ministry of Natural Resources and*

Forestry. A review of land coverage for the watershed shows that the land use is predominantly woods, water, and cultivated land. A summary of land coverage percentage is provided in Table 4-2 below.

Table 4-2: Napanee River Upper Lakes Overall Watershed Land Cover Summary

Land Cover	Area (km^2)	Land Coverage (%)
Woods	84.13	57
Cultivated	22.77	15
Urban	1.69	1
Water	30.90	21
Bedrock	9.04	6

4.1.3 Meteorologic Inputs

Environment and Climate Change Canada (ECCC) intensity-duration frequency (IDF) curves for data collected at the Kingston station is the best available data record (see Appendix F). Jewell reviewed the rainfall data at Kingston, Tweed, Smith Falls, and Hartington. The Tweed and Smith Falls records do not have a sufficient duration with only 21 years of data. The Hartington station has a sufficient length of data record at 45 years, however it does not have published IDF curves. The Hartington station *does* have snowmelt plus rainfall frequency values which were applied in the AEP snowmelt events (see Appendix C-1). It is also noted that the rainfall frequency values for the Hartington station have a published 1% AEP, 1-day rainfall total of 92.1mm.

The Kingston station is the closest station that has a set of IDF curves *and* a sufficient length (63 years) of record. The Kingston station has a 1% AEP, 1-day rainfall total of 97.1mm. This is greater than the 24-hr total from the Hartington station that is closer to Verona, suggesting the Kingston IDFs offer a conservative estimate of rainfall depths for the subject region.

Additionally, Quinte Conservation (QC) provided precipitation records for use in the rainfall-runoff model calibration and validation process. QC provided records at the 2nd Depot, Camden, and Tamworth rainfall gauges. Since the precipitation at these gauges is not verified by ECCC and does not have standardized sensor selection, calibration, and placement under the control of ECCC, the *distribution* of the rainfall gauges was the primary interest from the received rain gauge data set. The rainfall totals from the QC records were compared to the total depth observed at the Environment Canada Hartington station.

ECCC provided stream flow gauge data with shorter (5-minute) time intervals than the publicly available daily records for the Napanee River at Camden East station (02HM007). The discharge values are part of the Water Survey of Canada’s primary products and considered a reliable data source.

Major rainfall events occurred locally in May of 2017 and November of 2006. These rainfall events were used to calibrate and validate the rainfall-runoff model. The rainfall record for each of these events is shown in Figures 4-2 and 4-3. These events are discussed further in Section 4.3.

An important consideration in the precipitation data is the potential impacts on rainfall depths due to climate change. QC, in partnership with FHIMP representatives, provided the recommended approach to quantify increased rainfall depths due to climate change. This approach is completed by scaling rainfall intensities based on projected temperature increases. The methodology, rainfall depths, and impacts on peak flows are discussed further in Section 4.6.

Figure 4-2: Rainfall Data Applied in May 2017 Calibration Event for Rainfall-Runoff Model

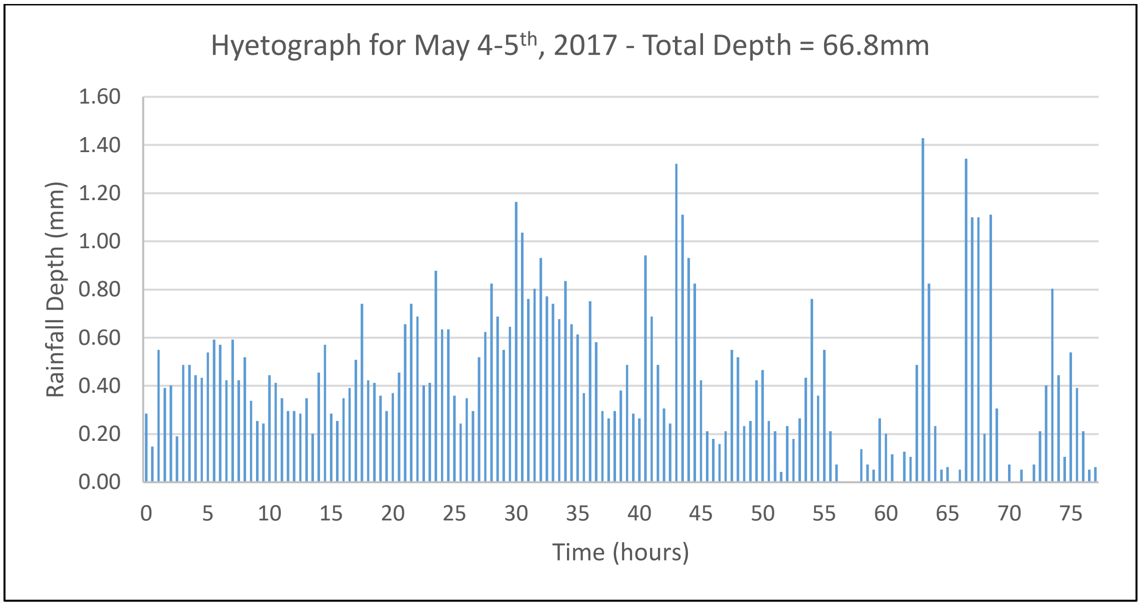
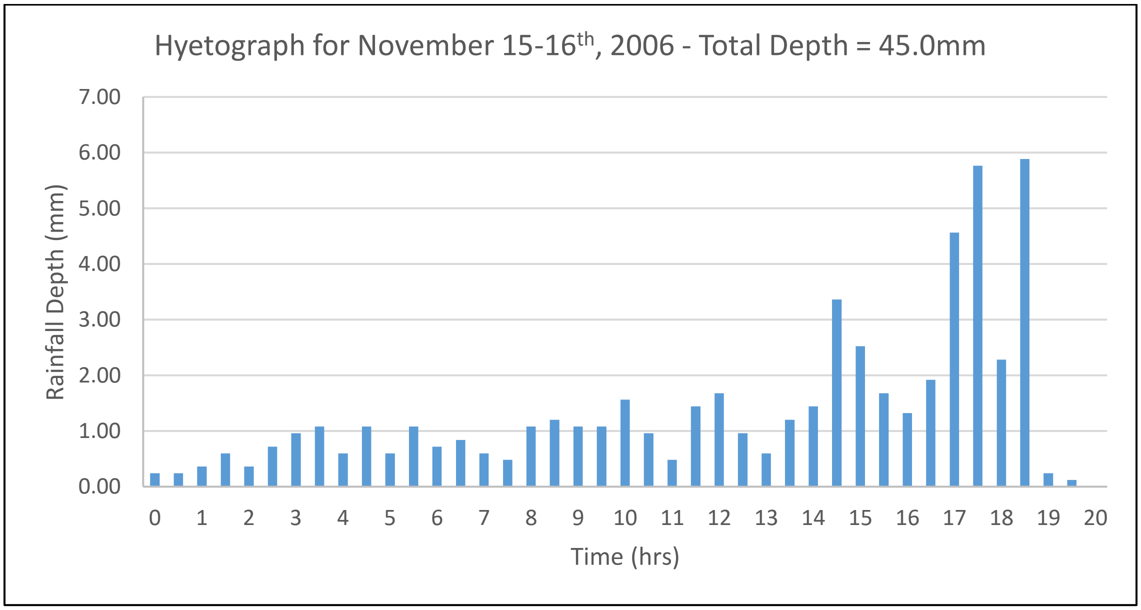


Figure 4-3: Rainfall Data Applied in November 2006 Validation Event for Rainfall-Runoff Model



Jewell participated in recent discussions with ECCC staff regarding precipitation statistics. As part of these discussions, Jewell acquired and reviewed the ECCC precipitation statistics tool. This review confirmed Jewell's in-house spreadsheet is consistent with the ECCC methodology. Jewell's in-house precipitation tool was used to determine the 0.5% AEP statistical rainfall since this AEP is not included in the standard Environment Canada IDF curves. The spreadsheet calculates the precipitation frequency curve using a Gumbel distribution.

The recommended AEP storms for floodplain mapping are derived from the SCS distribution based on the 2002 *MNR Technical Guide for Ontario Flood Hazard Limits* with varying durations. In an assessment of the critical AEP storm, Jewell compared peak outflows from a HEC-HMS model (see Section 4.3) for the 12 and 24-hr duration events. Any event less than 12 hours is not recommended for the Napanee River Upper Lakes since shorter duration events do not produce significant enough rainfall volumes to govern as the regulatory storm event. This is particularly pertinent to the subject watershed as the storage in the reservoirs, and subsequently the peak outflows from the lakes, will be governed by high runoff volumes that occupy storage within the lakes and create a driving head on the outflow controls that drain to the receiving channels.

In the rainfall simulations, the 24-hr duration produced the largest peak runoff rate. Therefore, the 24-hr duration was considered the critical storm for the rainfall-runoff model. A comparison of statistical rainfall volumes for the 12-hr and 24-hr durations is provided in Table 4-3.

Table 4-3: Runoff Volumes for 12- and 24-Hr Storm Durations for Kingston IDF Curves

AEP	Rainfall Volume (mm)	
	12-Hr	**24-Hr**
50	41.2	47.1
10	63.8	69.3
1	92.0	97.1
0.5	99.7	105.3

4.1.4 Water Survey of Canada Stream Flows

There is a stream flow gauge located along Napanee River at *Water Survey of Canada (WSOC)* Station 02HM007 titled 'Napanee River at Camden East'.

The flow data of interest is the *Annual Maximum Instantaneous Peak Discharge.* The record length for the gauge is from 1974 to 2022, with 46 years of annual instantaneous maximum peaks.

Discharge data was received from ECCC in 5-minute intervals for use in the calibration and validation model runs. The Depot Creek at Bellrock (02HM002) WSOC flow gauge was also applied in the calibration/validation process. Table 4-4 and Figure 4-4 summarize the station data and gauge locations.

Table 4-4: List of Local Stream Flow Gauges for Extended Data Record

Name	Station ID	Length of Record	Gross Drainage Area (km^2)
Depot Creek at Bellrock	02HM002	1957 - 2023	203
Napanee River at Camden East	02HM007	1974 - 2022	718
Napanee River at Hardwood Dam	N/A	N/A	149

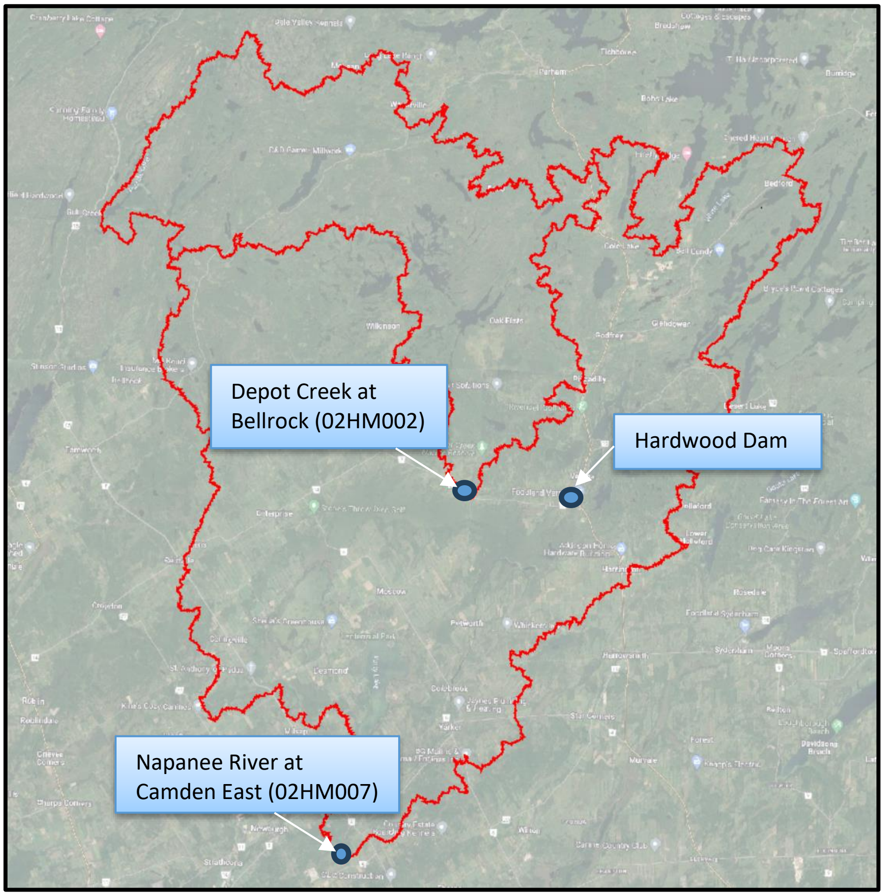


Figure 4-4: ***Napanee River at Camden East*** **Water Survey of Canada Stream Flow Gauge Locations**

4.2 Flood Frequency Analysis

A primary benefit of updated hydrologic models is that they can be calibrated to observed stream flow gauge data that has occurred since the previous hydrologists completed their assessment of the peak flows. While models are a simplification of the complex hydrologic system, the flow gauge provides the true answers. Fortunately, the WSOC follows strict procedures to ensure the flow observations are accurate and suitable for use in statistical analysis programs. The previous study of the Upper Napanee Lakes occurred in 1981. The *Napanee River at Camden East* WSOC flow gauge has records from 1974 to present. Therefore, 40+ years of "new" flow data has been incorporated into this floodplain mapping update.

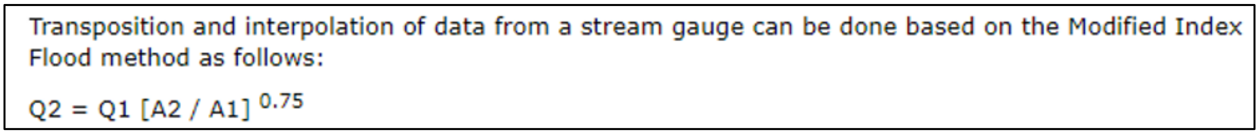
The flood frequency analysis (FFA) was completed using the Canada Frequency Analysis program. This modeling approach employs stream flow gauge records into the hydrology results similar to the HEC-SSP (Statistical Software Package) software. The statistical software program was applied to calculate the AEP flows using a Three Parameter Log Normal distribution as recommended in previous discussions with ECCC. In Ontario, the Three Parameter Log Normal distribution can be applied with the maximum annual instantaneous peak data as the preferred data set.

For the purposes of obtaining AEP flood flows, the General Frequency Analysis (GFA) component can be employed and is a recommended method in the 2002 MNR guidelines. Parameters other than peak flows, such as stage or precipitation data, can also be calculated using a GFA.

In performing a GFA, data is provided to the program and the calculated results are output in graphical and tabular formats. Prior to providing input data, a variety of settings are defined by the user. Some notable settings and their descriptions are shown in Table 4-5.

From an assessment of the stream flow records, it is evident that the majority of the annual instantaneous peaks occur in the spring. For the 46-yr data record of annual instantaneous peaks at the WSOC Camden East flow gauge, only three (3) years had instantaneous peaks outside of December 30th to May 1st. This suggests a 93% probability that a future flood event would be the result of a snow-melt event, or a combination of a snow-melt and rainfall event. Therefore, the stream flow gauge records provide the best indication of the anticipated flow rates produced at the Camden East station in a snow-melt plus rain scenario.

The CFA program results for the respective AEPs are summarized in Table 4-6. For AEP flows at the downstream limit of the Napanee River Upper Lakes study area, a transposition of flows is required (see Figure 4-5). The transposed flows are useful for comparison purposes, but due to the large difference in areas subject to the transposition equation, further investigation is recommended. This further investigation is described in the following subsections (Sections 4.3 and 4.4). A transposition of flows to the Cameron Swamp outlet was also completed since the Cameron Swamp is the downstream limit of the hydrologic model used in the calibration simulations.



Transposition and interpolation of data from a stream gauge can be done based on the Modified Index Flood method as follows:

$Q2 = Q1\ [A2 / A1]^{0.75}$

Where Q1 = known peak discharge
Q2 = unknown peak discharge
A1 = known basin area
A2 = known basin area of unknown peak discharge

Figure 4-5: Excerpt from MTO Online Drainage Manual

Table 4-5: HEC-SSP Settings and Descriptions

Setting	Description
Log Transform	○ This setting can be selected to have the frequency analysis performed on the logs of the data ○ Log Transform needs to be used to allow for the LogNormal and LogPeason III distributions to be selected ○ If the Log Transform setting is not used, the Normal and Pearson III distributions can be selected
Confidence Limits	○ Confidence limits measure the uncertainty of the computed value for a selected exceedance probability ○ Default settings calculate the 90% confidence interval, with confidence limits of 0.05 and 0.95
Distribution	○ This setting provides the analytical distribution options used to perform the frequency analysis ○ Distribution choices are None, Normal, LogNormal, Pearson III, and LogPearson III
Generalized Skew	○ Computes a skew value for the data ○ Three options that can be selected are Station Skew, Weighted Skew, and Regional Skew ○ The default option is Station Skew, where the skew of the computed curve is based solely on computing a skew from the provided data points

Table 4-6: Summary of Maximum Peak Flows from HEC-SSP General Frequency Analysis

AEP (%)	Peak Flow (m^3/s)		
	Camden East (718 km^2)	Hardwood Dam (149 km^2)	Cameron Swamp (670 km^2)
50	43.2	13.2	41.0
10	61.5	18.9	58.4
1	80.7	24.7	76.6
0.5	86.0	26.4	81.7

4.3 Rainfall-Runoff Modeling

The SCS Curve Number (CN) method is commonly applied in hydrology models for precipitation-driven runoff modeling applications. It relies on the soils and land use data to establish the loss method with calculation of a CN. The modeling approach is supported by Visual OTTHYMO (VO) and HEC-HMS.

All modelling programs are simplifications of reality and are limited in their capabilities. While VO and HMS are both well-established and recommended software programs, they are limited by input parameters and the uncertainty associated in the data sets and calculations used to produce these inputs. Both modelling programs are acceptable for simulating peak flows to be used in the hydraulic model. The most recent software publications have been used for this project.

While VO was initially selected, HEC-HMS was ultimately preferred due to its use of timestamps in the model runs. The timestamp feature is useful in calibrating the hydrologic model since it allows the user to compare timing of the hydrograph peaks. The objective is to ensure the hydrograph peaks, start time, and lag times are similar in both the observed results and modeled results. Shape files for land cover and soil type prepared in GIS software were applied to develop the attribute tables used to calculate the weighted CN value for each sub-catchment. This replicates the GIS features available in Visual OTTHYMO. The shape files are included in the final deliverables package.

Notable input parameters for the HMS model include:

- Precipitation – intensity, duration and frequency as well as distribution.
- Catchment area.
- Percent imperviousness – runoff volume, time to peak and peak flow increase with percent imperviousness.
- Soil conditions – these determine how much and how quickly water will be removed from runoff through infiltration. This may be expressed as a curve number, or by a runoff coefficient or using an infiltration model such as Horton's Infiltration.
- Slope – peak flows increase with slope.
- Initial abstraction – depth of precipitation input that is subtracted from the model and does not contribute to runoff.
- Manning's n – frictional coefficient that affects the time to peak.
- Basin lag or time to peak.

The peak flows simulated in HMS for each storm event at each lake outlet and major road crossing are summarized in Subsection 4.3.8 that follows.

It is noted that the urbanization in the subject watershed is predominantly limited to cottages and the community of Verona. Future development is not expected to yield an appreciable impact to the hydrologic findings described herein.

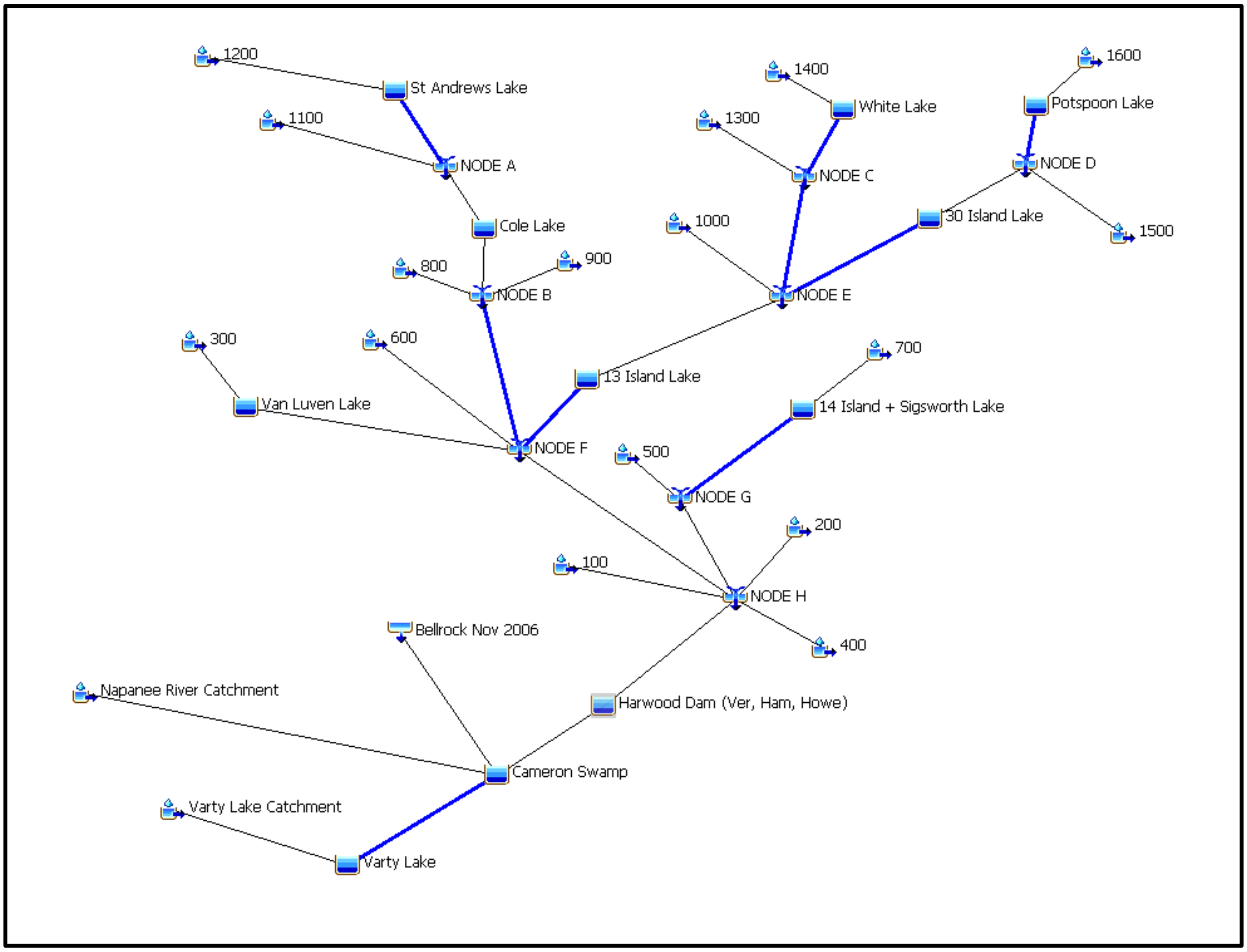


Figure 4-6: HEC-HMS Model Schematic for Initial Calibration

A consideration in the hydrology model is the starting water levels at or above the invert of each individual lake outlet. In the absence of a sufficient record of stage data for each lake, the best available data set is the stream flow record, which has 43 of its 46 annual instantaneous peaks occurring in the snowmelt period. The annual instantaneous peaks in the GFA include all data that contribute to the flows, including baseflows and flows that occurred prior to the main snowmelt event.

An alternative measure that was included in the HEC-HMS model is the near-zero initial abstraction value (0.1mm) that was applied in both the snowmelt and rainfall-runoff models. Whereas initial abstraction can range from approximately 2 – 15mm based on the default parameters in HMS, setting this value to 0.1mm essentially omits the initial precipitation removal and encourages immediate runoff that simulates early depths of water above the invert prior to the peak that occurs later in the runoff event. While the ideal condition would be to have a long record of stage data for each lake, the above approach provides confidence that the amount of water level rise above the invert would error on the side of caution.

4.3.1 Calibration

The rainfall model was calibrated using the event that occurred in May of 2017. This event was selected as the calibration storm since it produced the largest annual instantaneous peak outside of the spring melt season. It also produced the seventh (7th) highest annual instantaneous peak out of the 46-year data record. The other six (6) were produced from spring melt events that are discussed further in Section 4.4.

The measured precipitation data (see Figure 4-2) was supplied as a meteorologic input to the HMS model. The objective is to obtain an outflow hydrograph from the HMS model that produces similar peak flow and lag time values to the measured flow gauge hydrographs.

The measured flow gauge hydrograph is shown in Figure 4-8. On May 9th of 2017, the stream flow gauge recorded its maximum peak flow of 58.9 m^3/s.

It is important to note that in the spring of 2017, runoff was released from the snowpack by April 8th and majority of the runoff had subsided by April 30th based on a review of historic climate data and the local snowmelt model created by Dr. H. O. Schroeter (see further snowmelt discussion in Section 4.4). The May 2017 rainfall event began shortly after the spring melt season on the evening of May 4th. Therefore, antecedent moisture condition (AMC) III was selected for the model calibration to account for saturated ground conditions. The flow measurement preceding the rainstorm is considered baseflow for the purpose of the calibration, and is subtracted from the flow readings associated with the May 4-5th rainfall event; the baseflow is 24.4 m^3/s. With the flow gauge peak of 58.9m^3/s, subtracting the baseflow yields a *target peak flow* rate of 34.5 m^3/s.

Per discussions with federal representatives on similar local FHIMP projects, the curve number (CN) is the primary input parameter subject to calibration. Lag time is also an important consideration, and the lag times of the calibrated model were adjusted to provide consistency with the *measured* lag times.

Ideally, a flow gauge would be present at the downstream limit of the study area near the Hardwood Dam. A unique component of the Napanee River Upper Lakes is that the study area terminates *prior* to, or upstream of, the available flow gauge location.

Given the flow gauge location downstream of the study area, an alternative calibration approach would be a regional frequency analysis. Since the lake outlet configurations for the Upper Napanee Lakes (several of which are man-made in the form of dams, weirs, or culvert crossings) are different than the controls (if any) located upstream of the stream flow gauges at adjacent watersheds, the regional approach was not selected. Rather, the local Upper Napanee River system and flow gauge results were applied in the calibration process (i.e. a single station approach).

In an effort to accommodate the “unknowns” between the Upper Lakes study area and the Camden East flow gauge, Jewell reviewed the watershed characteristics and flow controls for the downstream catchment areas that contribute to the flow gauge location. These "external" catchments are listed below and shown in Figure 4-7.

1. **Catchment Ext-1** represents the 203 km^2 drainage area that contributes to the Depot Creek at Bellrock flow gauge located downstream of the Depot Lake outflow control structures. This runoff drains to the Cameron Swamp and ultimately to the flow gauge at Camden East. A benefit of the Bellrock flow gauge is that its data record provides known values into the calibration events for 28% (203/718) of the total catchment area that drains to the Camden East gauge. This increases the accuracy of the calibration for the Upper Napanee Lakes watershed by reducing uncertainties in the external catchments that contribute to the model calibration run. The flow records for the Bellrock gauge were input directly into the calibration model via an inflow hydrograph as a Source element in the HMS model.

2. **Catchment Ext-2** represents the 283 km^2 drainage area outside of Catchments Ext-1 and Ext-3 that drains to the Cameron Swamp. The storage-discharge relationship for the Cameron Swamp was obtained from the Crysler & Lathem study and included in a reservoir-routing simulation. There is significant flow attenuation from the Cameron Swamp due to the large storage volume within its reservoir. The CN for this catchment was calculated with the same methodology applied to the Upper Lakes sub-catchments. The lag time for Catchment Ext-2 however was calculated using the *measured* lag time. Lag time is defined as the time separation from the centroid of the rainfall to the centroid of the outflow hydrograph. Therefore, it was back-calculated from the precipitation and stream flow gauge records for the subject rainstorm.

3. **Catchment Ext-3** represents the 23.1 km^2 drainage area that contributes to Varty Lake and outlets to the Cameron Swamp. The storage-discharge relationship for the Varty Lake outlet was obtained from the Crysler & Lathem study and included in the reservoir-routing of Varty Lake.

4. **Catchment Ext-4** represents the drainage area between the outlet of the Cameron Swamp and the flow gauge at Camden East. This catchment is different than the others in that its control structures are not expected to provide any significant flow attenuation. The main control structure within Catchment Ext-4 is the Colebrook Dam. The inflows and outflows for large storm events at the Colebrook dam were presented in the 2022 Colebrook Dam Safety Study by Hatch Limited. The document showed that no appreciable flow attenuation is provided by the Colebrook Dam in a large flood event. Since Catchment Ext-4 represents a small (7%) portion of the catchment to the Camden East gauge and does not receive substantial flow attenuation, it was not included in the calibration model. Therefore, the downstream limit of the calibration model is up to and including the outlet from the Cameron Swamp.

The subject watershed for the total Upper Napanee Lakes is 148.5 km^2. The contributing area to the flow gauge at Camden East is 718 km^2. The objective of the "external" catchment review and calibration is to assess the suitability of standard hydrology inputs for the Upper Lakes sub-catchments. If the model produces lower or higher values than observed, then the input parameters can be adjusted accordingly. Since the external catchments are similar to the Upper Lakes watershed with significant lake/wetland coverage and significant outflow controls, adjustments made to the external catchments can reasonably be applied to the Upper Lakes sub-catchments. Although the Upper Lakes total watershed is only 21% of the catchment area to the *Napanee River at Camden East* WSOC gauge, the known values at the Bellrock Creek flow gauge, combined with the storage-discharge relationships for Varty Lake and Cameron Swamp, allows for an accurate representation of the flows for the Upper Lakes system.

The HEC-HMS model compares well with the observed flow in the May 2017 calibration event (see Table 4-7). The *validation* component is described in the following subsection.

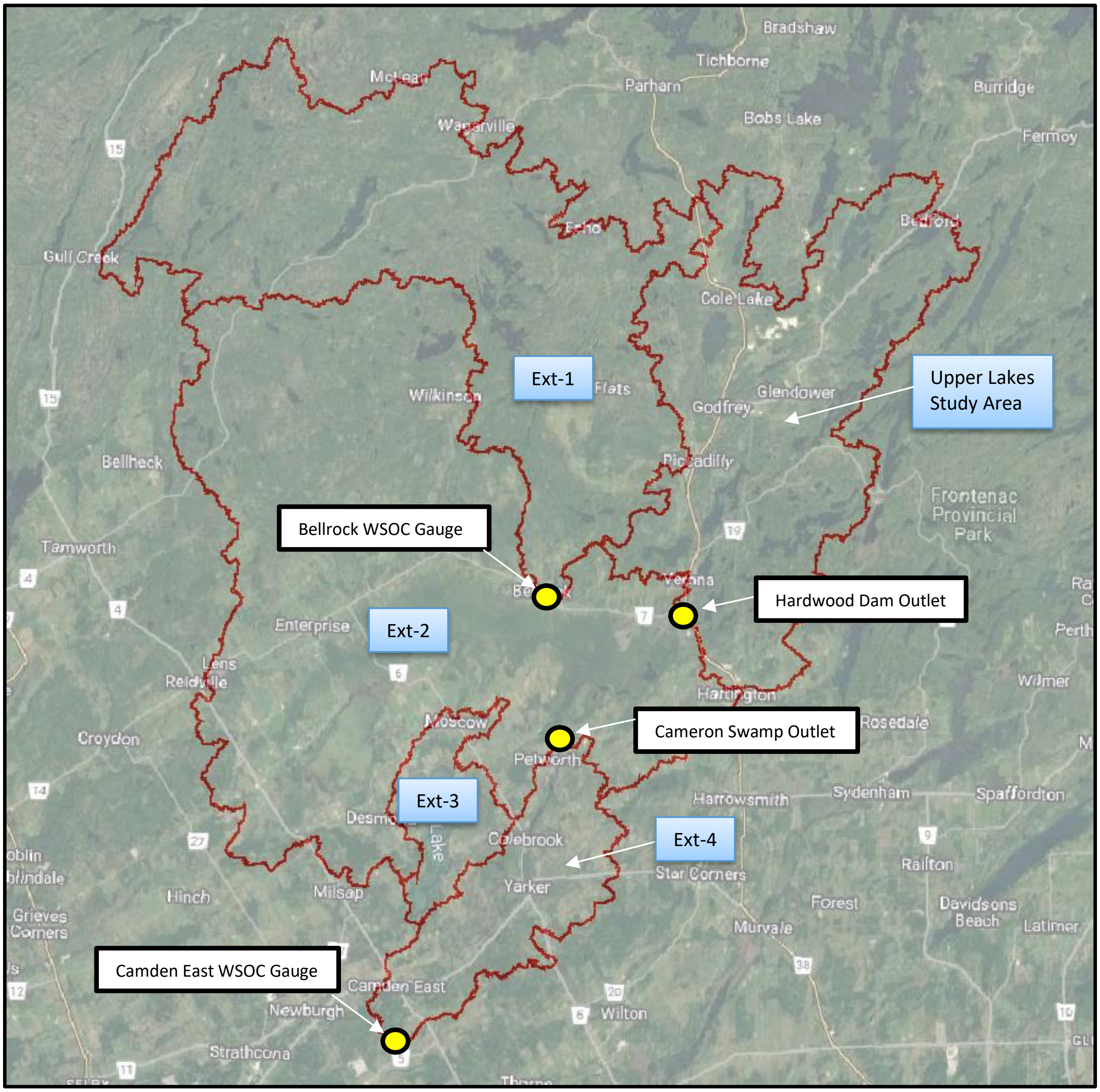


Figure 4-7: "External" Catchments Applied in Calibration Model

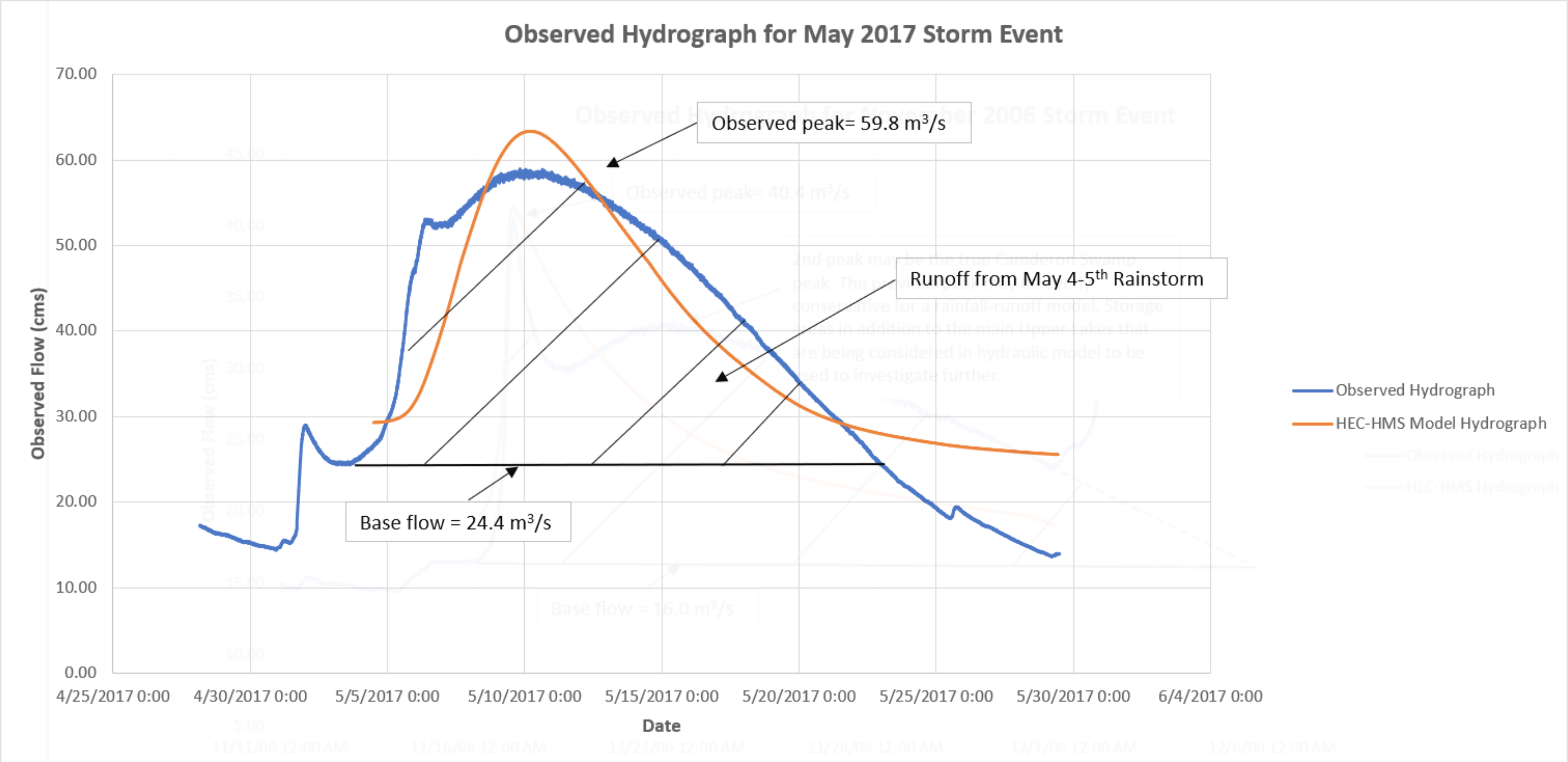


Figure 4-8: Observed Hydrograph for May 2017 Calibration Event

4.3.2 Validation

The precipitation event that primarily occurred on November 15th and 16th of 2006 was selected as the validation event since it is the next largest annual instantaneous peak flow outside of the May 2017 calibration storm. This approach is consistent with the 2002 MNR Technical Guide that recommends model testing be performed on the largest available storm events.

The flow gauge readings prior to the rain event are considered baseflow for the purpose of the calibration, and subtracted from the flow readings associated with the November 15-16th rainfall event; the baseflow is 16.0 m^3/s. With the flow gauge peak of 40.4 m^3/s, subtracting the baseflow yields a target peak flow rate of 24.4 m^3/s.

The calibrated parameters were applied to the validation event; the only exception is a conversion of CN values from AMC III to AMC II since the validation event occurred in late fall and was not subject to the same saturated ground conditions as the calibration event that occurred in May of 2017. In the AMC II scenario, CNs were increased by 7% to better replicate the peak flows observed in the validation event.

A comparison of peak flow results between observed and modeled outputs for the calibration and validation storm events confirm the hydrologic model yields a realistic representation of the flows produced by a large rainfall-runoff event measured at the Cameron Swamp, and by extension, the Napanee River Upper Lakes study area. Therefore, the same rainfall-runoff model parameters, with AMC II + 7% CN values, were selected for the statistical AEP events.

Table 4-7: Measured vs. Modeled Peak Flows for Rainfall-Runoff Storm Events

	Calibration Storm		**Validation Storm**	
Moisture Condition:	AMC III		AMC II + 7%	
Rainfall Depth (mm):	66.7		45.0	
	Measured	HEC-HMS	Measured	HEC-HMS
Peak Flow (m^3/s)	34.5	38.4	16.8	17.6
Hydrograph Volume (ha-m)	1,883	1,732	1,425	1,114
Time of Peak	5/9/2017 20:00	5/9/2017 15:45	11/20/2006 21:00	11/20/2006 22:00
Lag Time (hrs)	106	103	108	109

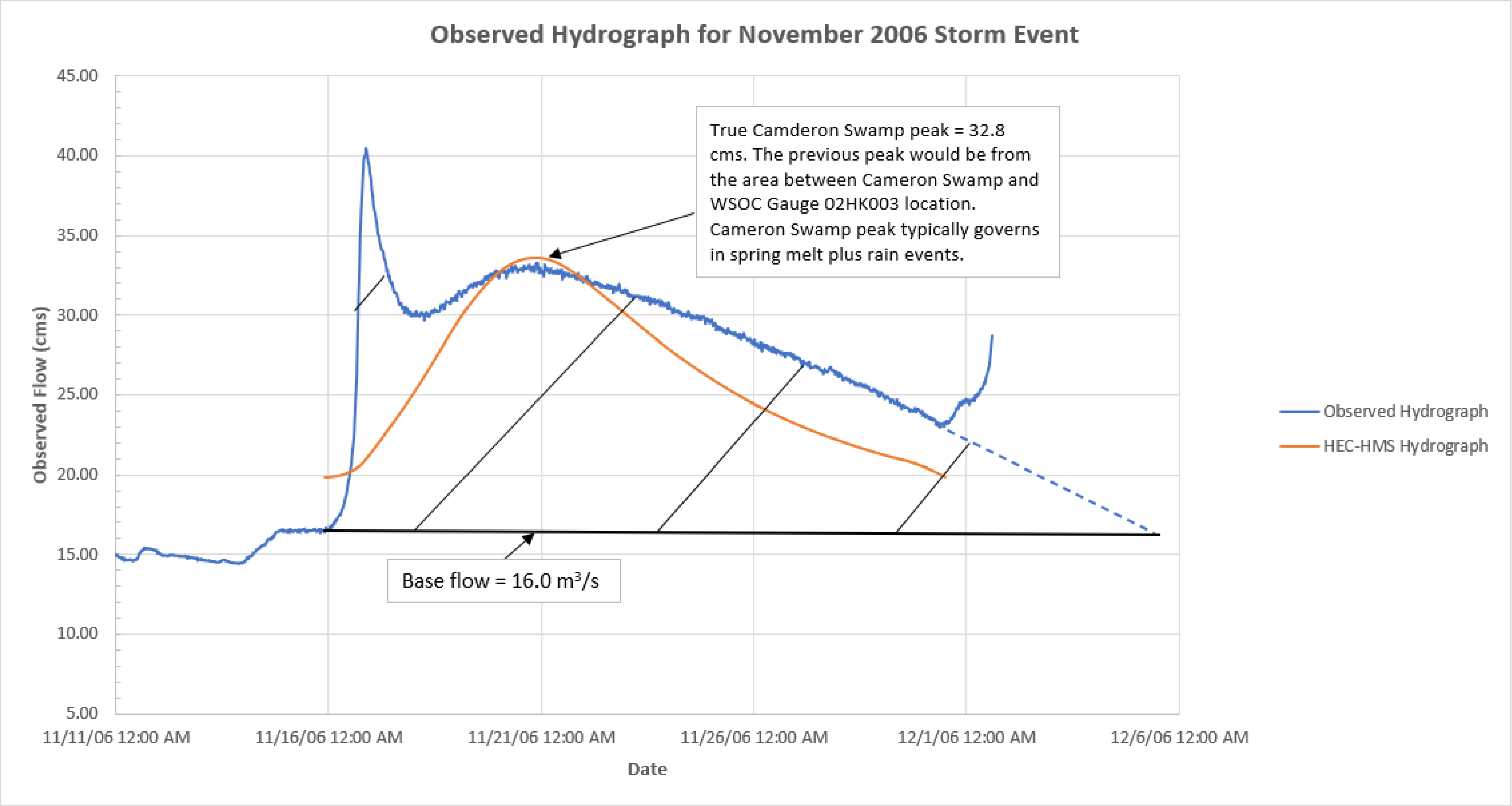


Figure 4-9: Observed Hydrograph for November 2006 Validation Event

4.3.3 Loss Method

The curve number (CN) loss method was selected since it accounts for both land cover and hydrologic soils group information. It was also selected because of the reputable sources available for this information. CNs were selected based on guidance from the CVC SWM guidelines in addition to MTO Design Charts. A look-up table was used to connect each land cover sub-area to its corresponding soil type. Attribute tables in GIS software applications were utilized to develop the detailed weighted CN applied to each sub-catchment.

AMC II, per Chapter 8 of the MTO Drainage Manual, was applied for antecedent moisture conditions (AMC) in the rainfall-runoff model. This represents 'average' soil conditions and AMC II values were increased by 7% based on the calibration/validation process. AMC II was used in the rainfall-driven AEP peak flow estimates as presented in Section 4.7. Saturated soil conditions (AMC III) were not selected for the rainfall-runoff event because this condition, combined with the statistical AEP rainfall events, would produce an event beyond the selected AEP frequency. Saturated conditions are applied separately in the snowmelt plus rain basin model that has been prepared to address spring melt conditions.

The individual basin inputs for the CN value were calculated with 28 combinations of HSG and land cover. For example, HSG A coverage could correspond with a woods, meadows, cultivated, lawns, impervious, or water land cover. The same process is repeated for HSGs B, C and D to develop the individual weightings for each sub-catchment. A brief description of each sub-area is provided in Appendix A-2.

4.3.4 Lag Time

Jewell applied the SCS Lag Time method to determine time of concentration and lag time values. This method was selected since it is derived from a study of watersheds that have drainage areas up to 24 km^2 with an upper limit of approximately 50 km^2. The sub-catchments within the Napanee River Upper Lakes are within this upper limit. The largest sub-catchment within the study area is 16 km^2. The SCS lag time method was also selected because it accounts for land cover and soil types by incorporating the CN value to estimate a retardance factor. The SCS lag time method is described in the *Hydrology National Engineering Handbook* published by the United States Department of Agriculture and the Natural Resources Conservation Service.

The individual lag time calculations were determined using the longest flow path and the mean overland slope specific to each sub-basin. The longest flow path was measured using LiDAR topography. The mean overland slope is higher than the channel slope as it includes direct runoff from the sub-basins before they reach the generally shallow sloping channels.

The lag times for the large external catchments in the calibration and verification models were adjusted based on observed precipitation and flow gauge recordings. The lag time is defined as the time differential between the centroid of the precipitation and the centroid of the runoff volume, which can be measured when these inputs are available.

4.3.5 Channel Routing

Channel routing was completed using the Muskingum-Cunge method for the initial model calibration. This method is applicable for reaches with relatively small slopes. The Napanee River Upper Lakes watershed has an average channel slope of 0.2%. This routing method allows the user to input a cross-section to represent the ground surface data for the channel and overbank areas. Cross-sections were obtained from the terrain data and then simplified into an eight-point cross-section.

The Muskingum-Cunge method was also selected since it incorporates Manning's n values to represent expected roughness for the channel and overbank areas. The applied Manning's n values are based on the design charts in the *MTO Drainage Manual*.

4.3.6 Reservoir Routing

Reservoir routing was included in the hydrologic model to account for the thirteen (13) lakes of interest. The storage-discharge relationship for each reservoir was established based on field survey, GIS applications, and a review of background documents. The field survey is used to identify the elevation and size of the outlet structures, the GIS applications are used to established the footprint area and volume of the reservoir, and the background documents identified the storage-discharge relationship for reservoirs beyond the subject study limits for their use in the calibration model.

The storage-discharge for Cole Lake is presented in Figure 4-10. The governing control is a beaver dam downstream of the natural Cole Lake outlet. The beaver dam is approximately 15m wide and is simulated using broad-crested weir flow.

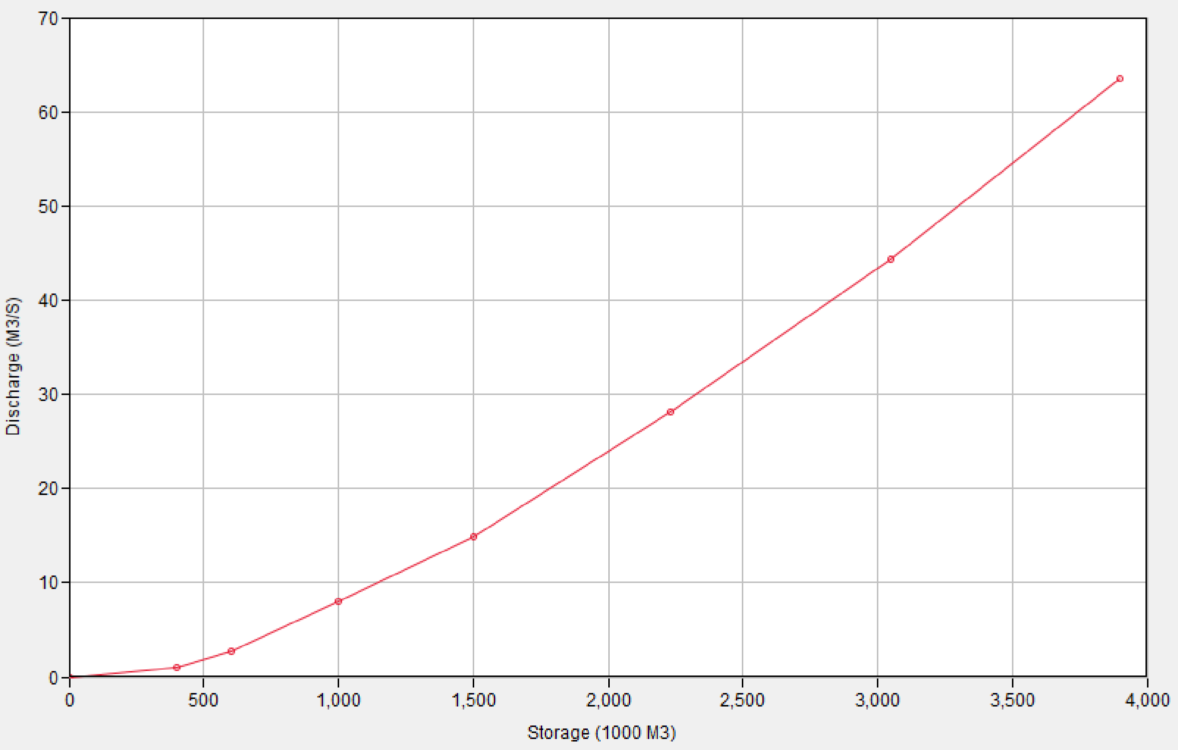


Figure 4-10: Cole Lake Storage-Discharge Relationship

The tailwater at the Hardwood Dam, imposed by the Cameron Swamp (see Section 5.1.3) controls the water levels in Verona, Howes, Van Luven and Hambly Lakes. The rating curves at the Cameron Swamp and Hardwood Dam outlets are provided in Figure 5-2 of the *Hydraulics* section of this report.

Potspoon Lake is controlled by a 6m weir and its storage-discharge relationship is shown below.

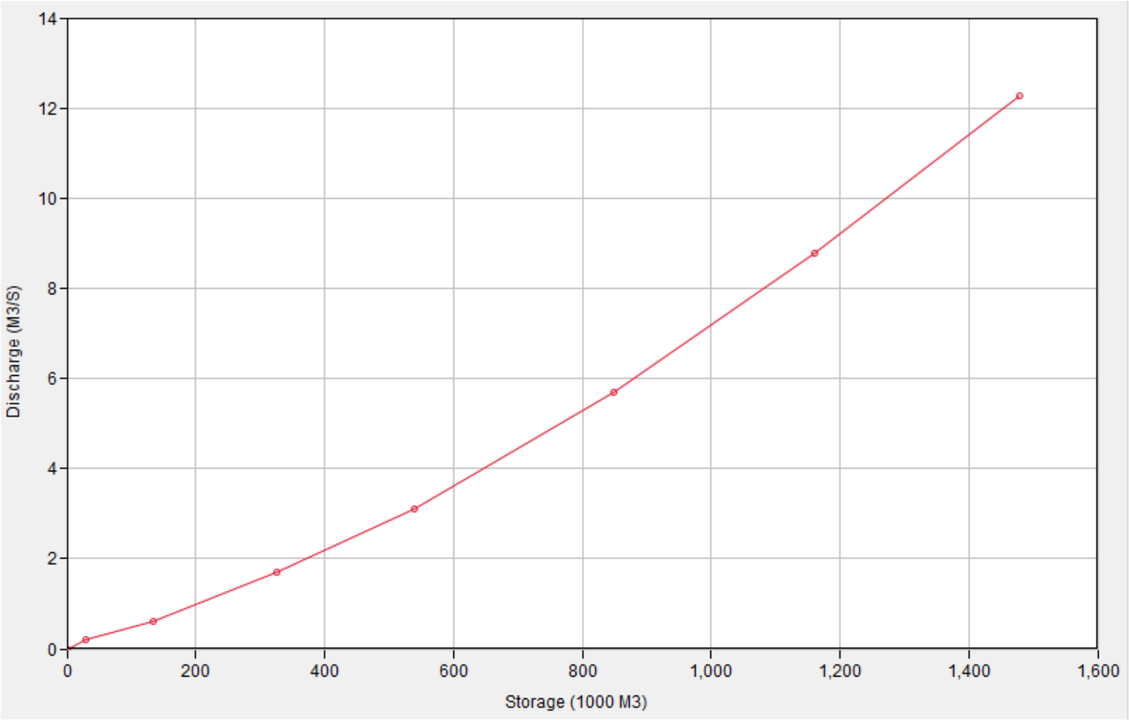


Figure 4-11: Potspoon Lake Storage-Discharge Relationship

The St. Andrew Lakes outflow is limited by the culvert crossing at St. Andrew Lakes Lane. Three (3) 750mm diameter pipes and a relatively flat roadway were analyzed to prepare the storage-discharge relationship presented in Figure 4-12.

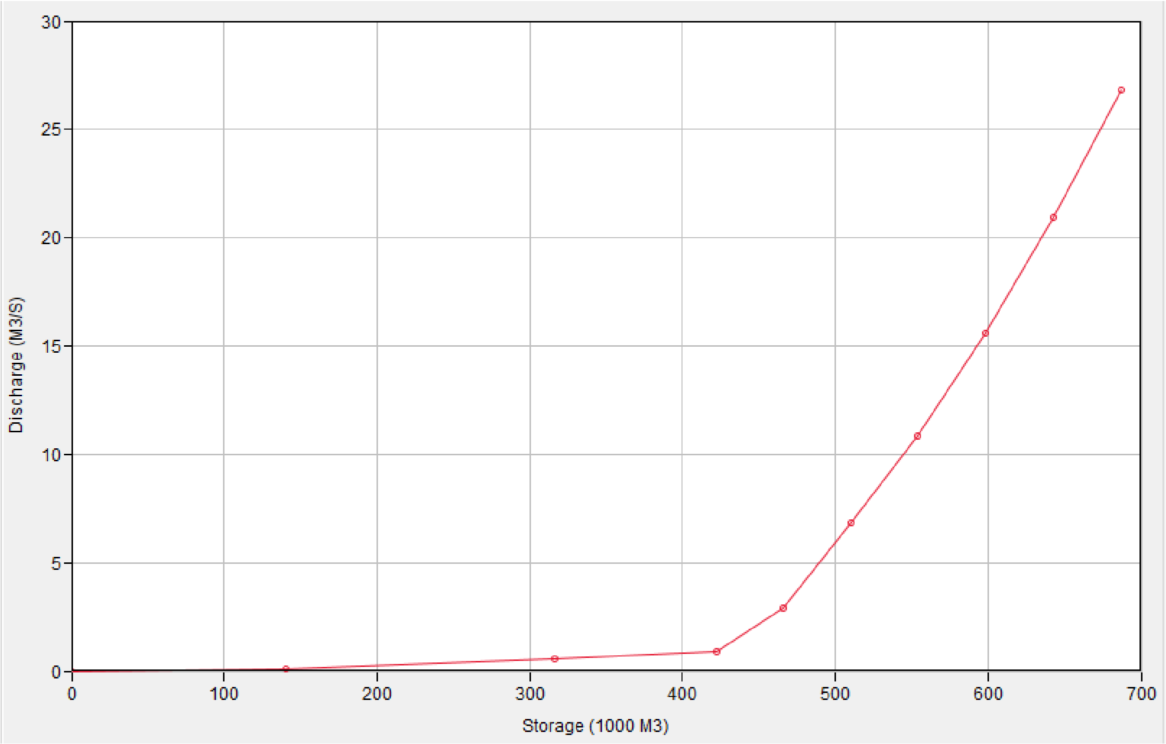


Figure 4-12: St Andrew Lakes Storage-Discharge Relationship

Van Luven Lake was assumed to be controlled by the Cameron Swamp & Hardwood Dam outlet in the 1981 study. However, a review of LiDAR data and 2023 field survey indicates that Van Luven Lake is controlled by the concrete box culvert crossing at County Road 38 before it drains into Howes Lake. The backwater impacts from the Cameron Swamp do influence the water levels in Van Luven Lake and subsequently the water levels for Van Luven and Howes Lake will be the same in large storm events. However, the headloss imposed by the box culvert could results in slightly higher water levels in Van Luven Lake relative to Howes Lake in smaller, more routine rainfall events or in standard summer water level conditions. The box culvert and road profile were included in the hydraulic calculations to prepare the storage-discharge relationship in Figure 4-13.

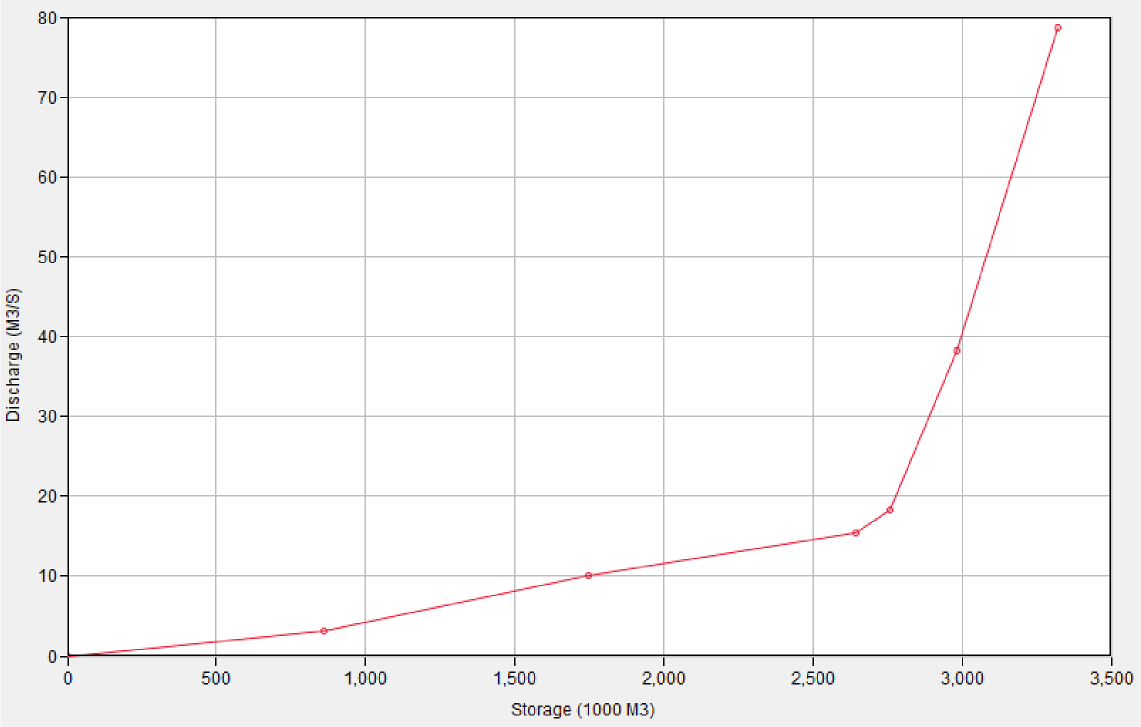


Figure 4-13: Van Luven Lake Storage-Discharge Relationship

Figure 4-14 below illustrates the storage-discharge relationship for Varty Lake. This relationship was obtained from the appendices of 1981 Crysler & Lathem study for use in the calibration model.

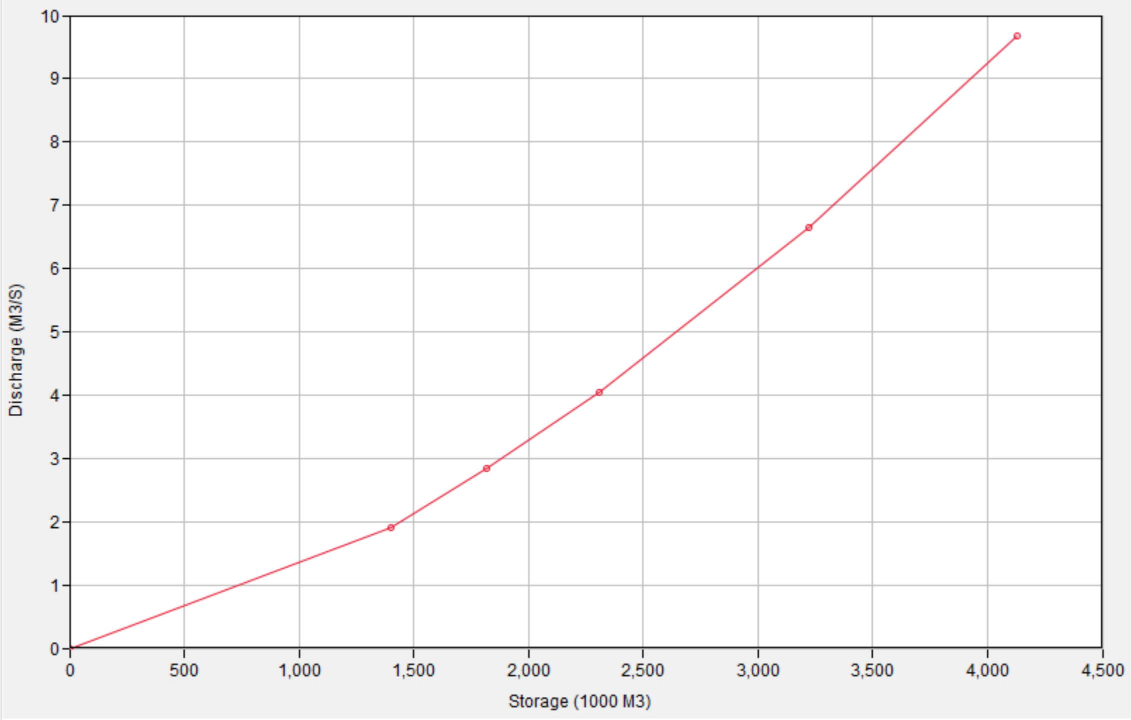


Figure 4-14: Varty Lake Storage-Discharge Relationship

The White Lake outlet was difficult to quantify in the field survey due to its remote location. A 4m length beaver dam is expected to be the current flow control based on satellite imagery and LiDAR and was simulated using broad-crested weir flow.

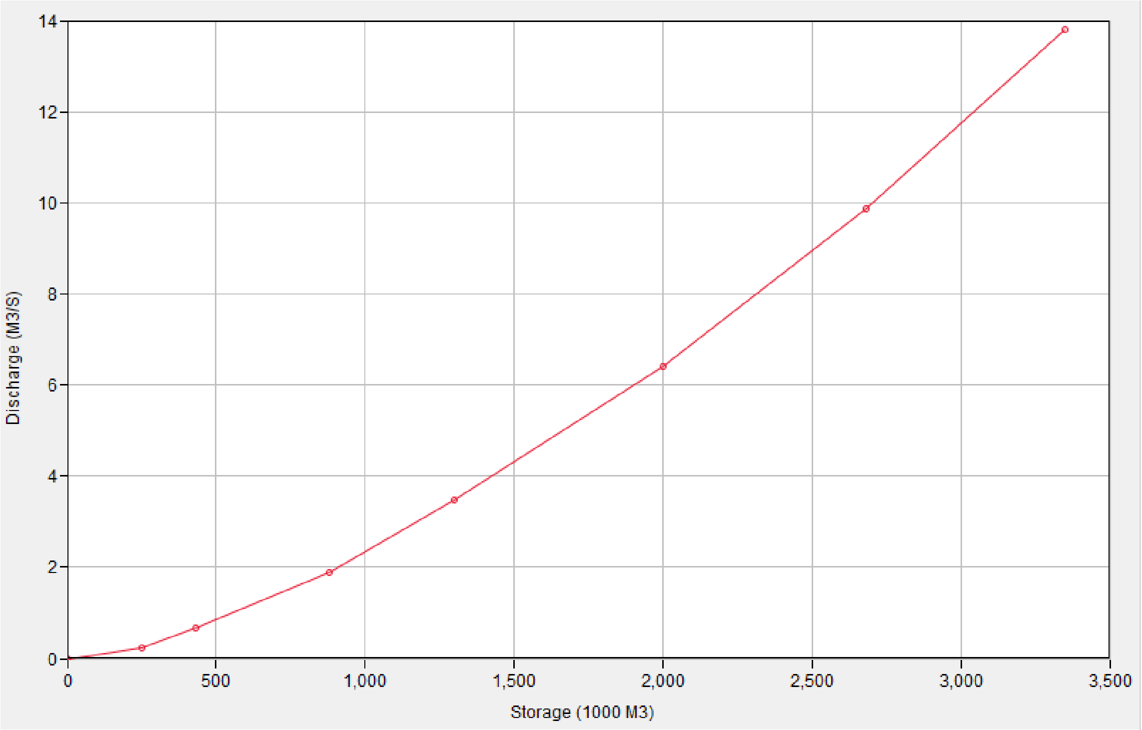


Figure 4-15: White Lake Storage-Discharge Relationship

Recent improvements to the Thirteen Island Lake Dam were completed as described in Section 2. The three (3) 1.8m x 0.9m concrete box culverts, stop logs at normal operating level, and road profile were used to establish the storage-discharge relationship shown below. For the winter setting, there are two logs in the west and middle log bays, and three logs in the east bay as directed by QC staff.

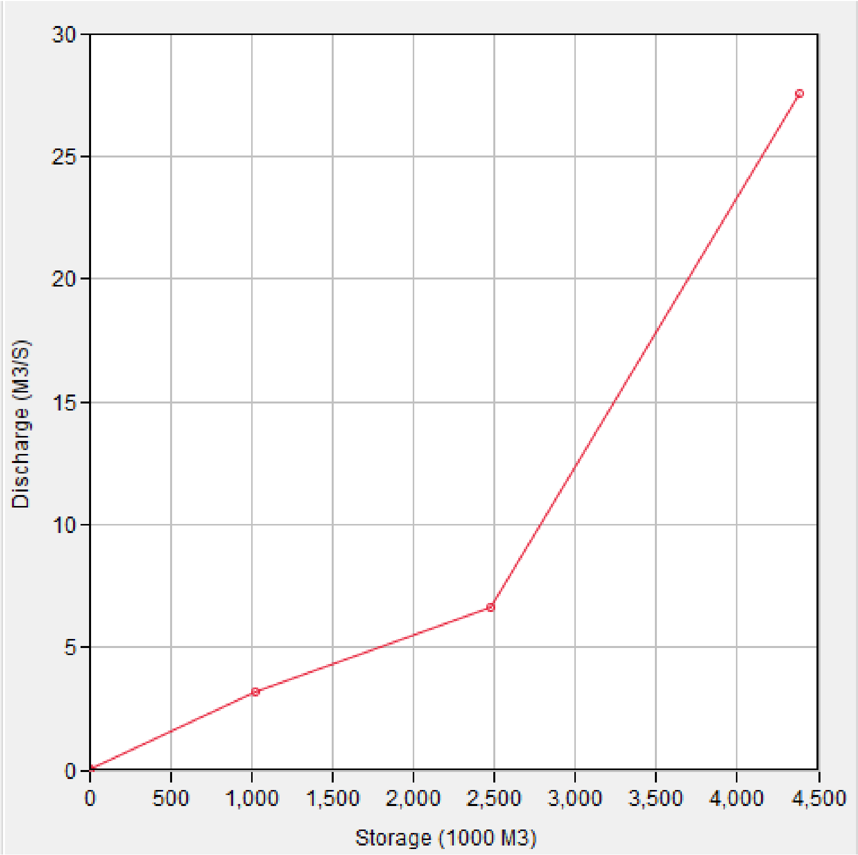


Figure 4-16: 13 Island Lake Storage-Discharge Relationship (Winter)

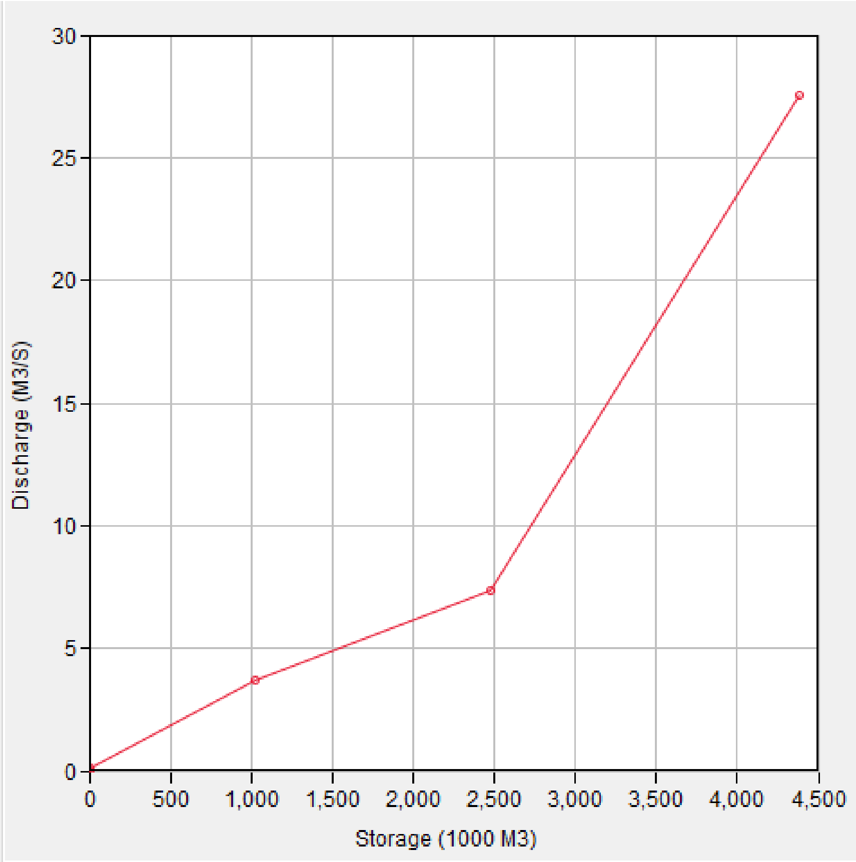


Figure 4-17: 13 Island Lake Storage-Discharge Relationship (Summer)

Fourteen Island Lake and Sigsworth Lake are controlled by the same outlet. The outlet includes a concrete two-stage weir with a 0.76m wide 1st stage and 9.2m wide 2nd stage. This weir yields the storage-discharge relationship shown below in Figure 4-18.

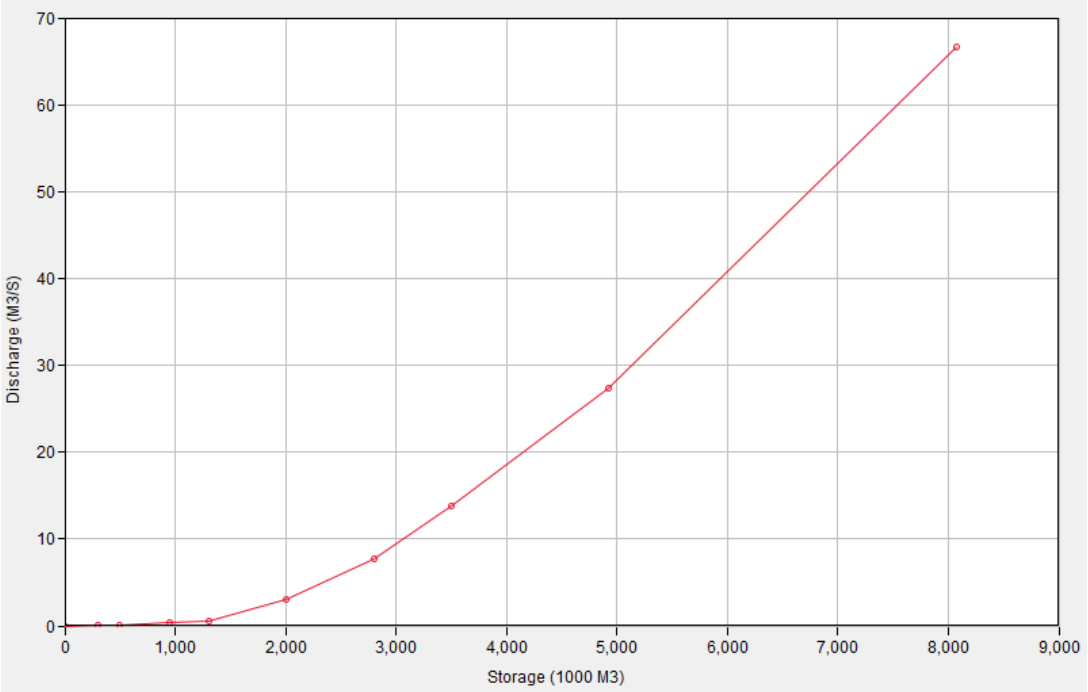


Figure 4-18: Fourteen Island + Sigworth Lake Storage-Discharge Relationship

Thirty Island Lake is controlled by a narrow open channel and a private crossing a short distance downstream. The entrance crossing includes two (2) 450mm diameter plastic pipes causing low outflows until overtopping of the driveway occurs. The result is very low outflows for majority of storm events as shown by the storage-discharge relationship presented in Figure 4-19.

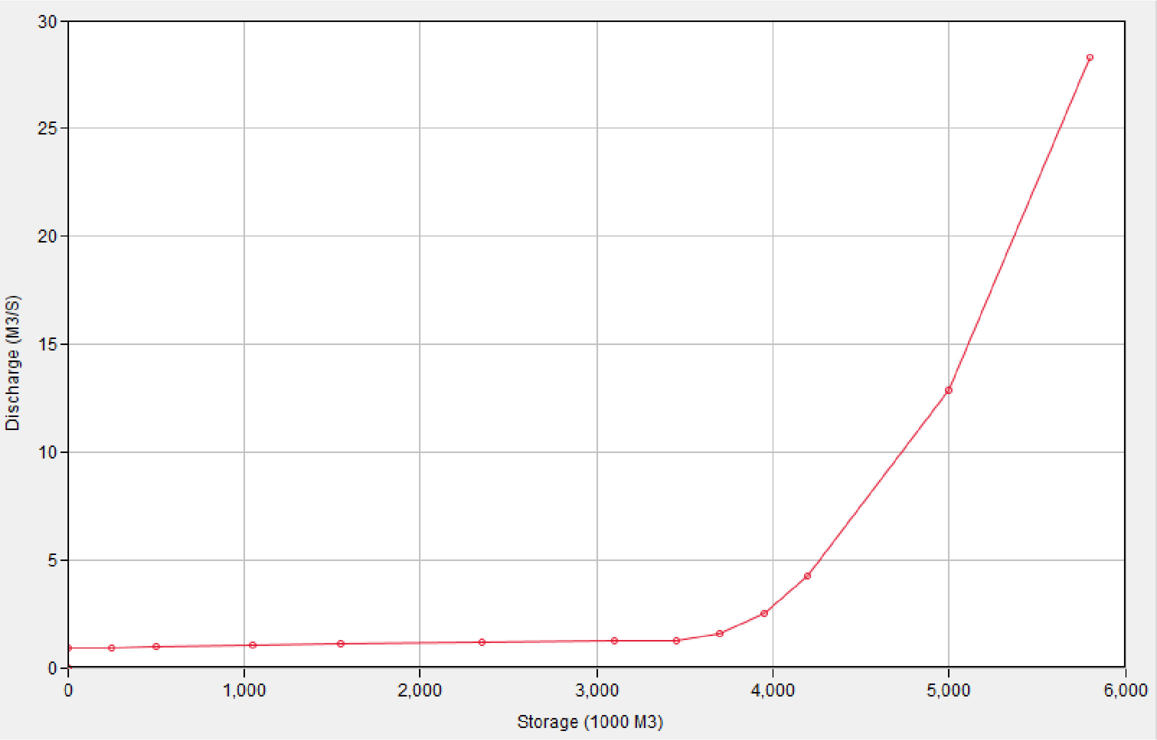


Figure 4-19: Thirty Island Lake Storage-Discharge Relationship

4.3.7 Hydrologic Input Summary

A hydrology input summary is provided below. This summarizes the area, curve number, and lag time (T_p) applied for each sub-catchment.

Table 4-8: Summary of Hydrology Inputs for HEC-HMS Model

Catchment ID	Area (km^2)	Mean Slope (%)	Watershed Length (km)	T_p (hr)	CN
100	2.56	5.5%	0.4	0.28	70.4
200	11.29	5.0%	4.9	2.05	74.3
300	10.07	4.8%	2.7	1.42	70.7
400	2.00	5.1%	2.3	1.25	69.1
500	6.86	6.5%	3.9	1.71	68.7
600	13.92	5.2%	4.7	2.07	71.2
700	16.39	5.7%	5.9	2.55	68.2
800	8.33	5.7%	1.2	0.48	72.8
900	3.64	5.4%	2.6	1.23	72.4
1,000	11.76	1.9%	2.3	1.97	70.8
1,100	14.63	1.3%	4.2	3.69	72.4
1,200	7.17	1.4%	3.4	2.93	73.7
1,300	7.65	3.4%	2.7	1.58	73.5
1,400	12.73	2.1%	2.2	1.91	67.1
1,500	14.63	4.5%	4.7	2.52	65.4
1,600	4.91	2.5%	2.2	1.74	67.9

4.3.8 Peak Flow Summary

A summary of annual exceedance probability peak flows for the rainfall-runoff scenario at each lake outlet and node of interest is shown in the table below. The rise in water levels associated with the 1% AEP regulatory event is presented in Section 4.7.

Table 4-9: Peak Flow Summary for HEC-HMS Rainfall-Runoff Model, m^3/s

Outlet of Basin No.	Location	Return Period		
		10%	1%	*1% + CC
1600	Potspoon Lake Outlet	0.5	1.0	1.4
1500	30 Island Lake Outlet	0.9	1.0	1.0
1400	White Lake Outlet	0.5	1.0	1.6
1300	Westport Rd near Glendower	16.0	26.5	36.4
1200	St Andrews Lakes Outlet	0.2	0.7	1.7
1100	Cole Lake Outlet	0.8	3.1	5.2
1000	13 Island Lake Outlet	4.1	6.9	8.9
900	South Frontenac Rd at Godfrey	8.4	14.1	19.4
800	Cole Creek at Godfrey	28.2	47.3	65.4
700	14 Island Lake Outlet	0.1	0.3	0.4
600	Howes Lake Outlet	7.3	12.5	20.8
500	Spring Lake Outlet	0.5	1.2	1.5
400	Little Mud Lake Outlet	3.6	4.7	6.3
300	Van Luven Lake Outlet	0.5	1.5	7.1
200	Hambly Lake Outlet	2.0	2.8	3.8
100	Hardwood Dam Outlet	7.6	13.3	20.0

**Denotes 1% AEP plus climate change with scaled increases in rainfall intensities per Section 4.6.*

4.4 Snowmelt + Rainfall Model

As described in the 2002 MNR Technical Guide, Canadian flow data records commonly show that annual peaks and runoff volumes occur in the spring. The nearby Napanee River at Camden East flow gauge is consistent with this national trend. The local gauge has 93% percent of its annual instanteous peak occurring between December 30 and April 30 across its 46-yr data record.

A separate basin model was prepared in HEC-HMS for the snowmelt plus rainfall scenario, since spring melt events have different characteristics than rainfall only events. These characteristics generally include longer runoff durations, higher runoff volumes, saturated and/or frozen ground conditions, and increased lag times.

The same calibration process that was applied to the rainfall-runoff model was applied to the snowmelt plus rain model. The largest historical event on record that occurred in April of 2014 was selected as the calibration storm, and the Bellrock flow gauge in addition to the information on the Varty Lake and Cameron Swamp reservoirs were used to fill in the missing ‘gaps’ between the Upper Lakes watershed and the Camden East flow gauge. In the snowmelt plus rain calibration event, it was concluded that AMC III (i.e. saturated) conditions alone were not enough to produce the runoff rates observed in the 2014 event. Therefore, AMC III conditions in *combination* with a 7% increase in CN value (up to a maximum

CN value of 98) was applied. With this adjustment, the calibrated peak flow is within three (3) percent of the observed stream flow record (see Table 4-10); note that a minor transposition of flows was applied for the Cameron Swamp outlet per the same reasoning described in Section 4.3.

An essential component of the calibration for the HEC-HMS snowmelt basin model was the establishment of the distribution and runoff volume released from the snowpack in the 2014 event. Quinte Conservation provided Jewell with their snow melt model that was created by Dr. H. O. Schroeter in 2000 with revisions in September 2008 and February of 2010. The spreadsheet snowpack model is based on the GAWSER snowpack routine that has been through rigorous testing under separate projects prior to its use in the Napanee River Upper Lakes flood hazard mapping.

There are four key inputs into the Schroeter model: daily maximum temperature, daily minimum temperature, daily rainfall, and daily precipitation. For historical events, such as the 2014 flood, the historical climate inputs from the ECCC station at Hartington were supplied to the model. The historical climate inputs provide a reasonable estimate of the snow water content (SWC) and daily runoff that contribute to the corresponding stream flow gauge readings at the *Napanee River at Camden East*. Jewell converted the daily runoff output from the Schroeter model into hourly depths with the application of the sine function to represent the diurnal pattern of spring runoff that would occur due to daily temperature fluctuations (see Appendix C-2).

Table 4-10: Comparison of Observed vs. Modeled Peak Flows for the 2014 Flood Event

	Measured	HEC-HMS
Peak Flow (m^3/s)	62.7	61.0
Time of Peak	4/15/2014 19:00	4/13/2014 19:00
Lag Time (hrs)	214.0	166.0

The adjustments to the CN values in the snowmelt basin model result in higher CN values and higher peak flow rates due to a greater amount of runoff volume rather than infiltration. This adjustment is consistent with the discussion in the 2002 Technical Guide that indicates runoff coefficients, directly related to the CN, may be 3 to 4 times higher in winter or spring melt events relative to other times of the year. The adjustments required to calibrate the snowmelt plus rainfall model are consistent with the provincial technical guidelines and thereby suitable for use in the statistical snowmelt events. The adjustments are also consistent with recent discussions with ECCC representatives in August of 2023 where ECCC confirmed that CN is the preferred parameter to be adjusted in the calibration process.

For the *statistical* snowmelt AEP events, the degree day method was applied with consideration of the two Meteorological Services of Canada (MSC) snowmelt equations for Ontario as indicated in the 2002 MNR Technical Guide. The MSC snowmelt equation for Model 5 was selected since it is intended for Southern Ontario and yields higher runoff volumes relative to the alternative MSC equation, Model 4, for Southern Ontario. The snowmelt plus rainfall frequency values published by MSC for the Hartington station were used to prepare the hyetographs supplied to the snowmelt simulations in HEC-HMS. The Hartington station has 45 years of record and located in close proximity to the Upper Lakes. The MSC frequency values range from 50 to 1% AEPs with daily volumes from 1 to 30 days (see Appendix C-1**)**.

Local snowmelt characteristics were reviewed further by populating the Schroeter model with historic climate data from 1976 to 2023 to identify which durations produced the largest snowmelts. Out of the ten (10) largest annual instantaneous peaks that were produced by a snowmelt plus rainfall event at the

Camden East stream flow gauge, the average duration was 8.9 days. This suggests a 9-day snowmelt event is most likely to produce a 1% AEP storm event. However, since the historical record does not include all possible duration scenarios, Jewell tested the 1 to 5-day, 10 day, 15-day, 20-day, and 30-day durations to identify the critical duration.

Jewell concluded that the 3-day snowmelt event for the MSC snowmelt frequency values is the critical duration since it yields the largest peak flow at the downstream limit of the Upper Lakes study area.

A summary of AEP peak flows for the snowmelt plus rainfall scenario at each lake outlet and node of interest is shown in the table below. The maximum rise in water levels associated with the 1% AEP regulatory event is presented in Section 4.7.

Table 4-11: Peak Flow Summary for Snowmelt Plus Rainfall AEP Events (3-Day Duration), cms

Outlet of Basin No.	Location	AEP		
		10%	1%	0.5%
1600	Potspoon Lake Outlet	1.0	1.5	1.6
1500	30 Island Lake Outlet	1.0	1.1	1.1
1400	White Lake Outlet	1.5	2.4	2.7
1300	Westport Rd near Glendower	4.4	5.3	5.6
1200	St Andrews Lakes Outlet	1.5	1.9	2.1
1100	Cole Lake Outlet	4.9	6.5	9.4
1000	13 Island Lake Outlet	7.6	8.1	15.1
900	South Frontenac Rd at Godfrey	2.1	2.5	2.7
800	Cole Creek at Godfrey	4.9	5.9	6.2
700	14 Island Lake Outlet	0.4	1.5	1.9
600	Howes Lake Outlet	14.5	20.6	22.9
500	Spring Lake Outlet	1.3	2.2	2.5
400	Little Mud Lake Outlet	1.7	2.5	2.9
300	Van Luven Lake Outlet	1.6	2.0	2.2
200	Hambly Lake Outlet	1.6	1.8	2.1
100	Hardwood Dam Outlet	16.9	21.7	26.1

4.5 Index Flood Analysis

Jewell employed the Index Flood Analysis following the methodology established by the Ontario Ministry of Natural Resources to estimate design flows and assess the hydrology of the contributing drainage area. The Index Flood Analysis was included since its methodology relies on historical stream flow gauge data and based on experience it has shown to generally produce reliable flow estimates and often compares well with HEC-HMS modeling outputs. The Index Flood Analysis may be less suitable for the subject watershed since the Index Flod method relies in hydrologically similar watershed characteristics; the subject watershed has unique characteristics when considering its large lakes and outflow control structures at Hardwood Dam, Thirteen Island Lake Dam, and Fourteen Island Lake Dam. However, the Index Flood method was included for comparison purposes.

The Index Flood method relates the annual peak instantaneous flow determined for 247 stream gauges across Ontario to drainage area based on the *User Guide for Ontario Flow Assessment Tool (OFAT)* published by the Ontario Ministry of Natural Resources. Twelve regions across the province were identified as having similar characteristics and a regression curve was developed for each region. See Figure 4-22. The Upper Napanee Lake watershed is located in Region 1. The 1% AEP peak flow estimated from the Index Flood Analysis, located at the Hardwood Dam, is 50.7m^3/s. The peak flows from the Index Flood analysis are included in the presentation of peak flows in Section 4.7.

The 50% AEP flows are resolved directly from the equation using the constant and exponent from Table 4-12. Other AEP flows may be derived from the 50% AEP flow by multiplying with the factors provided in Table 4-13.

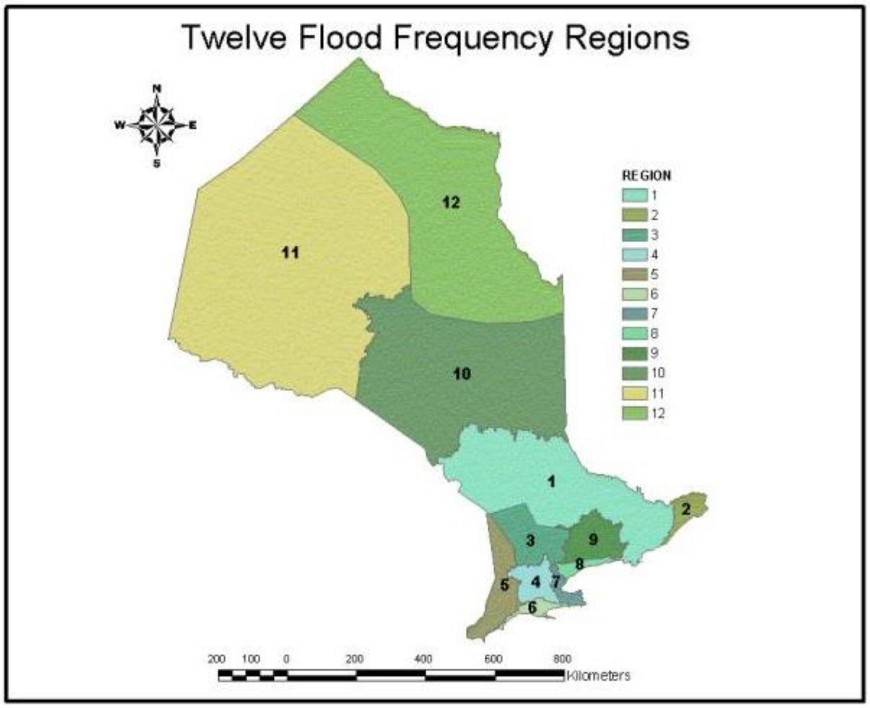


Figure 4-20: Index Flood Regions (Ministry of Natural Resources and Forestry, 2020)

Equation: Index Flood Method

$$Q_2 = CA^n$$

Where:

Q_2 = 50% AEP (3 parameter Log Normal) flood
A = Drainage Area (km^2)
C = constant
n = exponent (slope of the line)

Table 4-12: Table of Constant (C) and Exponent (n) for use in the Modified Index Flood Equation (Ministry of Natural Resources and Forestry, 2020)

Region	Constant (C)	Exponent n
1(a)	0.22 (A < 60 km^2)	1.000
1 (b)	0.73 (A > 60 km^2)	0.707
2	0.51	0.896
3	0.20	0.957
4	0.71	0.842
5	0.45	0.775
6	0.41	0.806
7	1.13	0.696
8	0.73	0.785
9	0.40	0.810
10	0.28	0.849
11	0.38	0.706
12	0.59	0.765

Table 4-13: Ratio of Various Flood Frequencies to Q_2 (Ministry of Natural Resources and Forestry, 2020)

Region	$Q_{1.25}/Q_2$	Q_2/Q_2	Q_5/Q_2	Q_{10}/Q_2	Q_{20}/Q_2	Q_{50}/Q_2	Q_{100}/Q_2	Q_{200}/Q_2	Q_{500}/Q_2
1	0.95	1.00	1.24	1.43	1.62	1.86	2.04	2.23	2.48
2	0.94	1.00	1.29	1.52	1.74	2.04	2.25	2.45	2.72
3	0.93	1.00	1.33	1.62	1.89	2.25	2.54	2.82	3.19
4	0.93	1.00	1.32	1.57	1.80	2.13	2.37	2.60	2.92
5	0.94	1.00	1.27	1.50	1.74	2.06	2.34	2.62	2.96
6	0.91	1.00	1.43	1.78	2.13	2.60	2.96	3.33	3.84
7	0.94	1.00	1.27	1.47	1.66	1.90	2.07	2.24	2.47
8	0.92	1.00	1.43	1.85	2.30	2.96	3.46	4.00	4.77
9	0.94	1.00	1.27	1.50	1.72	2.02	2.26	2.49	2.80
10	0.95	1.00	1.20	1.35	1.48	1.64	1.77	1.90	2.07
11	0.93	1.00	1.33	1.62	1.90	2.32	2.67	3.05	3.55
12	0.94	1.00	1.22	1.38	1.52	1.68	1.80	1.90	2.05

Table 4-14: Limitation of Application of Index Flood Method Based on Drainage Area (Ministry of Natural Resources and Forestry, 2020)

Region	Minimum (km^2)	Maximum (km^2)
1	0.11	9270
2	76.1	3816
3	86.0	3960
4	2.5	5910
5	14.2	4300
6	5.2	697
7	63.5	293
8	4.9	800
9	24.3	1520
10	18.6	11900
11	0.7	24200
12	4250	94300

4.6 Climate Change

In QC's meeting with the federal partners, it was noted that a preferred method to assess climate change scenarios is scaling rainfall intensity based on projected increase in degrees of warming. Jewell completed this preferred approach using the technical requirements outlined in the ECCC memorandum titled *Incorporating Climate Change in Floodplain Mapping under the Flood Hazard Identification and Mapping Program.* The 0.5% AEP was also assessed as a potential climate change scenario. The 0.5% AEP flows were included in the rainfall-runoff and snowmelt plus rain runoff models described in the previous subsections.

Recall that the Napanee River Upper Lakes are located within Zone 2 of the *Flood Hazard Criteria Zones of Ontario and Conservation Authorities*. The 1% AEP is the regulatory event.

The hourly rainfall that corresponds to the regulatory storm was adjusted using the mean annual temperature change obtained from the federal climate data portal for Verona, ON. Jewell followed the Ontario MNRFs recommendation of obtaining the value for the 50th percentile of the mean annual temperature change based on the CMIP5, RCP 4.5 scenario.

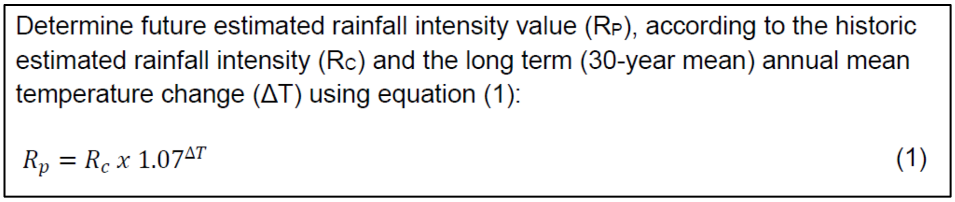
The year 2071 was selected since this is the furthest projected date in the Excel download from the federal climate data portal. The mean annual temperature change for the year 2071 is an increase of 3.3 degrees Celsius (see Appendix E). An excerpt from the technical memo defining the equation used to convert historic rainfall intensity and temperature change to the future estimated rainfall intensity is provided in Figure 4-23.

The increase in temperature results in a significant (25%) increase in precipitation volume (see Table 4-15).

The rainfall-runoff model is particularly sensitive to climate change since the increased runoff produces higher inflows to the lakes, and also depletes the storage within the reservoirs. The storage-discharge charts in Section 4.3.6 show that the outflow rates generally increase at a faster rate as the storage becomes depleted. The result is that the rainfall-runoff model is very sensitive to the increased rainfall projected in the climate change scenario.

Table 4-15: Future Estimated Rainfall Intensities for 1%, 24-Hr AEP

Time	Historic Intensity (R_c)	Percent of 24 Hour	Future Estimated Intensity (R_p)	% Increase in Intensity
Hour	mm/hr	mm	mm/hr	
1	1.1	1.1	1.3	25.0%
2	1.1	1.1	1.3	
3	1.3	1.3	1.6	
4	1.3	1.3	1.6	
5	1.6	1.6	1.9	
6	1.6	1.6	1.9	
7	1.9	2.0	2.4	
8	1.9	2.0	2.4	
9	2.6	2.7	3.3	
10	3.3	3.4	4.1	
11	5.2	5.4	6.6	
12	41.6	42.8	52.0	
13	10.6	10.9	13.2	
14	4.7	4.8	5.8	
15	2.9	3.0	3.6	
16	2.9	3.0	3.6	
17	1.7	1.8	2.2	
18	1.7	1.8	2.2	
19	1.7	1.8	2.2	
20	1.7	1.8	2.2	
21	1.2	1.2	1.5	
22	1.2	1.2	1.5	
23	1.2	1.2	1.5	
24	1.2	1.2	1.5	
Total	**97.1**	**100**	**121.4**	**25.0%**



Determine future estimated rainfall intensity value (R_P), according to the historic estimated rainfall intensity (R_C) and the long term (30-year mean) annual mean temperature change (ΔT) using equation (1):

$$R_p = R_c \, x \, 1.07^{\Delta T} \qquad (1)$$

Figure 4-21: Excerpt from Technical Memo with Equation for Future Estimated Rainfall Intensities (Environment and Climate Change Canada)

It should be noted that climate change impacts on peak flows are inherently difficult to quantify due to the reality of Earth's extremely complex global atmospheric and hydrologic systems. The climate change adjustment applied above relies on the relationship between temperature increase and rainfall depth. Therefore, the adjustment addresses a climate change scenario for a precipitation-driven flood event.

Based on calculations and an assessment of the data, climate change is expected to have a greater impact on rainfall-driven runoff events rather than a snowmelt driven runoff event.

The stream flow gauge data presented in Section 4 generally illustrates the expected AEP flows that would occur during a freeze-thaw/snowmelt condition. This is because most annual instantaneous peaks occur in the spring months. These events produce high peak flows due to a large volume of stored water content that is released when warmer temperatures occur.

With warmer seasonal temperatures generally expected due to climate change, it is reasonable to expect less stored water content during the winter months, since the period of below-freezing temperatures would be shortened with higher average temperatures. With less stored water content, it is possible that instantaneous peaks produced in a spring melt condition may not increase even with increased rainfall depths for single event conditions. Jewell investigated this further by testing the sensitivity of the Schroeter model to the projected temperature and precipitation increases. *Individual* increases for temperature and precipitation were also completed to better understand their individual effects on the model.

The Schroeter model predicts that an increase in precipitation by 25%, with no temperature adjustments, would *increase* the maximum snow water content (SWC) by 51%. The model predicts a mean temperature increase of 3 degrees Celsius, with no precipitation adjustments, would *decrease* the maximum SWC by 36%. It predicts that the *combination* of temperature and precipitation increases will produce net reduction of 9% in the maximum SWC.

A review of average monthly temperatures, with the mean daily maximum and minimums increased by 3 degrees Celsius, is presented in Figure 4-24. The 3-degree temperature increase would result in a daily maximum average temperature in the coldest month (January) that is near zero. This would encourage more frequent intermittent melting periods, and results in the net decrease in maximum SWC in the Schroeter model.

While there are many combinations of future temperature and precipitation that could produce higher or lower maximum SWC values, the key takeaway is that climate change is expected to have a greater impact on rainfall-driven flood events rather than spring melt events. Since higher future temperatures will likely offset some of the future increases in precipitation, the extent of the net change to the maximum SWC and subsequent snowmelt plus rain events is largely unknown. It is recommended that potential impacts due to climate change be accommodated by utilizing the federal climate data adjustments for rainfall-driven events, and the 0.5% AEP for snowmelt-driven events.

Table 4-16: Temperature and Precipitation Impacts on Maximum SWC per the Schroeter Snowmelt Model

Adjustment	Average Maximum SWC (mm)	Percent Change in Maximum SWC
No adjustment	75	-
Temperature +3°C	48	-36%
Precipitation +25%	113	+51%
Temperature +3°C, Precipitation +25%	68	-9%

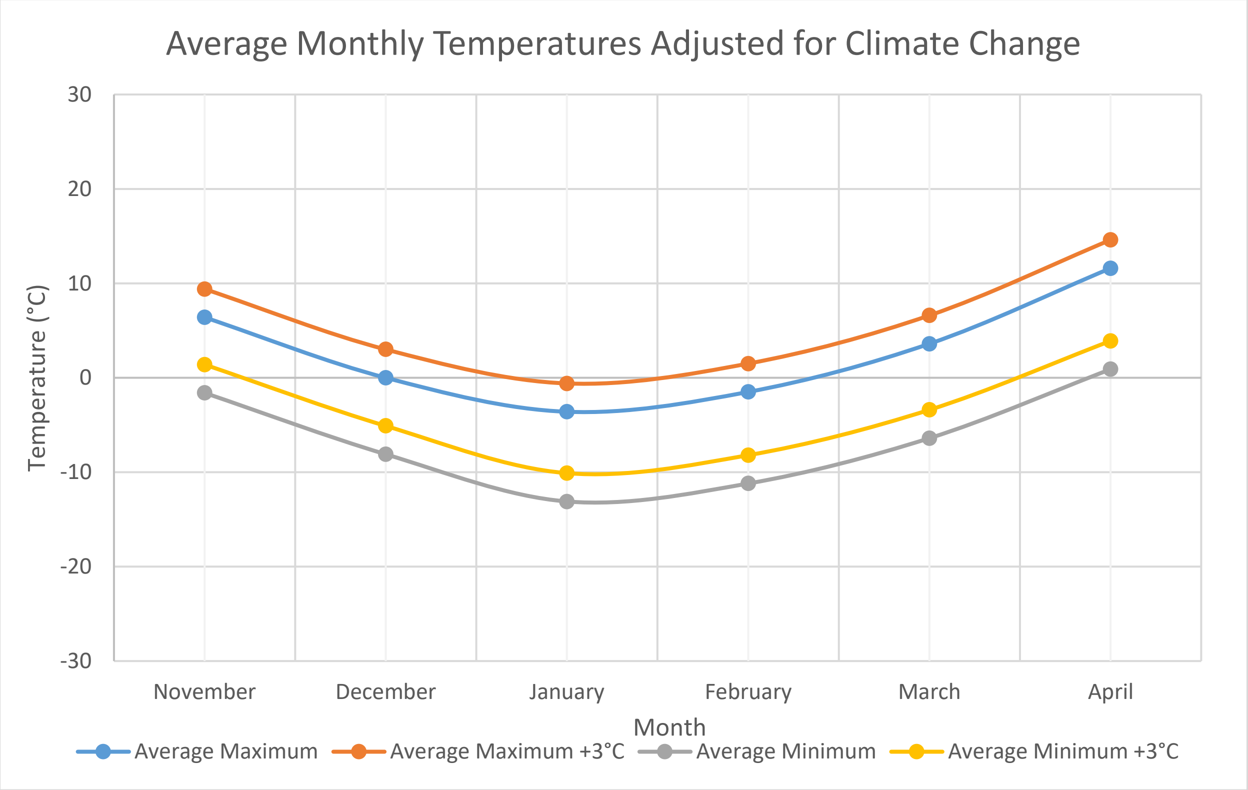


Figure 4-22: Projected Temperature Increases at Hartington ECCC Station Due to Climate Change

4.7 Presentation of Peak Flows

The peak flows for the Napanee River Upper Lakes are summarized below in Table 4-17. The peak flow rates in the table below are applied to identify the flood hazard limits. The climate change peak flows in Table 4-9 (see Section 4.3.8) will also be included in the hydraulic model computations.

Table 4-17: Peak Flow Summary for Napanee River Upper Lakes

Outlet of Basin No.	Location	100-Yr, 3-Day Snowmelt + Rain		100-Yr, 24-Hr Rainfall	
		Peak Flow (cms)	*Max. Water Level Rise (m)	Peak Flow (cms)	*Max. Water Level Rise (m)
1600	Potspoon Lake Outlet	1.5	0.35	1.0	0.26
1500	30 Island Lake Outlet	1.1	0.54	1.0	0.24
1400	White Lake Outlet	2.4	0.46	1.0	0.26
1300	Westport Rd near Glendower	5.3	-	26.5	-
1200	St Andrews Lakes Outlet	1.9	-	0.7	-
1100	Cole Lake Outlet	6.5	-	3.1	-
1000	13 Island Lake Outlet	8.1	1.1	6.9	0.8
900	South Frontenac Rd at Godfrey	2.5	-	14.1	-
800	Cole Creek at Godfrey	5.9	-	47.3	-
700	14 Island Lake Outlet	1.5	0.65	0.3	0.32
600	Howes Lake Outlet	20.6	1.78	12.5	1.33
500	Spring Lake Outlet	2.2	-	1.2	-
400	Little Mud Lake	2.5	-	4.7	-
300	Van Luven Lake	2.0	1.78	1.5	1.33
200	Hambly Lake Outlet	1.8	1.67	2.8	1.27
100	Hardwood Dam Outlet	21.7	1.67	13.3	1.27

**Maximum water level rise measured from outlet invert.*

Table 4-18 provides a comparison of peak flows for each of the hydrologic modeling methods. The 2023 regulatory peak flow of 21.7m^3/s is below the peak flow from the transposed GFA result; however, the 21.7m^3/s accounts for the high tailwater imposed by the Cameron Swamp at the outlet of the study area, whereas the GFA and Index Flood methods do not. In a free-flowing condition, the peak outflow from the study area would be 31.4 m^3/s. The 2024 peak flow is less than the 1981 study, however the water level at the outlet and lower lakes is higher than the 1981 results. This is in large part due to the tailwater condition at the Cameron Swamp which is discussed further in Section 5.1.3. The high tailwater at Cameron Swamp increases the water level and reduces the peak flow in the 2024 assessment.

Table 4-18: Summary of Peak Flows from Alternative Methods for Napanee River Upper Lakes (m3/s)

Return Period	1981 Crysler & Lathem		GFA (Transposed)		Index Flood	HEC-HMS	
	Rain Only	Spring Melt + Rain	Rain Only	Spring Melt + Rain		Rain Only	Spring Melt + Rain
100-Yr	25	50	16.4	24.7	50.7	12.7	21.7

**Denotes regulatory 1% AEP peak flow.*

4.8 Combined HEC-HMS & HEC-RAS Models

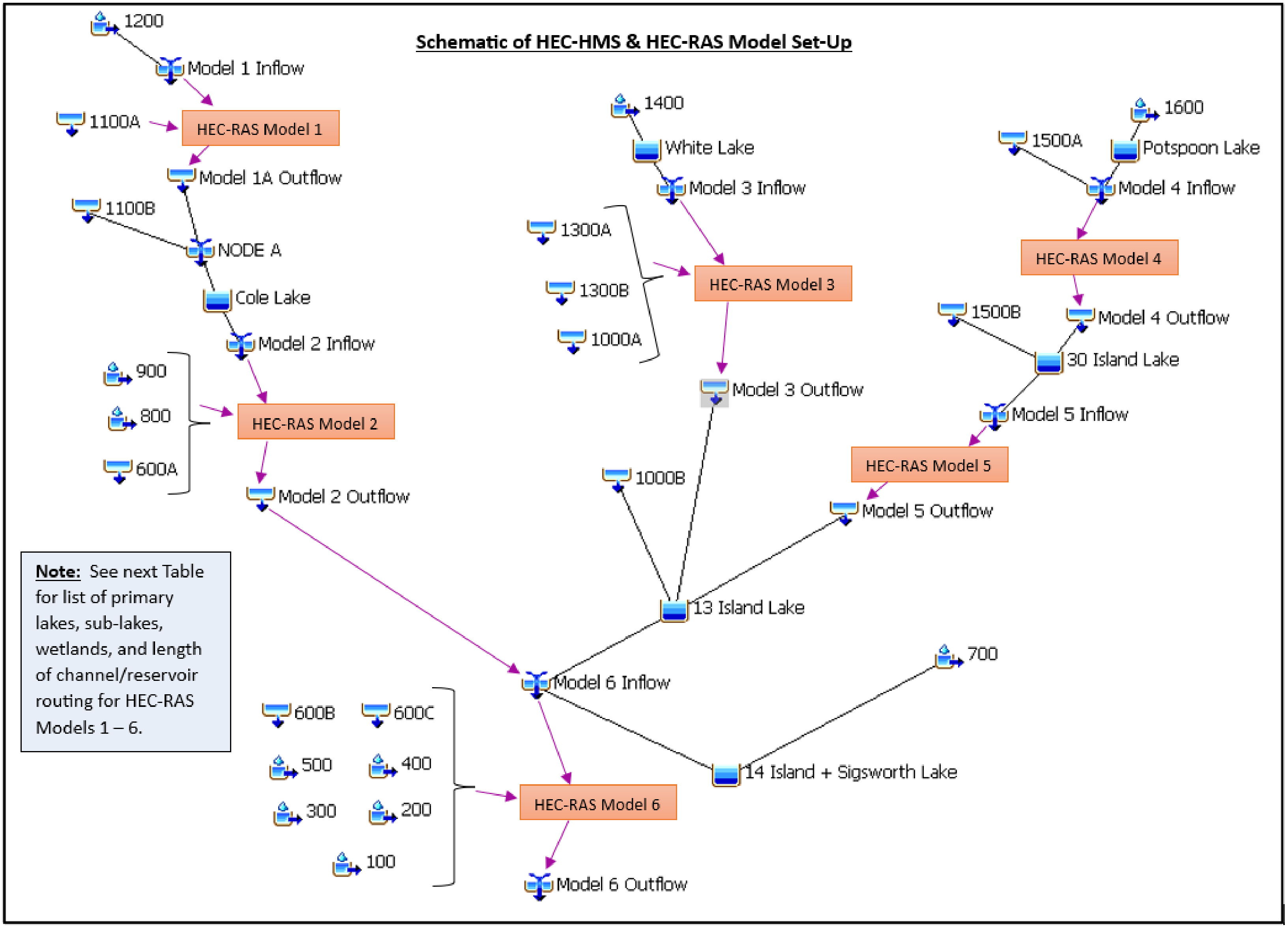
The HEC-HMS model used in the model calibration (Section 4.3.1) was advanced further in Section 5 that follows to include the channel routing that occurs as part of the hydraulic simulations. Since the hydraulic model is predominantly a 2D, unsteady flow model, the travel time and roughness of the channel and overbank areas are reflected in the outflow hydrographs. The wetlands and smaller lakes are also included in the hydraulic model as they have been either modeled as a 2D flow area or as a storage area depending on their size and dimensions.

The annotated schematic below illustrates the sequence of the HEC-HMS and HEC-RAS model runs. In model testing, it was found that reservoir-routing in HMS and RAS produced similar results. For simplicity and faster run times, each lake that has a free-flowing outlet was modeled in HEC-HMS. For lakes with substantial backwater impacts, particularly at the bottom end of the study area (Verona, Howes, Hambly, Van Luven), they were modeled as a storage area in HEC-RAS. St. Andrews Lake was also modeled in RAS due to the strong backwater imposed by the K&P Trail crossing.

Figure 4-25 shows that there are six (6) HEC-RAS models applied to calculate the hydraulic outputs for the study area. Table 4-19 summarizes the corresponding Reach Number (see Section 5), route length, primary lake, and wetland/sub-lake associated with each hydraulic model.

Note that the peak flows presented in Section 4.7 were obtained using the modeling approach presented in Figure 4-25.

A seventh (7th) hydraulic model was prepared as a separate 1D, steady flow model to identify the shape of the rating curve for the Cameron Swamp outlet that is necessary to identify the tailwater conditions for the Napanee River Upper Lakes study area. This 7th model is 7.3 km downstream of the study area and upstream of Petworth Road; it is discussed in detail in Section 5.1.3.



Note: See next Table for list of primary lakes, sub-lakes, wetlands, and length of channel/reservoir routing for HEC-RAS Models 1 – 6.

Figure 4-23: Schematic of Interactive HEC-HMS & HEC-RAS Models

Table 4-19: HEC-RAS Models with Corresponding Reach, Route Lengths, Primary Lake(s), Wetland(s) and Sub-Lake(s)

HEC-RAS Model	Reach No.	Route Length (km)	Primary Lake(s)	Wetland # / Sub-Lake
1	1	1.7	St. Andrews Lakes	1A, 1B, 1C
2	2	6.2	N/A	2A, 2B, 2C
3	6	5.3	N/A	6A, 6B
4	7	2.5	N/A	Connector Lake 7A, 7B
5	8	1.2	N/A	8A, 8B
6	3, 4, 5, 9, 10, 11	N/A - Lake Dominated	Verona, Howes, Hambly, Van Luven Lakes	Bass, Spring, Mud Lakes, Wetland 9

5 Hydraulics

The hydraulic analysis was prepared using HEC-RAS version 6.4.1. The HEC-HMS peak flows from Section 4 were applied in the hydraulic model to delineate the flood hazard limits for the Napanee River Upper Lakes drainage system. The HEC-RAS model simulates both the 1% AEP snowmelt plus rain and 1% AEP rainfall only events as separate scenarios to determine the governing condition for each portion of the watershed.

In addition to the thirteen main lakes of interest, the hydraulic system is defined by many wetlands and smaller lakes that act as hydraulic connections among the Napanee River Upper Lakes system. More traditional channels with moderate slopes and defined overbank areas are present to a much lesser extent. This subsection describes the modeling approach, bridge and culvert crossings, storages areas, and water levels.

5.1 Model Set-Up

HEC-RAS Version 6.4.1 and HEC-HMS Version 4.11 were used for the modeling of the Napanee River Upper Lakes (Brunner, 2023), (Bartles, et al., 2022). The HEC-RAS model applies the hydraulics software used to simulate the flood limits that result from a large surface runoff event. This section describes the model set-up including the field survey, computational mesh, hydraulic structures, storage areas and model run scenarios.

Due to the large size of the study area, its several branches, and many lakes and wetlands, the hydraulic model was discretized into eleven (11) reaches (see Figure 5-3). The model discretization for the eleven reaches is summarized in Section 5.2.

5.1.1 Field Survey

The LiDAR data described in Section 4.1 was supplemented by site-specific survey data from Jewell's survey crew using a GPS and a total station. The GPS was the main equipment used for the field survey. The GPS survey results were converted to the CGVD 2013 datum and imported into the terrain layer as an overlay to the LiDAR data. For local surveyors, a conversion of -0.33m can be used to convert from datum CGVD28 to CGVD 2013. This conversion is based on a comparison of elevations in the field measured at the same location in each datum. The projection settings in the model are NAD 1983 UTM Zone 18.

Historically, 1-dimensional hydraulic models have been used for floodplain mapping. This type of model requires cross-section data to be set up by the user to represent the geometry data applied in the hydraulic model calculations. With advancements in the HEC-RAS modelling software that is developed and distributed freely by the U.S. Army Corps of Engineers, 2-dimensional modelling presents an alternative that can provide added benefits depending on the river of interest.

A 2-dimensional model was selected for the Napanee River Upper Lakes for the following reasons:

- To improve upon the channel routing options in HEC-HMS; the Napanee River Upper Lakes do not have a uniform river cross-section throughout the study area due to the many wetlands and connector lakes. A 2D hydraulic model substitutes a 'representative' cross-section with a pre-determined number of grid cells set throughout the study area to allow flow to be routed using its proper geospatial geometry.
- To investigate further flow attenuation that would be present within the additional wetlands and smaller lakes using storage areas or 2D flow areas.
- To achieve more realistic modeling results in low-lying areas.

- To take advantage of detailed terrain and survey data; HEC-RAS software uses this data to produce output results for depth, velocity, and water surface elevations at any georeferenced location within the flood study area.

5.1.2 Computational Mesh

The terrain layer was used to develop a computational mesh that ultimately controls the movement of water through portions of the Napanee River Upper Lakes channels and surrounding overbank or wetland areas. For each computation cell, an elevation-volume relationship is calculated to produce a single water surface elevation.

The cell sizes for the 2D flow areas, including refined areas for creek sections and roads, are summarized by the attribute tables included in Appendix I.

5.1.3 Boundary Conditions

The Napanee River Upper Lakes hydraulic model includes three different types of boundary conditions (BCs). One is an inflow BC and the other two are outflow BCs.

The inflow BCs are represented by an inflow hydrograph. The 2D unsteady flow model received its flow data from an *inflow* hydrograph where the incoming flows change with time. The inflow hydrographs were obtained from the HEC-HMS model for individual sub-catchments. Each inflow BC corresponds to an inflow hydrograph. The two types of *outflow* BCs applied in the Napanee River Upper Lakes hydraulic model are a stage hydrograph and normal depth.

The stage hydrograph is used to reflect the potential backwater impacts from downstream lakes and ensures the water levels in the upstream channels are adjusted accordingly. The normal depth outflow BC is used in locations where there is no immediate lake downstream of a channel outflow. The normal depth was set to 1% to simulate free-flowing conditions.

Cameron Swamp

In spring melt or high flow conditions, the Hardwood Dam is submerged due to the backwater imposed by the Cameron Swamp. The Cameron Swamp is a large reservoir that receives majority of runoff that contributes to WSOC flow gauge *02HM007 Napanee River at Camden East.* This reservoir establishes the tailwater for the lower lakes of the study area (i.e. Verona, Howes, Hambly, Van Luven) and is critical to accurately model their water levels.

The Cameron Swamp does not have a hydraulic structure controlling its outflows. From site observations, review of LiDAR data, and a review of bridge elevations at the nearest hydraulic structure downstream of the swamp (Petworth Road bridge), it was confirmed that it is a natural channel outlet with a constriction point 3.5km upstream of Petworth Road that controls the water levels in the Cameron Swamp. This natural outlet channel was modeled in HEC-RAS to develop a rating curve that is representative of the Cameron Swamp outlet (see Figure 5-1).

The Cameron Swamp outlet rating curve is presented in Figure 5-2. Fortunately, the Cameron Swamp receives majority of the runoff that contributes to WSOC stream flow gauge *02HM007 Napanee River at Camden East.* Therefore, the flows selected to develop the rating curve are the same as those obtained from the General Frequency Analysis (GFA) described previously in Section 4.2 and presented in Table 4-6. This approach applies an assumption that the GFA results at the stream flow gauge are representative of the Cameron Swamp outflows (i.e. no transposition of flows). This is a reasonable assumption since the massive amount of storage in the Cameron Swamp would result in a peak outflow that occurs at a largely different timestamp relative to the peak outflows from the much smaller downstream catchments of EXT-3 and EXT-4 from Figure 4-7. The application of a transposition of flow for the production of the rating curve would be an over-simplification that would not account for the timing of the hydrographs. Therefore, a transposition of flows was not utilized in the development of the Cameron Swamp rating curve.

The GFA peak flows for the 2-, 10-, 50-, 100-, 200-, and 500-yr return periods were applied in a 1D steady flow model of the outlet channel to develop the Cameron Swamp rating curve. Note that this 1D steady flow model is separate from the hydraulic model used for the Napanee River Upper Lakes study area; the sole purpose of the 1D steady flow model for this channel is to identify the water surface elevation vs. flow relationship at the Cameron Swamp outlet.

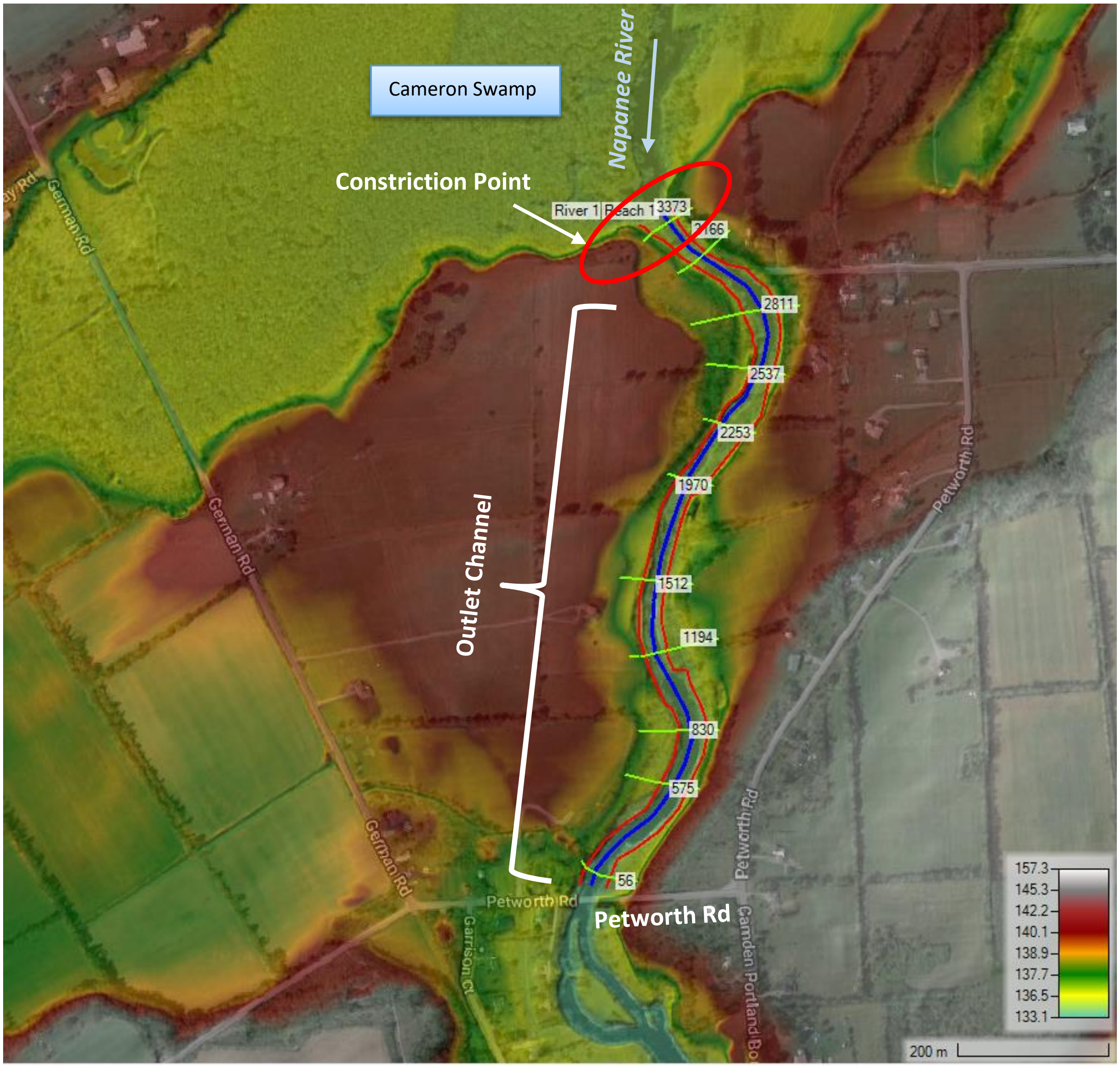


Figure 5-1: Cameron Swamp Constriction Point and Outlet Channel in HEC-RAS to Obtain Outlet Rating Curve

Once the Cameron Swamp outlet rating curve was established, it was verified by matching field measurements of water levels in the vicinity of the Hardwood Dam to the flows at the WSOC *02HM007* stream flow gauge during the time of measurement. The Jewell surveyors measured the water level and noted the time of measurement on November 1, 2023 and March 6, 2024. Then, the WSOC flow gauge was reviewed for its nearest timestamp to obtain the corresponding flow measurement. The measured water level and stream flow gauge data was used to identify the observed data points denoted as a red "X" in Figure 5-2.

Field measurements #1 (Nov. 1, 2023) and #2 (Mar. 6, 2024) were obtained from Jewell staff. Field measurement #3 was provided from Quinte Conservation for the peak water level on April 15, 2014.

Field measurement #1 represents a low flow condition where the tailwater of the study area is below the invert of the Hardwood Dam. Field measurement #2 represents a common spring-melt condition where the Harwood Dam is submerged. Field measurement #3 represents the high tailwater condition that would be similar to a 1% AEP event since the measurement was obtained at the same time as a 79.7 m^3/s peak flow at the stream flow gauge that is similar to the 1% AEP flow of 80.8 m^3/s from the GFA. Field Measurement #3 was obtained at the Desert Lake Road bridge; this measurement was conservatively assumed to be equal to the water level in the vicinity of the Hardwood Dam, although in reality the water level would likely have been slightly lower at Hardwood Dam.

The Cameron Swamp rating curve is used to provide the general shape of the graph of tailwater vs. flow that would occur near the Hardwood Dam. The massive size of the Cameron Swamp is evident in a measurement from the length of flow path a water particle would travel from the Hardwood Dam to the Cameron Swamp outlet; this distance is 7.3 km. At this size, even a minimal gradient creates a minor difference in water level between the Cameron Swamp outlet and the Hardwood Dam outlet. In low flow conditions, this gradient is 0.0055% (0.000055 m/m) and creates a 0.41m difference in elevation. As the flows become greater, the gradient becomes lower and the water level at the Cameron Swamp become closer to the Hardwood Dam outlet, although still slightly lower. This is evident in the two blue lines shown in Figure 5-2.

The dashed blue line in Figure 5-2 was derived from field measurements and was matched to the general shape of the Cameron Swamp rating curve. This dashed blue line was applied as the tailwater condition for each respective return period event in both *rainfall only* and *rainfall plus spring melt* conditions.

For rainfall only conditions, it would be unrealistic to apply the GFA return period results from Table 4-6 since these results are derived from a dataset that is dominated by annual instantaneous peak flows that occurred in a *spring melt plus rain* condition. ECCC provided Jewell with the flow records at WSOC Flow Gauge *02HM007* at 15 to 30-minute intervals for its full length of record (1974 – 2022). Jewell used this data to identify the maximum instantaneous peak flow that occurred between May 1st and December 31st for each year. This set of maximum instantaneous peaks was used to prepare the dataset to calculate a GFA on *rainfall only* events. As expected, the rainfall only events (i.e. storms between May 1st and December 31st) generally produce lower instantaneous peak flows at the stream flow gauge, meaning they would produce a lower water level in the Cameron Swamp, and subsequently a lower tailwater condition for the Napanee River Upper Lakes study area.

The 2nd column in Table 5-1 below is supplemental to the Flood Frequency Analysis described in Section 4.2 of this report; it represents the statistical return period flows for *rainfall only* events. The dashed blue line in Figure 5-2 was used to obtain the tailwater elevations for the study area under both spring melt plus rainfall conditions and rainfall only conditions (see Table 5-1).

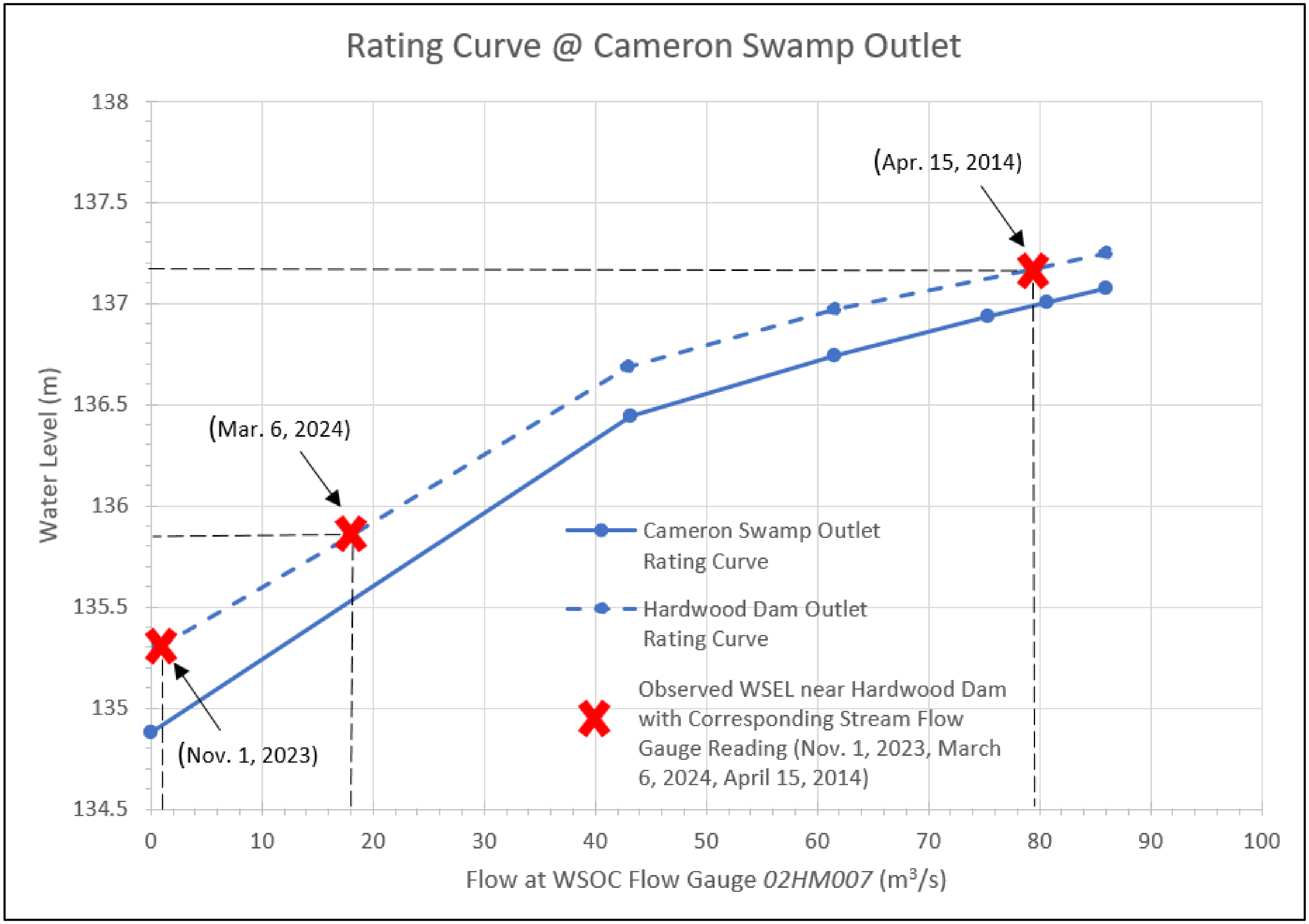


Figure 5-2: Rating Curve at Cameron Swamp Outlet with Comparison to Observed Water Levels near Hardwood Dam

Table 5-1: Tailwater Elevations for Napanee River Upper Lakes Study Area

AEP (%)	Rain Only		Snowmelt Plus Rain	
	GFA Q_{peak} (m^3/s)	Tailwater (m)	GFA Q_{peak} (m^3/s)	Tailwater (m)
50	23.0	136.02	43.2	136.69
10	37.5	136.51	61.5	136.97
2	48.9	136.78	75.3	137.12
1	53.5	136.85	80.7	137.18
0.5	58.0	136.92	86.0	137.24

**Tailwater represents water level at Hardwood Dam.*

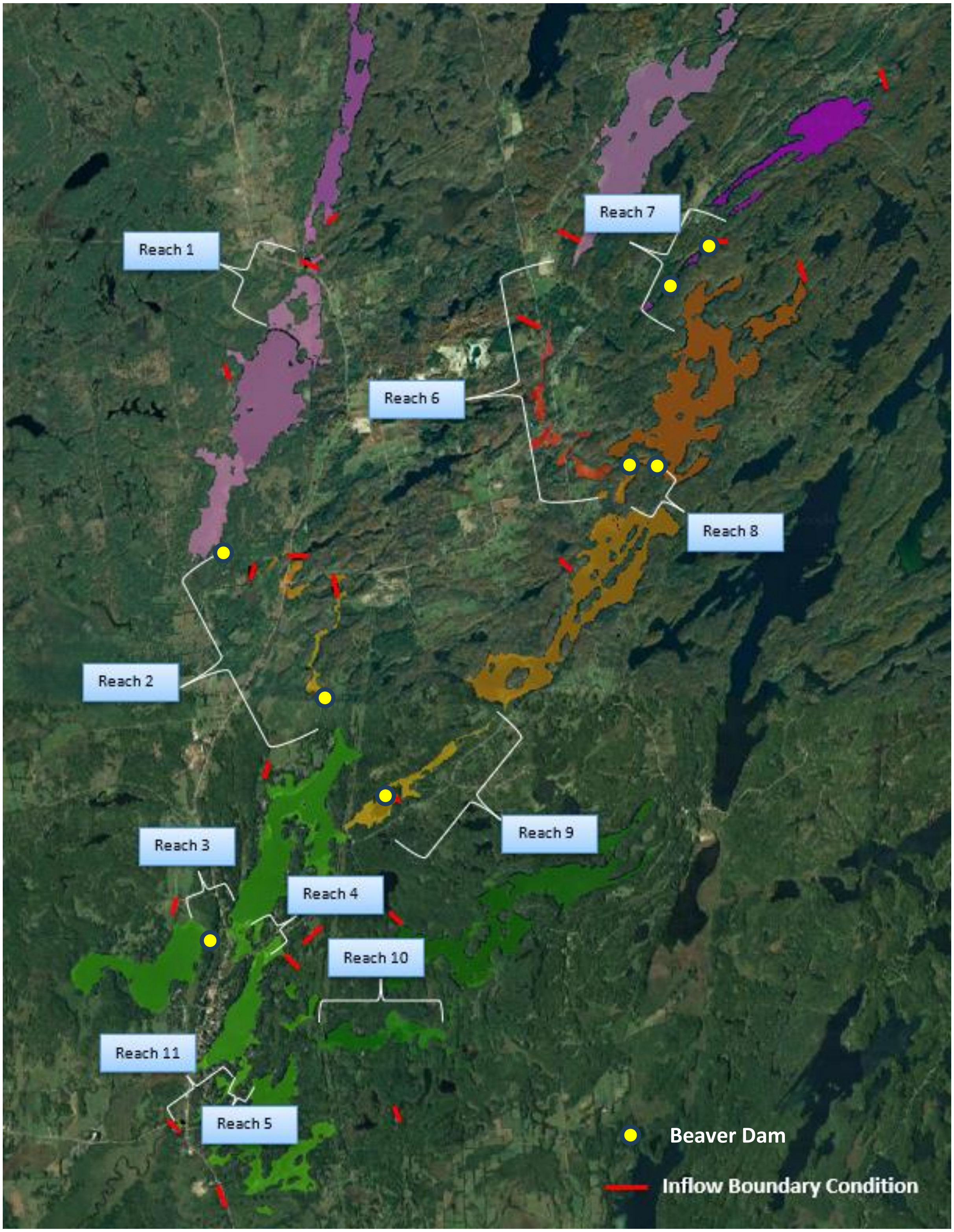


Figure 5-3: Reach and Inflow Boundary Condition Location Summary

5.1.4 Storage Areas

For areas with significant level pools (i.e. wetlands, lakes, and swamps), storage areas were connected within the hydraulic model using a boundary condition or hydraulic connection. The storage areas within the HEC-RAS model simulate the reservoir routing for prominent lakes, sub-lakes, and wetlands throughout the study area. The storage areas are routed using their stage-storage relationship combined with their outlet configuration using an SA/2D connection. The SA/2D connection feature is used to connect lakes and wetlands, and is also used to connect lakes and wetlands to road crossings and/or the lake outlet control structures.

5.1.5 Model Run Scenarios

Several model runs were completed to cover different runoff scenarios. These scenarios are listed below.

- 10% AEP rainfall event.
- 10% AEP snowmelt plus rain event.
- 1% AEP rainfall event.
- 1% AEP snowmelt plus rain event.
- 0.5% AEP snowmelt plus rain event (i.e. spring melt climate change scenario).
- 1% AEP rainfall event with increased rainfall and sub-catchment flows based on ECCC methodology for climate change as applied in the *Section 4.6.*
- Simulation with beaver dams in place for the 1% snowmelt plus rain event.
- Simulation with high Manning's n values to assess the hydraulic model sensitivity to this parameter (see Section 7).
- 2-, 5-, and 50% AEPs were also modeled for rainfall only and rainfall plus snowmelt conditions.

The model run scenarios above were applied in the model set-up to obtain the results presented in Section 6.

5.2 Napanee River Upper Lakes Model Discretization

The eleven (11) reaches that comprise the Napanee River Upper Lakes study area are individually summarized below.

5.2.1 Reach #1: St. Andrews Lake to Cole Lake

Reach #1 extends from the outlet of St. Andrews Lake to the inlet of Cole Lake (see Figure 5-4). Reach #1 is defined by a series of wetlands, and includes Crossings #1-4. The culvert crossings are summarized in Section 5.3.

Per Section 4.3, St. Andrews Lake is controlled by three 750mm diameter culverts at St. Andrews Lake Lane. It can also be controlled by the backwater imposed by the crossing at the K&P Trail. The wetland upstream of the K&P Trail acts as the tailwater for the St. Andrews Lake Lane crossing and subsequently can affect the St. Andrews Lake water level. Given the series of wetlands that affect the tailwater immediately downstream of St. Andrews Lake, this lake was included as part of the HEC-RAS hydraulic model for Reach #1.

Downstream of the K&P trail there is a wetland at a lower elevation, followed by another wetland on the downstream side of Highway 38. The series of wetlands were modelled using a 2D flow area. The flood limit and water surface elevations (WSELs) depicted in Figure 5-4 are governed by the 1% AEP rainfall plus snowmelt event.

Stage and flow hydrographs for the two crossings that can control the water levels in St. Andrews Lake are provided in Figures 5-5 and 5-6. The stage hydrographs represent the headwater (HW) and tailwater (TW) on each side of the crossing. The flow hydrograph represents the outflow from the culvert crossings.

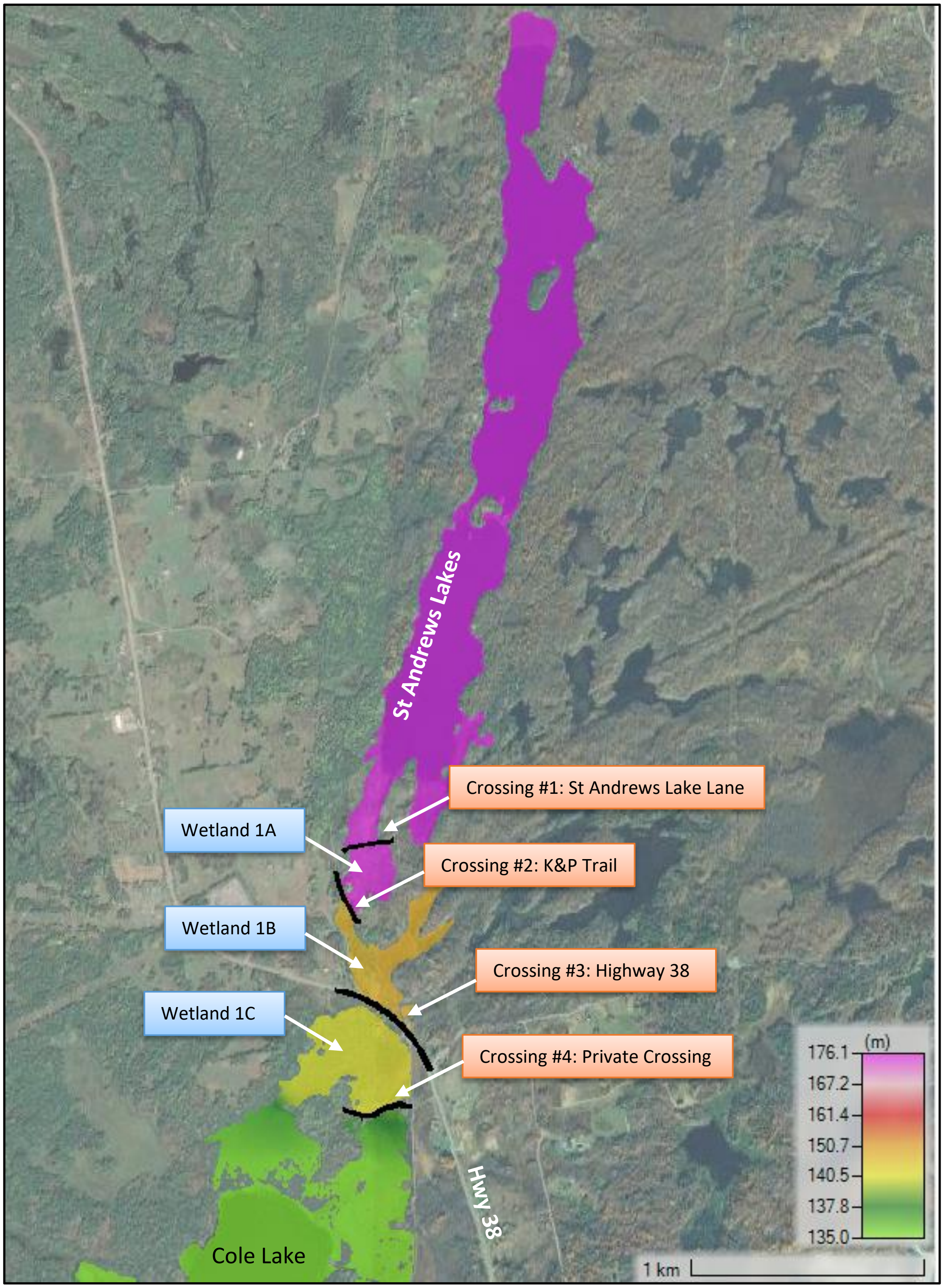


Figure 5-4: Reach#1 - St. Andrews Lake to Cole Lake

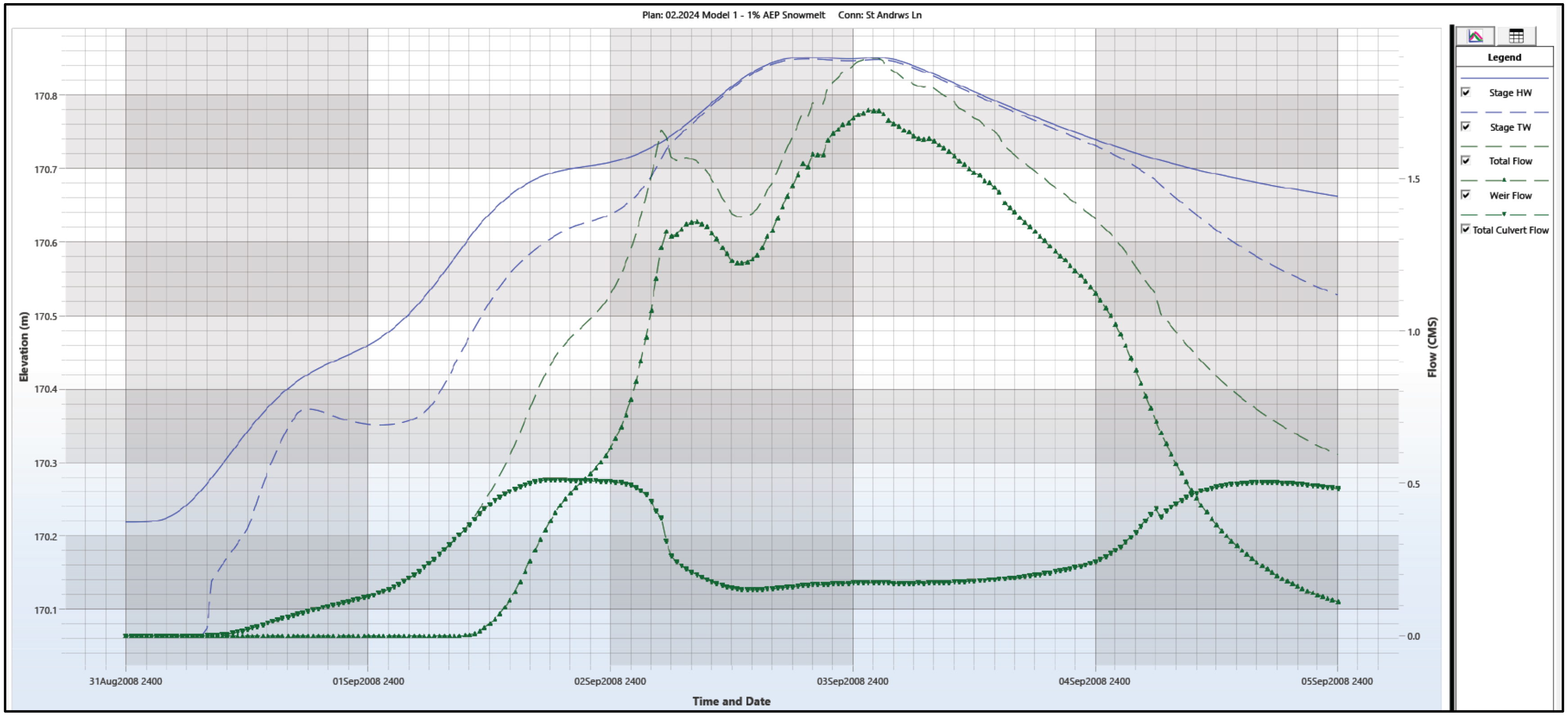


Figure 5-5: St. Andrews Lake Lane Stage and Flow Hydrograph; 1% AEP Rainfall Plus Snowmelt

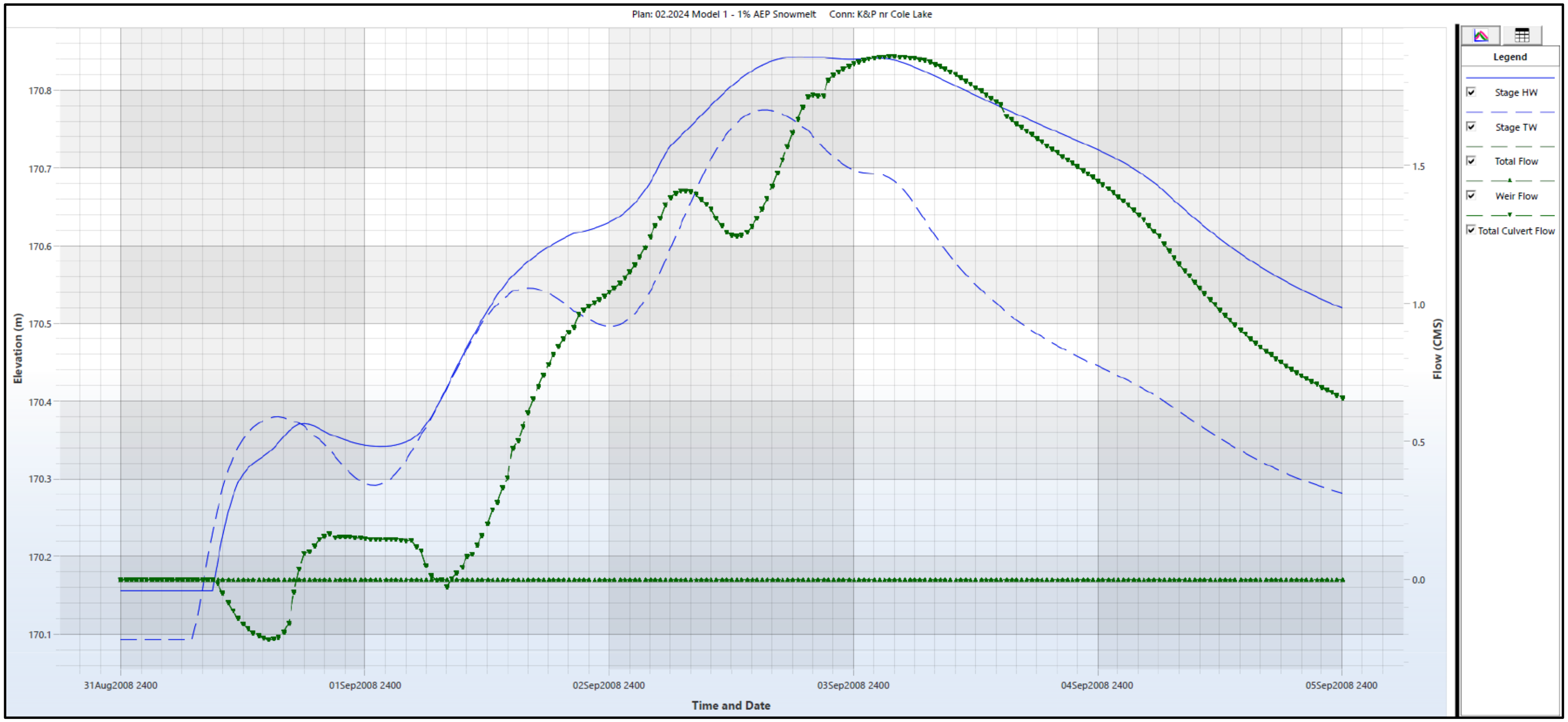


Figure 5-6: K&P Trail Outlet Stage and Flow Hydrographs; 1% AEP Rainfall Plus Snowmelt

5.2.2 Reach #2: Cole Lake to Howes Lake

Reach #2 extends from the outlet of Cole Lake to the inlet of Howes Lake (see Figure 5-7). Reach #2 is defined by a combination of channels and wetlands, and includes Crossings #5-9. The culvert crossings are summarized in Section 5.3.

A beaver dam currently establishes the lake level for Cole Lake. Since beaver dams will not be relied upon as a flood control structure, the beaver dam is removed in the model and a free-flowing channel is used for the outlet. Since there is no reservoir immediately downstream of the Cole Lake outlet, Cole Lake was not modelled in HEC-RAS since the HMS reservoir-routing would be sufficient.

The abrupt change in colour in Figure 5-7 illustrates the presence of the crossings and the backwater they impose near Crossings #5, #6, and #9. Crossing #7 is immediately upstream of a wetland and has lesser backwater impacts upstream.

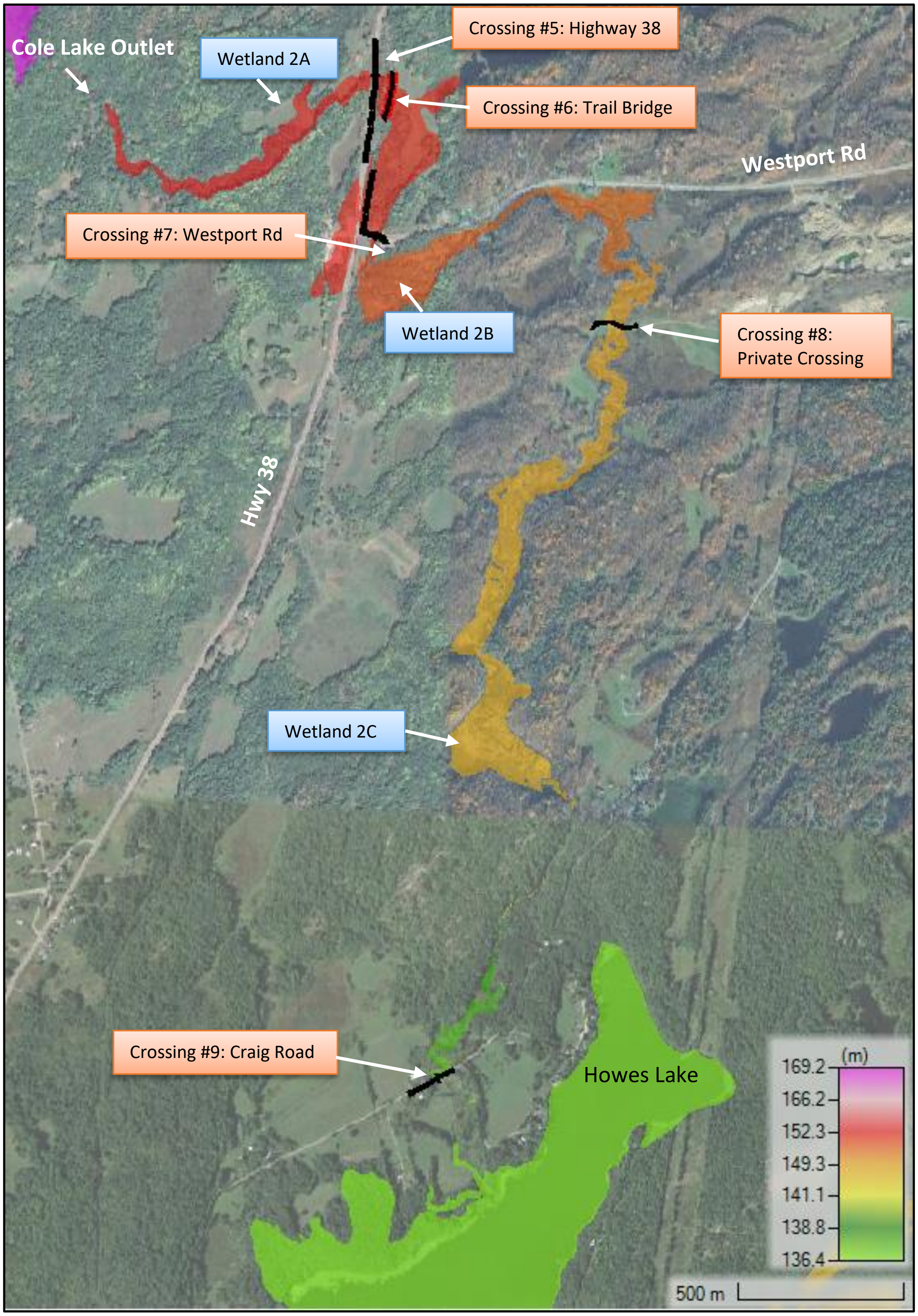


Figure 5-7: Reach #2 – Cole Lake to Howes Lake

5.2.3 Reach #3: Van Luven Lake to Howes Lake

Reach #3 connects Van Luven Lake to Howes Lake (see Figure 5-8). Reach #3 is a relatively short reach and its purpose is to investigate the backwater impacts from Howes Lake on the Van Luven water levels. Crossing #10 is a concrete box culvert across Highway 38 that acts as the control for Van Luven Lake. The rainfall plus snowmelt condition governs the 1% AEP regulatory flood limit. A plot of the stage and flow hydrographs for Van Luven outlet control crossing is provided in Figure 5-9.

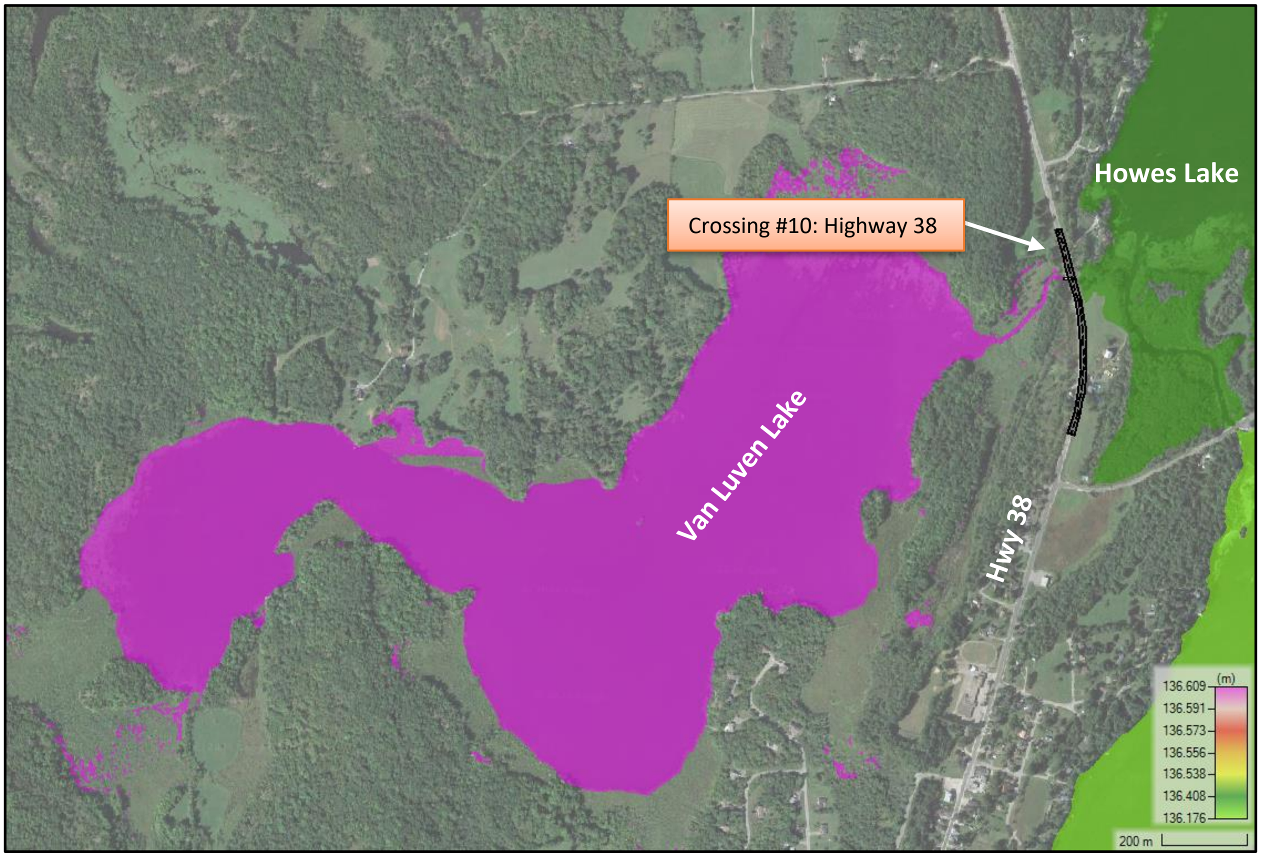


Figure 5-8: Reach #3 Plus Van Luven Lake

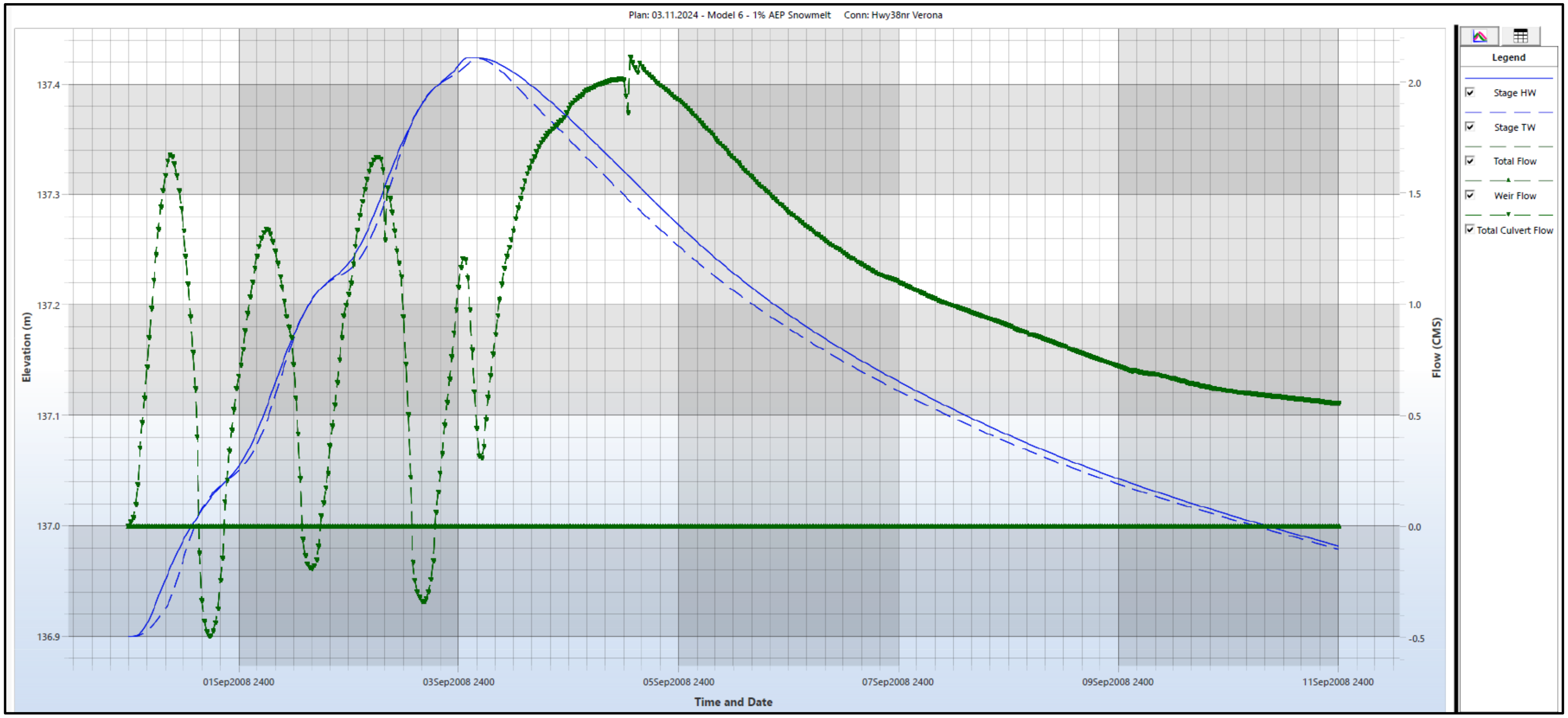


Figure 5-9: Reach #3 - Van Luven Lake Outlet (Crossing #10) Stage and Flow Hydrograph

5.2.4 Reach #4: Howes Lake to Verona Lake

Reach #4 connects Howes Lake to Verona Lake with the bridge at Crossing #11: Desert Lake Road (see Figure 5-10). Howes Lake receives significant inflow peaks and runoff volumes since it is the confluence for the majority of the Napanee River Upper Lakes system. The Desert Lake Road bridge has a large span and the contraction for the outlet channel provides some flow attenuation before runoff enters Verona Lake. Figure 5-11 shows the flow and stage hydrographs for the Desert Lake Road crossing that represents the outlet of the connector channel from Howes Lake to Verona Lake.

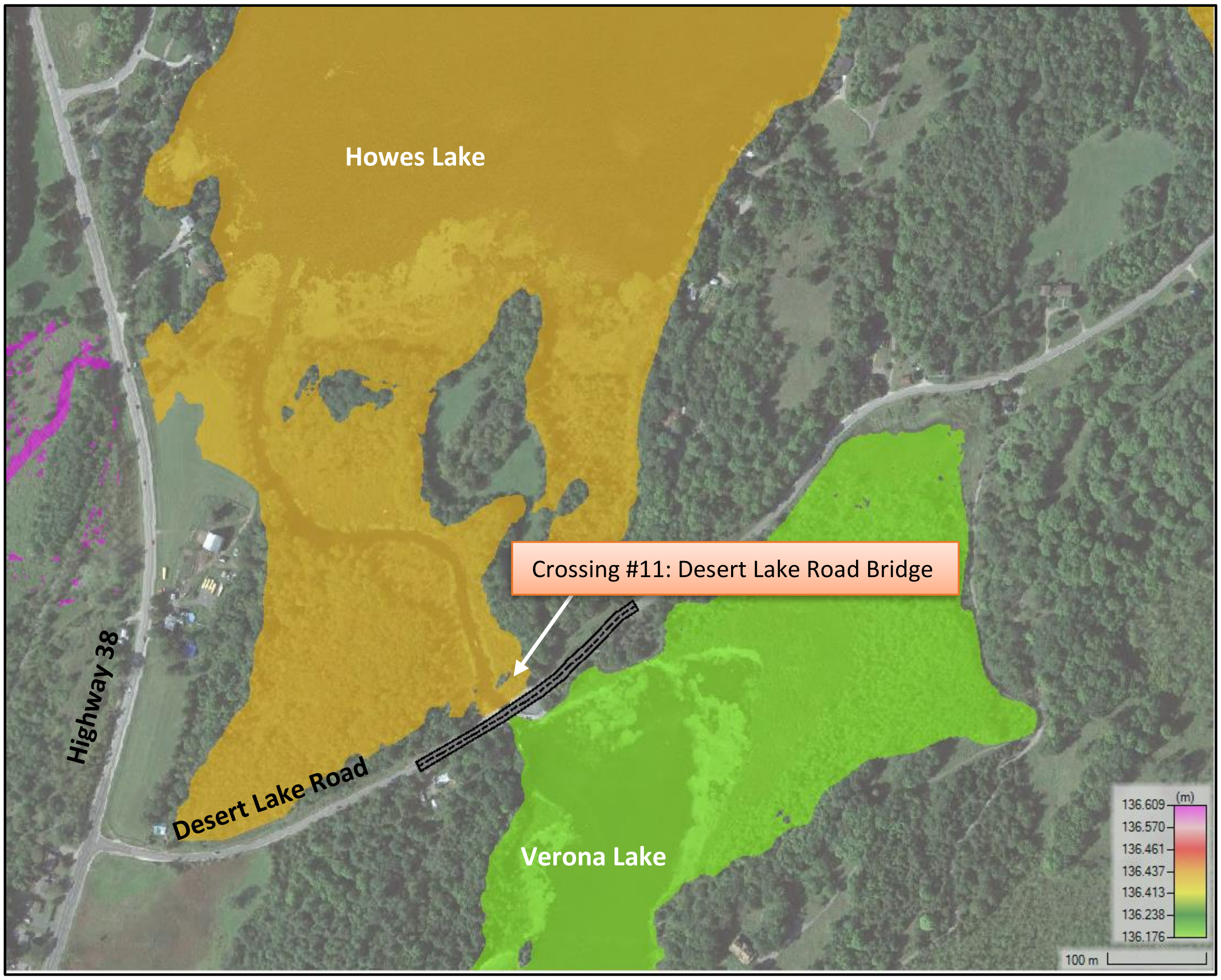


Figure 5-10: Reach #4 – Howes Lake to Verona Lake

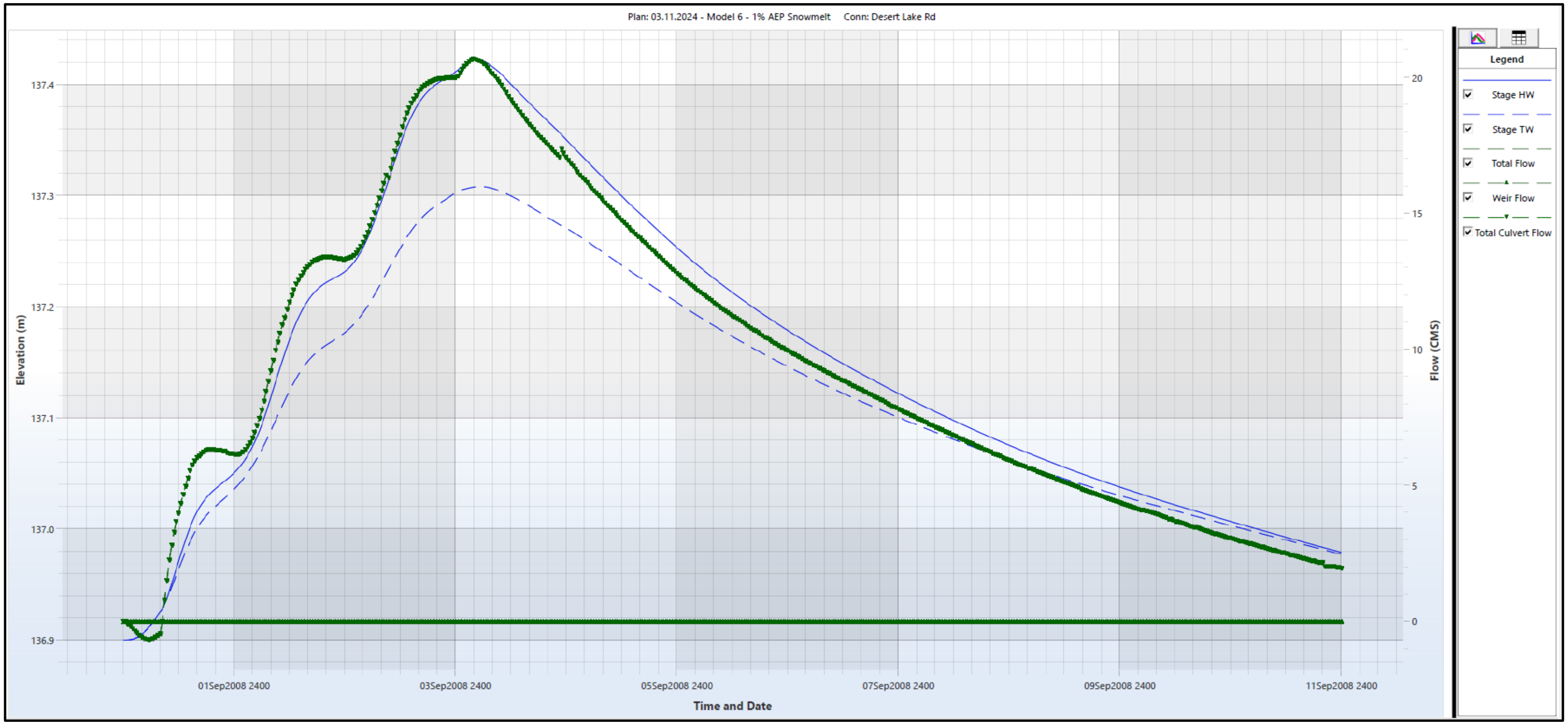


Figure 5-11: Stage and Flow Hydrograph for Reach #4 Outlet at Desert Lake Road for 1% AEP Snowmelt Plus Rain Event

5.2.5 Reach #5: Hambly Lake to Verona Outlet Channel

Reach #5 is the outlet channel from Hambly to Verona Lake. The Cedarwoods Drive crossing (Crossing #12) is within this reach. The Cameron Swamp controls the regulatory water level for Hambly Lake similar to the Cameron Swamp controls for Verona Lake (see Figure 5-12).

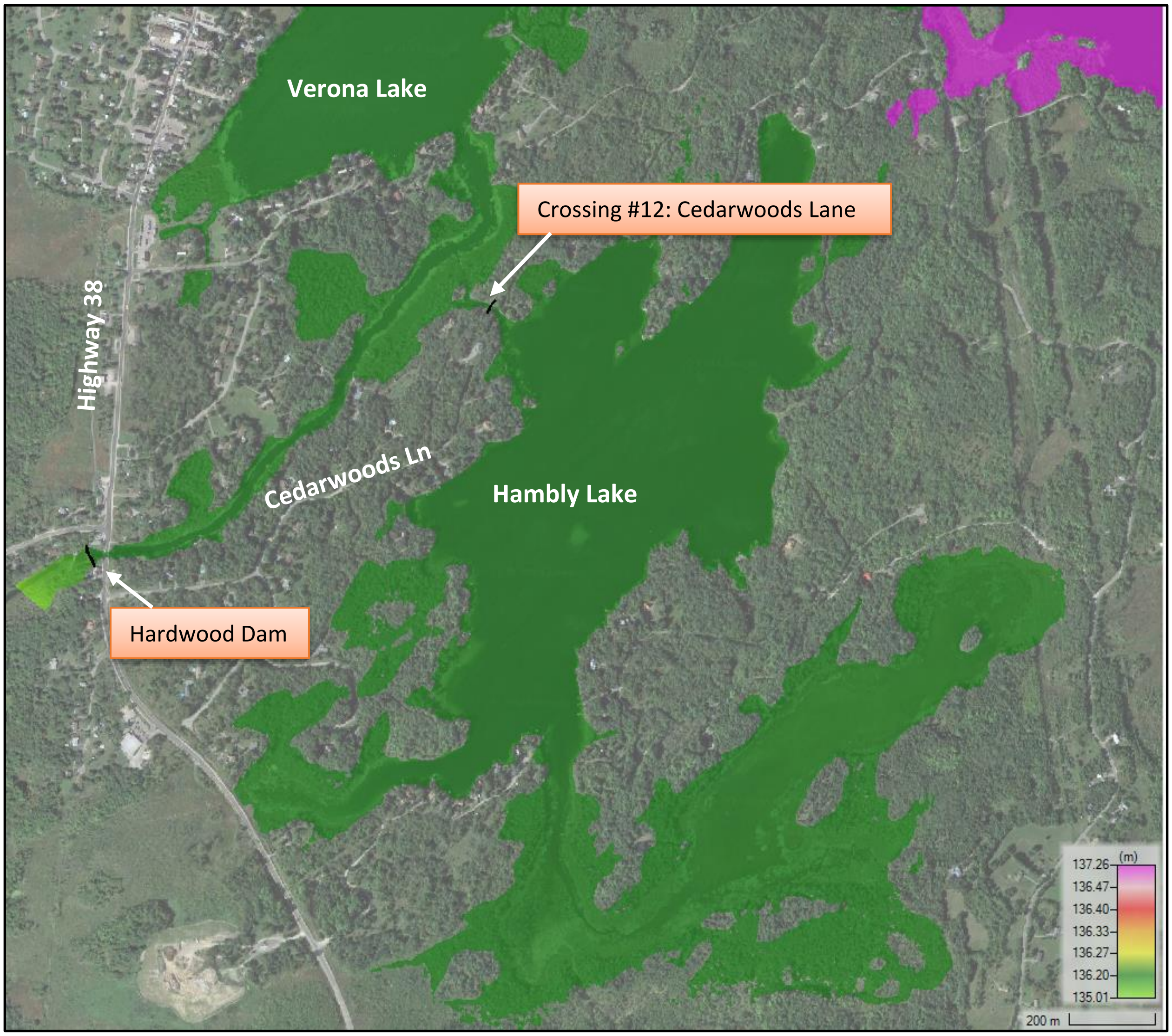


Figure 5-12: Reach #5 and Hambly Lake

5.2.6 Reach #6: White Lake to 13 Island Lake

Reach #6 extends from the outlet of White Lake to the inlet of Thirteen Island Lake (see Figure 5-13). Reach #6 is defined by a combination of channels and wetlands, and includes Crossings #13-17.

The outlet of White Lake is currently a beaver dam; the beaver dam was removed in the model to allow the outlet control to be the natural channel outlet. The White Lake channel outlet and the entirety of Reach #6 is modeled with a 2D flow area. The natural channel outlet for White Lake outlets to a wetland upstream of Buck Bay Road. Buck Bay Road is also bound by a wetland on its downstream side. With the

2D flow area and topographic data in the terrain model, the TW condition is accounted for in the hydraulic calculations.

The remaining crossings within Reach #6 have similar characteristics to Buck Bay Road; meaning they are bound by wetland areas. Bunker Hill Road A (Crossing #17) is the most downstream crossing within this reach and its TW condition is set by the stage hydrograph applied at Thirteen Island Lake.

Section 3 showed the 1% AEP rainfall event produces the largest peak flows from individual sub-catchments, whereas the 1% AEP rainfall plus snowmelt event produces the larger lake elevations and lake outflows due to the greater runoff volume in snowmelt events that overwhelms the lake storage capacities. Reach #6 is governed by the peak flows from the 1% AEP rainfall event rather than the snowmelt scenario since Sub-Catchment 1300 drains directly to the river reach without flow attenuation.

5.2.7 Reach #7: Potspoon Lake to 30 Island Lake

Reach #7 connects Potspoon Lake to Thirty Island Lake (see Figure 5-14). Potspoon Lake outlets to a channel that crosses Sperling Road. The hydrograph at Sperling Road is also representative of the outflows from Potspoon Lake given its proximity to the Potspoon Lake outlet (see Figure 5-15).

Downstream of Sperling Road, there are two smaller lakes that are modelled as storage areas. These two smaller lakes have different elevations, and the connection between the two is currently a beaver dam. The beaver dam is removed in the hydraulic model to allow the connection between the two lakes to be the natural constriction point at the downstream end of the upper reservoir (Connector Lake 7A). The lower reservoir (Connector Lake 7B) is connected to the 2D flow area that includes the creek channel that crosses McColl Lane and outlets to Thirty Island Lake. The stage hydrograph for Thirty Island Lake was applied as the downstream boundary condition for Reach #7.

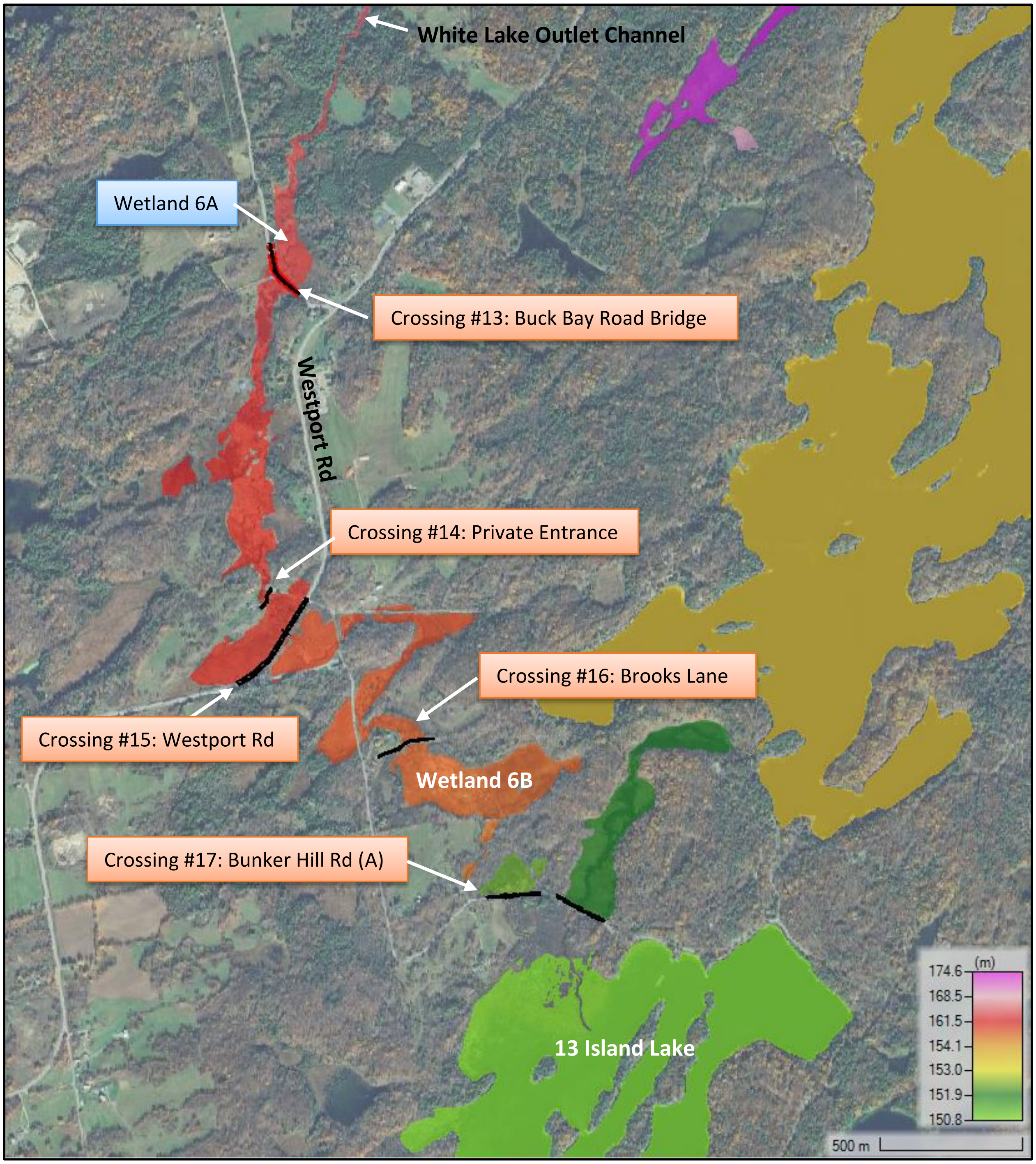


Figure 5-13: Reach #6 - White Lake to 13 Island Lake

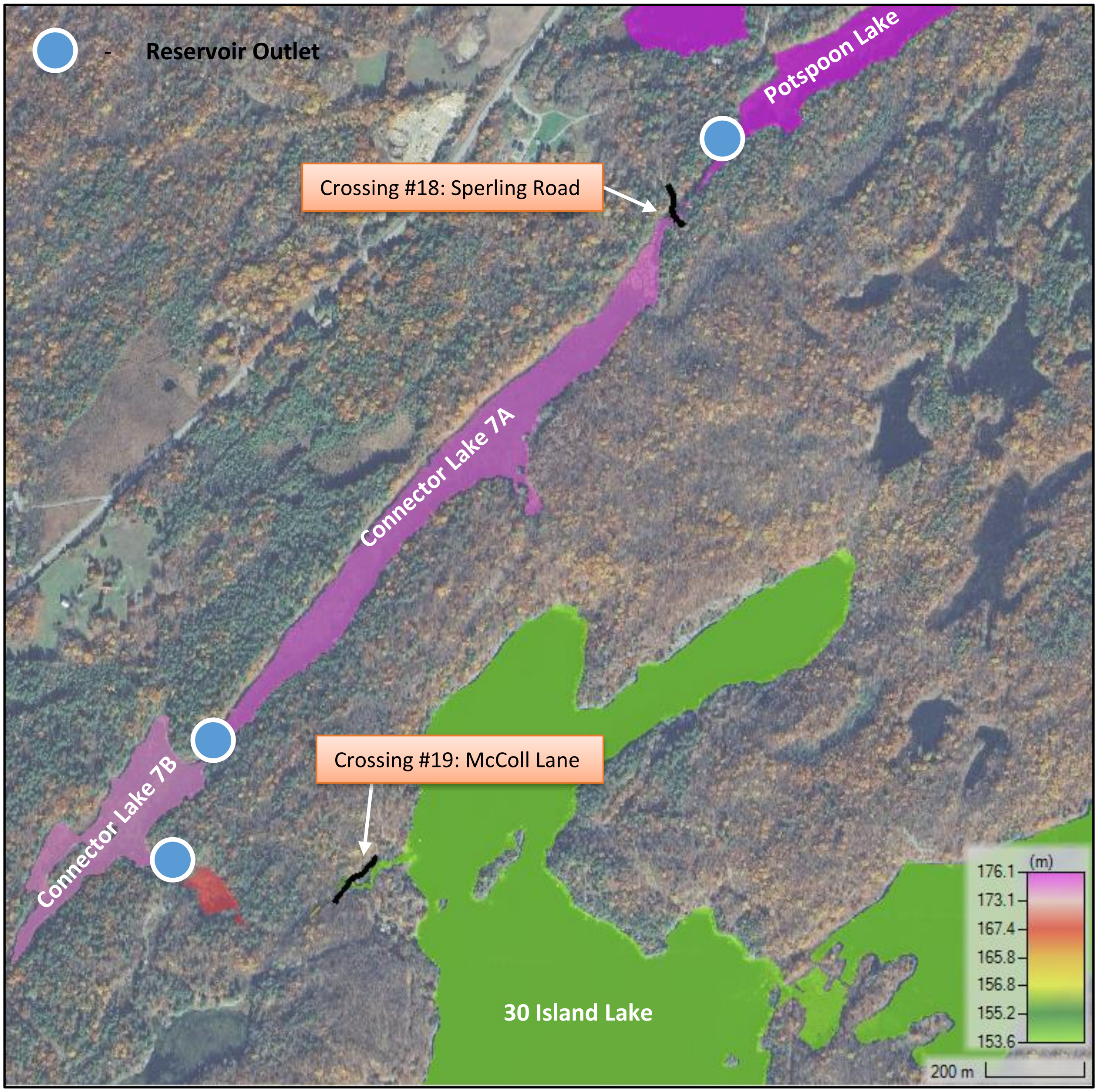


Figure 5-14: Reach #7

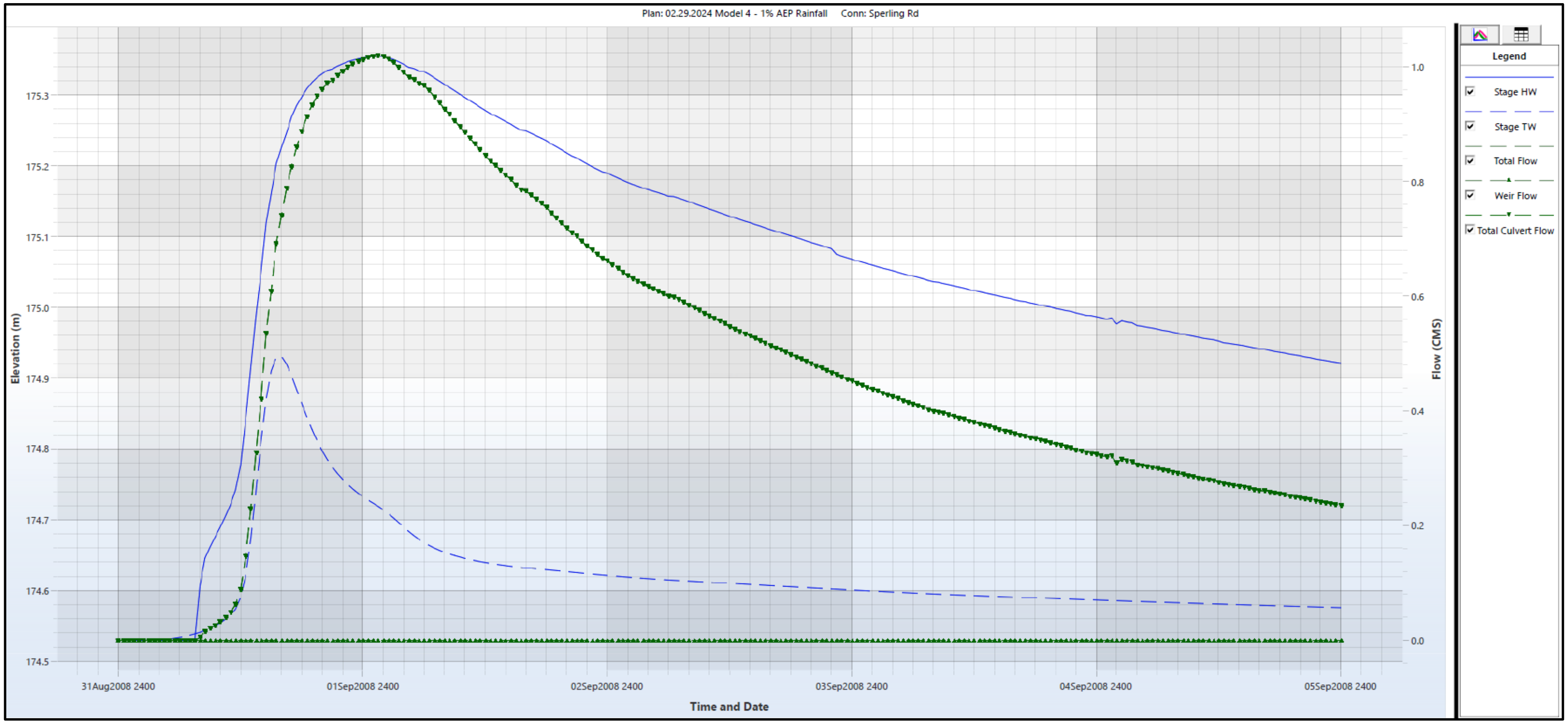


Figure 5-15: Stage and Flow Hydrograph for Sperling Road near Potspoon Lake Outlet; 1% AEP Snowmelt + Rain Event

5.2.8 Reach #8: 30 Island Lake to 13 Island Lake

Reach #8 represents the channel and two wetlands between Thirty Island Lake and Thirteen Island Lake.

The outlet from Thirty Island Lake is currently a beaver dam that was removed in the hydraulic model. There is a natural channel that is very narrow; within this narrow channel there is a private crossing that outlets to a well-defined wetland area. This wetland area had a shallow pool of water at the time of the field visit due to beaver activity between Wetlands 8A and 8B (see Figure 5-16). A local resident also noted that there is a steady flow of water from underneath the bedrock between Thirty Island Lake and Wetland 8A. The water daylights downstream of the private crossing, and may contribute to lower lake levels in 30 Island Lake during dry periods. The downstream connection for Wetland 8B is Bunker Hill Road B (Crossing #21).

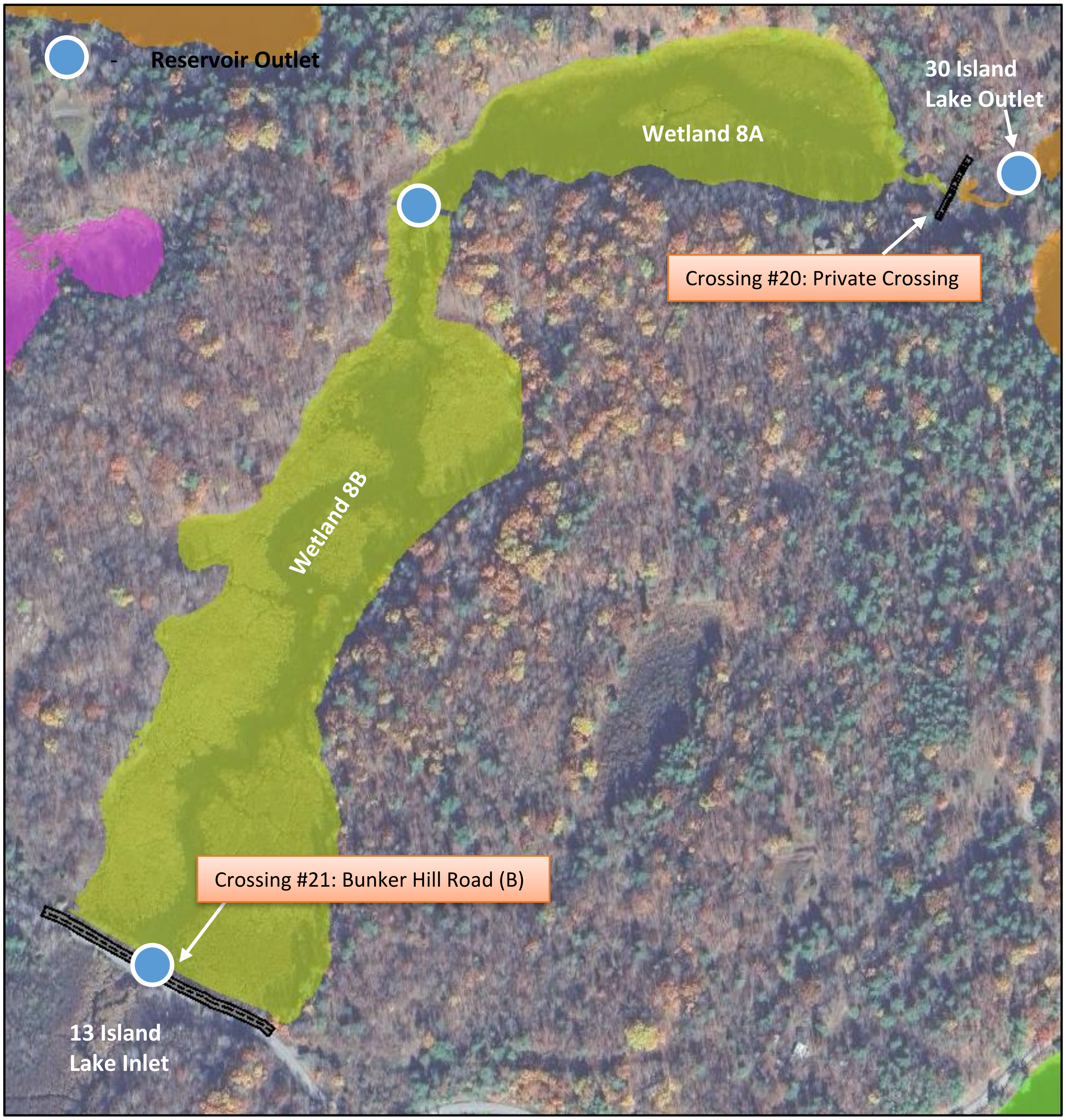


Figure 5-16: Reach #8

5.2.9 Reach #9: 13 Island Lake to Howes Lake

Reach #9 is predominantly a series of two smaller lakes that connect 13 Island Lake to Howes Lake (see Figure 5-17). This includes a connector lake with a longitudinal shape that outlets to Bass Lake. The two lakes were modelled as storage areas due to their size and subsequent storage capacities that would contribute to flow attenuation. They are connected by a narrow channel that was simulated as a storage area connection in the hydraulic model.

The outlet for Bass Lake is currently a beaver dam, however the beaver dam was removed in the hydraulic model and the culvert at Hinchinbrooke Road North is the outlet control for Bass Lake. On the downstream side of Bass Lake there is a steep drop off to Howes Lake. With the sudden drop in elevation, the water levels within Reach #9 are unaffected by the water levels in Howes Lake.

The stage and flow hydrograph for the Hinchinbrooke Road culvert control of Bass Lake is provided in Figure 5-18).

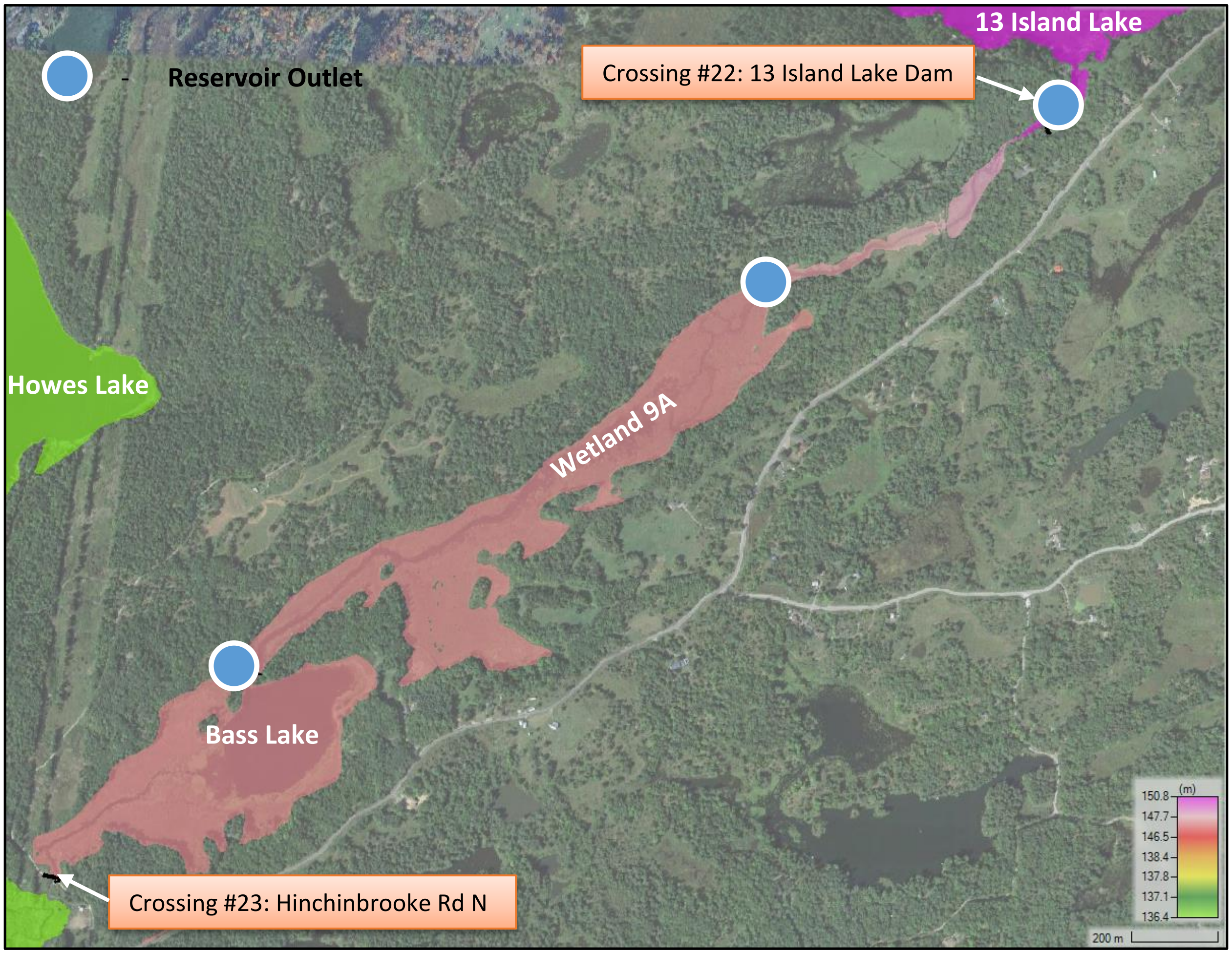


Figure 5-17: Reach #9

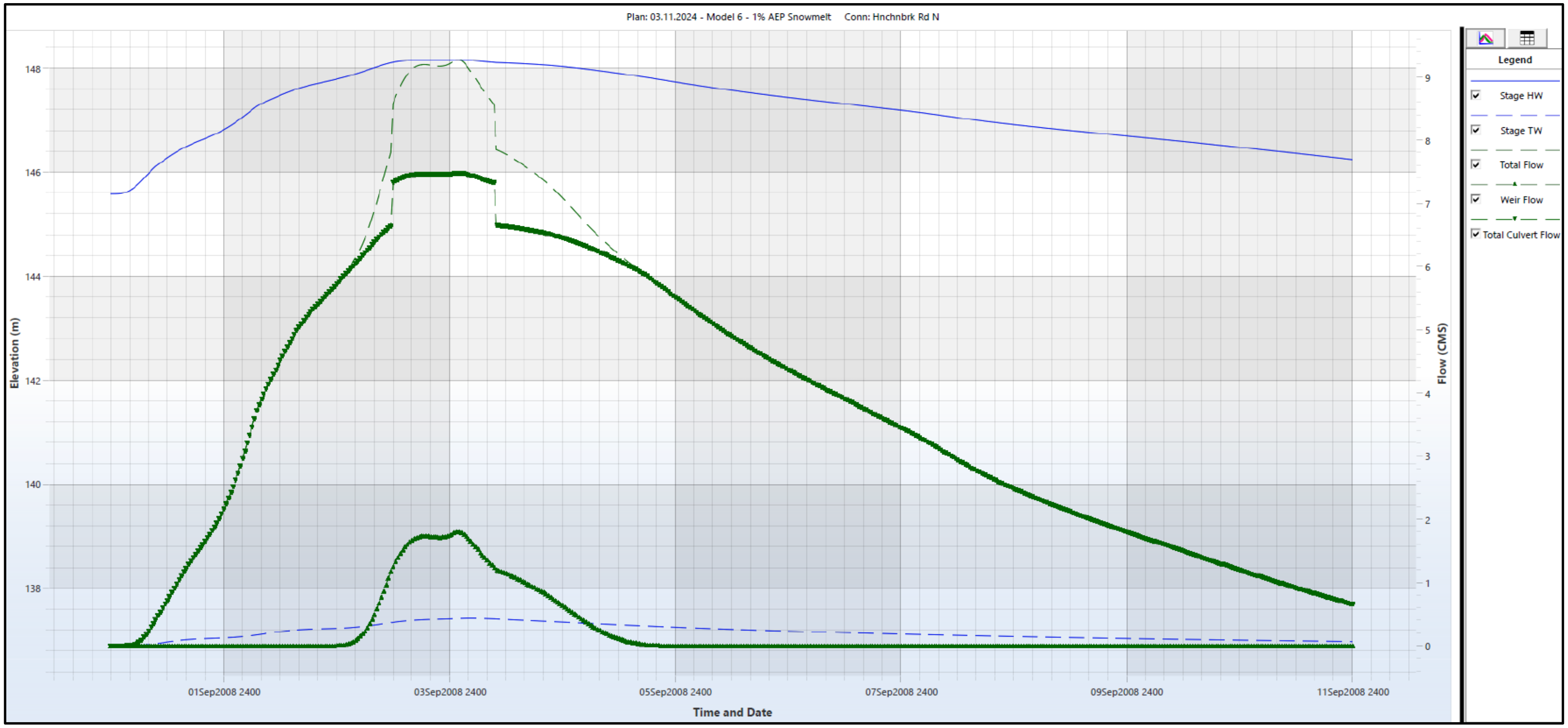


Figure 5-18: Hinchinbrooke Road North Stage and Flow Hydrograph Control of Bass Lake; 1% AEP Rainfall Plus Snowmelt Event

5.2.10 Reach #10: Fourteen Island Lake to Verona Lake

The upstream limit of Reach #10 is the Fourteen Island Lake dam outlet; the downstream limit of Reach #10 is the channel outlet to Verona Lake (see Figure 5-19). The Fourteen Island Lake Dam outlets to a short stretch of channel and wetland area before entering Spring Lake. Spring Lake is controlled by the culvert crossing at Hinchinbrooke Road and drains to Little Mud Lake. Little Mud Lake outlets at a constriction point into a short channel that inlets to Verona Lake. A stage hydrograph for Verona Lake is the downstream boundary condition for Reach #10.

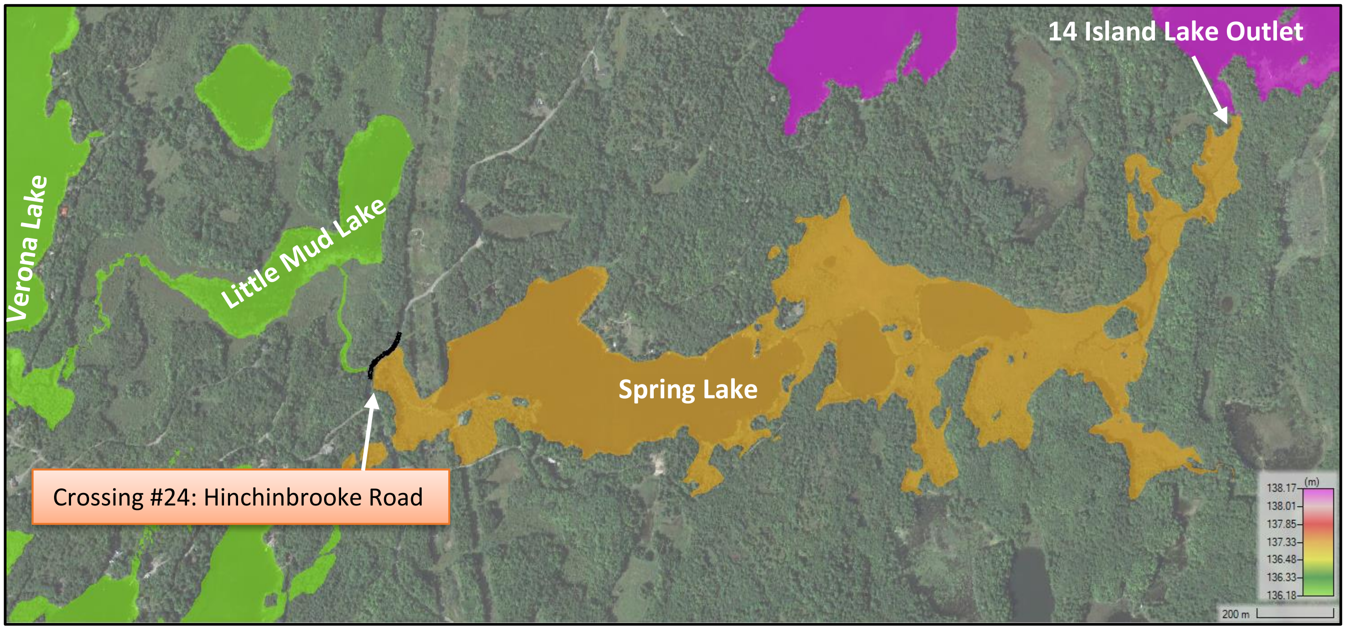


Figure 5-19: Reach #10; Depth Overlay

5.2.11 Reach #11: Verona Lake Outlet Channel to Hardwood Dam

Reach #11 is represented by the Verona Lake outlet channel that is controlled by the Hardwood Dam in summer conditions (see Figure 5-20). This is an important location in the hydraulic model because the reach inflows account for all upstream lake, reservoir, and channel routing. Section 4 concluded the flow attenuation in the lakes is a critical component of the Napanee River Upper Lakes system due to the amount of storage held within each of the main lakes. Since the lakes and their natural channel outlets can reduce peak inflow rates by factors up to 5 to 10 times (depending on the lake and outlet configuration), the outflow hydrographs at Hardwood Dam in the hydraulic model are of interest given that it accounts for backwater impacts, storage areas, and intermittent natural outlet controls throughout the eleven (11) river reaches described herein.

Figure 5-20 presents the outflow hydrograph at the Hardwood Dam for the 1% AEP spring melt event.

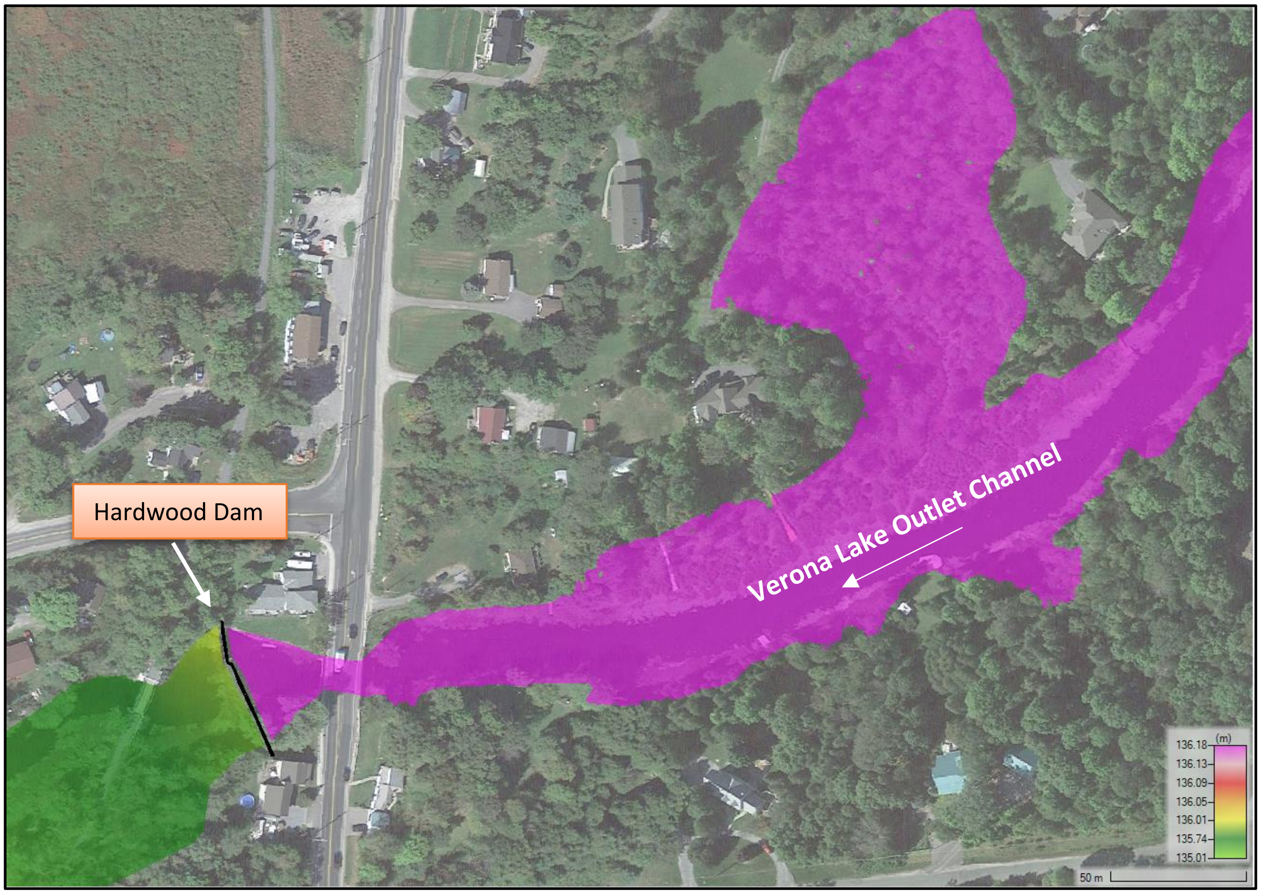


Figure 5-20: Reach #11

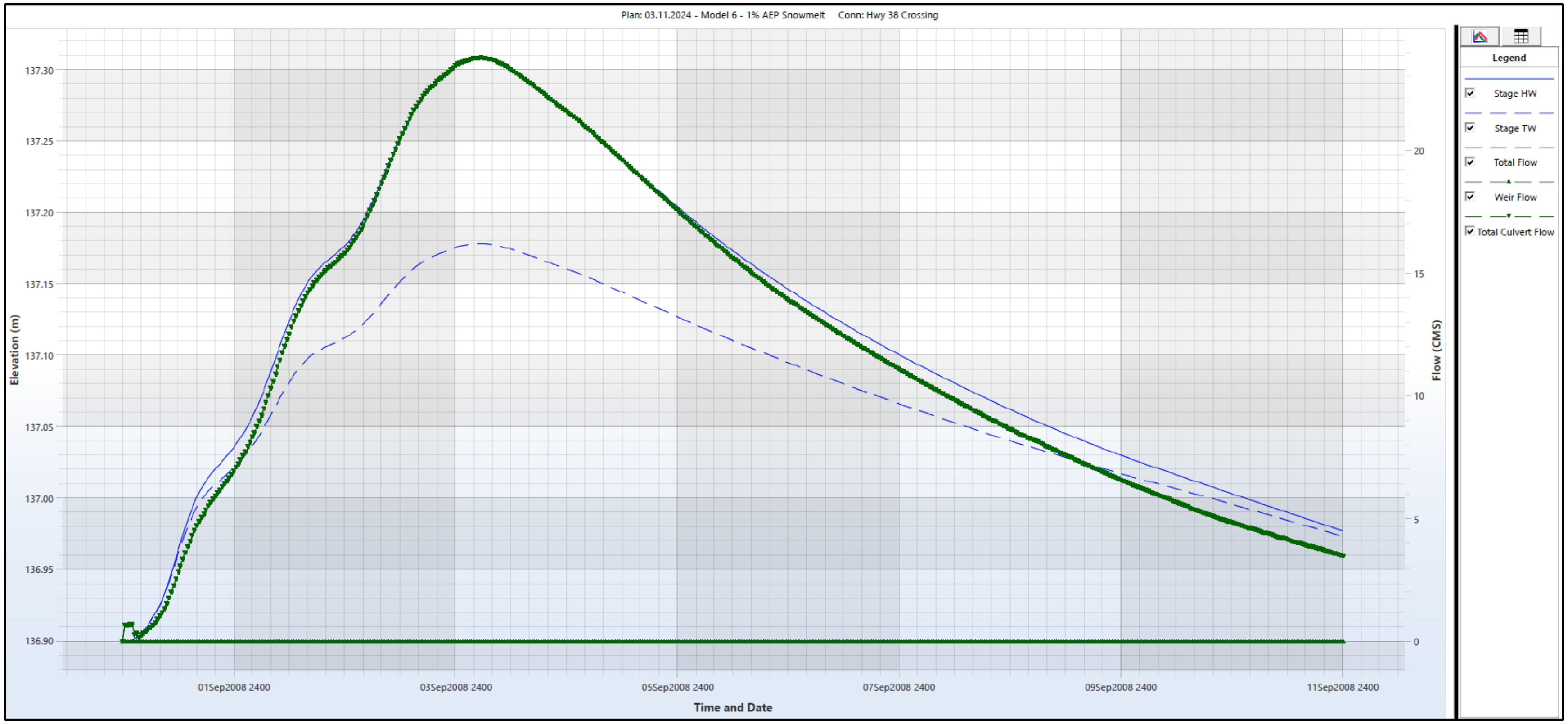


Figure 5-21: Highway 38 Stage and Flow Hydrograph; 1% AEP Rainfall Plus Snowmelt Event

5.3 Culvert & Bridge Crossings

There are twenty-six (26) crossings within the study area as previously depicted throughout Subsection 5.2. Tables 5-2 and 5-3 summarize the type of each crossing, its governing 1% AEP peak flow, and its corresponding headwater (HW) and tailwater (TW) elevations. The maximum relief flow depths are also included.

The governing peak flow and relief flow depth are based on the greater peak flow received from the 1% AEP rainfall or spring melt scenario since some crossings are less ‘protected’ by upstream flow attenuation than others. Recall that the rainfall-only events are more susceptible to flow attenuation by the lakes and intermittent wetlands relative to the snowmelt plus rain events. Therefore, crossings without upstream flow attenuation tend to receive greater peak flows from the 1% AEP rainfall only event, whereas the outflows for the main lakes and their immediate downstream crossings have greater peaks in the 1% AEP spring melt condition. The governing condition is included as a column in the tables below.

Some stage and flow hydrographs were presented within the discussion in Section 5.2; Appendix I provides the stage and flow hydrographs for each crossing. Culvert/bridge data sheets are provided in Appendix J.

Table 5-2: Summary of Crossings #1-12

Crossing #	Name	Type	Low Point of Road (m)	Governing 1% AEP Event	Governing 1% AEP Q_{peak}	HW_{peak}	TW_{peak}	ΔH_{peak}	Max. Relief Flow Depth
				m	m^3/s	m			
Reach 1: St Andrew Lakes Ln to Howes Lake									
1	St. Andrews Lakes Lane	Three (3) 750mm Φ HDPE culverts	170.59	Spring melt	1.9	170.85	170.85	0.00	0.26
2	K&P Trail	3m span x 1.5m rise concrete box culvert	171.13	Spring melt	1.9	170.84	170.77	0.07	0.00
3	Highway 38 near Cole Lake	3m span x 2.1m rise concrete box culvert	170.99	Spring melt	3.6	170.75	170.38	0.37	0.00
4	Private Crossing: 8985 B Hwy 38	Assumed 400mm diameter dirveway culvert	169.47	Spring melt	2.0	169.66	169.35	0.31	0.19
Reach 2: Cole Lake to Howes Lake									
5	Hwy 38 near Godfrey	4m span x 2m rise concrete box culvert	153.52	Rainfall	11.7	154.65	152.94	1.71	1.13
6	K&P Trail near Godfrey	4m span bridge	154.28	Rainfall	11.7	152.74	152.66	0.08	0.00
7	Westport Road near Godfrey	3.2m span x 2.4m rise CSP arch culvert	151.66	Rainfall	20.6	152.47	152.11	0.36	0.81
8	Private Crossing: 7297 Hinchinbrooke Rd N	Assumed 400mm diameter dirveway culvert.	148.94	Rainfall	34.2	150.30	150.26	0.04	1.36
9	Craig Road	4.4m span x 2.9m rise CSP arch culvert	139.31	Rainfall	27.6	139.12	138.26	0.86	0.00
Reach 3: Van Luven Lake to Howes Lake									
10	Highway 38 near Howes Lake	3m span x 1.5m rise concrete box culvert	138.22	Spring melt	21.9	137.29	137.18	0.11	0.00
Reach 4: Howes Lake to Verona Lake									
11	Desert Lake Road Bridge	10.0m span bridge	139.16	Spring melt	17.8	137.38	137.29	0.09	0.00
Reach 5: Hambly Lake to Verona Outlet Channel									
12	Cedarwoods Lane	2.4m span concrete box culvert	137.20	Spring melt	2.2	137.31	137.29	0.02	0.11

Table 5-3: Summary of Crossings #13-26

Reach 6: White Lake to 13 Island Lake									
13	Buck Bay Road Bridge	9.1m span bridge	162.74	Rainfall	12.2	163.26	163.17	0.09	0.52
14	Private Crossing	Assumed 400mm diameter dirveway culvert	161.00	Rainfall	20.2	161.44	161.24	0.20	0.44
15	Westport Road near Glendower	1800mm Φ CSP culvert	160.68	Rainfall	21.9	161.14	160.13	1.01	0.46
16	Brooks Lane	1.4m x 1.2m CSP arch culvert	158.13	Rainfall	16.0	158.62	158.40	0.22	0.49
17	Bunker Hill Road A	1800mm Φ CSP culvert	152.22	Rainfall	14.4	152.68	152.14	0.54	0.46
Reach 7: Potspoon Lake to 30 Island Lake									
18	Sperling Road	1600mm Φ CSP culvert	175.41	Rainfall	1.0	175.35	174.93	0.42	0.00
19	McColl Lane	Two 600mm Φ CSP culverts	154.59	Rainfall	3.7	155.17	155.16	0.01	0.58
Reach 8: 30 Island Lake to 13 Island Lake									
20	Private Crossing	Assumed 400mm diameter dirveway culvert	155.13	Spring melt	7.1	155.58	152.49	3.09	0.45
21	Bunker Hill Road B	1200mm Φ CSP culvert	151.84	Rainfall	0.1	151.56	151.56	0.00	0.00
Reach 9: 13 Island Lake to Howes Lake									
22	13 Island Lake Dam	Dam with three (3) stoplog bays	151.40	Spring melt	8.1	151.50	150.43	1.07	0.10
23	Hinchinbrooke Road North	1800mm Φ CSP culvert	147.76	Spring melt	9.3	148.16	137.42	10.74	0.40
Reach 10: 14 Island Lake to Verona Lake									
24	Hinchinbrooke Road	2400mm Φ CSP culvert	137.81	Spring melt	2.2	137.40	137.31	0.09	0.00
Reach 11: Verona Lake Outlet Channel to Hardwood Dam									
26	Highway 38 near Verona	11.3m span bridge	138.29	Spring melt	2.1	137.42	137.42	0.00	0.00

6 Water Level Summary

The water levels are discussed in this section for the 0.5%, 1%, and 10% AEP events. The 0.5% AEP event is included as the climate change condition for the spring melt plus rain scenario. A separate scenario for climate change based on forecast temperature and rainfall increases is also included per Section 4.6.

The water levels summarized in this section primarily focus on the core Napanee River Upper Lakes; however, results for the governing 1% AEP event are also summarized for the sub-lakes and wetlands distributed throughout the study area. Recall that both the 1% AEP snowmelt plus rain, and rainfall only scenarios, were applied to determine the governing regulatory flood hazard limit for each reach.

6.1 Napanee River Upper Lakes Water Level Summary

The AEP Lake levels for both the rainfall and spring melt scenarios are presented in Table 6-1. Further to the 1% AEP regulatory flood limits, the 10% AEP and 0.5% events were simulated for the snowmelt plus rain scenario. The 1% AEP plus climate change scenario was also simulated as an individual model run.

Table 6-1 concludes that the Napanee River Upper Lakes water levels are governed by the spring melt condition as described in the *Section 3*. For Reaches 2 and 6, their channel and wetland areas are governed by the rainfall only condition.

There are several prominent beaver dams throughout the study area (see Figure 5-1). A model simulation was included to assess the potential impact of the beaver dams on the lake levels. The height of the beaver dams was based on LiDAR imagery and local survey data where available. A comparison of water levels for the 1% AEP snowmelt plus rain event with and without beaver dams is presented in Table 6-2. The beaver dams provide an increase in storage volume prior to their intended outlet controls becoming utilized. As a result, there is some reduction in water levels in the lower reaches if the beaver dams were to maintain structural stability in a large runoff event. On the other hand, the beaver dams result in an increase the water levels at their respective upstream lake or wetland area.

6.2 Comparison to 1981 Regulatory Water Levels

A comparison of lake level rise (i.e. maximum depth) between the 1981 study and the 2024 results is shown in Table 6-3. The primary differences between the previous and current mapping include 1) decades of ‘new’ flow gauge data at the Napanee River at Camden East, 2) the addition of the Schroeter model to investigate spring melt events, 3) a more detailed investigation of sub-lakes and wetlands, and 4) improved modeling software and data capabilities relative to historical modeling software.

An important observation was the water level measurement taken by Quinte Conservation on April 15 of 2014 at the Desert Lake Road bridge that connects Howes and Verona Lakes. This measurement occurred during a nearly 1% AEP peak flow at the Napanee Camden East gauge and provided excellent benchmark information to establish the tailwater condition and subsequent lake levels in the lower lakes (i.e. Hambly, Howes, Verona, Van Luven).

6.3 Sub-Lakes and Wetlands Water Level Summary

The sub-lakes and wetlands are the dominant characteristic among the river reaches between the thirteen main lakes of interest. The larger sub-lakes and wetlands were modeled using storage areas. Smaller sub-lakes and wetlands were modeled using 2D flow areas. A water level summary for the most prominent sub-lakes and wetlands is presented in Table 6-4. The names of each sub-lake and wetland in the table below correspond to the labels in the figures shown in Section 5.2 of this report.

Table 6-1: Water Level Summary for 10% AEP, 1% AEP, 0.5% AEP, and Climate Change Scenarios

Lake	Outlet Inv. (m)	10% AEP *Water Level (m)		1% AEP *Water Level (m)		Climate Change *Water Level (m)	
		Rainfall	Rainfall + Snowmelt	Rainfall	Rainfall + Snowmelt	Rainfall (ECCC Method)	Rainfall + Snowmelt (0.5% AEP)
St. Andrews	170.20	170.51	170.73	170.68	170.85	170.84	170.90
Cole	168.90	168.98	169.14	169.11	169.25	169.19	169.27
Van Luven	136.20	136.63	137.11	137.03	137.37	137.43	137.45
Howes	135.50	136.60	137.10	137.03	137.36	137.17	137.44
White	168.25	168.40	168.59	168.51	168.71	168.60	168.75
Potspoon	175.91	176.09	176.19	176.18	176.27	176.26	176.30
30 Island	153.79	153.93	154.13	154.04	154.34	154.15	154.41
13 Island	150.43	150.34	150.70	150.48	150.83	150.62	150.89
Sigsworth	137.57	137.76	138.05	137.90	138.23	138.03	138.28
14 Island	137.57	137.76	138.05	137.90	138.23	138.03	138.28
Hambly	135.48	136.56	137.05	136.98	137.29	137.03	137.36
Verona	135.47	136.55	137.04	136.97	137.27	137.03	137.34
Little John	146.30	146.54	146.70	146.73	146.78	146.90	146.80
**Water levels in datum CGVD 2013*							

Table 6-2: Water Level Summary for 2% AEP, 5% AEP, and 50% AEP Scenarios

Lake	Outlet Inv. (m)	2% AEP *Water Level (m)		5% AEP *Water Level (m)		50% AEP *Water Level (m)	
		Rainfall	Rainfall + Snowmelt	Rainfall	Rainfall + Snowmelt	Rainfall	Rainfall + Snowmelt
St. Andrews	170.20	170.63	170.81	170.56	170.76	170.38	170.63
Cole	168.90	169.08	169.22	169.04	169.19	168.96	169.08
Van Luven	136.20	136.90	137.33	136.74	137.21	136.34	136.82
Howes	135.50	136.90	137.31	136.73	137.20	136.09	136.81
White	168.25	168.48	168.67	168.44	168.62	168.32	168.49
Potspoon	175.91	176.15	176.25	176.12	176.21	176.04	176.12
30 Island	153.79	154.01	154.28	153.89	154.20	153.86	154.01
13 Island	150.43	150.44	150.77	150.38	150.69	150.26	150.49
Sigsworth	137.57	137.86	138.18	137.80	138.10	137.66	137.89
14 Island	137.57	137.86	138.18	137.80	138.10	137.66	137.89
Hambly	135.48	136.85	137.25	136.69	137.15	136.12	136.77
Verona	135.47	136.85	137.23	136.69	137.13	136.04	136.77
Little John	146.30	146.67	146.76	146.59	146.72	146.39	146.62

**Water levels in datum CGVD 2013*

Table 6-3: Comparison of 1% AEP Lake Levels With and Without Beaver Dams

Lake	Without Beaver Dams	With Beaver Dams
St. Andrews	170.85	170.85
Cole	169.25	169.42
Van Luven	137.37	137.38
Howes	137.36	137.35
White	168.71	168.91
Potspoon	176.27	176.27
30 Island	154.34	154.41
13 Island	150.83	150.81
Sigsworth	138.23	138.23
14 Island	138.23	138.23
Hambly	137.29	137.29
Verona	137.27	137.27
Little John	146.78	146.78

Table 6-4: Comparison of Maximum Lake Flood Depths (m) Between 1981 and 2024 Output Results

Lake	Starting Elevation (m)	1% AEP Rainfall			1% AEP Spring Melt		
		1981	2024	Diff.	1981	2024	Diff.
*Howes	135.64	0.76	1.40	0.64	1.31	1.73	0.42
*Van Luven	136.20	0.76	1.01	0.25	1.31	1.35	0.04
*Hambly	135.64	0.76	1.35	0.59	1.31	1.66	0.35
*Verona	135.64	0.76	1.34	0.58	1.31	1.64	0.33
Fourteen Island	137.58	0.31	0.35	0.04	0.63	0.68	0.05
Thirteen Island	150.43	0.31	0.35	0.04	1.27	0.70	(0.57)
Thirty Island	153.80	0.22	1.10	0.88	0.76	1.40	0.64
Potspoon	175.92	0.16	0.22	0.06	0.48	0.31	(0.17)
White	167.99	0.12	0.16	0.04	0.28	0.36	0.08

**Depths measured above 2024 Hardwood Dam outlet for consistency with 1981 comparison.*

Table 6-5: Sub-Lakes and Wetlands 1% AEP Water Level Summary

Sub-Lake / Wetland #	Governing 1% AEP Event	Starting Elevation	1% AEP Elevation	Max. Depth
	m	m		
Reach 1: St Andrew Lakes Ln to Howes Lake				
1A	Spring melt	170.38	170.85	0.47
1B	Spring melt	169.78	170.76	0.98
1C	Spring melt	169.48	169.70	0.22
Reach 2: Cole Lake to Howes Lake				
2A	Rainfall	152.20	154.65	2.45
2B	Rainfall	150.80	151.87	1.07
2C	Rainfall	147.20	148.53	1.33
Reach 3: Van Luven Lake to Howes Lake				
N/A				
Reach 4: Howes Lake to Verona Lake				
N/A				
Reach 5: Hambly Lake to Verona Outlet Channel				
N/A				
Reach 6: White Lake to 13 Island Lake				
6A	Rainfall	162.60	163.30	0.70
6B	Rainfall	157.68	158.12	0.44
Reach 7: Potspoon Lake to 30 Island Lake				
7A	Rainfall	174.53	174.93	0.40
7B	Rainfall	173.85	174.46	0.61
Reach 8: 30 Island Lake to 13 Island Lake				
8A	Springmelt	151.53	151.95	0.42
8B	Spring melt	150.90	151.95	0.05
Reach 9: 13 Island Lake to Howes Lake				
9A	Spring melt	146.92	147.56	0.64
9B	Spring melt	145.57	147.55	1.98
Reach 10: 14 Island Lake to Verona Lake				
10A	Spring melt	136.10	137.64	1.54
10B	Spring melt	136.28	137.29	1.01
Reach 11: Verona Lake Outlet Channel to Hardwood Dam				
N/A				

7 Sensitivity Analysis

Flood hazard limits are derived from the runoff rates supplied to the hydraulic model. It is important to assess the sensitivity of the selected peak flows to their input parameters to understand the potential variance in peak flows due to uncertainties in the modeling input. Uncertainties are inherent in all scientific modeling programs, and individual models can be used responsibly when the user understands the limitations and potential factors that can influence the model output.

Figures 7-1 to 7-3 illustrate the parameters with the greatest sensitivity impact on the HEC-HMS flows. These parameters include CN, lag time, and rainfall depth. The CN affects the losses, and unsurprisingly has a significant influence on the peak runoff. The lag time has the least impact of the three, but still has sensitivity impacts on the model results. The lag time has less influence than usual since the reservoir routing governs in the timing of the peak outflows throughout the Napanee River Upper Lakes drainage system. The rainfall volume is of particular interest. It is evident that there is an appreciable increase in peak flows with an increase in the rainfall volume. Since climate change considerations include increasing the rainfall depth by 25%, the increase in the peak runoff rate is significant (see further discussion in Section 4.6).

Given the sensitivity of the HEC-HMS results to the rainfall depths, it is important to consider the data being supplied to the input hyetographs. As discussed in Section 4.2, the Kingston station has a long historical data record (recall that the Kingston station has a greater depth than the Hartington 1%, 1-day AEP rainfall depth and is expected to be a conservative input into the hydrologic model).

With the hydraulic model, there is a sensitivity check for the Manning's roughness values. Since the majority of the study area is comprised of lakes, wetlands, and low velocity areas, the hydraulic model has minimal sensitivity to the Manning's n values. The low, medium, and high Manning's n values used in the sensitivity analysis are summarized in Table 7-1. A model run was completed to compare the water levels with the high and low Manning's values. The water levels showed minimal sensitivity, with several lakes showing no change and the maximum change in elevation being 2cm. Evidently, the Napanee River Upper Lakes and their sub-reaches have minimal sensitivity to the Manning's roughness value considering that the vast majority of the study area is dominated by storage areas.

8 Public Information Center

A public information center (PIC) was held from 5:30pm to 7:00pm on February 6, 2024 at the Sydenham Public Library. The PIC included display boards for each of the draft floodplain maps, and a PowerPoint presentation was available. The PIC was hosted by Quinte Conservation staff along with the project engineers from Jewell Engineering. No major concerns were brought forward by the public and the project proceeded to finalization following the PIC.

Table 8-1: Manning's n Values Applied in Hydraulic Model Sensitivity Tests

Land Cover	Low	Medium	High
Swamp	0.035	0.045	0.06
Clear open water	0.028	0.032	0.035
Community infrastructure	0.035	0.05	0.12
Tree upland	0.05	0.07	0.09
Marsh	0.035	0.045	0.06
Deciduous treed	0.05	0.07	0.09
Mixed treed	0.05	0.07	0.09
Coniferous treed	0.05	0.07	0.09
Agriculture and undifferentiated rural	0.035	0.05	0.07
Plantations - treed cultivated	0.035	0.05	0.07
Hedge rows	0.04	0.05	0.07
Sand gravel mine tailings extraction	0.017	0.025	0.033

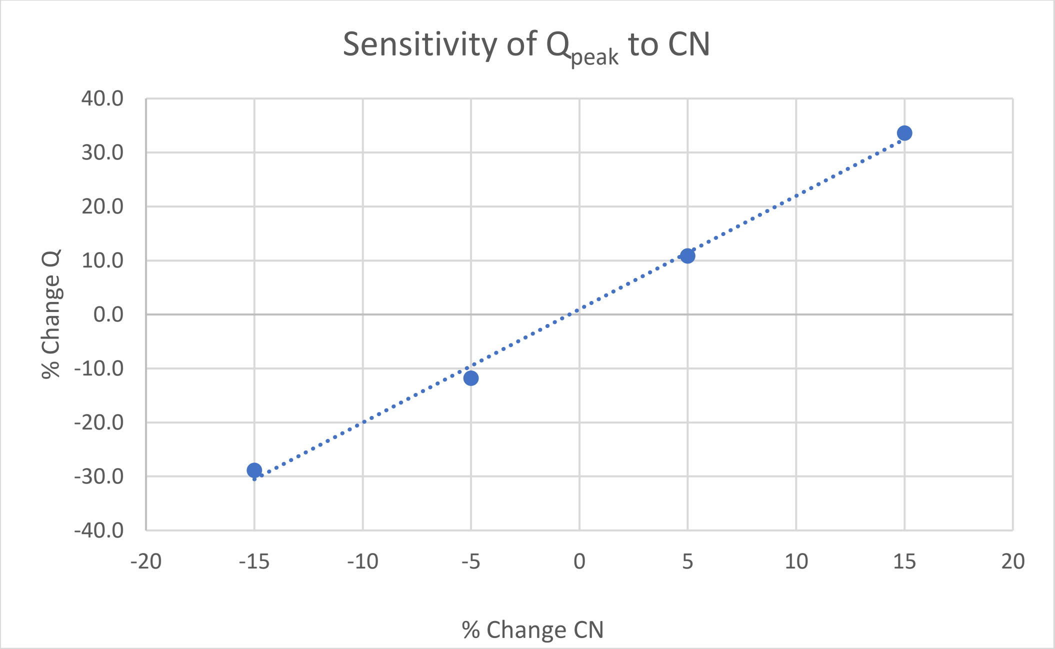


Figure 8-1: Sensitivity of Peak Runoff Rates to CN

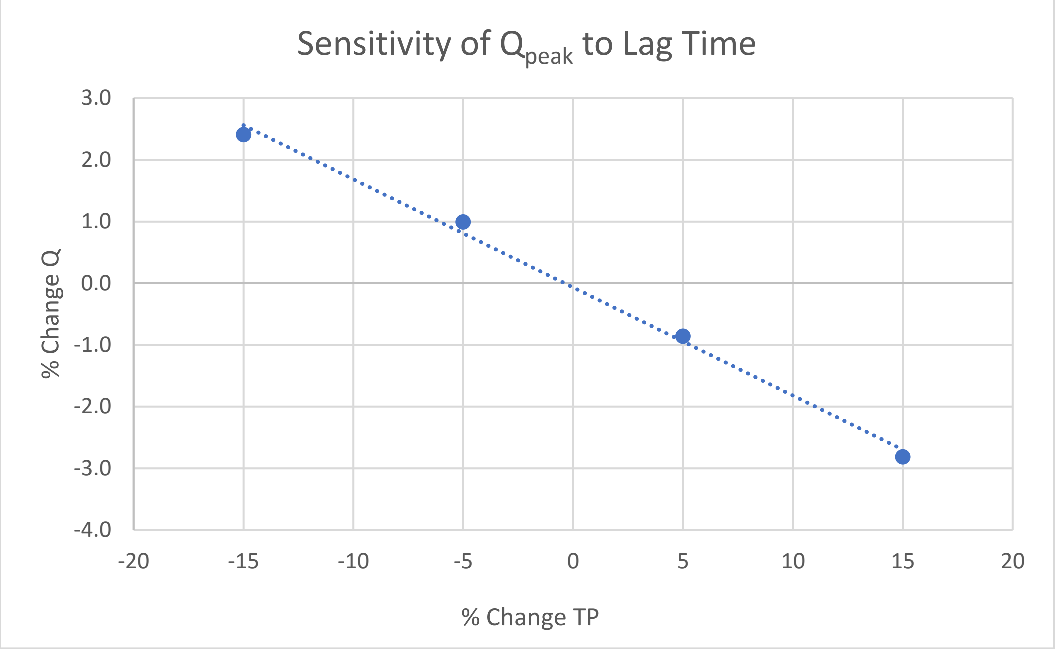


Figure 8-2: Sensitivity of Peak Runoff Rates to Lag Time

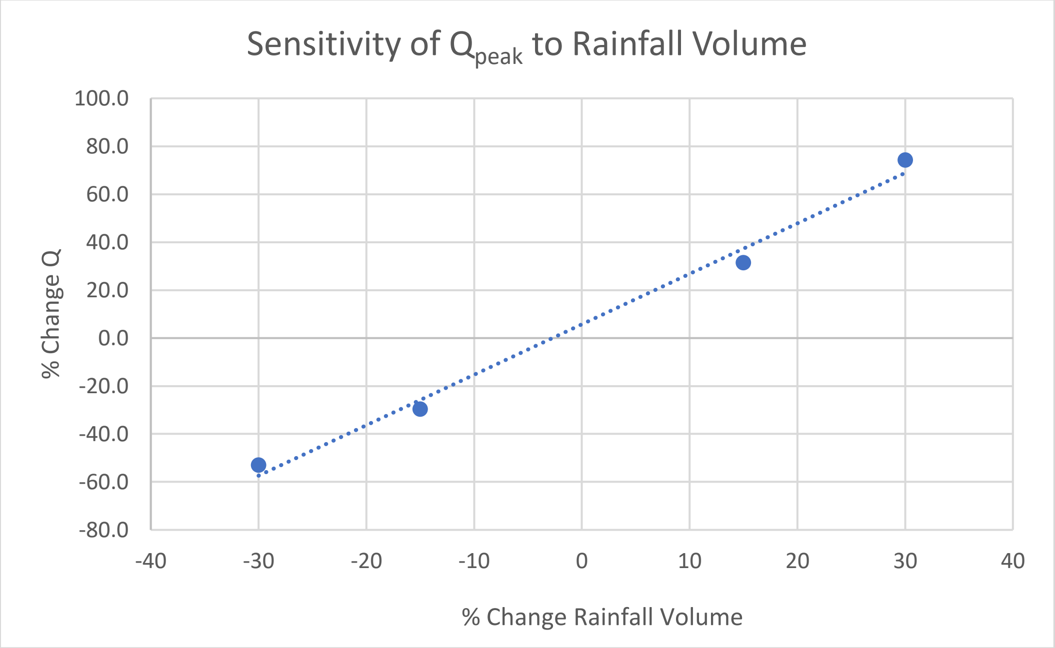


Figure 8-3: Sensitivity of Peak Runoff Rates to Rainfall Volume

Prepared by:

E.J.W. FLEDDERUS
100502141
June 10,2024

Elliott Fledderus, P.Eng.
Jewell Engineering Inc.

B. C. KEENE
Jun 10/24

Bryon Keene, P.Eng.
Jewell Engineering Inc.

9 References

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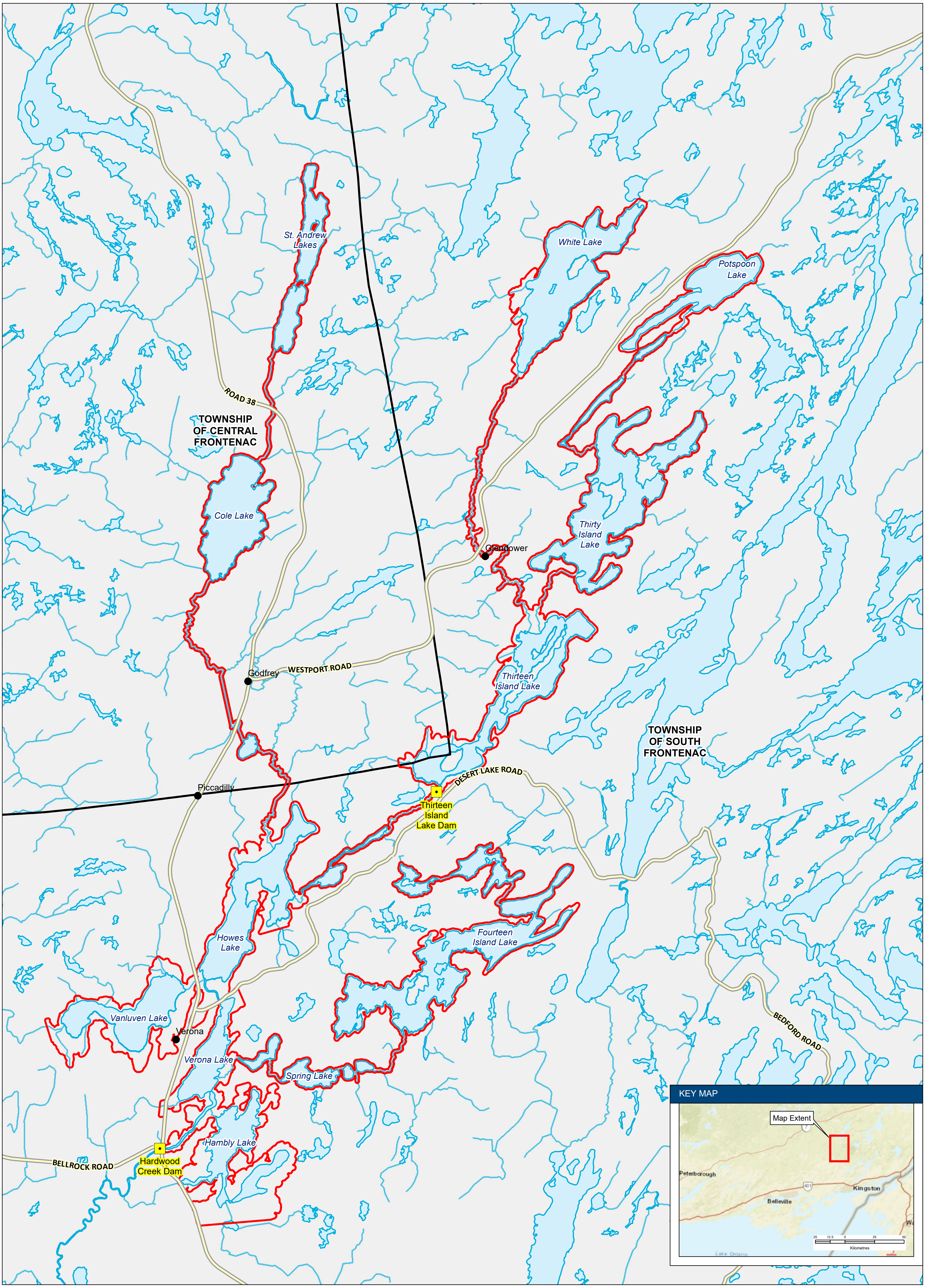
Appendix A-1:
Quinte Conservation – Napanee River Upper Lakes FHIMP Study Area



Quinte CONSERVATION

DEPARTMENT:

Water Resources

TITLE:

FHIMP Application Area
Upper Napanee River

SCALE:	1:60,000	Moira River, Napanee Region and Prince Edward Region Watersheds. RR # 2, 2061 Old Highway # 2, Belleville, Ontario, K8N 4Z2. www.quinteconservation.ca, 613-968-3434 Produced by Quinte Conservation 2023-04-25 under license with the Ontario Ministry of Natural Resources. Copyright Quinte Conservation and the Queen's Printer for Ontario, 2023. Data is projected in NAD 83 UTM Zone 18N. Digital Mapping Sources: Base Map - Ontario Ministry of Natural Resources Imagery - 2008 Copyright © of Aéro-Photo (1961) Inc. – All Rights Reserved Imagery - DRAPE 2019 Ontario Ministry of Natural Resources Imagery - SCOOP 2018 Ontario Ministry of Natural Resources Key Map - ArcGIS Online Services Disclaimer: This map is for illustrative purposes only. Quinte Conservation makes no warranties and assumes no liability whatsoever regarding the truth, accuracy, currency, or completeness of this map and its associated data.	03	Area extension	25/04/23
SHEET:	1 of 1		02	Area extension	23/02/23
DRAWING:	C.D.		01	Draft for comment / review	02/09/22
CHECK:	C.P.		No.	REVISION	DD/MM/YY

LEGEND / NOTES

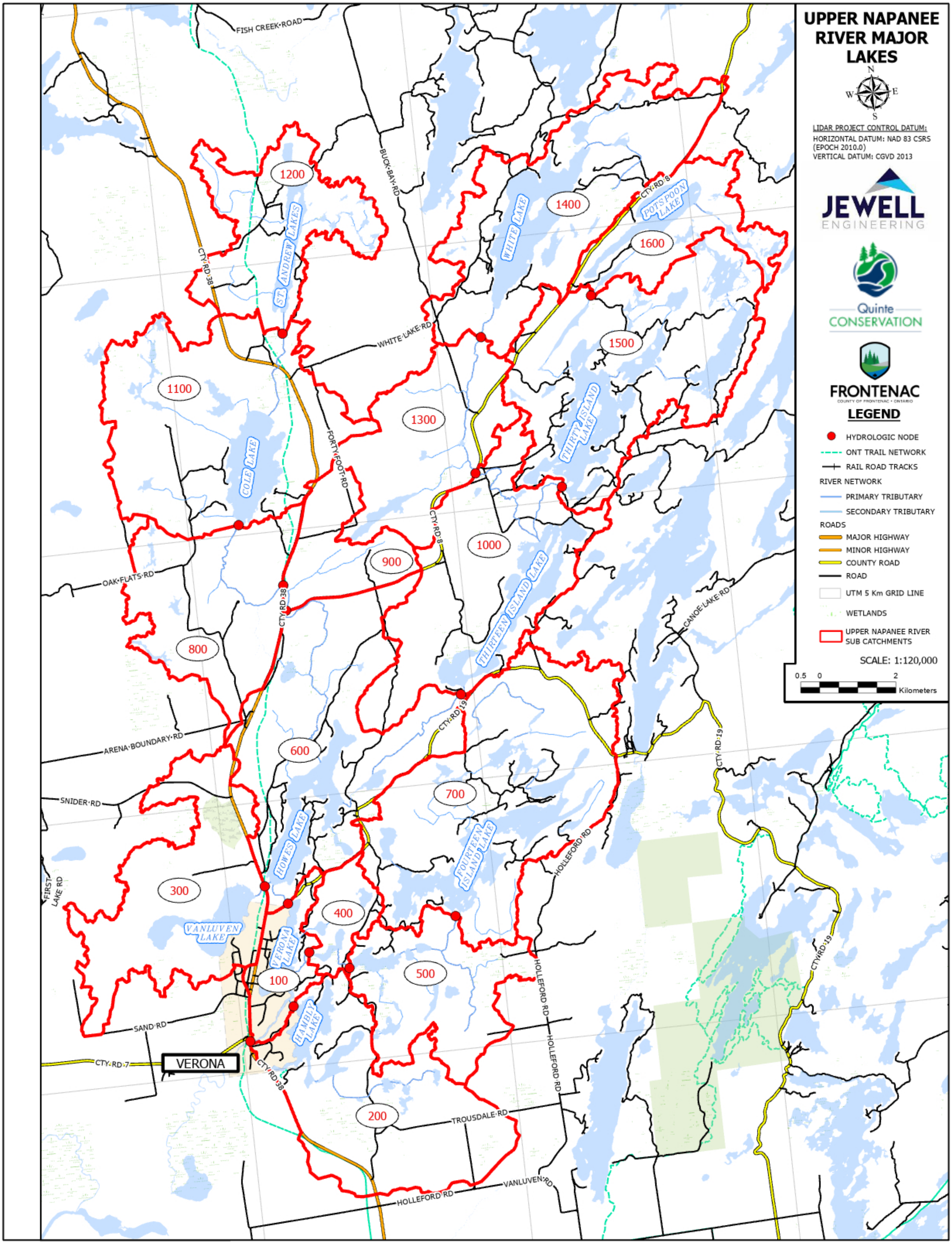
- 🟥 Application Area
- ▢ Lower/Single-Tier Municipality
- ● Population Centre
- Waterbody
- Watercourse
- ▣ Water Control Structure

NORTH

0 500 1,000 2,000
Metres

Path: E:\Projects\WR\FHIMP\2023\Upper Napanee River - Update.mxd   Original Document: 11 x 17 in

Appendix B-2:
Sub-Catchment Areas and Descriptions



UPPER NAPANEE RIVER MAJOR LAKES

LIDAR PROJECT CONTROL DATUM:
HORIZONTAL DATUM: NAD 83 CSRS (EPOCH 2010.0)
VERTICAL DATUM: CGVD 2013

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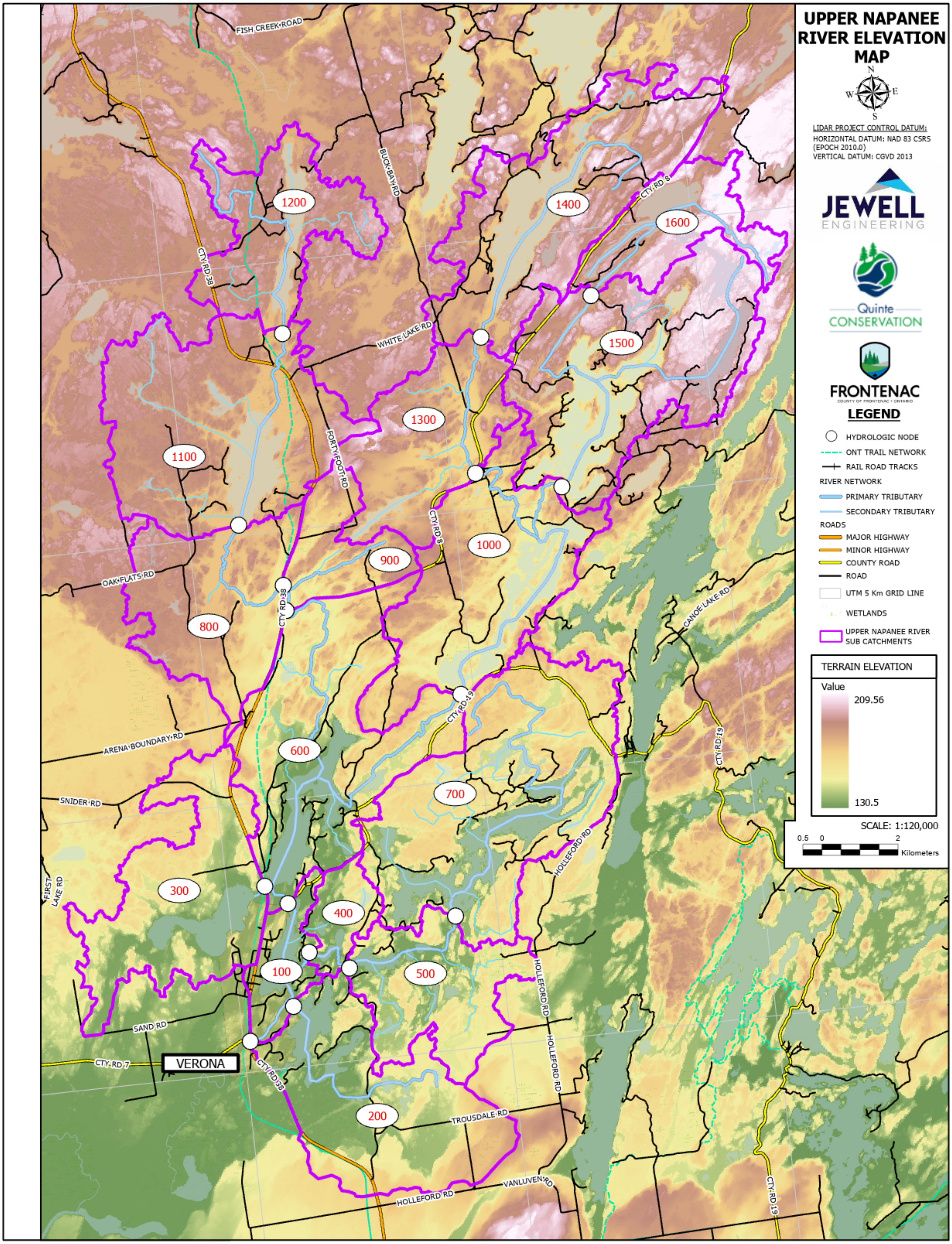

UPPER NAPANEE RIVER ELEVATION MAP

LIDAR PROJECT CONTROL DATUM:
HORIZONTAL DATUM: NAD 83 CSRS (EPOCH 2010.0)
VERTICAL DATUM: CGVD 2013

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LEGEND

- ○ HYDROLOGIC NODE
- ONT TRAIL NETWORK
- RAIL ROAD TRACKS
- RIVER NETWORK
  - PRIMARY TRIBUTARY
  - SECONDARY TRIBUTARY
- ROADS
  - MAJOR HIGHWAY
  - MINOR HIGHWAY
  - COUNTY ROAD
  - ROAD
- UTM 5 Km GRID LINE
- WETLANDS
- UPPER NAPANEE RIVER SUB CATCHMENTS

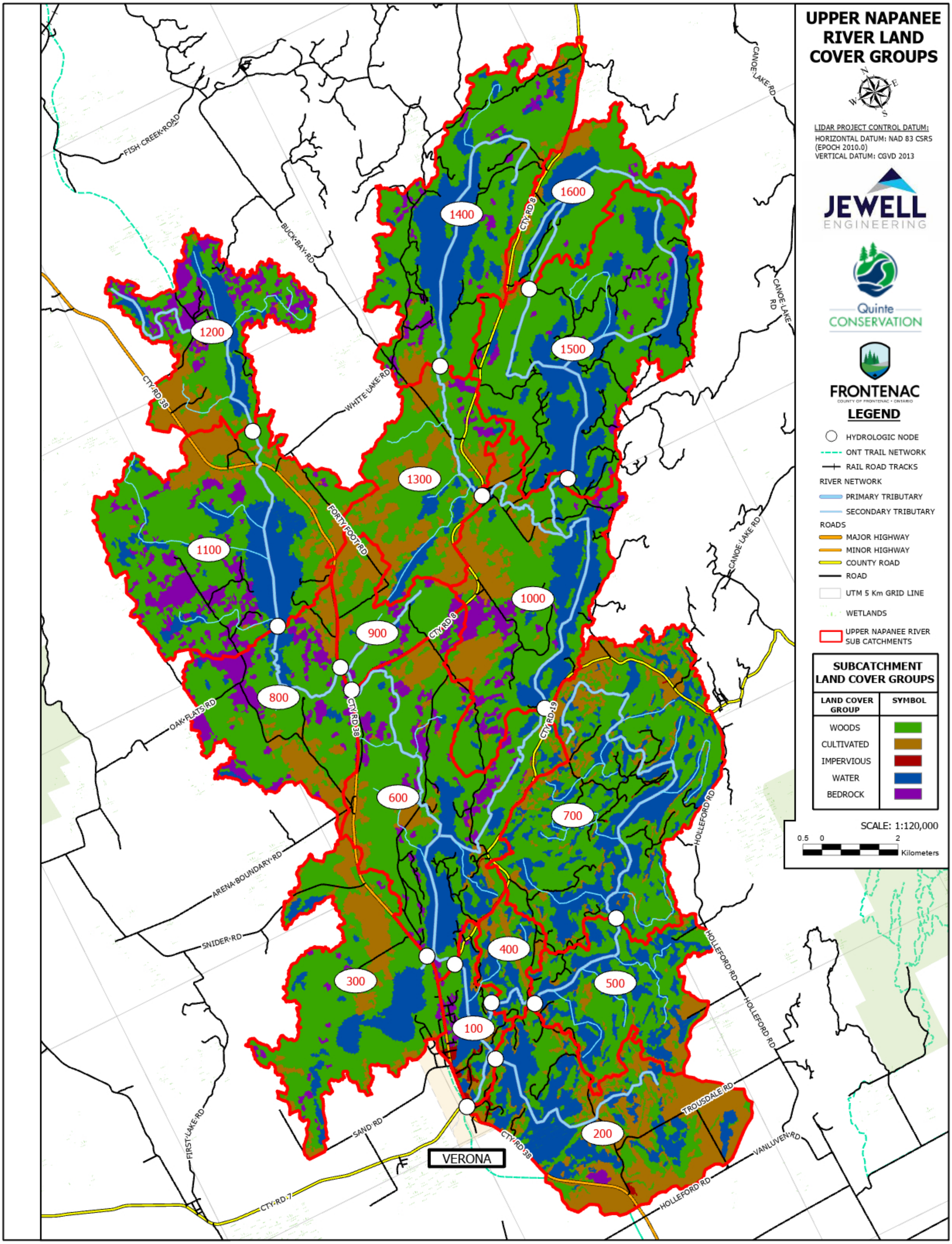
TERRAIN ELEVATION

Value
209.56
130.5

SCALE: 1:120,000

Appendix B:
Soil and Land Cover Maps

UPPER NAPANEE RIVER LAND COVER GROUPS



LIDAR PROJECT CONTROL DATUM:

HORIZONTAL DATUM: NAD 83 CSRS (EPOCH 2010.0)

VERTICAL DATUM: CGVD 2013

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LEGEND

- ○ HYDROLOGIC NODE
- ONT TRAIL NETWORK
- RAIL ROAD TRACKS
- RIVER NETWORK
  - PRIMARY TRIBUTARY
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- ROADS
  - MAJOR HIGHWAY
  - MINOR HIGHWAY
  - COUNTY ROAD
  - ROAD
- UTM 5 Km GRID LINE
- WETLANDS
- UPPER NAPANEE RIVER SUB CATCHMENTS

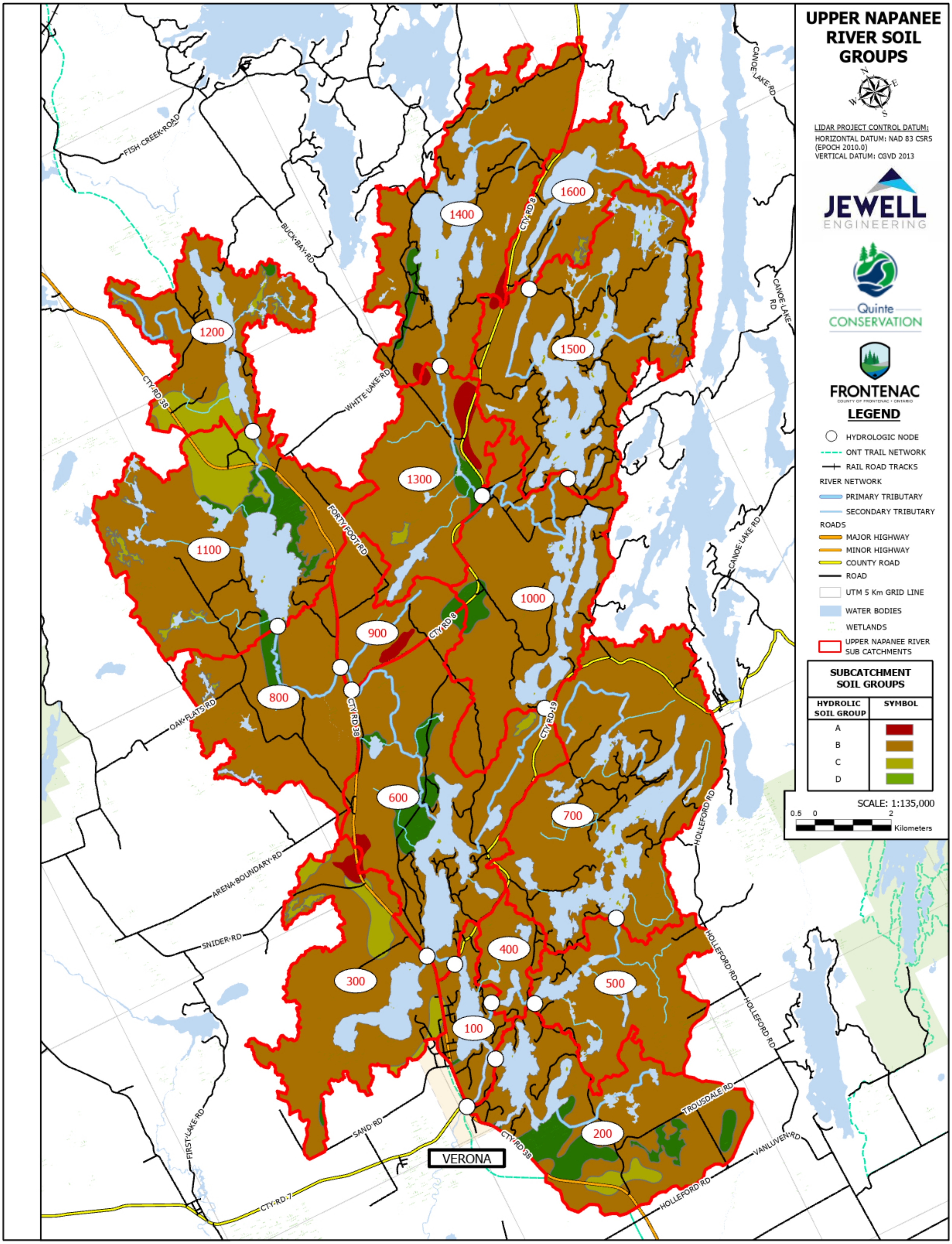
SUBCATCHMENT LAND COVER GROUPS

LAND COVER GROUP	SYMBOL
WOODS	🟩
CULTIVATED	🟫
IMPERVIOUS	🟥
WATER	🟦
BEDROCK	🟪

SCALE: 1:120,000

0.5 0 2 Kilometers

UPPER NAPANEE RIVER SOIL GROUPS



SUBCATCHMENT SOIL GROUPS

HYDROLIC SOIL GROUP	SYMBOL
A	🟥
B	🟫
C	🟨
D	🟩

Appendix C-1:
Hartington Snowmelt + Rainfall MSC Frequency Values

```
RASM2013A 03/2015                                                                                                Processed 2016-01-27

                                            METEOROLOGICAL SERVICE OF CANADA
                                     RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                    PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
************************************************************************************************************************************
 STATION : HARTINGTON IHD                                                                                         STATION NUMBER  6103367

 LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

 ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)

 SNOWMELT MODEL 1 - Eastern Canada Forested Basin

 CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                               NOTE : MODIFIED GUMBEL 12/82

      TOTAL %      START                                                                                                       MAX
  YR  DAYS VALID FLAG MAX   1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY   SNPK

 1968 198    72  **   M/D    2/ 2   2/ 1   2/ 1   1/30   1/29   1/28   1/28   1/28   1/28   3/10   3/ 9   1/14   1/14   1/14
                      .1MM    297    468    468    492    586    591    591    591    591    627    721    871    871    871
 1969 273   100       M/D   11/28   1/23   1/22   1/22   1/22  11/28  11/28   1/23   1/22   1/22   1/18   1/18   1/18   1/18
                      .1MM    310    332    392    392    392    475    539    643    703    732    871    925    925    925    547
 1970 242    89  **   M/D   12/10  12/10  12/10  12/ 9   3/22   3/21   3/20   3/19   3/19   3/19   3/20   3/18   3/13   3/ 4
                      .1MM    340    416    465    510    556    645    764    814    842    867   1139   1246   1250   1309
 1971 273   100       M/D    4/19   4/12   4/18   4/18   4/17   4/16   4/15   4/12   4/12   4/12   4/ 7   4/ 2   3/29   3/29
                      .1MM    225    422    580    729    828    953   1038   1171   1361   1509   1828   1994   2212   2212   2098
 1972 274   100       M/D    2/13   2/13   2/13   4/11   4/10   4/ 9   4/ 9   4/ 9   4/ 9   4/ 9   3/31   3/29   3/21   3/16
                      .1MM    302    381    449    517    572    611    611    611    611    611    887   1032   1337   1556    852
 1973 273   100       M/D   12/31   2/ 1   1/17   1/16   1/15   1/17   1/17   1/16   1/15   1/14   1/14   1/15   1/14  12/30
                      .1MM    288    318    424    484    519    583    665    725    759    784    878   1201   1257   1320    696
 1974 273   100       M/D    4/ 3   1/26   4/ 1   3/31   3/30   3/29   3/29   3/29   1/20   1/20   1/18   1/18   1/20   1/18
                      .1MM    301    385    541    646    801    847    847    847    864    919   1040   1040   1085   1090    628
 1975 273   100       M/D    3/19   3/18   3/17   3/17   3/16   3/16   3/13   3/12   3/12   3/12   3/ 6   2/16   2/23   2/18
                      .1MM    421    562    622    652    681    681    710    752    782    782    827    847   1269   1525    504
 1976 274   100       M/D   12/14   3/24   3/24   3/24   3/23   3/20   3/20   3/20   3/19   3/19   3/13   2/15   2/10   2/27
                      .1MM    249    433    568    747    777    809    944   1123   1218   1218   1251   1517   1727   1847   1157
 1977 273   100       M/D    3/12   3/11   3/10   3/ 9   3/ 8   3/ 7   3/ 6   3/ 5   3/ 4   3/ 3   2/26   2/24   3/ 4   2/11
                      .1MM    362    542    723    863    887    937   1006   1112   1389   1402   1560   1820   1874   2024   1275
 1978 273   100       M/D    1/24   1/24   4/11   4/11   4/10   4/ 9   4/ 7   4/ 6   4/ 6   4/ 4   3/31   3/27   3/20   3/14
                      .1MM    495    495    610    710    734    763    816    941   1041   1177   1614   2053   2354   2512   1664
 1979 273   100       M/D   12/31  12/31  12/30  12/30   3/ 1   3/ 3   3/ 3   3/ 1   3/ 1   2/28   2/23   2/21   2/21   2/21
                      .1MM    282    535    575    575    646    719    816    874    971    993   1237   1381   1381   1381    733
 1980 274   100       M/D    3/21   3/20   3/19   3/18   3/17   3/17   3/17   3/17   3/17   3/17   3/10   3/ 5   3/ 5   2/21
                      .1MM    349    529    546    600    678    678    678    678    678    678    718    726    726    797    356
 1981 273   100       M/D    2/19   2/18   2/17   2/16   2/15   2/15   2/15   2/15   2/11   2/10   2/ 8   2/ 1   1/26   1/26
                      .1MM    409    590    712    860    863    863    863    863    988   1230   1239   1309   1474   1474    565
 1982 273   100       M/D    3/25   3/12   3/11   3/11   3/11   3/11   3/19   3/18   3/11   3/11   3/11   3/11   3/11   3/11
                      .1MM    233    313    402    460    491    508    595    621    691    772   1197   1197   1197   1197    810
 1983 273   100       M/D   12/15  12/14  12/14   4/20   4/20   4/20   4/20   4/20   4/20  12/15  12/14  11/28  11/28  11/28
                      .1MM    191    236    236    251    251    251    251    251    251    347    392    470    470    626    168
 1984 274   100       M/D    2/14   2/13   2/12   2/11   2/11   2/11   2/11   2/11   2/11  12/ 5   2/ 2   2/ 2   1/24  11/15
                      .1MM    487    689    760    893    944    944    944    944    944    979   1197   1197   1319   1371    565
 1985 273   100       M/D    2/23   2/22   2/22   2/21   2/21   2/21   2/21   2/22   2/21   2/21   2/22   2/22   2/21   2/13
```

```
                        .1MM    410    674    796    886    939    979    979    998   1088   1168   1168   1803   1933   1991       865
1986   273   100        M/D    1/19   1/19   1/18   1/17   1/17   1/17   3/13   3/13   3/11   3/10   3/11   3/10   3/ 2   3/ 2
                        .1MM    290    453    573    637    663    708    752    752    819    913   1075   1168   1251   1251       798
1987   273   100        M/D    3/ 1   2/28   2/28   2/28   2/28   2/28   2/28   3/ 1   2/28   2/28   2/23   2/28   2/23   2/ 7
                        .1MM    257    377    422    422    422    448    483    638    758    758    789    800    831    842       465
1988   274   100        M/D   11/28  11/28  11/28  11/26  11/26  11/26  11/26  11/26  11/26  11/26  11/26   3/ 7  11/28  11/26
                        .1MM    380    705    705    740    740    740    740    740    740    740    783   1059   1088   1123       634
1989   273   100        M/D    3/27   3/26   3/25   3/24   3/24   3/24   3/24   3/24   3/24   3/24   3/14   3/14   3/ 4   3/ 4
                        .1MM    212    325    414    528    579    579    579    579    579    579    839    839    899    899       510
1990   273   100        M/D    2/22   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/ 8   1/ 3  12/31
                        .1MM    331    444    444    444    444    444    520    640    779    824    914   1054   1212   1362       540
1991   273   100        M/D   12/29  12/29  12/29   2/ 3   2/ 3   3/ 1   3/ 1   3/ 1   3/ 1   3/ 1   2/20   2/18   2/18   2/ 3
                        .1MM    390    390    390    394    394    498    498    498    498    498    712    854    864   1048       374
1992   274   100        M/D    3/26   3/26   3/25   3/25   3/ 6   3/26   3/25   3/25   3/25   3/25   3/25   3/ 7   3/ 6   3/ 5
                        .1MM    373    486    579    582    663    736    829    910    925    925    925   1010   1389   1610       413
1993   273   100        M/D    3/28   3/28   3/27   3/26   3/25   3/24   3/24   3/24   3/22   3/21   3/21   3/21   3/16   3/ 7
                        .1MM    195    375    501    582    672    762    821    821    866    915   1117   1158   1195   1368       891
1994   272   100        M/D    2/20   2/19   3/22   3/21   3/21   3/21   3/21   3/21   3/21   3/21   3/19   3/13   3/ 7   3/ 5
                        .1MM    209    326    423    538    578    618    654    735    806    864    992   1159   1258   1283       906
1995   273   100        M/D    1/14   1/13   1/12   1/12   1/12   1/12   1/12   3/ 6   3/ 5   3/ 5   3/ 5   1/12   2/18  12/16
                        .1MM    267    418    486    486    486    486    486    501    541    541    541    546    670    806       246
1996   274   100        M/D    2/20   2/20   1/16   2/20   2/20   2/19   2/19   2/19   1/16   1/16   1/14   1/14   1/16   1/14
                        .1MM    349    463    529    690    763    781    781    781    856    856   1088   1088   1306   1387       591
1997   273   100        M/D    3/25   2/20   2/19   3/25   3/25   3/25   3/25   3/25   3/25   3/25   3/20   3/14   3/10   3/ 1
                        .1MM    278    403    570    637    830    915    950   1008   1008   1008   1021   1044   1092   1232       646
1998   273   100        M/D    1/ 5   1/ 5   2/17   2/17   2/17   2/17   2/17   2/17   2/12   2/11   2/10   2/ 2   2/ 1   1/24
                        .1MM    206    242    282    344    383    383    383    383    420    465    507    564    577    587       335
1999   273   100        M/D    1/23   1/22   1/22   1/17   1/19   1/18   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17
                        .1MM    217    293    337    372    417    584    696    741    741    741    741   1021   1092   1092       585
2000   274   100        M/D    2/24   2/23   2/23   2/24   2/23   2/22   2/22   2/22   2/22   2/22   2/22   2/22   2/22   2/16
                        .1MM    298    425    503    659    786    821    821    821    821    821    849    880   1060   1068       594
2001   273   100        M/D    2/ 9  12/16   4/ 4   4/ 3   4/ 3   4/ 2   4/ 1   3/31   3/30   3/29   3/23   3/19   3/14   3/10
                        .1MM    425    503    517    625    719    805    844    884    935    979   1068   1478   1656   1744      1338
2002   273   100        M/D    3/ 2   2/20   2/19   3/27   2/20   2/16   2/15   2/15   2/15   2/15   2/16   2/15   2/10   2/10
                        .1MM    246    301    321    326    327    406    496    496    496    522    763    853    924    994       325
2003   273   100        M/D    3/20   3/20   3/20   3/20   3/20   3/20   3/17   3/17   3/17   3/16   3/12   3/ 8   3/17   3/12
                        .1MM    272    469    613    748    869   1025   1062   1184   1340   1429   1486   1508   1563   1709      1169
2004   274   100        M/D    3/ 5   3/ 4   3/ 3   3/ 2   3/ 1   3/ 1   2/29   2/28   2/28   2/28   2/28   2/21   2/19   2/19
                        .1MM    277    405    513    653    802    883    955   1004   1016   1033   1189   1215   1297   1317       841
2005   273   100        M/D   12/23   2/14   2/14   2/12   2/12   2/12   2/12   2/ 8   2/ 7   2/ 6   2/ 4   2/ 4  12/22  12/16
                        .1MM    207    333    333    359    359    359    359    472    616    633    637    637    801    837       301
2006   273   100        M/D   11/29  11/28  11/27  11/27  11/27  11/27  11/27  11/27  11/27  11/27  11/27  11/27  11/27  11/27
                        .1MM    482    717    780    780    780    780    780    780    780    780    780    780    780   1070       290
2007   273   100        M/D    3/13   3/13   3/12   3/11   3/10   3/10   3/10   3/10   3/10   3/10   3/ 1   3/ 3   3/ 1   2/22
                        .1MM    144    273    353    443    470    470    470    470    470    470    592    612    668    676       486
2008   274   100        M/D   12/23  12/22   1/ 6   1/ 5   3/31  12/23  12/23  12/22  12/22   3/26  12/23  12/22   3/12   3/ 7
                        .1MM    435    488    510    556    613    667    730    783    783    818    906   1353   1400   1445      1017
2009   273   100        M/D    2/11   2/11   2/10   2/10  12/24  12/24  12/24  12/24  12/24  12/24  12/14  12/14   2/11   2/10
                        .1MM    326    497    519    519    637    705    705    705    705    705    941   1009   1203   1413       681
2010   273   100        M/D   12/26  12/25  12/25  12/25  12/25  12/25  12/25  12/25  12/25  12/25  12/13  12/13  12/25  12/25
                        .1MM    159    276    330    338    338    338    351    404    404    404    456    530    623    623       219
2011   226    83   **   M/D    3/10   3/10   3/10   3/10   3/10   3/ 5   3/ 5   3/10   3/10   3/10   3/ 5   3/ 5   2/27   2/18
                        .1MM    421    544    602    665    696    744    867   1034   1224   1264   1587   1751   1923   1934
2012   274   100        M/D    1/17   1/23   1/23   1/23   1/23   1/23   1/23   1/17   1/23   1/23   1/17   1/13   1/12   1/ 6
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                         .1MM    151    172    180    290    293    297    305    323    401    451    553    619    649    704     130
 2013  273  100          M/D    3/11   3/10   3/ 9   3/ 8   3/ 7   3/ 6   3/ 6   3/ 6   1/ 6   1/ 6   2/25   1/11   1/ 6   1/ 6
                         .1MM    347    478    531    575    629    673    673    673    682    682    908    989   1122   1122     480
 2014  273  100          M/D    1/ 5   2/20   2/20   2/19   2/19   2/19   3/29   3/28   3/28   3/28   3/21   3/19   3/11   3/ 8
                         .1MM    321    504    590    639    647    647    703    869    889    889    953   1167   1379   1493     981
 2015  273  100          M/D   11/23   4/ 2   4/ 2   4/ 1   3/30   3/30   3/30   3/10   3/ 9   3/25   3/21   3/16   3/10   3/ 9
                         .1MM    215    385    447    464    518    580    580    606    650    670    804    975   1347   1454    1109
 2016  114   42   **     M/D   12/31  12/31  12/31  12/29  12/29  12/29  12/29  12/29  12/29  12/29  12/20  12/20  12/20  12/20
                         .1MM     57     84    100    118    134    134    134    134    134    134    141    141    141    141
*************************************************************************************************************************************

                               1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY

      MEAN EXTREME     (MM)    30.2   43.0   50.3   57.0   61.8   66.1   69.6   74.1   79.3   82.7   95.2  107.7  119.4  127.6
      STD. DEV.        (MM)     9.2   12.6   14.2   16.6   18.7   19.7   20.5   22.2   25.4   27.2   30.5   37.4   41.3   43.0
      YEARS ANALYSED             45     45     45     45     45     45     45     45     45     45     45     45     45     45
      MAX EXTREME      (MM)    49.5   71.7   79.6   89.3   94.4  102.5  106.2  118.4  138.9  150.9  182.8  205.3  235.4  251.2
      YEAR                     1978   2006   1985   1984   1984   2003   2003   2003   1977   1971   1971   1978   1978   1978


  ** NOTE **  VALUE IN FLAG INDICATES YEAR NOT INCLUDED IN ANALYSIS BASED ON % DAYS OPERATIONAL ( <90.0% )

                                                   METEOROLOGICAL SERVICE OF CANADA
                                            RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                           PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
*************************************************************************************************************************************
 STATION : HARTINGTON IHD                                                                                  STATION NUMBER  6103367

 LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

 ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)

 SNOWMELT MODEL 1 - Eastern Canada Forested Basin

 CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                            NOTE : MODIFIED GUMBEL 12/82

                                                RETURN PERIOD VALUES  (MM)  WITH 50% CONFIDENCE LIMITS
*************************************************************************************************************************************

RETURN PERIOD
 YEARS                                    1 DAY           2 DAY           3 DAY           4 DAY           5 DAY

   2                                28.66+/- 0.84   40.96+/- 1.16   47.97+/- 1.31   54.25+/- 1.53   58.76+/- 1.72
   5                                36.75+/- 1.42   52.09+/- 1.96   60.47+/- 2.20   68.88+/- 2.57   75.26+/- 2.90
  10                                42.11+/- 1.92   59.46+/- 2.64   68.75+/- 2.97   78.56+/- 3.47   86.19+/- 3.92
  25                                48.88+/- 2.59   68.78+/- 3.56   79.22+/- 4.00   90.80+/- 4.68   99.99+/- 5.28
  50                                53.91+/- 3.10   75.69+/- 4.26   86.98+/- 4.79   99.88+/- 5.60  110.23+/- 6.32
 100                                58.90+/- 3.61   82.55+/- 4.97   94.68+/- 5.58  108.89+/- 6.53  120.39+/- 7.36

RETURN PERIOD
 YEARS                                    6 DAY           7 DAY           8 DAY           9 DAY          10 DAY

   2                                62.84+/- 1.82   66.20+/- 1.89   70.47+/- 2.05   75.09+/- 2.34   78.23+/- 2.51
   5                                80.29+/- 3.07   84.36+/- 3.19   90.12+/- 3.45   97.50+/- 3.94  102.28+/- 4.23
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  10                             91.84+/- 4.14   96.38+/- 4.31  103.13+/- 4.66  112.33+/- 5.32  118.20+/- 5.71
  25                            106.43+/- 5.58  111.57+/- 5.81  119.56+/- 6.29  131.08+/- 7.17  138.32+/- 7.70
  50                            117.26+/- 6.68  122.84+/- 6.95  131.76+/- 7.52  144.99+/- 8.58  153.25+/- 9.21
 100                            128.00+/- 7.78  134.03+/- 8.10  143.86+/- 8.77  158.79+/-10.00  168.07+/-10.73

RETURN PERIOD
 YEARS                            15 DAY          20 DAY          25 DAY          30 DAY

   2                             90.17+/- 2.82  101.59+/- 3.45  112.62+/- 3.81  120.51+/- 3.96
   5                            117.15+/- 4.74  134.65+/- 5.81  149.15+/- 6.42  158.49+/- 6.67
  10                            135.01+/- 6.40  156.53+/- 7.85  173.33+/- 8.67  183.63+/- 9.01
  25                            157.58+/- 8.63  184.18+/-10.58  203.89+/-11.69  215.40+/-12.15
  50                            174.32+/-10.33  204.70+/-12.66  226.55+/-13.99  238.97+/-14.54
 100                            190.94+/-12.04  225.06+/-14.75  249.06+/-16.30  262.36+/-16.94

                                            METEOROLOGICAL SERVICE OF CANADA
                                     RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                    PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
************************************************************************************************************************************
 STATION : HARTINGTON IHD                                                                                  STATION NUMBER  6103367

 LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

 ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)

 SNOWMELT MODEL 2 - Western North America Mountain Basin

 CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                            NOTE : MODIFIED GUMBEL 12/82

      TOTAL %       START                                                                                                          MAX
  YR  DAYS VALID FLAG MAX   1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY    SNPK

 1968  198   72  **   M/D    2/ 2   2/ 1   2/ 1   3/16   3/15   3/15   3/15   3/15   3/15   3/10   3/ 9   3/ 9   3/ 9   3/ 9
                      .1MM    315    477    477    561    604    604    604    604    604    701    807    862    862    862
 1969  273  100       M/D    3/24   3/23   3/22   3/21   3/20   3/19   3/18   3/17   3/17   3/15   3/18   3/17   3/15   3/15
                      .1MM    441    462    560    649    835    866    934    967    967    988   1115   1274   1295   1295    692
 1970  242   89  **   M/D   12/10   4/ 8   4/ 7   4/ 6   4/ 6   3/21   3/20   4/ 2   4/ 1   4/ 1   3/26   3/21   3/19   3/19
                      .1MM    340    449    555    597    597    607    691    817    838    838    997   1446   1553   1553
 1971  273  100       M/D    4/19   4/19   4/18   4/17   4/16   4/15   4/15   4/12   4/12   4/11   4/ 9   4/ 2   3/29   3/29
                      .1MM    351    631    869    984   1148   1235   1315   1551   1831   1957   2221   2342   2466   2466   2309
 1972  274  100       M/D    2/13   4/14   4/13   4/12   4/11   4/11   4/11   4/10   4/ 9   4/ 9   4/ 3   3/29   3/22   3/21
                      .1MM    284    426    613    781    934   1022   1157   1190   1193   1193   1265   1454   1486   1737   1100
 1973  273  100       M/D   12/31   1/18   1/17   3/ 4   3/ 3   3/ 2   1/17   1/16   1/16   1/17   1/16   1/16   1/16  12/30
                      .1MM    259    393    530    596    690    693    761    803    803    803    854   1172   1175   1213    863
 1974  273  100       M/D    4/ 3   4/ 2   4/ 1   3/31   3/30   3/29   3/29   3/29   3/29   3/29   2/19   2/13   2/13   2/13
                      .1MM    397    470    646    738    888    934    934    934    934    934    980    993   1003   1003    692
 1975  273  100       M/D    3/19   3/18   3/18   3/17   3/18   3/18   3/18   3/18   3/17   3/17   3/17   3/12   3/12   3/18
                      .1MM    470    620    718    759    861    920   1027   1116   1157   1157   1243   1323   1386   1760    733
 1976  274  100       M/D    3/20   3/24   3/24   3/24   3/24   3/20   3/20   3/19   3/19   3/19   3/12   2/15   3/ 2   2/26
                      .1MM    341    640    817    817    817   1068   1245   1331   1331   1331   1399   1435   1753   2195   1243
 1977  273  100       M/D    3/28   3/11   3/10   3/ 9   3/ 9   3/ 7   3/ 6   3/ 5   3/ 4   3/ 3   2/26   2/24   3/ 4   2/27
                      .1MM    358    597    863   1055   1055   1078   1138   1264   1540   1553   1672   1918   1992   2086   1317
 1978  273  100       M/D    1/24   4/11   4/11   4/11   4/11   4/11   4/11   4/11   4/ 6   4/ 4   3/31   3/27   3/21   3/20
                      .1MM    509    533    808    924   1030   1120   1120   1120   1178   1288   1788   2247   2419   2694   1795
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1979  273  100        M/D    1/ 1  12/31  12/30   3/ 3   3/ 3   3/ 3   3/ 3   3/ 3   3/ 1   3/ 1   2/23   2/22   2/21   2/21
                      .1MM    278    548    588    608    671    760    923    969   1015   1062   1219   1382   1471   1536      803
1980  274  100        M/D    3/21   3/20   3/20   3/18   3/17   3/17   3/17   3/17   3/17   3/17   3/10   3/10   3/10   2/21
                      .1MM    452    700    700    729    788    788    788    788    788    788    792    792    792    805      466
1981  273  100        M/D    2/19   2/18   2/17   2/16   2/16   2/16   2/16   2/16   2/11   2/10   2/10   2/ 1   1/26   1/26
                      .1MM    362    607    764    937    937    937    937    937   1054   1284   1284   1354   1538   1538      632
1982  273  100        M/D    3/25   3/30   3/29   3/11   3/11   3/25   3/25   3/24   3/24   3/22   3/17   3/12   3/11   3/11
                      .1MM    268    453    466    479    479    518    769    832    832    862   1124   1507   1604   1604     1050
1983  273  100        M/D    1/10   1/10   1/10   1/10   1/10   1/10   1/10   1/10   1/10  12/15   1/10  12/23  12/23  12/14
                      .1MM    280    367    367    367    367    367    367    367    367    399    422    536    536    776      243
1984  274  100        M/D    2/14   2/13   2/13   2/11   2/11   2/11   2/11   2/11   2/11   2/11   2/ 2   2/ 2   1/24  11/15
                      .1MM    580    820    909   1029   1118   1182   1182   1182   1182   1182   1340   1340   1450   1491      735
1985  273  100        M/D    2/23   2/22   2/22   2/21   2/21   2/21   2/21   2/22   2/21   2/21   2/22   2/22   2/21   2/13
                      .1MM    437    727    872    962    992    996    996   1031   1121   1201   1209   1874   1964   2003      897
1986  273  100        M/D    1/19   1/19   1/18   1/17   1/17   1/17   3/13   3/19   3/18   3/17   3/13   3/10   3/10   3/10
                      .1MM    342    507    651    683    683    696    733    813    961    974   1278   1402   1402   1402     1023
1987  273  100        M/D    3/ 1   3/ 7   3/ 7   3/ 7   3/ 7   3/ 7   3/ 1   3/ 1   2/28   2/28   2/28   2/28   2/28   2/28
                      .1MM    239    372    372    372    372    372    400    624    744    744    744    943    998    998      642
1988  274  100        M/D    3/25  11/28  11/28   3/23   3/23   3/23   3/23   3/23   3/23   3/23  11/28   3/ 7  11/28  11/28
                      .1MM    467    723    764    841    841    841    841    841    841    841    922   1156   1259   1288      658
1989  273  100        M/D    3/27   3/26   3/25   3/24   3/24   3/24   3/24   3/24   3/24   3/24   3/14   3/14   3/ 4   3/ 4
                      .1MM    315    455    552    658    729    729    729    729    756    756   1006   1033   1066   1093      667
1990  273  100        M/D    1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/ 9   1/17   1/17
                      .1MM    342    507    507    507    507    507    559    680    836    849    895    967   1177   1321      540
1991  273  100        M/D   12/29  12/29   2/ 3   2/ 3   2/ 3   3/ 1   3/ 1   3/ 1   3/ 1   3/ 1   2/20   2/18   3/ 1   2/ 3
                      .1MM    390    390    470    470    470    569    569    569    569    569    731    854    917   1124      471
1992  274  100        M/D    3/26   3/25   3/ 8   3/ 7   3/ 6   3/ 6   3/ 6   3/25   3/25   3/25   3/25   3/ 7   3/ 7   3/ 6
                      .1MM    403    483    602    747    831    831    831    891    946    967   1008   1231   1559   1829      644
1993  273  100        M/D    1/ 4   1/ 3   3/27   3/26   3/25   3/24   3/24   3/22   3/21   3/24   3/24   3/21   3/16   3/ 8
                      .1MM    513    627    699    780    877    974    974    987   1008   1014   1234   1268   1288   1461      984
1994  272  100        M/D    2/20   3/22   3/22   3/21   3/21   3/21   3/22   3/21   3/21   3/22   3/21   3/14   3/15   3/14
                      .1MM    264    414    579    659    663    667    678    758    821    868   1219   1340   1422   1451      959
1995  273  100        M/D    3/ 7   1/13   1/12   1/12   1/12   1/12   3/ 7   3/ 6   3/ 5   3/ 5   3/ 5   3/ 5   2/19  12/16
                      .1MM    284    418    486    486    486    486    575    648    688    688    688    688    785    806      392
1996  274  100        M/D   11/11   1/18   1/16   1/16   2/20   2/20   2/19   2/20   2/20   2/19   1/16   2/ 8   2/19   1/27
                      .1MM    382    476    609    720    823    946    964    986   1024   1042   1093   1205   1321   1397      804
1997  273  100        M/D    3/25   3/28   3/27   3/27   3/25   3/25   3/25   3/25   3/25   3/25   3/25   3/14   3/14   3/ 1
                      .1MM    278    474    656    744    989   1077   1077   1124   1157   1157   1157   1180   1180   1292      732
1998  273  100        M/D    1/ 7   3/ 8   1/ 5   1/ 5   1/ 3   1/ 2   1/ 2   1/ 2   1/ 2   1/ 2   2/24   2/18   2/17   2/25
                      .1MM    254    363    466    486    541    587    607    617    617    617    722    856   1018   1110      395
1999  273  100        M/D    1/23   3/17   2/10   2/10   3/17   1/18   1/17   1/17   1/17   1/17   2/ 2   1/17   1/18   1/17
                      .1MM    245    291    341    341    383    476    573    586    586    586    588    827    963   1169      585
2000  274  100        M/D    2/24   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23
                      .1MM    339    497    562    712    838    838    838    838    838    838    883    883   1118   1154      610
2001  273  100        M/D    2/ 9  12/16   4/ 4   4/ 4   4/ 4   4/ 3   4/ 2   4/ 1   3/31   3/30   3/29   3/21   3/15   3/12
                      .1MM    424    551    690    867   1034   1165   1254   1258   1262   1282   1295   1688   1785   1880     1493
2002  273  100        M/D    3/ 2   2/20   2/19   3/27   1/23   1/22   2/15   2/15   2/15   3/27   2/19   2/15   2/10   1/23
                      .1MM    216    335    355    383    438    451    542    542    542    548    709    896    968   1140      398
2003  273  100        M/D    3/17   3/20   3/20   3/20   3/20   3/17   3/17   3/17   3/16   3/16   3/16   3/16   3/17   3/16
                      .1MM    300    488    683    864   1021   1114   1296   1452   1550   1621   1621   1621   1748   1846     1303
2004  274  100        M/D   12/10  12/10   3/ 3   3/ 2   3/ 1   3/ 1   2/29   2/28   2/28   2/28   2/29   2/28   3/ 1   2/28
                      .1MM    492    508    621    811    970   1050   1114   1135   1135   1135   1249   1316   1386   1471      930
2005  273  100        M/D    1/13   2/14   2/14  12/30  12/30  12/30  12/30  12/30   2/ 7   2/ 7  12/30  12/22  12/22  12/22
                      .1MM    199    350    350    425    489    489    489    489    637    637    766    778   1044   1044      360
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 2006  273  100       M/D   11/29  11/28  11/27  11/27  11/27  11/27  11/27  11/27  11/27  11/27   1/ 4   1/ 4  12/25  12/23
                      .1MM    426    730    780    780    780    780    780    780    780    780    933    933   1096   1223    290
 2007  273  100       M/D    3/13   3/13   3/12   3/11   3/10   3/10   3/10   3/10   3/10   3/10   3/10   3/ 3   3/ 1   3/ 1
                      .1MM    198    385    465    562    572    572    572    572    572    572    648    687    707    707    535
 2008  274  100       M/D   12/23  12/22   1/ 6   1/ 5   4/ 1   3/31   3/31   3/31   3/28   3/27   3/26   3/18   3/15   3/ 8
                      .1MM    500    530    646    666    781    907    908    908    953   1000   1082   1416   1583   1593   1200
 2009  273  100       M/D    2/11   2/11   3/ 6   3/ 5  12/24  12/24  12/24  12/24  12/24   2/26  12/14  12/ 9   2/11   2/11
                      .1MM    381    574    577    583    677    725    725    725    725    743    981   1035   1318   1492    704
 2010  273  100       M/D    1/24   1/24   1/24   1/24   1/24   1/24   1/19   1/19   1/19   1/16   1/14   1/14   1/ 1  12/27
                      .1MM    442    850    871    871    871    871    880    901    901    947   1045   1045   1053   1083    457
 2011  226   83  **   M/D    3/10   3/10   3/16   3/16   3/16   3/ 5   3/ 5   3/10   3/10   3/10   3/ 5   2/27   2/27   2/18
                      .1MM    420    563    657    661    661    740    883   1022   1305   1309   1629   1778   1917   2032
 2012  274  100       M/D   11/24   1/31   1/31   1/23   1/23   1/23   1/26   1/26   1/24   1/23   1/23   1/17   1/17   1/17
                      .1MM    152    161    161    236    236    236    271    271    310    398    461    543    606    650    187
 2013  273  100       M/D    3/11   3/10   3/10   3/ 9   3/ 8   3/ 7   3/ 6   3/ 6   3/ 6   3/ 6   2/27   1/11   1/ 6   2/25
                      .1MM    499    673    809    838    851    881    893    893    893    893    993   1091   1144   1159    677
 2014  273  100       M/D    4/ 7   2/20   2/20   4/ 4   4/ 3   4/ 2   4/ 1   3/31   3/30   3/29   3/28   3/19   3/15   3/10
                      .1MM    358    500    589    727    740    854    934   1048   1086   1158   1334   1536   1633   1827   1038
 2015  273  100       M/D    4/ 3   4/ 2   4/ 2   4/ 2   3/30   3/30   3/30   3/30   3/30   3/26   3/21   3/16   3/10   3/ 9
                      .1MM    291    533    588    600    613    668    681    685    731    748    866    989   1367   1498   1140
 2016  114   42  **   M/D    1/ 9   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8  12/31  12/29  12/29  12/20  12/20
                      .1MM    205    219    219    219    219    219    219    219    219    258    292    292    312    312
************************************************************************************************************************************

                            1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY

      MEAN EXTREME    (MM)   35.6   51.5   61.3   68.5   74.9   79.7   84.2   88.3   92.8   95.5  106.8  120.8  131.6  141.6
      STD. DEV.       (MM)   10.0   14.0   16.8   19.6   22.5   24.7   25.7   27.5   30.2   31.8   34.8   39.9   41.6   44.6
      YEARS ANALYSED           45     45     45     45     45     45     45     45     45     45     45     45     45     45
      MAX EXTREME     (MM)   58.0   85.0   90.9  105.5  114.8  123.5  131.5  155.1  183.1  195.7  222.1  234.2  246.6  269.4
      YEAR                   1984   2010   1984   1977   1971   1971   1971   1971   1971   1971   1971   1971   1971   1978


  ** NOTE **  VALUE IN FLAG INDICATES YEAR NOT INCLUDED IN ANALYSIS BASED ON % DAYS OPERATIONAL ( <90.0% )

                                            METEOROLOGICAL SERVICE OF CANADA
                                     RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                    PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
************************************************************************************************************************************
 STATION : HARTINGTON IHD                                                                                   STATION NUMBER  6103367

 LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

 ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)

 SNOWMELT MODEL 2 - Western North America Mountain Basin

 CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                             NOTE : MODIFIED GUMBEL 12/82

                                         RETURN PERIOD VALUES  (MM)  WITH 50% CONFIDENCE LIMITS
************************************************************************************************************************************

RETURN PERIOD
 YEARS                             1 DAY           2 DAY           3 DAY           4 DAY           5 DAY
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   2                             33.92+/- 0.92   49.16+/- 1.29   58.55+/- 1.55   65.29+/- 1.81   71.23+/- 2.07
   5                             42.76+/- 1.55   61.56+/- 2.18   73.44+/- 2.62   82.65+/- 3.05   91.10+/- 3.49
  10                             48.62+/- 2.10   69.78+/- 2.94   83.29+/- 3.53   94.15+/- 4.12  104.25+/- 4.72
  25                             56.01+/- 2.83   80.15+/- 3.97   95.75+/- 4.77  108.67+/- 5.56  120.87+/- 6.36
  50                             61.50+/- 3.39   87.85+/- 4.75  104.99+/- 5.70  119.45+/- 6.65  133.20+/- 7.61
 100                             66.95+/- 3.95   95.49+/- 5.53  114.16+/- 6.64  130.14+/- 7.75  145.44+/- 8.86

RETURN PERIOD
 YEARS                             6 DAY           7 DAY           8 DAY           9 DAY          10 DAY

   2                             75.60+/- 2.28   79.95+/- 2.37   83.77+/- 2.54   87.85+/- 2.78   90.24+/- 2.93
   5                             97.40+/- 3.83  102.68+/- 3.99  108.10+/- 4.28  114.51+/- 4.69  118.30+/- 4.93
  10                            111.84+/- 5.18  117.72+/- 5.39  124.21+/- 5.78  132.16+/- 6.33  136.89+/- 6.66
  25                            130.08+/- 6.98  136.73+/- 7.27  144.56+/- 7.79  154.47+/- 8.53  160.37+/- 8.98
  50                            143.62+/- 8.35  150.83+/- 8.70  159.66+/- 9.32  171.02+/-10.21  177.78+/-10.75
 100                            157.05+/- 9.73  164.82+/-10.14  174.65+/-10.85  187.44+/-11.90  195.07+/-12.52

RETURN PERIOD
 YEARS                            15 DAY          20 DAY          25 DAY          30 DAY

   2                            101.13+/- 3.21  114.22+/- 3.68  124.82+/- 3.83  134.25+/- 4.11
   5                            131.85+/- 5.40  149.51+/- 6.20  161.54+/- 6.45  173.65+/- 6.92
  10                            152.18+/- 7.29  172.88+/- 8.38  185.85+/- 8.72  199.74+/- 9.35
  25                            177.88+/- 9.83  202.41+/-11.30  216.57+/-11.75  232.70+/-12.61
  50                            196.94+/-11.76  224.31+/-13.52  239.36+/-14.06  257.15+/-15.09
 100                            215.86+/-13.70  246.05+/-15.75  261.98+/-16.38  281.42+/-17.58

 ** WARNING ** : 100 YEAR VALUES IN  1971 BASED ON 10 DAYS ACCUMULATION
 ** WARNING ** : 100 YEAR VALUES IN  1971 BASED ON 15 DAYS ACCUMULATION
                                            METEOROLOGICAL SERVICE OF CANADA
                                     RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                    PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
************************************************************************************************************************************
 STATION : HARTINGTON IHD                                                                                  STATION NUMBER  6103367

 LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

 ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)

 SNOWMELT MODEL 3 - Western Canada Mountain Basin

 CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                            NOTE : MODIFIED GUMBEL 12/82

      TOTAL %      START                                                                                                      MAX
  YR  DAYS VALID FLAG MAX   1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY   SNPK

 1968  198   72  **   M/D    2/ 2   2/ 1   3/18   3/16   3/16   3/15   3/15   3/15   3/15   3/15   3/ 9   3/ 9   3/ 9   3/ 9
                      .1MM    296    439    477    559    710    753    753    753    753    753    915    974    974    974
 1969  273  100       M/D    3/24   3/24   3/22   3/21   3/20   3/20   3/19   3/18   3/17   3/17   3/22   3/17   3/15   3/15
                      .1MM    463    533    545    618    779    849    866    915    933    933   1110   1428   1436   1436    713
 1970  242   89  **   M/D   12/10   4/ 8   4/ 7   4/ 6   4/ 6   4/ 8   4/ 7   4/ 6   4/ 6   4/ 6   4/ 1   3/21   3/20   3/19
                      .1MM    340    485    568    593    593    764    846    872    872    872   1078   1290   1653   1662
 1971  273  100       M/D    4/19   4/19   4/19   4/18   4/18   4/17   4/16   4/15   4/12   4/12   4/ 9   4/ 3   3/29   3/29
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                     .1MM    387    646    872   1072   1221   1313   1446   1512   1739   1966   2357   2381   2522   2522   2357
1972  274  100       M/D    2/13  12/ 9   4/13   4/12   4/14   4/13   4/13   4/12   4/11   4/11   4/10   4/ 1   3/29   3/22
                     .1MM    284    397    579    719    856   1040   1185   1325   1450   1541   1559   1647   1732   1964   1345
1973  273  100       M/D   12/31   1/18   1/17   3/ 4   3/ 3   3/ 2   1/17   1/16   1/16   1/17   1/16   1/16  12/30  12/26
                     .1MM    259    433    568    679    760    763    790    815    815    815    851   1169   1174   1217    913
1974  273  100       M/D    4/ 3   4/ 3   3/ 4   4/ 1   3/30   3/30   3/29   3/29   3/29   3/29   2/21   2/19   2/13   3/ 6
                     .1MM    387    489    644    693    816    917    963    963    963    963   1115   1153   1162   1163    754
1975  273  100       M/D    3/19   4/17   4/16   4/15   4/14   4/13   4/13   4/13   3/17   3/17   3/12   3/17   3/12   3/19
                     .1MM    466    599    791    941   1032   1041   1041   1041   1049   1049   1112   1170   1233   1751    883
1976  274  100       M/D    3/25   3/24   3/24   3/24   3/24   3/20   3/20   3/20   3/19   3/19   3/13   3/12   3/ 3   2/27
                     .1MM    470    759    909   1142   1142   1176   1326   1558   1625   1625   1645   1693   1995   2205   1322
1977  273  100       M/D    3/12   3/11   3/10   3/ 9   3/ 9   3/ 9   3/ 7   3/ 6   3/ 4   3/ 4   2/27   2/24   3/ 4   2/27
                     .1MM    431    656    979   1138   1258   1258   1267   1309   1554   1675   1749   2016   2132   2206   1332
1978  273  100       M/D    1/24   4/11   4/11   4/11   4/11   4/11   4/11   4/11   4/11   4/11   4/ 5   3/31   3/27   3/21
                     .1MM    477    481    735    826    909   1059   1192   1384   1664   1664   1955   2385   2687   2930   1910
1979  273  100       M/D   12/31  12/31  12/30  12/30   3/ 3   3/ 3   3/ 3   3/ 3   3/ 1   3/ 1   2/23   3/ 3   3/ 1   2/21
                     .1MM    250    497    537    537    565    633    773    803    853    883   1026   1313   1393   1641    952
1980  274  100       M/D    3/21   3/20   3/20   3/18   3/17   3/17   3/17   3/17   3/17   3/17   3/17   3/17   3/17   3/17
                     .1MM    515    767    767    782    824    824    824    824    824    824    824    824    824    824    502
1981  273  100       M/D    2/18   2/18   2/17   2/16   2/16   2/16   2/16   2/16   2/11   2/10   2/10   2/ 1   1/26   1/26
                     .1MM    330    651    828    985    985    985    985    985   1083   1313   1313   1383   1538   1538    665
1982  273  100       M/D    3/31   3/30   3/30   3/31   3/30   3/30   3/30   3/24   3/24   3/25   3/20   3/12   3/11   3/11
                     .1MM    518    691    728    818    991    991    991   1007   1044   1262   1397   1528   1903   1933   1156
1983  273  100       M/D    2/ 2   2/ 2   2/ 2   1/31   1/30   1/30   1/30   1/30   1/30   1/25   1/23   1/30   1/10   1/10
                     .1MM    380    538    538    556    566    566    566    566    566    581    623    636   1007   1007    260
1984  274  100       M/D    2/14   2/13   2/13   2/11   2/13   2/11   2/11   2/11   2/11   2/11   2/ 3   2/ 2   1/24   1/24
                     .1MM    730    938   1005   1124   1209   1267   1396   1396   1396   1396   1467   1527   1637   1637    858
1985  273  100       M/D    2/23   2/22   2/22   2/21   2/21   2/21   2/21   2/22   2/21   2/21   2/21   2/22   2/21   2/13
                     .1MM    412    701    820    910    925    925    925    935   1025   1093   1093   1679   1844   1866    912
1986  273  100       M/D    3/26   3/25   3/25   3/23   3/23   3/23   3/23   3/19   3/18   3/18   3/13   3/10   3/10   3/10
                     .1MM    523    703    703    792    792    792    792   1023   1153   1153   1403   1495   1495   1495   1116
1987  273  100       M/D   11/26   4/ 3  11/24  11/23  11/23  11/23  11/23   3/ 1   2/28   2/28   2/28   2/28   2/28   3/ 7
                     .1MM    231    344    389    420    420    420    420    536    656    656    656    799   1042   1044    694
1988  274  100       M/D    3/25   3/25   3/24   3/23   3/23   3/23   3/23   3/23   3/23   3/23   3/12   3/ 7  11/28  11/28
                     .1MM    410    723    843    913    913    913    913    913    913    913    944   1175   1217   1373    658
1989  273  100       M/D    3/28   3/27   3/26   3/25   3/24   3/24   3/24   3/24   3/24   3/24   3/14   3/14   3/ 4   3/ 4
                     .1MM    435    704    816    891    978    978    978    978   1018   1018   1208   1248   1268   1308    909
1990  273  100       M/D    1/17   1/17   1/17   3/10   3/10   3/10   3/10   1/17   1/17   1/17   2/ 9   2/22   1/17   1/17
                     .1MM    310    457    457    530    530    530    530    594    724    724    772    916    997   1191    556
1991  273  100       M/D   12/29   3/ 1   2/ 3   2/ 3   2/ 3   3/ 1   3/ 1   3/ 1   3/ 1   3/ 1  12/17   2/18   3/ 1   2/ 3
                     .1MM    390    427    495    495    495    627    627    627    627    627    768    854    975   1149    495
1992  274  100       M/D    3/26   3/25   3/25   3/ 7   3/ 6   3/ 6   3/25   3/25   3/25   3/25   3/25   3/25   3/ 7   3/ 6
                     .1MM    413    493    571    656    740    740    758    818    856    863   1196   1196   1415   1619    726
1993  273  100       M/D    1/ 4   1/ 3   3/28   3/27   3/26   3/25   3/24   3/24   3/24   3/24   3/24   3/21   3/16   3/ 8
                     .1MM    549    663    754    889    949   1024   1099   1099   1099   1139   1359   1366   1386   1542   1083
1994  272  100       M/D    2/20   2/19   3/22   4/ 2   4/ 1   3/31   3/30   4/ 2   3/28   3/31   3/22   3/21   3/21   3/15
                     .1MM    281    401    480    570    592    660    682    749    787    839   1277   1537   1537   1624   1065
1995  273  100       M/D    3/ 7   1/13   1/12   1/12   1/12   1/12   3/ 7   3/ 7   3/ 6   3/ 5   3/ 5   3/ 5   2/19   2/15
                     .1MM    250    417    485    485    485    485    490    629    685    725    725    725    800    810    429
1996  274  100       M/D   11/11   1/18   1/16   1/16   2/20   2/20   2/19   2/20   2/20   2/19   1/16   2/ 8   1/16   2/20
                     .1MM    395    435    570    660    730    827    845    867    890    908    976   1056   1159   1346    887
1997  273  100       M/D    3/25   3/28   3/27   3/27   3/25   3/25   3/25   3/25   3/25   3/25   3/25   3/25   3/14   3/14
                     .1MM    278    439    589    657    905    972    972   1002   1137   1249   1249   1249   1272   1272    823
1998  273  100       M/D    1/ 7   3/ 8   1/ 5   1/ 5   1/ 3   1/ 2   1/ 2   1/ 2   1/ 2   2/28   2/25   2/18   2/17   2/25
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                            .1MM    254    380    466    486    573    604    624    634    634    678    843    931   1093   1202     395
  1999  273  100            M/D    1/23   2/28   2/28   2/28   2/28   1/18   1/17   1/17   1/17   1/17   3/17   1/17   1/18   1/17
                            .1MM    215    280    280    320    320    400    480    480    480    480    600    682    786    954     585
  2000  274  100            M/D    2/24   2/23   2/23   2/24   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23
                            .1MM    336    500    547    673    838    838    838    838    838    838    883    883   1093   1154     610
  2001  273  100            M/D    4/ 8   4/ 7   4/ 6   4/ 5   4/ 4   4/ 4   4/ 3   4/ 2   4/ 2   4/ 2   3/30   3/21   3/19   3/12
                            .1MM    460    607    891   1064   1229   1365   1470   1538   1538   1538   1558   1873   1888   2003    1606
  2002  273  100            M/D    3/ 2   2/20   1/26   1/26   1/26   1/23   1/23   1/23   1/23   1/23   2/19   2/15   2/10   1/23
                            .1MM    216    356    464    464    464    567    567    567    595    655    753    896    968   1246     514
  2003  273  100            M/D    3/17   3/20   3/20   3/20   3/20   3/20   3/17   3/17   3/17   3/16   3/16   3/16   3/17   3/16
                            .1MM    288    477    677    827    954   1161   1231   1359   1565   1640   1640   1640   1768   1865    1322
  2004  274  100            M/D   12/10  12/10   3/ 3   3/ 2   3/ 1   3/ 1   2/29   2/28   2/28   2/28   2/29   2/28   3/ 1   2/28
                            .1MM    480    521    545    757    892    952    997   1005   1005   1005   1100   1137   1418   1471     930
  2005  273  100            M/D    1/13   2/14   2/14  12/30  12/30  12/30  12/30   3/22   2/ 7   2/ 7  12/30  12/30  12/22  12/22
                            .1MM    211    335    350    399    444    444    444    465    581    596    721    721    979    979     496
  2006  273  100            M/D   11/29  11/28  11/27  11/27  11/27  11/27  11/27  11/27   1/12   1/11   1/11   1/ 4   1/ 4  12/23
                            .1MM    468    730    780    780    780    780    780    780    824    899    945   1067   1158   1289     318
  2007  273  100            M/D    3/14   3/13   3/12   3/11   3/10   3/10   3/10   3/10   3/10   3/10   3/10   3/ 3   3/ 1   3/ 1
                            .1MM    264    443    503    578    588    588    588    588    588    588    664    687    707    707     535
  2008  274  100            M/D   12/23   1/ 7   1/ 6   1/ 5   4/ 1   4/ 1   3/31   3/31   3/31   3/31   3/26   3/19   3/15   3/15
                            .1MM    487    610    726    746    784    964   1067   1125   1125   1125   1245   1493   1663   1663    1281
  2009  273  100            M/D    2/11   2/11   3/ 6   3/ 5   3/ 6   3/ 6   3/ 5   3/ 5   3/ 5   2/27   2/26   2/26   2/11   2/11
                            .1MM    408    594    628    634    708    773    779    779    779    790    987    987   1304   1582     779
  2010  273  100            M/D    1/24   1/24   1/24   1/24   1/24   1/24   1/19   1/19   1/19   1/16   1/15   1/15   1/ 1  12/27
                            .1MM    430    816    823    823    823    823    831    838    838    871    923    923    931    946     525
  2011  226   83   **       M/D    3/18   3/17   3/16   3/16   3/16   3/13   3/12   3/11   3/10   3/10   3/ 5   2/27   2/27   2/18
                            .1MM    487    692    805    805    805    835    857    979   1374   1374   1665   1801   1844   2141
  2012  274  100            M/D   11/24   3/ 7   3/ 7   3/ 7   3/ 7   3/ 3   3/ 2   3/ 2   3/ 2   3/ 2   2/23   2/22   2/15   2/15
                            .1MM    152    246    246    246    246    325    377    377    377    377    444    519    646    646     273
  2013  273  100            M/D    3/11   3/11   3/10   3/10   3/ 9   3/ 9   3/ 7   3/ 7   3/ 7   3/ 7   2/27   1/11   1/ 9   2/25
                            .1MM    566    744    900    915    930    930    945    945    945    945   1015   1102   1134   1157     710
  2014  273  100            M/D    4/ 7   4/ 7   4/ 7   4/ 6   4/ 4   4/ 4   4/ 2   4/ 2   3/31   3/31   3/28   3/21   3/19   3/11
                            .1MM    408    676    760    813    984   1069   1074   1159   1224   1309   1538   1553   1708   1940    1102
  2015  273  100            M/D    4/ 3   4/ 2   4/ 2   4/ 2   3/30   4/ 2   4/ 2   4/ 3   4/ 2   4/ 2   3/30   3/25   3/17   3/14
                            .1MM    314    520    558    558    580    640    685    892   1098   1098   1158   1280   1355   1532    1140
  2016  114   42   **       M/D    1/10   1/ 9   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8  12/29  12/29  12/20  12/20
                            .1MM    293    489    503    503    503    503    503    503    503    503    560    560    580    580
**********************************************************************************************************************************************

                                  1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY


      MEAN EXTREME    (MM)    38.2   55.1   64.8   72.4   78.9   84.0   87.6   92.3   98.1  101.8  112.8  124.3  136.4  146.6
      STD. DEV.       (MM)    11.8   15.5   18.4   21.9   24.6   25.6   28.0   30.0   33.8   36.3   39.1   43.1   44.9   47.5
      YEARS ANALYSED            45     45     45     45     45     45     45     45     45     45     45     45     45     45
      MAX EXTREME     (MM)    73.0   93.8  100.5  114.2  125.8  136.5  147.0  155.8  183.1  196.6  235.7  238.5  268.7  293.0
      YEAR                    1984   1984   1984   1976   1977   2001   2001   1976   1971   1971   1971   1978   1978   1978


   ** NOTE **  VALUE IN FLAG INDICATES YEAR NOT INCLUDED IN ANALYSIS BASED ON % DAYS OPERATIONAL ( <90.0% )

                                                   METEOROLOGICAL SERVICE OF CANADA
                                            RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                           PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
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 STATION : HARTINGTON IHD                                                                                  STATION NUMBER  6103367

 LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

 ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)

 SNOWMELT MODEL 3 - Western Canada Mountain Basin

 CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                            NOTE : MODIFIED GUMBEL 12/82

                                         RETURN PERIOD VALUES  (MM)  WITH 50% CONFIDENCE LIMITS
*************************************************************************************************************************************

RETURN PERIOD
 YEARS                             1 DAY           2 DAY           3 DAY           4 DAY           5 DAY

   2                             36.25+/- 1.09   52.61+/- 1.43   61.74+/- 1.69   68.80+/- 2.02   74.85+/- 2.27
   5                             46.65+/- 1.83   66.29+/- 2.41   77.97+/- 2.85   88.18+/- 3.41   96.63+/- 3.83
  10                             53.54+/- 2.47   75.35+/- 3.25   88.71+/- 3.85  101.01+/- 4.60  111.05+/- 5.17
  25                             62.24+/- 3.33   86.80+/- 4.38  102.28+/- 5.19  117.22+/- 6.20  129.27+/- 6.97
  50                             68.70+/- 3.98   95.29+/- 5.24  112.35+/- 6.21  129.24+/- 7.42  142.79+/- 8.34
 100                             75.11+/- 4.64  103.72+/- 6.11  122.34+/- 7.24  141.18+/- 8.64  156.21+/- 9.72

RETURN PERIOD
 YEARS                             6 DAY           7 DAY           8 DAY           9 DAY          10 DAY

   2                             79.78+/- 2.36   82.99+/- 2.59   87.38+/- 2.77   92.59+/- 3.11   95.88+/- 3.35
   5                            102.44+/- 3.98  107.78+/- 4.36  113.92+/- 4.66  122.42+/- 5.24  127.97+/- 5.64
  10                            117.44+/- 5.38  124.19+/- 5.88  131.50+/- 6.30  142.17+/- 7.08  149.21+/- 7.62
  25                            136.40+/- 7.25  144.92+/- 7.93  153.70+/- 8.50  167.13+/- 9.55  176.06+/-10.27
  50                            150.46+/- 8.68  160.30+/- 9.49  170.17+/-10.17  185.64+/-11.42  195.97+/-12.29
 100                            164.42+/-10.11  175.57+/-11.06  186.52+/-11.84  204.02+/-13.31  215.74+/-14.32

RETURN PERIOD
 YEARS                            15 DAY          20 DAY          25 DAY          30 DAY

   2                            106.35+/- 3.60  117.19+/- 3.98  129.03+/- 4.14  138.75+/- 4.38
   5                            140.87+/- 6.07  155.29+/- 6.70  168.70+/- 6.97  180.71+/- 7.37
  10                            163.73+/- 8.19  180.52+/- 9.04  194.97+/- 9.42  208.49+/- 9.96
  25                            192.61+/-11.05  212.39+/-12.19  228.15+/-12.70  243.58+/-13.43
  50                            214.04+/-13.22  236.04+/-14.59  252.77+/-15.19  269.62+/-16.07
 100                            235.30+/-15.40  259.51+/-17.00  277.21+/-17.70  295.46+/-18.72

 ** WARNING ** : 100 YEAR VALUES IN  1971 BASED ON 15 DAYS ACCUMULATION
                                            METEOROLOGICAL SERVICE OF CANADA
                                     RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                    PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
*************************************************************************************************************************************
 STATION : HARTINGTON IHD                                                                                  STATION NUMBER  6103367

 LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

 ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)
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SNOWMELT MODEL 4 - Southern Ontario

CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                    NOTE : MODIFIED GUMBEL 12/82

     TOTAL %       START                                                                                                             MAX
 YR  DAYS VALID FLAG MAX    1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY   SNPK

1968  199   73  **   M/D     2/ 2   2/ 1   1/31   3/19   1/29   3/16   3/16   3/15   3/15   3/15   3/ 8   3/ 8   3/ 1   2/29
                     .1MM     243    385    401    442    540    582    674    762    762    762    929    949    969    989
1969  273  100       M/D     3/24   3/23   3/22   3/22   3/20   3/20   3/19   3/17   3/17   3/19   3/18   3/13   3/13   3/ 3
                     .1MM     359    415    471    516    663    708    742    788    833    857   1055   1182   1185   1208    715
1970  242   89  **   M/D    12/10  12/10  12/ 8  12/ 8  12/ 8  12/ 7   3/20   3/19   3/18   3/18   3/19   3/20   3/17   3/12
                     .1MM     360    398    424    462    472    477    561    643    688    709    933   1200   1347   1368
1971  273  100       M/D     4/12   4/19   4/18   4/18   4/18   4/18   4/18   4/17   4/18   4/17   4/12   4/ 8   4/ 3   3/29
                     .1MM     160    293    425    504    590    707    823    899   1007   1083   1564   1917   2070   2269   2104
1972  274  100       M/D     2/13   2/13   2/13   4/15   4/14   4/13   4/12   4/11   4/10   4/ 9   4/ 4   3/30   3/28   3/21
                     .1MM     294    334    372    482    573    682    799    875    926    972   1013   1218   1342   1614    966
1973  273  100       M/D    12/31   2/ 1   2/ 1   2/ 1   3/ 3  12/30   3/ 1  12/ 5  12/ 5  12/ 5   1/19   1/16   1/15  12/ 5
                     .1MM     330    399    409    424    463    486    537    624    654    654    840   1018   1052   1257    596
1974  273  100       M/D     4/ 3   3/ 3   4/ 1   3/31   3/30   3/29   3/29   3/29   3/29   3/26   2/21   2/19   2/12   3/ 3
                     .1MM     319    376    497    564    719    765    799    799    799    815    967   1033   1096   1104    741
1975  273  100       M/D     3/19   3/18   3/18   3/19   3/18   3/17   3/18   3/18   3/17   3/16   3/16   3/15   3/12   3/18
                     .1MM     357    490    545    609    741    792    884    940    991   1031   1168   1312   1416   1749    797
1976  274  100       M/D     3/27   1/25   3/25   3/24   3/24   3/23   3/21   3/20   3/19   3/19   3/18   2/15   2/10   2/28
                     .1MM     254    380    478    657    733    794    825   1008   1094   1170   1211   1408   1643   1793   1116
1977  273  100       M/D     3/12   3/12   3/11   3/10   3/ 9   3/ 9   3/ 9   3/ 9   3/ 8   3/ 4   3/ 3   2/24   2/24   2/24
                     .1MM     309    467    604    711    818    900    994   1055   1095   1200   1480   1804   1890   2013   1190
1978  273  100       M/D     1/24   1/24   4/18   4/17   4/16   4/16   4/15   4/13   4/11   4/11   4/ 6   4/ 1   3/27   3/23
                     .1MM     451    461    559    656    763    843    919   1027   1129   1349   1595   1910   2348   2474   1685
1979  273  100       M/D     1/25  12/31  12/30  12/30  12/30  12/30   3/ 3   3/ 3   3/ 1   3/ 1   2/28   3/ 1   2/21   2/21
                     .1MM     249    447    496    506    506    506    581    613    702    734    966   1186   1328   1600    866
1980  274  100       M/D     3/21   3/20   3/20   3/18   3/17   3/17   3/17   3/17   3/17   3/17   3/ 9   3/ 4   3/ 4   2/24
                     .1MM     357    475    512    562    646    683    698    698    698    698    767    790    790    817    377
1981  273  100       M/D     2/19   2/19   2/18   2/19   2/18   2/17   2/16   2/15   2/15   2/15   2/ 8   2/ 8   2/ 1   1/25
                     .1MM     325    562    664    760    862    916   1011   1034   1034   1034   1454   1454   1561   1721    493
1982  273  100       M/D     1/ 4   3/30   3/29   3/29  12/31   3/25   3/25   3/24   3/24   3/23   3/18   3/12   3/10   3/ 4
                     .1MM     215    336    386    428    436    454    639    703    744    767    964   1290   1391   1410    867
1983  273  100       M/D     1/10   1/10   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8  12/15  12/11  12/23  12/23  12/14
                     .1MM     303    303    312    312    312    312    312    312    312    357    399    481    481    707    219
1984  274  100       M/D     2/14   2/13   2/13   2/11   2/13   2/13   2/13   2/13   2/11   2/10   2/10   2/ 5   2/ 2   1/27
                     .1MM     394    556    602    653    788    837    920    952   1017   1054   1319   1328   1512   1521    744
1985  273  100       M/D     2/23   2/22   2/21   2/21   2/21   2/21   2/21   2/21   2/21   2/21   2/21   2/21   2/21   2/21
                     .1MM     357    558    685    763    809    841    850    886    960    988   1024   1517   1650   1782    857
1986  273  100       M/D     1/19   1/19   3/25   3/25   3/25   3/23   3/23   3/22   3/18   3/18   3/15   3/10   3/ 4   3/ 2
                     .1MM     224    342    421    531    575    636    680    717    793    884   1176   1496   1498   1592   1093
1987  273  100       M/D    11/26   2/28   2/27  11/23  11/23  11/23   2/28   2/28   2/28   2/27   2/22   2/26   2/21   2/21
                     .1MM     229    347    374    405    420    420    438    521    630    658    722    817    881    881    516
1988  274  100       M/D    11/28  11/28  11/28  11/28  11/28  11/26  11/28  11/28  11/28  11/28  11/26   3/ 6  11/28  11/26
                     .1MM     380    691    746    755    755    764    764    764    774    774    844    897   1119   1271    533
1989  273  100       M/D     1/ 7   3/27   3/26   3/25   3/24   3/23   3/23   3/23   3/20   3/23   3/14   3/ 9   3/ 4   3/ 4
                     .1MM     174    277    350    414    501    538    538    538    547    569    810    856    943    974    480
1990  273  100       M/D     2/22   1/17   2/21   2/21   2/19   2/18   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17
                     .1MM     305    366    387    387    401    410    452    538    651    678    838    895   1163   1290    531
1991  273  100       M/D    12/29  12/29  12/29  12/29  12/29   3/ 1   2/28   2/28   2/28   2/28   2/20   2/18   3/ 1   2/ 5
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                      .1MM     412    412    412    412    412    538    557    557    557    557    701    854    886   1128    388
 1992  274  100       M/D     3/26   3/25   3/25   3/24   3/25   3/25   3/25   3/25   3/24   3/24   3/19   3/ 8   3/ 6   3/ 3
                      .1MM     306    441    537    556    615    688    761    806    825    825    880   1016   1353   1586    389
 1993  273  100       M/D     1/ 4   1/ 3   1/ 3   1/ 3  12/31  12/30  12/29   3/24   3/24   3/22   3/23   3/21   3/16   3/ 8
                      .1MM     482    637    637    637    657    687    764    784    824    866   1195   1291   1329   1411    928
 1994  272  100       M/D     4/ 2   4/ 2   4/ 2   4/ 2   4/ 1   3/31   3/30   3/29   3/28   3/27   3/22   3/20   3/15   3/10
                      .1MM     221    267    344    498    534    594    639    685    722    750   1116   1397   1509   1564    981
 1995  273  100       M/D     1/14   1/13   1/12   1/12   1/12   1/12   1/12   1/12   3/ 5   3/ 4   3/ 1   2/16   2/17  12/16
                      .1MM     245    333    466    466    466    466    466    466    499    517    536    584    705    763    264
 1996  274  100       M/D     2/20   2/20   1/16   1/16   2/20   2/20   2/20   2/20   2/20   2/19   1/14   2/ 7   2/19   2/19
                      .1MM     336    407    464    576    665    734    766    806    838    865    987   1014   1186   1337    694
 1997  273  100       M/D     3/25   2/20   2/19   2/18   3/25   3/24   3/25   3/25   3/24   2/18   2/18   2/15   2/18   2/18
                      .1MM     300    414    518    587    657    671    693    716    729    789    973   1018   1078   1133    508
 1998  273  100       M/D     1/ 7   1/ 7   1/ 5   1/ 5   1/ 5   1/ 5   1/ 2   1/ 5   1/ 5   1/ 5  12/24  12/24  12/24  12/15
                      .1MM     254    274    470    490    509    523    534    561    576    576    691    782    796    827    326
 1999  273  100       M/D     1/23   1/22   1/21   1/21   1/20   1/18   1/17   1/17   1/16   1/16   1/16   1/16   1/17   1/17
                      .1MM     183    259    282    300    319    451    551    569    583    583    583    817    909   1110    585
 2000  274  100       M/D     2/24   2/23   2/24   2/24   2/23   2/22   2/24   2/23   2/22   2/21   2/20   2/16   2/21   2/16
                      .1MM     236    301    357    474    538    584    689    754    800    818    868    886   1125   1148    555
 2001  273  100       M/D     2/ 9  12/16  12/16   4/ 4   4/ 3   4/ 2   4/ 2   4/ 1   3/31   3/30   3/25   3/19   3/15   3/10
                      .1MM     427    474    474    511    593    653    710    729    742    767    872   1282   1472   1663   1300
 2002  273  100       M/D     3/ 2   3/ 1   2/28   2/28   1/23   1/22   1/21   1/20   1/20   1/23   1/20   1/22   2/ 6   1/22
                      .1MM     246    273    296    296    313    350    359    382    382    461    548    693    801   1000    306
 2003  273  100       M/D     3/20   3/20   3/20   3/20   3/20   3/20   3/20   3/20   3/19   3/17   3/15   3/ 8   3/17   3/12
                      .1MM     255    390    472    563    650    816    921   1016   1034   1136   1377   1418   1456   1625   1082
 2004  274  100       M/D    12/10  12/10  12/10  12/10   3/ 1   2/29   2/28   2/28   2/27   2/27  12/10   2/25   2/20   2/25
                      .1MM     496    496    496    496    574    638    716    762    798    816   1041   1164   1230   1368    857
 2005  273  100       M/D    12/23  12/22  12/21  12/21   2/11  12/18  12/18  12/23  12/22   2/ 6   2/ 1   2/ 1  12/21  12/16
                      .1MM     217    316    334    334    343    357    357    392    490    536    637    637    810    861    293
 2006  273  100       M/D    11/29  11/28  11/27  11/27  11/27  11/27  11/27  11/27  11/27  11/27   1/ 4   1/ 4  12/24  12/22
                      .1MM     469    688    780    780    780    780    780    780    780    780    871    882   1052   1098    290
 2007  273  100       M/D     3/14   3/13   3/12   3/11   3/10   3/10   3/10   3/10   3/10   3/10   3/ 1   2/27   2/27   2/21
                      .1MM     166    258    317    376    432    450    450    450    460    460    530    562    629    670    456
 2008  274  100       M/D    12/23  12/22   1/ 7   1/ 6   1/ 7   1/ 6   4/ 1   3/31   3/30   3/30   3/25  12/23   3/14   3/11
                      .1MM     373    414    456    524    571    640    730    813    841    862   1013   1212   1438   1482   1090
 2009  273  100       M/D     2/11   2/11   2/10  12/24  12/24  12/24   3/ 5   3/ 5   3/ 6   3/ 6   2/25   2/25   2/25   2/10
                      .1MM     255    369    419    457    552    581    590    590    603    699    887   1059   1059   1334    811
 2010  273  100       M/D     1/24   1/24   1/24   1/24   1/24   1/24   1/19   1/19   1/17   1/16   1/14   1/14   1/ 1  12/27
                      .1MM     494    780    794    794    794    794    798    812    835    853    922    922    926    958    392
 2011  226   83  **   M/D     3/10   3/10   3/10   3/10   3/10   3/ 5   3/ 5   3/10   3/10   3/10   3/ 5   3/ 4   3/10   3/ 5
                      .1MM     386    461    484    511    539    703    778    809    901    937   1254   1396   1569   1886
 2012  274  100       M/D    11/24   1/31   1/31   1/23   1/22   1/23   1/17   1/17   1/23   1/23   1/17   1/16   1/12   1/ 6
                      .1MM     152    157    157    257    262    262    273    286    359    419    499    572    625    679    170
 2013  273  100       M/D     1/30   1/29   1/29   3/ 9   3/ 8   3/ 8   3/ 6   3/ 6   3/ 5   3/ 6   2/26   1/12   1/ 8   1/ 6
                      .1MM     347    460    524    542    584    606    643    666    675    689    770    968   1096   1115    595
 2014  273  100       M/D     4/ 7   4/ 7   4/ 7   4/ 7   4/ 4   4/ 4   4/ 4   4/ 3   4/ 2   4/ 1   3/27   3/22   3/18   3/14
                      .1MM     367    486    559    711    789    862   1014   1060   1115   1179   1452   1479   1698   1798   1054
 2015  273  100       M/D     4/10   4/ 9   4/ 8   4/ 7   4/ 6   4/ 5   4/ 4   4/ 3   4/ 2   4/ 1   3/29   3/24   3/17   3/12
                      .1MM     250    401    447    511    534    580    621    749    928    965   1070   1220   1302   1554   1067
 2016  114   42  **   M/D    12/29   1/ 7   1/ 6   1/ 6   1/ 6   1/ 3   1/ 2   1/ 2  12/31  12/29  12/29  12/20  12/20  12/20
                      .1MM      34     54     77     77     77     91     95     95    109    116    148    168    168    181
************************************************************************************************************************************

                             1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY
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      MEAN EXTREME    (MM)   30.7   41.3   47.3   52.8   58.3   62.9   68.0   72.2   76.4   80.2   96.0  110.1  121.8  133.9
      STD. DEV.       (MM)    9.2   12.7   13.3   13.7   15.7   16.7   18.7   20.1   20.9   22.7   29.3   34.7   38.6   41.3
      YEARS ANALYSED            45     45     45     45     45     45     45     45     45     45     45     45     45     45
      MAX EXTREME     (MM)   73.0   93.8  100.5  114.2  125.8  136.5  147.0  155.8  183.1  196.6  235.7  238.5  268.7  293.0
      YEAR                   1984   1984   1984   1976   1977   2001   2001   1976   1971   1971   1971   1978   1978   1978


  ** NOTE **  VALUE IN FLAG INDICATES YEAR NOT INCLUDED IN ANALYSIS BASED ON % DAYS OPERATIONAL ( <90.0% )

                                            METEOROLOGICAL SERVICE OF CANADA
                                     RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                    PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
************************************************************************************************************************************
 STATION : HARTINGTON IHD                                                                                  STATION NUMBER  6103367

 LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

 ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)

 SNOWMELT MODEL 4 - Southern Ontario

 CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                             NOTE : MODIFIED GUMBEL 12/82

                                         RETURN PERIOD VALUES  (MM)  WITH 50% CONFIDENCE LIMITS
************************************************************************************************************************************

RETURN PERIOD
 YEARS                             1 DAY           2 DAY           3 DAY           4 DAY           5 DAY

   2                           29.23+/- 0.85   39.20+/- 1.17   45.16+/- 1.23   50.52+/- 1.26   55.69+/- 1.44
   5                           37.38+/- 1.43   50.45+/- 1.98   56.93+/- 2.07   62.64+/- 2.13   69.52+/- 2.43
  10                           42.77+/- 1.93   57.89+/- 2.67   64.72+/- 2.79   70.66+/- 2.88   78.68+/- 3.28
  25                           49.59+/- 2.61   67.30+/- 3.60   74.56+/- 3.77   80.80+/- 3.88   90.25+/- 4.43
  50                           54.65+/- 3.12   74.28+/- 4.31   81.87+/- 4.51   88.32+/- 4.64   98.84+/- 5.30
 100                           59.67+/- 3.64   81.21+/- 5.02   89.11+/- 5.25   95.78+/- 5.41  107.36+/- 6.17

RETURN PERIOD
 YEARS                             6 DAY           7 DAY           8 DAY           9 DAY          10 DAY

   2                           60.14+/- 1.54   64.91+/- 1.72   68.89+/- 1.85   72.98+/- 1.93   76.49+/- 2.09
   5                           74.91+/- 2.60   81.39+/- 2.90   86.61+/- 3.12   91.44+/- 3.24   96.50+/- 3.52
  10                           84.69+/- 3.51   92.31+/- 3.91   98.35+/- 4.21  103.66+/- 4.38  109.76+/- 4.75
  25                           97.05+/- 4.73  106.10+/- 5.28  113.18+/- 5.67  119.09+/- 5.91  126.50+/- 6.41
  50                          106.22+/- 5.66  116.33+/- 6.31  124.18+/- 6.79  130.55+/- 7.07  138.93+/- 7.67
 100                          115.32+/- 6.59  126.49+/- 7.36  135.10+/- 7.91  141.92+/- 8.23  151.26+/- 8.93

RETURN PERIOD
 YEARS                            15 DAY          20 DAY          25 DAY          30 DAY

   2                           91.18+/- 2.70  104.38+/- 3.20  115.50+/- 3.56  127.13+/- 3.81
   5                          117.07+/- 4.55  135.05+/- 5.39  149.63+/- 6.00  163.62+/- 6.41
  10                          134.22+/- 6.15  155.36+/- 7.28  172.23+/- 8.10  187.78+/- 8.66
  25                          155.88+/- 8.29  181.02+/- 9.82  200.78+/-10.92  218.30+/-11.68
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 50                            171.95+/- 9.92  200.05+/-11.75  221.96+/-13.07  240.95+/-13.98
100                            187.90+/-11.55  218.94+/-13.68  242.99+/-15.23  263.43+/-16.28

                                           METEOROLOGICAL SERVICE OF CANADA
                                    RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                   PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
************************************************************************************************************************************
STATION : HARTINGTON IHD                                                                                  STATION NUMBER  6103367

LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)

SNOWMELT MODEL 5 - Modification of Model 4

CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                             NOTE : MODIFIED GUMBEL 12/82

     TOTAL %      START                                                                                                         MAX
 YR  DAYS VALID FLAG MAX   1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY    SNPK

1968  198   72  **   M/D    2/ 2   2/ 1   2/ 1   3/16   3/15   3/15   3/15   3/15   3/15   3/10   3/ 9   3/ 9   3/ 9   3/ 9
                     .1MM    303    454    454    605    648    648    648    648    648    740    840    899    899    899
1969  273  100       M/D    3/24   3/24   3/22   3/21   3/20   3/20   3/19   3/18   3/17   3/17   3/18   3/17   3/15   3/15
                     .1MM    466    543    567    648    826    902    921    981   1003   1003   1162   1457   1466   1466    735
1970  242   89  **   M/D   12/10   4/ 8   4/ 7   4/ 6   4/ 6   4/ 7   4/ 6   4/ 2   4/ 1   4/ 1   3/26   3/21   3/19   3/19
                     .1MM    340    526    627    658    658    725    756    862    871    871   1018   1424   1617   1617
1971  273  100       M/D    4/19   4/19   4/18   4/18   4/17   4/16   4/15   4/12   4/12   4/12   4/ 9   4/ 2   3/29   3/29
                     .1MM    365    654    897   1084   1195   1358   1439   1552   1840   2027   2318   2422   2511   2511   2336
1972  274  100       M/D    2/13   4/14   4/13   4/12   4/11   4/13   4/12   4/11   4/10   4/10   4/10   3/30   3/29   3/21
                     .1MM    284    420    600    762    914   1064   1225   1377   1399   1399   1399   1578   1601   1872   1224
1973  273  100       M/D    3/ 7   1/18   1/17   3/ 4   3/ 3   3/ 2   3/ 1   3/ 1   3/ 1   3/ 1   1/16   1/16   1/16  12/26
                     .1MM    261    389    523    688    769    772    797    797    797    797    818   1136   1139   1179    896
1974  273  100       M/D    4/ 3   4/ 2   4/ 1   3/31   3/30   3/29   3/29   3/29   3/29   3/29   2/21   2/19   2/13   3/ 5
                     .1MM    431    496    664    746    896    942    961    961    961    961   1060   1098   1109   1127    732
1975  273  100       M/D    3/19   3/18   3/18   3/17   3/18   3/18   3/18   3/18   3/17   3/17   3/12   3/12   3/12   3/19
                     .1MM    453    596    687    718    827    877    984   1065   1096   1096   1165   1227   1290   1772    866
1976  274  100       M/D    3/20   3/24   3/24   3/24   3/24   3/20   3/20   3/20   3/19   3/19   3/13   3/12   3/ 3   2/26
                     .1MM    344    657    840   1022   1022   1078   1261   1443   1519   1519   1539   1587   1917   2193   1254
1977  273  100       M/D    3/12   3/11   3/10   3/ 9   3/ 9   3/ 7   3/ 6   3/ 5   3/ 4   3/ 3   2/26   2/24   3/ 4   3/ 3
                     .1MM    398    672    947   1141   1141   1152   1203   1325   1589   1602   1712   1948   2009   2099   1327
1978  273  100       M/D    1/24   4/11   4/11   4/11   4/11   4/11   4/11   4/11   4/11   4/11   4/ 4   3/29   3/27   3/20
                     .1MM    491    526    810    921   1022   1205   1327   1327   1327   1327   1763   2220   2457   2784   1856
1979  273  100       M/D    1/ 1  12/31  12/30   3/ 3   3/ 3   3/ 3   3/ 3   3/ 3   3/ 1   3/ 1   2/23   3/ 1   2/24   2/21
                     .1MM    268    525    565    579    633    716    869    905    949    985   1132   1332   1387   1593    892
1980  274  100       M/D    3/21   3/20   3/20   3/18   3/17   3/17   3/17   3/17   3/17   3/17   3/17   3/17   3/17   3/17
                     .1MM    496    747    747    765    812    812    812    812    812    812    812    812    812    812    491
1981  273  100       M/D    2/19   2/18   2/17   2/16   2/16   2/16   2/16   2/16   2/11   2/10   2/10   2/ 1   1/26   1/26
                     .1MM    381    628    784    952    952    952    952    952   1059   1289   1289   1359   1538   1538    637
1982  273  100       M/D    3/31   3/30   3/30   3/30   3/30   3/30   3/25   3/24   3/24   3/24   3/17   3/12   3/11   3/11
                     .1MM    404    601    641    641    641    641    895    950    990    990   1197   1555   1686   1686   1133
1983  273  100       M/D    2/ 2   2/ 2   2/ 2   1/31   1/30   1/30   1/30   1/30   1/30   1/25   1/23   1/30   1/10   1/10
                     .1MM    380    533    533    552    562    562    562    562    562    581    623    632   1000   1000    260
1984  274  100       M/D    2/14   2/13   2/13   2/11   2/13   2/13   2/11   2/11   2/11   2/11   2/ 3   2/ 2   1/24   1/24
                     .1MM    558    794    876    987   1112   1180   1306   1373   1373   1373   1379   1506   1549   1616    828
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1985  273  100       M/D    2/23   2/22   2/22   2/21   2/21   2/21   2/21   2/22   2/21   2/21   2/22   2/22   2/21   2/13
                     .1MM    421    700    842    932    950    950    950    980   1070   1143   1145   1797   1975   2003    908
1986  273  100       M/D    3/26   3/25   1/18   3/23   3/23   3/23   3/23   3/19   3/18   3/18   3/13   3/10   3/10   3/10
                     .1MM    384    603    628    709    709    709    709    976   1113   1113   1389   1493   1493   1493   1113
1987  273  100       M/D    3/ 8   3/ 7  11/24  11/23  11/23  11/23  11/23   3/ 1   2/28   2/28   2/28   2/28   2/28   2/28
                     .1MM    228    374    385    420    420    420    420    602    722    722    722    896   1033   1033    680
1988  274  100       M/D    3/25  11/28   3/24   3/23   3/23   3/23   3/23   3/23   3/23   3/23  11/28   3/ 7  11/28  11/28
                     .1MM    456    710    807    877    877    877    877    877    877    877    933   1165   1240   1369    658
1989  273  100       M/D    3/27   3/27   3/26   3/25   3/24   3/24   3/24   3/24   3/24   3/24   3/14   3/14   3/ 4   3/ 4
                     .1MM    324    539    676    768    865    865    865    865    905    905   1127   1167   1187   1227    795
1990  273  100       M/D    1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/17   1/ 9   1/17   1/17
                     .1MM    329    494    494    494    494    494    534    647    797    797    806    881   1071   1285    540
1991  273  100       M/D   12/29   3/ 1   2/ 3   2/ 3   2/ 3   3/ 1   3/ 1   3/ 1   3/ 1   3/ 1   2/20   2/18   3/ 1   2/ 3
                     .1MM    390    402    484    511    511    602    602    602    602    602    742    854    950   1165    492
1992  274  100       M/D    3/26   3/25   3/ 8   3/ 7   3/ 6   3/ 6   3/ 6   3/25   3/25   3/25   3/25   3/ 7   3/ 7   3/ 6
                     .1MM    388    468    588    727    811    811    811    848    894    903   1093   1196   1502   1733    694
1993  273  100       M/D    1/ 4   1/ 3   3/27   3/26   3/25   3/24   3/24   3/24   3/24   3/24   3/24   3/21   3/16   3/ 8
                     .1MM    553    667    718    792    883    974   1030   1030   1030   1070   1290   1299   1319   1487   1016
1994  272  100       M/D    2/20   3/22   3/22   3/21   3/21   3/21   3/21   3/21   3/21   3/22   3/21   3/21   3/15   3/15
                     .1MM    262    420    585    665    665    665    675    748    803    832   1297   1407   1472   1509   1029
1995  273  100       M/D    3/13   1/13   1/12   1/12   1/12   1/12   3/ 7   3/ 6   3/ 5   3/ 5   3/ 5   3/ 5   2/19   2/15
                     .1MM    292    418    485    485    485    485    568    631    671    705    705    705    796    806    409
1996  274  100       M/D   11/11   1/18   1/16   1/16   2/20   2/20   2/19   2/20   2/20   2/19   1/16   2/ 8   2/19   2/19
                     .1MM    395    465    596    700    789    908    926    948    975    993   1042   1146   1264   1471    854
1997  273  100       M/D    3/25   3/28   3/27   3/27   3/25   3/25   3/25   3/25   3/25   3/25   3/25   3/14   3/14   3/ 1
                     .1MM    278    477    660    742    984   1066   1066   1103   1197   1197   1197   1220   1220   1264    771
1998  273  100       M/D    1/ 7   3/ 8   1/ 5   1/ 5   1/ 3   1/ 2   1/ 2   1/ 2   1/ 2   1/ 2   2/25   2/18   2/17   2/25
                     .1MM    254    380    466    486    561    597    617    627    627    627    811    912   1074   1206    395
1999  273  100       M/D    1/23   2/28   2/10   2/28   3/17   1/18   1/17   1/17   1/17   1/17   2/ 2   1/17   1/18   1/17
                     .1MM    238    292    324    332    353    432    519    519    519    519    554    744    880   1069    585
2000  274  100       M/D    2/24   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23   2/23
                     .1MM    328    484    540    687    837    837    837    837    837    837    882    882   1112   1153    610
2001  273  100       M/D    2/ 9  12/16   4/ 6   4/ 5   4/ 4   4/ 3   4/ 2   4/ 2   4/ 2   3/30   3/30   3/21   3/15   3/12
                     .1MM    408    538    783    994   1195   1323   1405   1405   1405   1425   1425   1783   1847   1933   1546
2002  273  100       M/D    3/ 2   2/20   1/26   3/27   1/23   1/23   2/15   2/15   1/23   1/23   2/19   2/15   2/10   1/23
                     .1MM    216    348    400    406    430    519    542    542    547    607    722    896    968   1221    467
2003  273  100       M/D    3/17   3/20   3/20   3/20   3/20   3/17   3/17   3/17   3/17   3/16   3/16   3/16   3/17   3/16
                     .1MM    310    472    668    851   1007   1107   1290   1446   1537   1628   1628   1628   1762   1853   1311
2004  274  100       M/D   12/10  12/10   3/ 3   3/ 2   3/ 1   3/ 1   2/29   2/28   2/28   2/28   2/29   2/28   3/ 1   2/28
                     .1MM    480    521    606    798    949   1022   1077   1086   1086   1086   1191   1237   1406   1471    930
2005  273  100       M/D    1/13   2/14   2/14  12/30  12/30  12/30  12/30  12/30   2/ 7   2/ 7  12/30  12/30  12/22  12/22
                     .1MM    236    350    368    420    475    475    475    475    624    642    778    778   1044   1044    384
2006  273  100       M/D   11/29  11/28  11/27  11/27  11/27  11/27  11/27   1/11   1/12   1/11   1/ 4   1/ 4   1/ 4  12/23
                     .1MM    428    730    780    780    780    780    780    789    793    871    957   1039   1130   1289    290
2007  273  100       M/D    4/12   3/13   3/12   3/11   3/10   3/10   3/10   3/10   3/10   3/10   3/10   3/ 3   3/ 1   3/ 1
                     .1MM    208    408    482    573    583    583    583    583    583    583    659    687    707    707    535
2008  274  100       M/D   12/23   1/ 7   1/ 6   1/ 5   4/ 1   4/ 1   3/31   3/31   3/31   3/28   3/26   3/18   3/15   3/ 8
                     .1MM    482    573    705    725    772    898   1018   1018   1018   1054   1164   1483   1634   1644   1251
2009  273  100       M/D    2/11   2/11   3/ 6   3/ 5   3/ 6   3/ 6   3/ 5   3/ 5   3/ 5   2/27   2/26  12/ 9   2/11   2/11
                     .1MM    369    556    658    664    738    770    776    776    776    820    990   1006   1289   1547    748
2010  273  100       M/D    1/24   1/24   1/24   1/24   1/24   1/24   1/19   1/19   1/19   1/16   1/15   1/15   1/ 1  12/27
                     .1MM    430    826    835    835    835    835    844    853    853    890    954    954    963    981    483
2011  226   83  **   M/D    3/10   3/10   3/16   3/16   3/16   3/ 5   3/ 5   3/10   3/10   3/10   3/ 5   2/27   2/27   2/18
                     .1MM    404    543    659    659    659    712    851    974   1266   1266   1574   1715   1834   1971
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 2012  274  100       M/D  11/24  11/24  11/24   1/23   1/23   3/ 2   1/26   1/26   1/24   1/23   1/23   1/17   1/17   1/17
                      .1MM   152    152    152    225    225    249    253    253    280    368    423    503    558    595    208
 2013  273  100       M/D   3/11   3/10   3/10   3/10   3/ 9   3/ 9   3/ 7   3/ 7   3/ 7   3/ 7   2/27   1/12   1/ 9   2/27
                      .1MM   483    657    812    830    849    849    867    867    867    867    944   1097   1134   1147    703
 2014  273  100       M/D   4/ 7   4/ 7   4/ 6   4/ 4   4/ 4   4/ 4   4/ 2   4/ 1   3/31   3/30   3/28   3/20   3/15   3/10
                      .1MM   440    578    642    780    918    918   1027   1100   1210   1238   1469   1551   1743   1926   1072
 2015  273  100       M/D   4/ 3   4/ 2   4/ 2   4/ 2   3/30   4/ 2   4/ 2   4/ 2   4/ 2   4/ 2   3/26   3/21   3/10   3/11
                      .1MM   301    540    586    586    613    686    741    890    890    890   1037   1145   1303   1571   1140
 2016  114   42  **   M/D   1/10   1/ 9   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8   1/ 8  12/29  12/29  12/20  12/20
                      .1MM   276    484    498    498    498    498    498    498    498    498    560    560    580    580
************************************************************************************************************************************

                            1 DAY  2 DAY  3 DAY  4 DAY  5 DAY  6 DAY  7 DAY  8 DAY  9 DAY 10 DAY 15 DAY 20 DAY 25 DAY 30 DAY

      MEAN EXTREME    (MM)  36.5   53.2   63.2   71.1   77.5   82.0   87.1   91.8   96.4   99.0  109.9  123.2  134.5  145.4
      STD. DEV.       (MM)   9.8   13.8   16.7   20.0   22.7   25.0   27.7   29.5   32.2   33.4   36.2   41.3   42.1   45.4
      YEARS ANALYSED          45     45     45     45     45     45     45     45     45     45     45     45     45     45
      MAX EXTREME     (MM)  73.0   93.8  100.5  114.2  125.8  136.5  147.0  155.8  184.0  202.7  235.7  242.2  268.7  293.0
      YEAR                  1984   1984   1984   1976   1977   2001   2001   1976   1971   1971   1971   1971   1978   1978


  ** NOTE **  VALUE IN FLAG INDICATES YEAR NOT INCLUDED IN ANALYSIS BASED ON % DAYS OPERATIONAL ( <90.0% )

                                            METEOROLOGICAL SERVICE OF CANADA
                                     RAIN+SNOWMELT DEPTH, DURATION, FREQUENCY VALUES
                                    PREPARED BY THE ENGINEERING CLIMATE SERVICES UNIT
************************************************************************************************************************************
 STATION : HARTINGTON IHD                                                                                  STATION NUMBER  6103367

 LATITUDE: 44.43N   LONGITUDE:  76.69W   ELEVATION (M):   160

 ARCHIVE: DLY04 (15/12/1967 - 31/12/2006) DLY44 (01/01/2007 - 22/01/2016)

 SNOWMELT MODEL 5 - Modification of Model 4

 CRITICAL PERIOD :  1ST OF MONTH 10 (PRECEDING YEAR) TO THE END OF MONTH 6                           NOTE : MODIFIED GUMBEL 12/82

                                         RETURN PERIOD VALUES  (MM)  WITH 50% CONFIDENCE LIMITS
************************************************************************************************************************************

RETURN PERIOD
 YEARS                             1 DAY           2 DAY           3 DAY           4 DAY           5 DAY

   2                             34.94+/- 0.90   50.89+/- 1.27   60.45+/- 1.54   67.82+/- 1.85   73.79+/- 2.10
   5                             43.57+/- 1.52   63.11+/- 2.15   75.20+/- 2.59   85.51+/- 3.11   93.89+/- 3.53
  10                             49.28+/- 2.05   71.19+/- 2.90   84.96+/- 3.50   97.22+/- 4.20  107.20+/- 4.77
  25                             56.50+/- 2.76   81.41+/- 3.91   97.30+/- 4.72  112.02+/- 5.66  124.02+/- 6.43
  50                             61.86+/- 3.31   88.99+/- 4.68  106.45+/- 5.65  123.00+/- 6.77  136.49+/- 7.70
 100                             67.17+/- 3.85   96.51+/- 5.45  115.54+/- 6.58  133.89+/- 7.89  148.87+/- 8.97

RETURN PERIOD
 YEARS                             6 DAY           7 DAY           8 DAY           9 DAY          10 DAY

   2                             77.94+/- 2.30   82.56+/- 2.55   86.94+/- 2.72   91.12+/- 2.97   93.55+/- 3.08
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   5                            100.00+/- 3.88  107.01+/- 4.30  113.03+/- 4.58  119.56+/- 5.00  123.11+/- 5.20
  10                            114.61+/- 5.24  123.20+/- 5.80  130.30+/- 6.19  138.39+/- 6.75  142.69+/- 7.02
  25                            133.06+/- 7.06  143.65+/- 7.83  152.12+/- 8.35  162.18+/- 9.10  167.41+/- 9.46
  50                            146.75+/- 8.45  158.83+/- 9.36  168.31+/- 9.99  179.83+/-10.89  185.76+/-11.32
 100                            160.34+/- 9.84  173.89+/-10.91  184.37+/-11.64  197.35+/-12.69  203.97+/-13.19

RETURN PERIOD
 YEARS                            15 DAY          20 DAY          25 DAY          30 DAY

   2                            103.93+/- 3.34  116.38+/- 3.81  127.63+/- 3.89  137.99+/- 4.18
   5                            135.91+/- 5.62  152.85+/- 6.41  164.86+/- 6.54  178.08+/- 7.05
  10                            157.09+/- 7.59  177.00+/- 8.66  189.51+/- 8.84  204.62+/- 9.52
  25                            183.84+/-10.24  207.51+/-11.67  220.66+/-11.92  238.16+/-12.83
  50                            203.69+/-12.25  230.14+/-13.97  243.76+/-14.26  263.04+/-15.35
 100                            223.39+/-14.27  252.61+/-16.27  266.70+/-16.61  287.74+/-17.89

 ** WARNING ** : 100 YEAR VALUES IN  1971 BASED ON 15 DAYS ACCUMULATION
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Appendix C-2:
Sinusoidal Hourly Snowmelt + Rainfall Runoff for 1%, 3-Day AEP

Time (hr)	Fraction	Snowmelt (mm/hr)
1	0.260	1.67
2	0.500	1.72
3	0.707	1.77
4	0.866	1.81
5	0.966	1.83
6	1.000	1.84
7	0.966	1.83
8	0.866	1.81
9	0.707	1.77
10	0.500	1.72
11	0.260	1.67
12	0.000	1.60
13	-0.260	1.54
14	-0.500	1.49
15	-0.707	1.44
16	-0.866	1.40
17	-0.966	1.38
18	-1.000	1.37
19	-0.966	1.38
20	-0.866	1.40
21	-0.707	1.44
22	-0.500	1.49
23	-0.260	1.54
24	0.000	1.60

100-Yr

3	# of days
115.5	total depth from Hartington AES Frequency Values

Daily snowmelt +rain= 38.5 mm

April:	Daily min temp	0.9
	Daily avg	6.3
	Daily max temp	11.6

Average hourly snowmelt+rain	1.60	mm
Center	1.60	mm
Amplitude	0.24	mm

Repeat 24-hr pattern for 3 days in HEC-HMS hyetograph.

Appendix D:

Historical Maximum Snow Water Content and Cumulative Runoff from Hartington Climate Data & Schroeter Snowmelt Routine

Year	Maximum SWC (mm)	Cumulative Snowmelt + Rain Runoff (mm)
1975	92	342
1976	190	426
1977	83	278
1978	205	361
1979	112	411
1980	23	367
1981	53	355
1982	79	239
1983	15	439
1984	101	465
1985	46	341
1986	68	299
1987	47	321
1988	56	423
1989	89	289
1990	57	418
1991	34	436
1992	62	297
1993	98	366
1994	67	302
1995	32	362
1996	127	350
1997	89	374
1998	23	307
1999	35	258
2000	27	382
2001	154	304
2002	64	432
2003	204	394
2004	221	527
2005	28	367
2006	26	388
2007	19	342
2008	131	373
2009	104	355
2010	45	313
2011	93	391
2012	45	319
2013	48	289
2014	80	351
2015	49	214
2016	73	396
2017	63	400
2018	65	395
2019	100	418
2020	31	395
2021	42	277
2022	56	316
2023	38	397

Appendix E:
Federal Climate Data Portal: ΔT Adjustment

time	rcp26_tg_mean_p10	rcp26_tg_mean_p50	rcp26_tg_mean_p90	rcp45_tg_mean_p10	rcp45_tg_mean_p50	rcp45_tg_mean_p90	rcp85_tg_mean_p10	rcp85_tg_mean_p50	rcp85_tg_mean_p90	rcp26_tg_mean_delta7100_p10	rcp26_tg_mean_delta7100_p50	rcp26_tg_mean_delta7100_p90	rcp45_tg_mean_delta7100_p10	rcp45_tg_mean_delta7100_p50	rcp45_tg_mean_delta7100_p90	rcp85_tg_mean_delta7100_p10	rcp85_tg_mean_delta7100_p50	rcp85_tg_mean_delta7100_p90
1/1/1951	6.9	7	7.2	6.9	7	7.2	6.9	7	7.2	-0.6	-0.3	-0.1	-0.6	-0.3	-0.1	-0.6	-0.3	-0.1
1/1/1961	7	7.1	7.2	7	7.1	7.2	7	7.1	7.2	-0.5	-0.3	-0.1	-0.5	-0.3	-0.1	-0.5	-0.3	-0.1
1/1/1971	7.2	7.3	7.5	7.2	7.3	7.5	7.2	7.3	7.5	0	0	0	0	0	0	0	0	0
1/1/1981	7.5	7.7	7.9	7.5	7.7	7.9	7.5	7.7	7.9	0.2	0.3	0.4	0.2	0.4	0.5	0.2	0.3	0.5
1/1/1991	7.9	8	8.4	7.8	8.1	8.4	7.9	8.2	8.4	0.5	0.7	1	0.5	0.8	1	0.6	0.8	1
1/1/2001	8.2	8.4	9	8.2	8.6	9	8.2	8.7	9	0.8	1.2	1.6	0.7	1.2	1.6	0.9	1.3	1.6
1/1/2011	8.3	8.8	9.5	8.4	9	9.7	8.5	9.2	9.8	1	1.4	2.1	1.1	1.7	2.3	1.3	1.8	2.4
1/1/2021	8.5	9.2	10	8.8	9.3	10.2	8.9	9.6	10.3	1.2	1.8	2.6	1.4	2	2.9	1.7	2.2	3
1/1/2031	8.5	9.4	10.3	9.1	9.7	10.8	9.4	10.2	11.3	1.3	2	2.9	1.7	2.4	3.4	2.2	2.8	3.9
1/1/2041	8.6	9.4	10.6	9.2	10.1	11.3	10.1	10.9	12.2	1.3	2.1	3.3	1.8	2.8	4	2.8	3.5	4.8
1/1/2051	8.6	9.4	10.8	9.3	10.3	11.8	10.8	11.6	13.3	1.2	2.1	3.4	1.9	2.9	4.5	3.4	4.2	6
1/1/2061	8.6	9.4	10.8	9.4	10.4	12.2	11.4	12.4	14.2	1.2	2.1	3.4	2	3.2	4.8	4.1	5	6.8
1/1/2071	8.6	9.4	10.7	9.5	10.6	12.1	11.8	13.1	15.1	1.2	2.1	3.3	2.2	3.3	4.7	4.6	5.7	7.7

Appendix F:
Kingston Environment Canada IDFs

```
                     Environment and Climate Change Canada
                 Environnement et Changement climatique Canada

           Short Duration Rainfall Intensity-Duration-Frequency Data
          Données sur l'intensité, la durée et la fréquence des chutes
                            de pluie de courte durée

                 Gumbel - Method of moments/Méthode des moments

                                   2022/10/31

================================================================================

 KINGSTON PUMPING STATION                               ON        6104175
 (composite)
 Latitude:  44 14'N    Longitude: 76 29'W    Elevation/Altitude: 76         m

 Years/Années :  1914 - 2007         # Years/Années :     63

================================================================================

********************************************************************************

Table 1 : Annual Maximum (mm)/Maximum annuel (mm)

********************************************************************************

          Year  5 min 10 min 15 min 30 min    1 h    2 h    6 h   12 h   24 h
         Année
          1914    5.8    7.9    9.7   12.2   19.3   25.4   29.2   37.1   40.1
          1915    3.6    5.3    7.6   10.2   16.0   28.2   45.2   58.9   65.0
          1921    8.1   16.0   17.0   18.0   18.3   18.3   25.9   27.9   45.0
          1922    4.8    6.9    9.7   15.7   20.6   22.6   32.3   32.3   36.1
          1926    8.6   13.0   18.0   23.4   33.5   48.8   54.6   54.6   57.9
          1927    8.6   13.0   16.5   21.8   39.1   39.9   40.1   40.1   49.8
          1928   10.9   16.8   22.6   29.0   34.8   35.8   41.1   41.7   48.0
          1929   10.7   14.7   14.7   18.8   23.9   28.4   30.2   39.6   52.8
          1930    8.4   11.4   11.4   13.2   15.7   17.0   21.8   34.8   44.4
          1931    6.9   10.7   14.2   17.5   18.8   25.9   27.7   39.4   39.4
          1932    8.9   15.7   18.3   21.3   21.3   21.3   26.9   34.3   50.8
          1933    7.1   11.2   12.2   14.7   15.5   18.3   38.4   47.0   51.1
          1934    5.1    9.1   11.4   15.2   18.5   20.1   26.7   40.4   45.0
          1935   10.2   14.2   19.8   34.5   40.4   55.4   59.4   59.4   64.5
          1936    4.6    8.1    8.4   10.9   15.0   22.6   32.8   47.5   49.5
          1937   10.2   15.0   19.8   28.7   42.4   52.3   62.5   78.7   79.8
          1938    8.9   13.0   13.0   13.0   19.0   33.5   42.7   42.7   57.9
          1961    5.3    9.4   13.2   13.2   13.2   20.6   32.3   34.5   35.8
          1962   10.7   13.2   19.8   24.1   24.4   25.4   30.2   40.6   42.2
          1963    7.6    8.9   12.4   17.8   21.6   27.9   32.3   32.8   39.6
          1964    4.1    6.3    6.6    7.6   10.4   16.3   23.6   32.8   33.3
          1965    5.6    8.1    9.4   16.0   23.4   26.2   26.7   33.5   37.3
          1966    5.1    9.1   10.9   15.0   23.6   24.1   46.7   47.0   47.0
          1967   12.4   14.2   16.3   24.9   35.8   37.1   37.1   46.2   51.3
          1968   10.4   13.2   16.0   19.3   21.1   22.9   30.2   43.7   45.0
          1969    6.9    8.4    9.9   10.4   15.7   19.6   32.0   39.9   47.8
          1970    5.6    9.1   12.4   21.6   24.1   26.7   26.9   28.2   28.4
          1971    8.1   10.2   10.7   14.0   15.2   17.5   25.4   30.0   47.0
          1972    9.7   11.4   12.7   15.5   20.8   36.1   54.1   79.2   79.5
          1973    8.6   10.4   12.2   16.5   24.1   26.9   33.5   34.8   43.4
          1974    4.8    6.3    7.1    7.6    8.9   14.0   17.3   20.8   23.9
          1975    7.6   13.2   15.2   16.3   17.0   22.6   40.1   52.1   65.0
          1976   10.9   14.5   16.0   16.3   27.4   35.8   37.1   38.4   41.7
          1977    8.1    9.7   11.4   13.0   14.2   19.0   42.2   45.2   45.5
          1978    7.4   10.0   12.8   16.4   17.1   23.8   36.0   40.2   43.0
```

```
          1979    7.4   10.2   12.4   14.1   22.4   37.9  100.6  126.0  127.1
          1980    8.6   11.7   14.8   19.9   28.0   43.9   44.8   44.8   53.0
          1981    6.4    8.1    9.5   17.6   28.8   39.3   56.3   57.0   59.1
          1982    9.3   14.4   15.8   16.0   16.0   23.7   39.7   45.0   45.0
          1983   15.4   18.2   18.6   21.0   26.9   34.1   50.8   55.4   70.6
          1984    6.4    6.6    7.1   10.4   15.7   22.5   30.6   38.6   45.4
          1985   15.8   19.8   26.7   34.3   39.0   50.5   53.6   53.6   53.7
          1986    7.0    9.0    9.7   15.0   19.8   26.7   50.2   65.3   74.2
          1987    4.0    6.5    9.7   10.5   14.3   16.8   30.0   48.4   56.6
          1988    6.6   10.3   12.8   16.2   25.5   28.1   28.8   28.8   30.2
          1989    3.8    6.6    8.4   11.5   12.0   15.2   30.5   33.7   42.0
          1990    7.4   10.8   14.3   14.3   16.5   20.7   37.9   38.7   41.4
          1991   11.4   12.7   13.1   19.3   33.9   34.6   37.4   37.6   43.4
          1992    7.6   10.8   14.2   24.0   35.1   41.9   44.7   46.2   46.2
          1993    8.0   12.8   16.0   24.6   28.6   31.7   32.5   32.9   64.6
          1994   11.1   14.1   16.4   20.3   25.6   29.4   47.7   51.8   52.8
          1995    4.4    5.7    7.2    8.5   13.0   18.3   33.7   49.2   56.1
          1996    5.7    7.7    8.5   10.9   13.0   18.0   28.0   33.8   44.5
          1997    9.4   13.2   15.5   21.2   21.2   28.3   33.1   34.0   39.2
          1998   10.4   14.1   16.6   19.0   20.8   21.0   28.9   32.9   35.0
          1999    6.5    9.8   10.8   12.0   16.2   22.0   28.3   41.2   44.7
          2000    7.7    8.1    9.8   11.4   17.8   20.8   28.1   35.7   49.4
          2001    5.8    8.8   11.9   19.3   20.8   21.2   27.4   36.9   44.8
          2002    8.0   10.0   10.4   12.6   15.2   19.7   26.4   36.9   43.1
          2003    8.4   15.4   17.7   25.1   28.0   31.6   38.2   43.2   45.0
          2005    9.2   13.8   14.9   20.0   20.8   24.3   49.2   63.2   65.1
          2006    9.0   11.6   12.9   15.7   22.8   25.8   28.8   35.0   39.1
          2007    7.1   12.0   13.4   14.5   19.6   21.2   24.4   34.5   36.6
        ---------------------------------------------------------------------
        # Yrs.     63     63     63     63     63     63     63     63     63
        Années
          Mean    7.9   11.1   13.3   17.2   22.0   27.4   37.0   43.8   49.6
       Moyenne
     Std. Dev.    2.5    3.2    4.0    5.8    7.8    9.5   12.9   15.4   15.2
    Écart-type
         Skew.   0.73   0.32   0.70   0.90   0.88   1.14   2.21   2.89   2.42
   Dissymétrie
      Kurtosis   4.18   2.78   3.95   4.10   3.34   3.97  11.33  15.59  13.18

          *-99.9 Indicates Missing Data/Données manquantes

 Warning: annual maximum amount greater than 100-yr return period amount
 Avertissement : la quantité maximale annuelle excède la quantité
                 pour une période de retour de 100 ans
          Year/Année      Duration/Durée        Data/Données          100-yr/ans
                1979                6 h                100.6                77.5
                1979               12 h                126.0                92.0
                1979               24 h                127.1                97.1
                1985              15 min                26.7                25.9

********************************************************************************

Table 2a : Return Period Rainfall Amounts (mm)
           Quantité de pluie (mm) par période de retour

********************************************************************************

 Duration/Durée        2        5       10       25       50      100   #Years
                  yr/ans   yr/ans   yr/ans   yr/ans   yr/ans   yr/ans   Années
          5 min      7.5      9.7     11.2     13.1     14.5     15.9       63
         10 min     10.6     13.4     15.3     17.7     19.5     21.2       63
         15 min     12.6     16.2     18.5     21.5     23.7     25.9       63
         30 min     16.2     21.4     24.8     29.1     32.3     35.5       63
          1 h       20.7     27.6     32.2     37.9     42.2     46.4       63
```

```
          2 h       25.8     34.2     39.8     46.8     52.1     57.3       63
          6 h       34.9     46.3     53.8     63.4     70.5     77.5       63
         12 h       41.2     54.8     63.8     75.2     83.7     92.0       63
         24 h       47.1     60.5     69.3     80.5     88.8     97.1       63

********************************************************************************

Table 2b :

 Return Period Rainfall Rates (mm/h) - 95% Confidence limits
 Intensité de la pluie (mm/h) par période de retour - Limites de confiance de 95%

********************************************************************************

 Duration/Durée        2        5       10       25       50      100   #Years
                  yr/ans   yr/ans   yr/ans   yr/ans   yr/ans   yr/ans   Années
          5 min     89.9    116.8    134.7    157.2    173.9    190.5       63
                +/-  6.9 +/- 11.6 +/- 15.7 +/- 21.2 +/- 25.4 +/- 29.5       63
         10 min     63.5     80.6     91.9    106.3    116.9    127.4       63
                +/-  4.4 +/-  7.4 +/- 10.0 +/- 13.5 +/- 16.1 +/- 18.7       63
         15 min     50.6     64.8     74.2     86.1     94.9    103.6       63
                +/-  3.6 +/-  6.1 +/-  8.3 +/- 11.2 +/- 13.4 +/- 15.6       63
         30 min     32.5     42.8     49.6     58.2     64.6     70.9       63
                +/-  2.6 +/-  4.5 +/-  6.0 +/-  8.1 +/-  9.7 +/- 11.3       63
          1 h       20.7     27.6     32.2     37.9     42.2     46.4       63
                +/-  1.8 +/-  3.0 +/-  4.0 +/-  5.4 +/-  6.5 +/-  7.5       63
          2 h       12.9     17.1     19.9     23.4     26.0     28.6       63
                +/-  1.1 +/-  1.8 +/-  2.5 +/-  3.3 +/-  4.0 +/-  4.6       63
          6 h        5.8      7.7      9.0     10.6     11.7     12.9       63
                +/-  0.5 +/-  0.8 +/-  1.1 +/-  1.5 +/-  1.8 +/-  2.1       63
         12 h        3.4      4.6      5.3      6.3      7.0      7.7       63
                +/-  0.3 +/-  0.5 +/-  0.7 +/-  0.9 +/-  1.1 +/-  1.2       63
         24 h        2.0      2.5      2.9      3.4      3.7      4.0       63
                +/-  0.1 +/-  0.2 +/-  0.3 +/-  0.4 +/-  0.5 +/-  0.6       63

********************************************************************************

Table 3 : Interpolation Equation / Équation d'interpolation: R = A*T^B

R = Interpolated Rainfall rate (mm/h)/Intensité interpolée de la pluie (mm/h)
RR = Rainfall rate (mm/h) / Intensité de la pluie (mm/h)
 T = Rainfall duration (h) / Durée de la pluie (h)

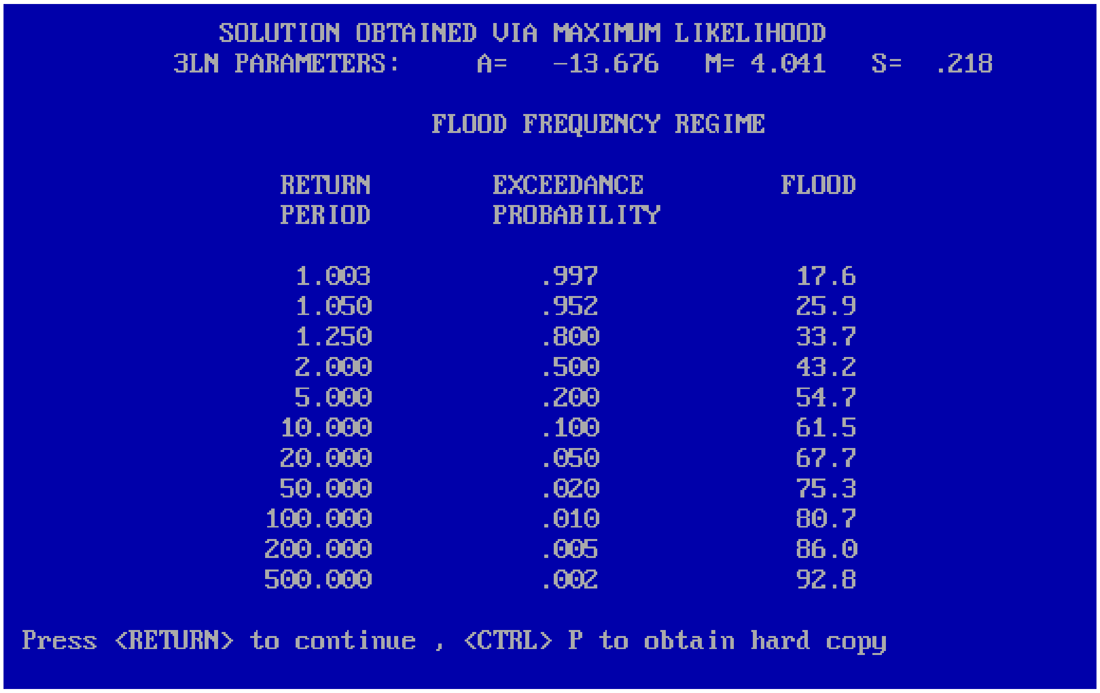
********************************************************************************

       Statistics/Statistiques      2      5     10     25     50    100
                               yr/ans yr/ans yr/ans yr/ans yr/ans yr/ans
      Mean of RR/Moyenne de RR   31.3   40.5   46.6   54.4   60.1   65.8
    Std. Dev. /Écart-type (RR)   30.8   39.6   45.5   52.9   58.3   63.8
        Std. Error/Erreur-type    5.3    6.8    7.8    9.1   10.1   11.1
               Coefficient (A)   19.1   24.9   28.8   33.6   37.3   40.9
         Exponent/Exposant (B) -0.681 -0.677 -0.676 -0.674 -0.673 -0.672
 Mean % Error/% erreur moyenne    6.6    7.4    7.7    8.1    8.3    8.5
```

Appendix G:

CFA Output – Three Parameter Log Normal

All Maximum Instantaneous Peaks (1974 – 2022):



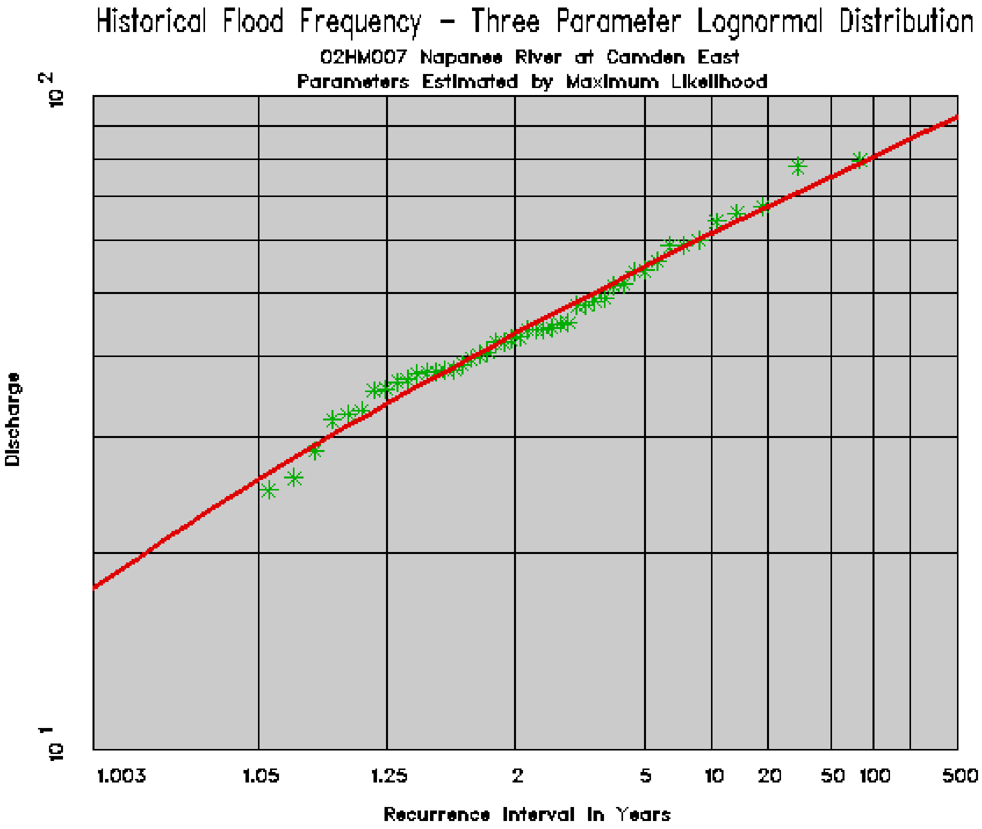
```
              SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD
           3LN PARAMETERS:     A=    -13.676    M= 4.041    S=   .218

                          FLOOD FREQUENCY REGIME

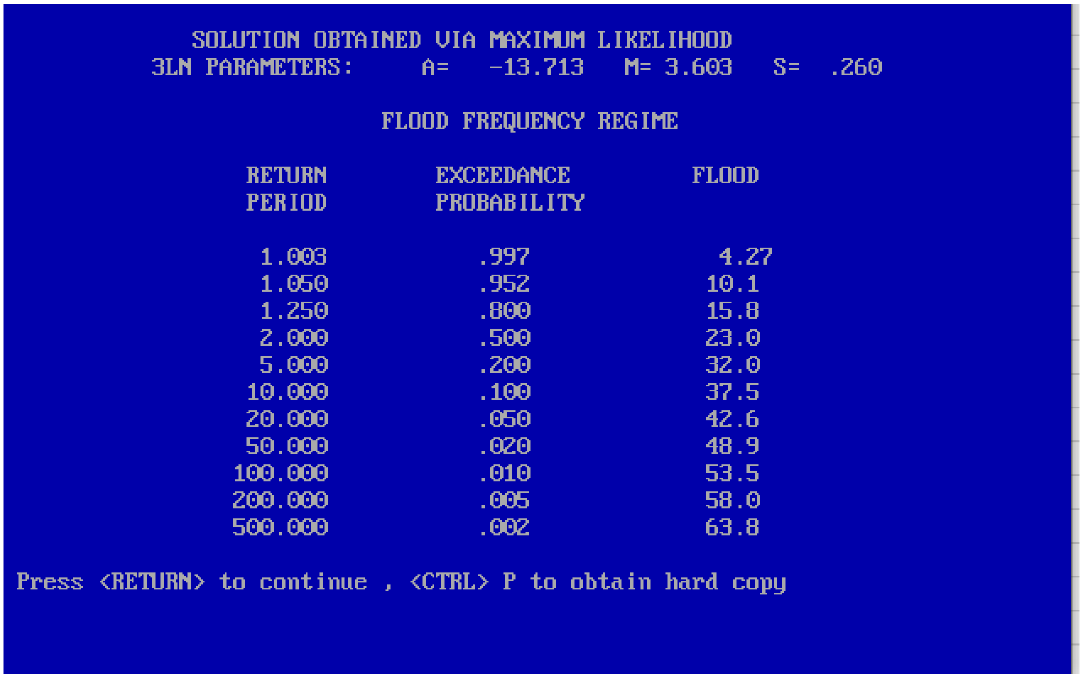
                RETURN          EXCEEDANCE          FLOOD
                PERIOD          PROBABILITY

                 1.003              .997             17.6
                 1.050              .952             25.9
                 1.250              .800             33.7
                 2.000              .500             43.2
                 5.000              .200             54.7
                10.000              .100             61.5
                20.000              .050             67.7
                50.000              .020             75.3
               100.000              .010             80.7
               200.000              .005             86.0
               500.000              .002             92.8

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



Rainfall Only Maximum Instantaneous Peaks (May 1st to December 31st, 1974 – 2022):



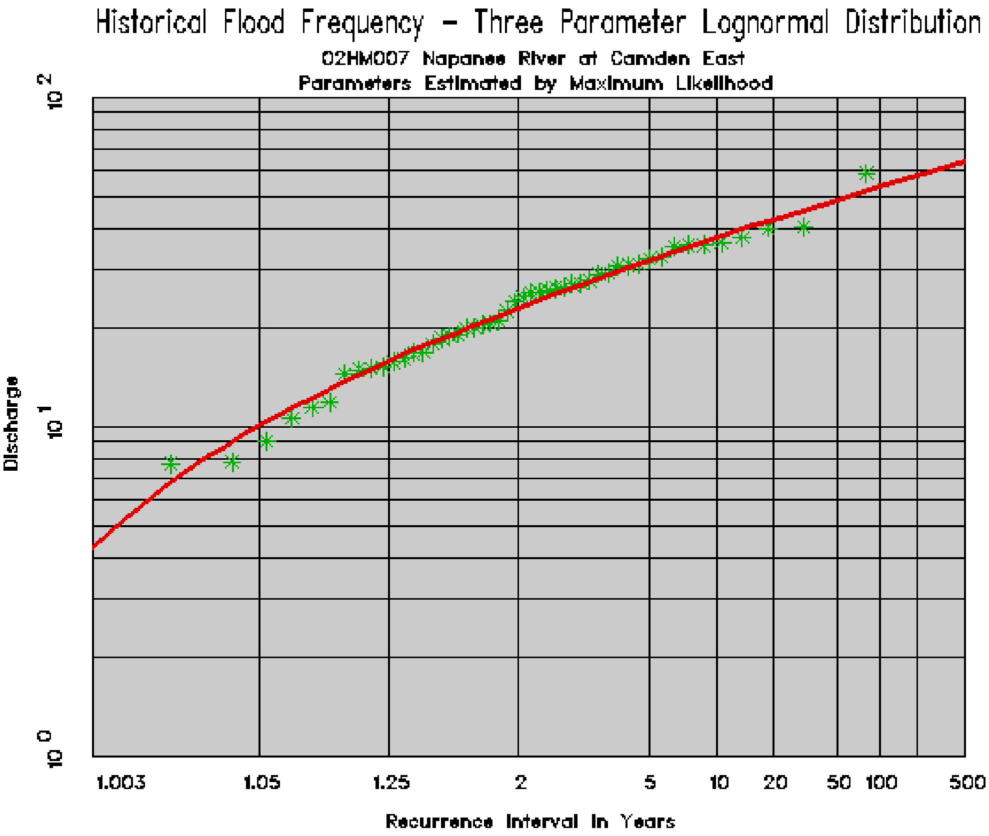
```
             SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD
          3LN PARAMETERS:     A=   -13.713   M= 3.603   S=  .260

                            FLOOD FREQUENCY REGIME

                 RETURN         EXCEEDANCE         FLOOD
                 PERIOD         PROBABILITY

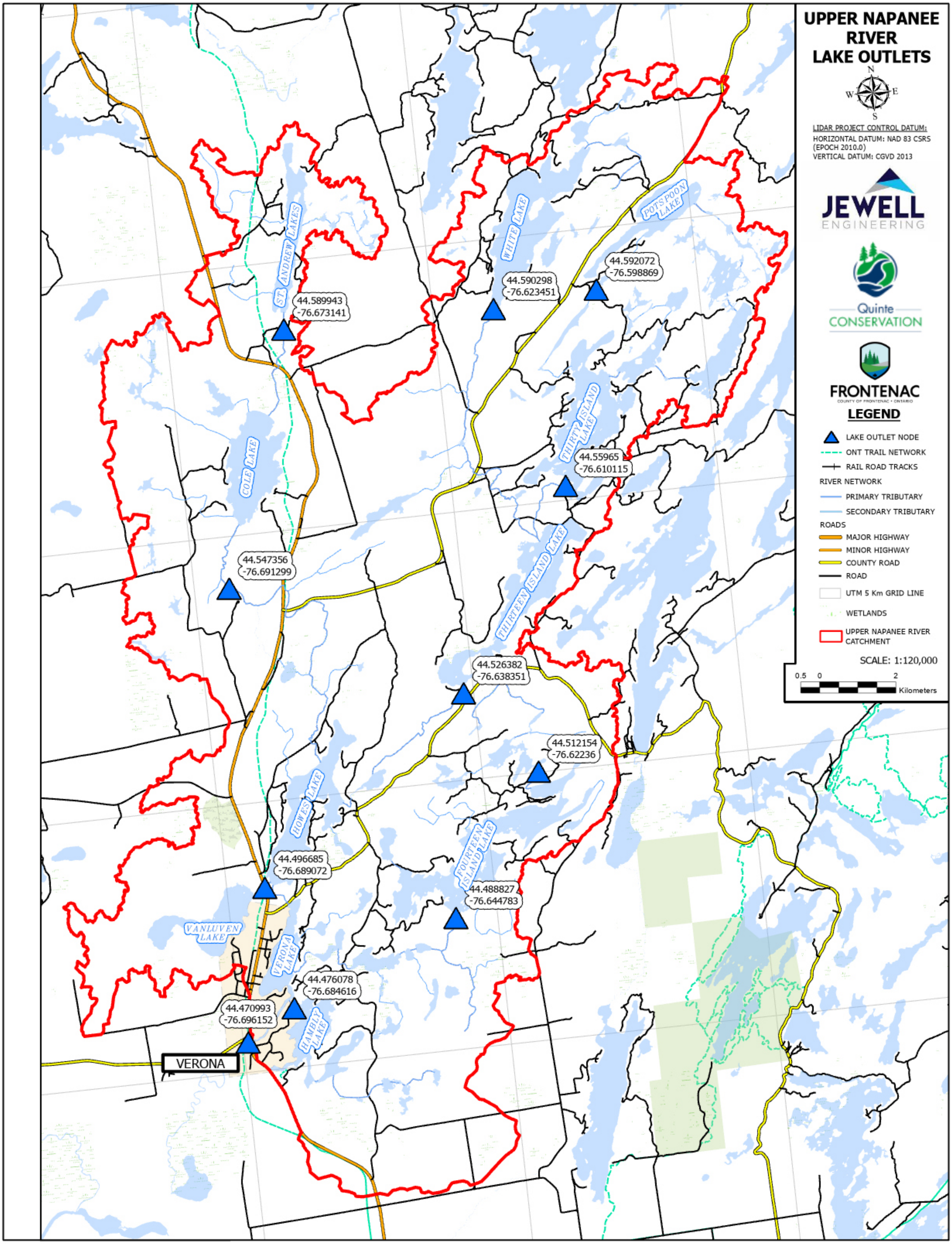
                  1.003            .997              4.27
                  1.050            .952             10.1
                  1.250            .800             15.8
                  2.000            .500             23.0
                  5.000            .200             32.0
                 10.000            .100             37.5
                 20.000            .050             42.6
                 50.000            .020             48.9
                100.000            .010             53.5
                200.000            .005             58.0
                500.000            .002             63.8

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



Appendix H:
Lake Outlet Locations

UPPER NAPANEE RIVER LAKE OUTLETS



LIDAR PROJECT CONTROL DATUM:

HORIZONTAL DATUM: NAD 83 CSRS (EPOCH 2010.0)

VERTICAL DATUM: CGVD 2013

JEWELL ENGINEERING

Quinte CONSERVATION

FRONTENAC
COUNTY OF FRONTENAC • ONTARIO

LEGEND

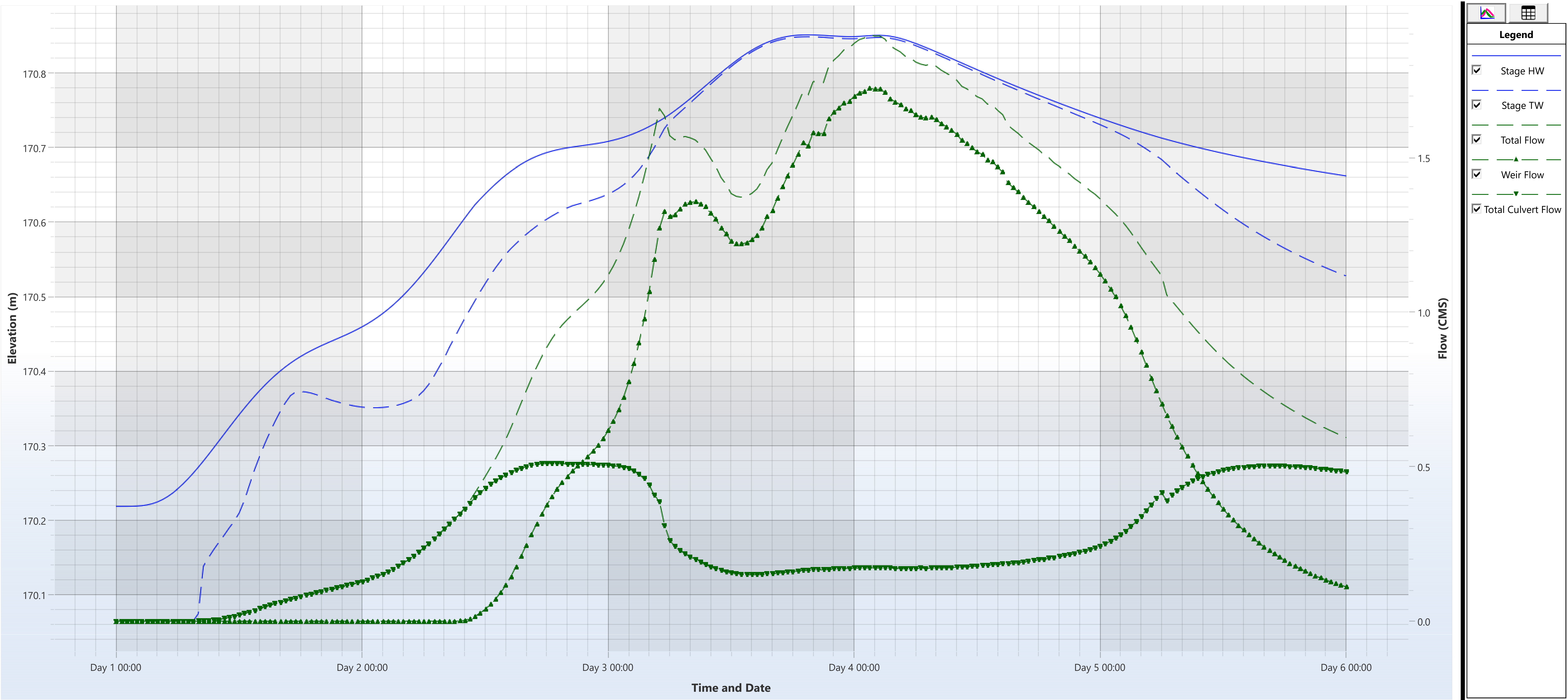
▲	LAKE OUTLET NODE
- - -	ONT TRAIL NETWORK
─┼─	RAIL ROAD TRACKS
	RIVER NETWORK
─	PRIMARY TRIBUTARY
─	SECONDARY TRIBUTARY
	ROADS
─	MAJOR HIGHWAY
─	MINOR HIGHWAY
─	COUNTY ROAD
─	ROAD
☐	UTM 5 Km GRID LINE
	WETLANDS
☐	UPPER NAPANEE RIVER CATCHMENT

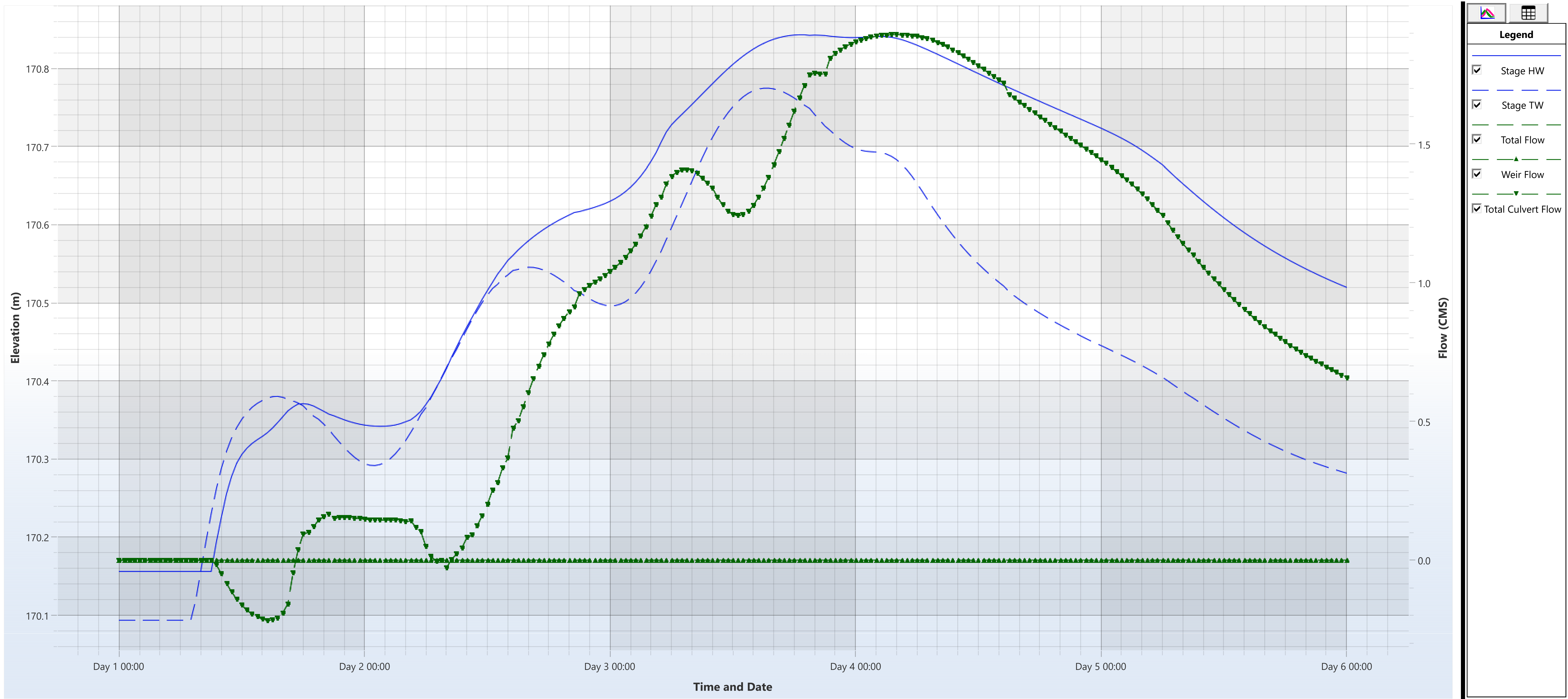
SCALE: 1:120,000

0.5 0 2 Kilometers

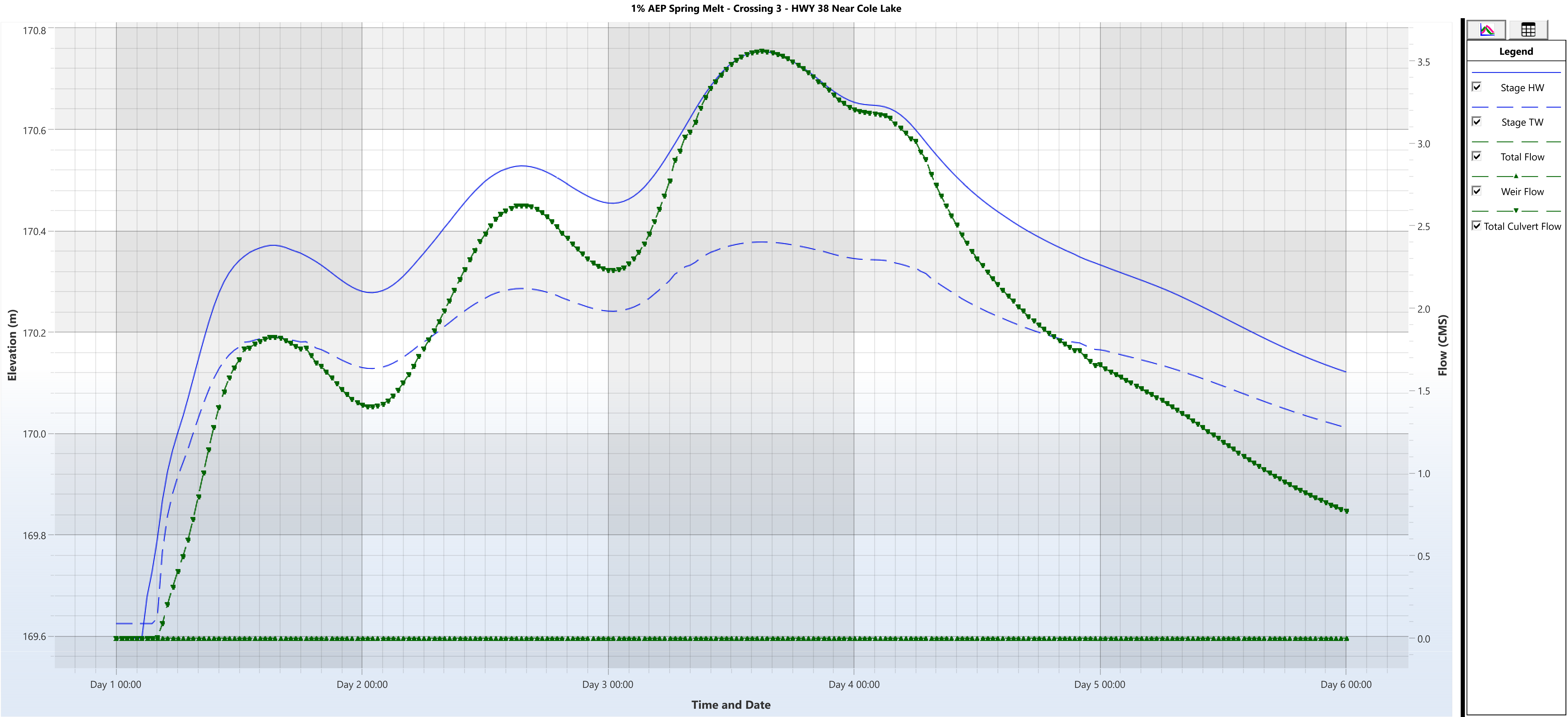
Appendix I:
Culvert & Bridge Stage-Flow Hydrographs

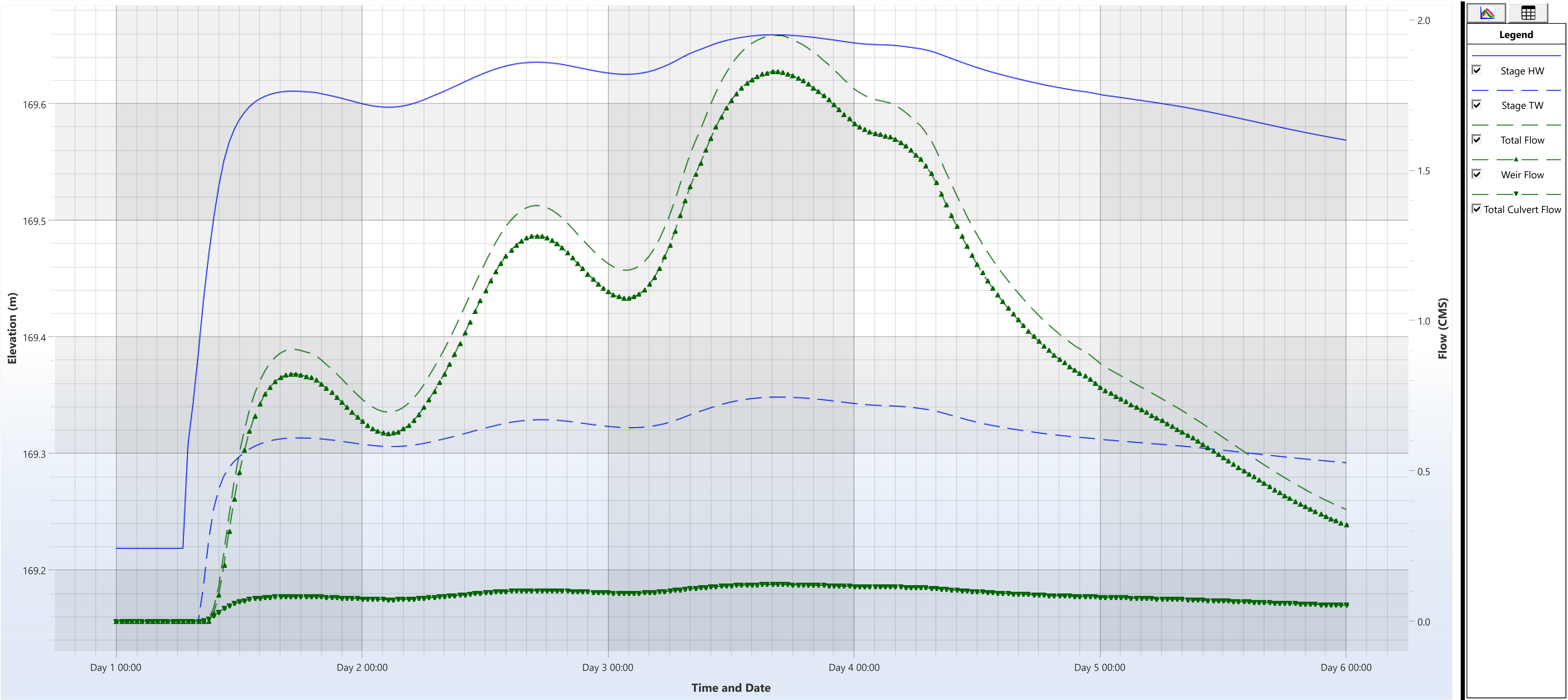
1% AEP Spring Melt - Crossing 1 - St Andrew Lakes Lane



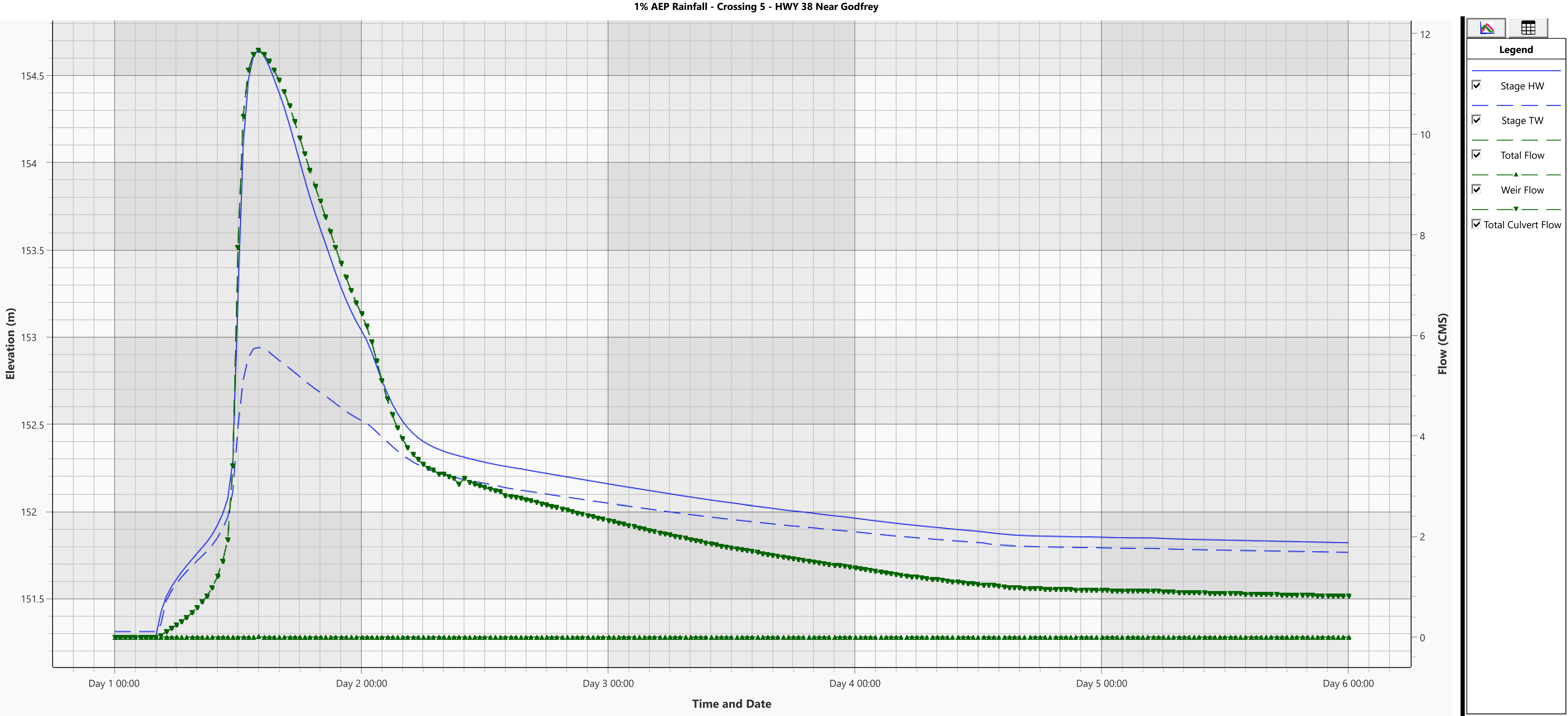


1% AEP Spring Melt - Crossing 2 - K&P Trail

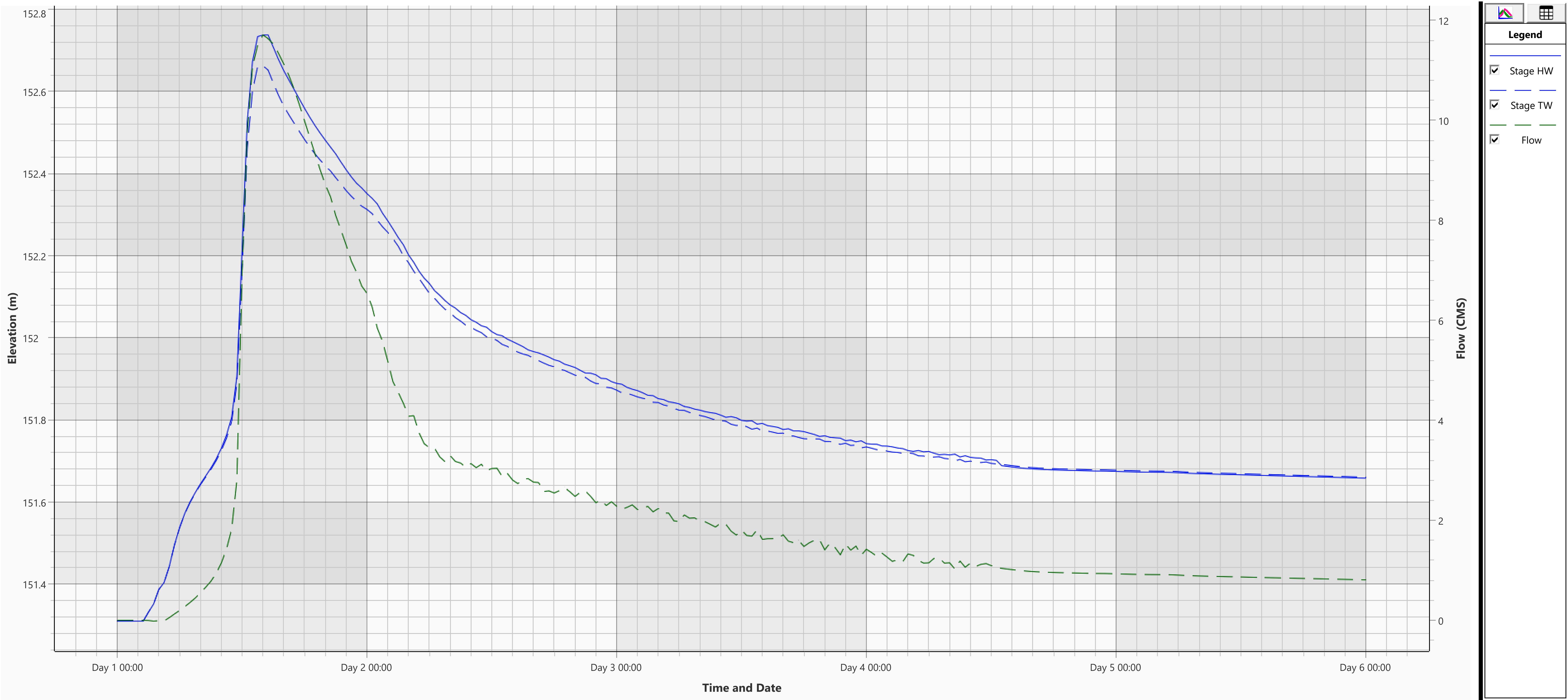

1% AEP Spring Melt - Crossing 3 - HWY 38 Near Cole Lake



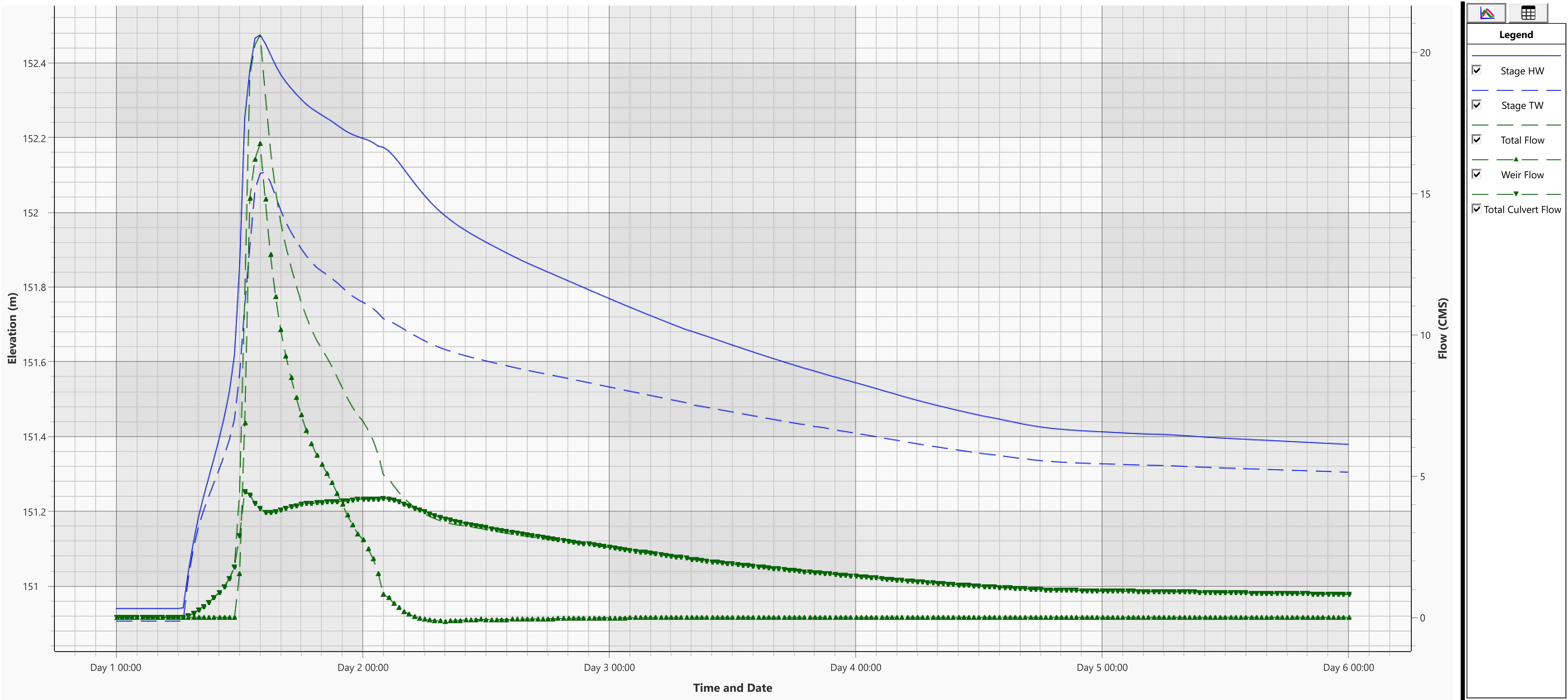
1% AEP Spring Melt - Crossing 4 - Private Crossing, 8985 Hwy 38

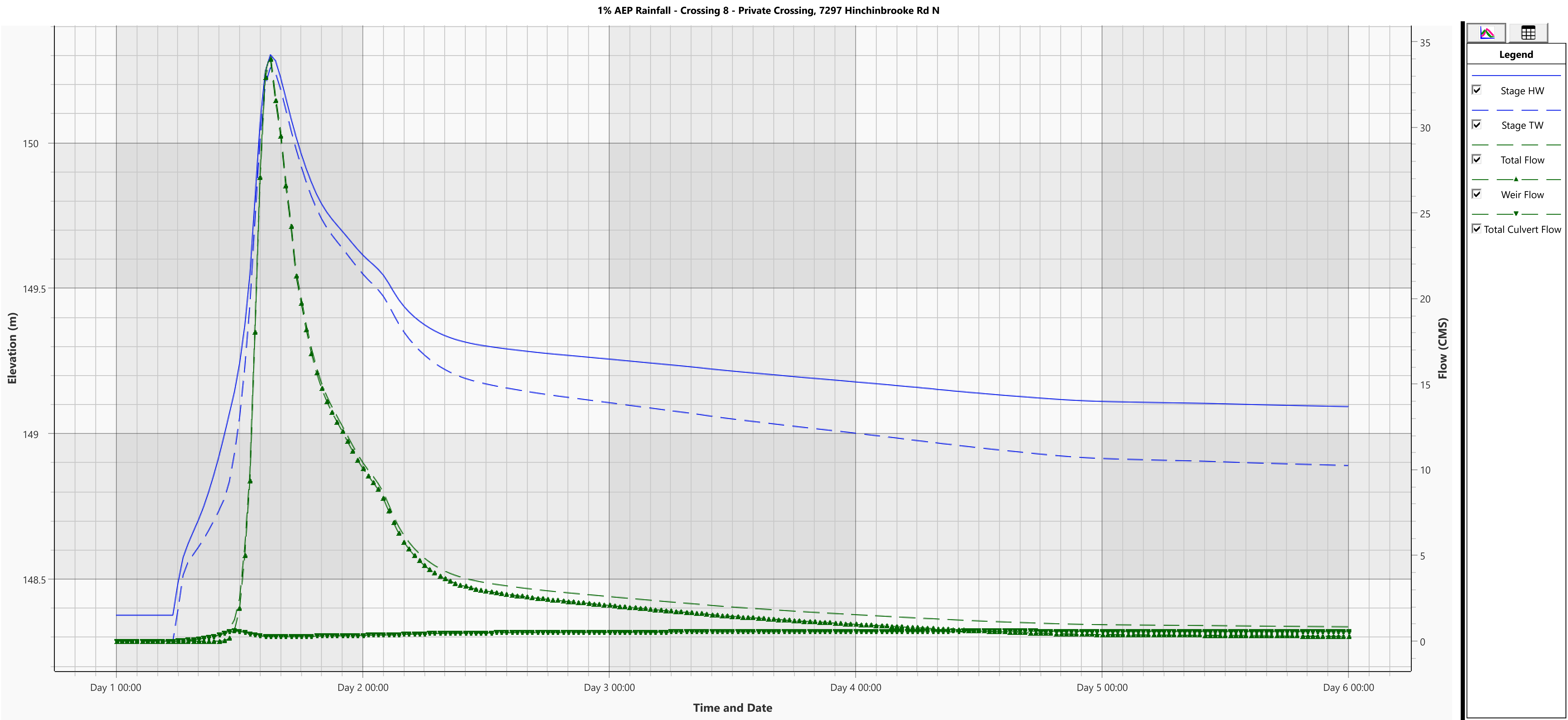

1% AEP Rainfall - Crossing 5 - HWY 38 Near Godfrey
Elevation (m)
154.5
154
153.5
153
152.5
152
151.5
Flow (CMS)
12
10
8
6
4
2
0
Day 1 00:00
Day 2 00:00
Day 3 00:00
Day 4 00:00
Day 5 00:00
Day 6 00:00
Time and Date
Legend
☑ Stage HW
☑ Stage TW
☑ Total Flow
☑ Weir Flow
☑ Total Culvert Flow

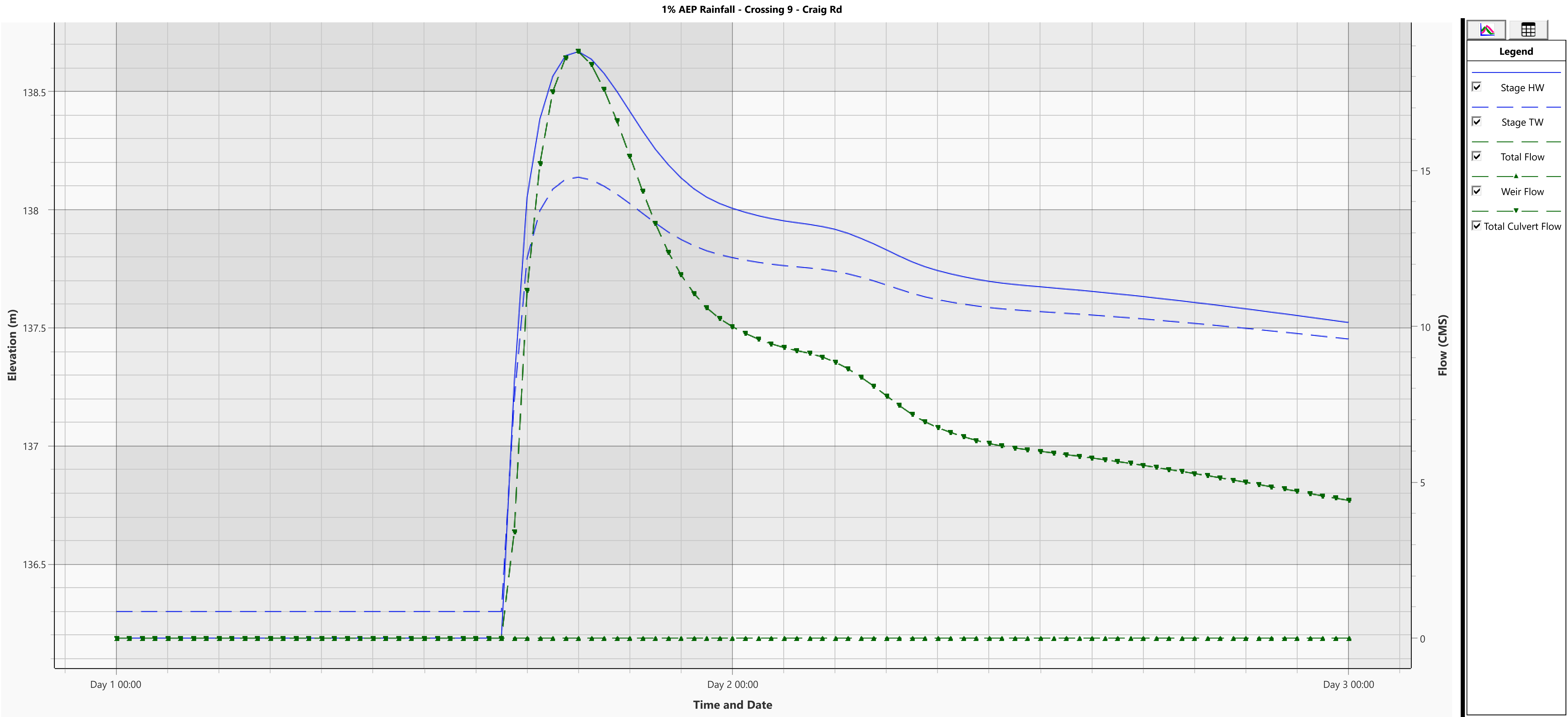
1% AEP Rainfall - Crossing 6 - K&P Trail Near Godfrey



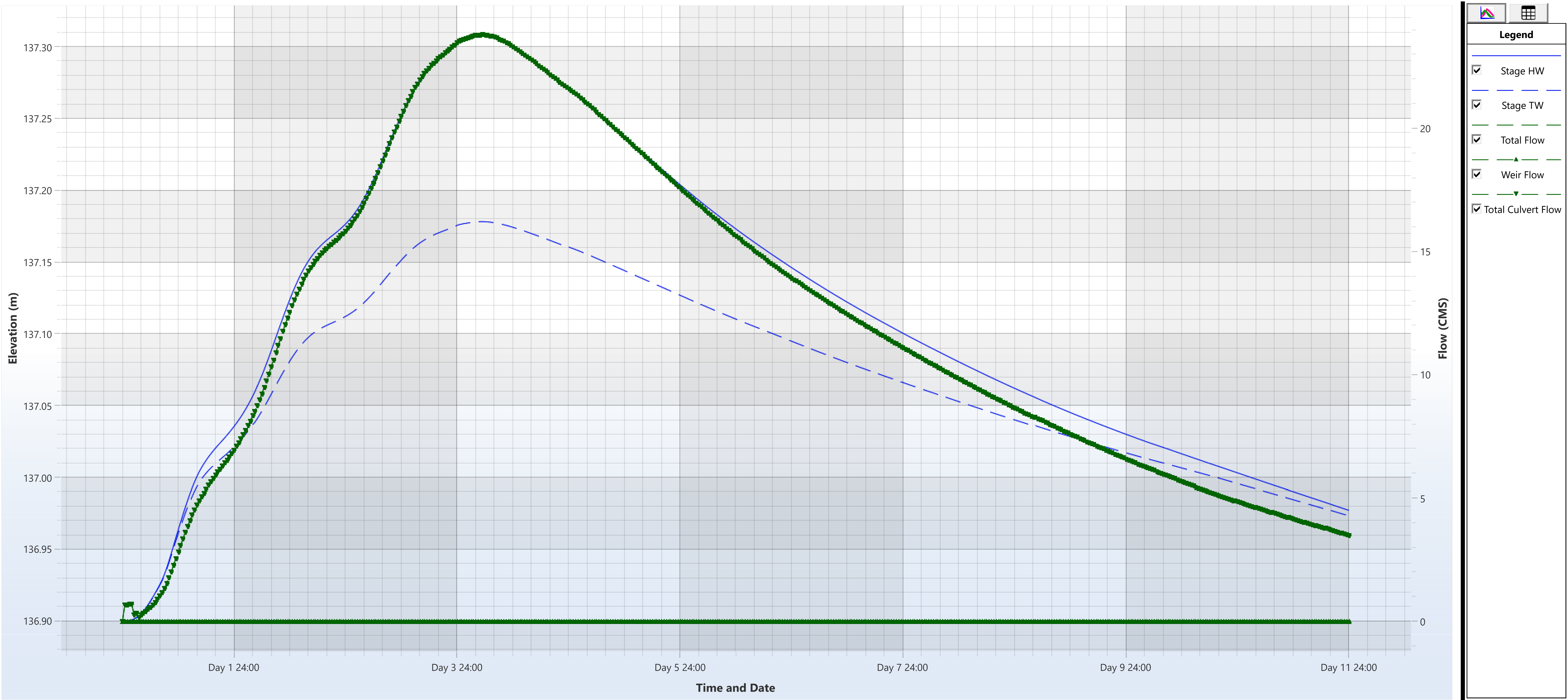
1% AEP Rainfall - Crossing 7 - Westport Rd Near Godfrey

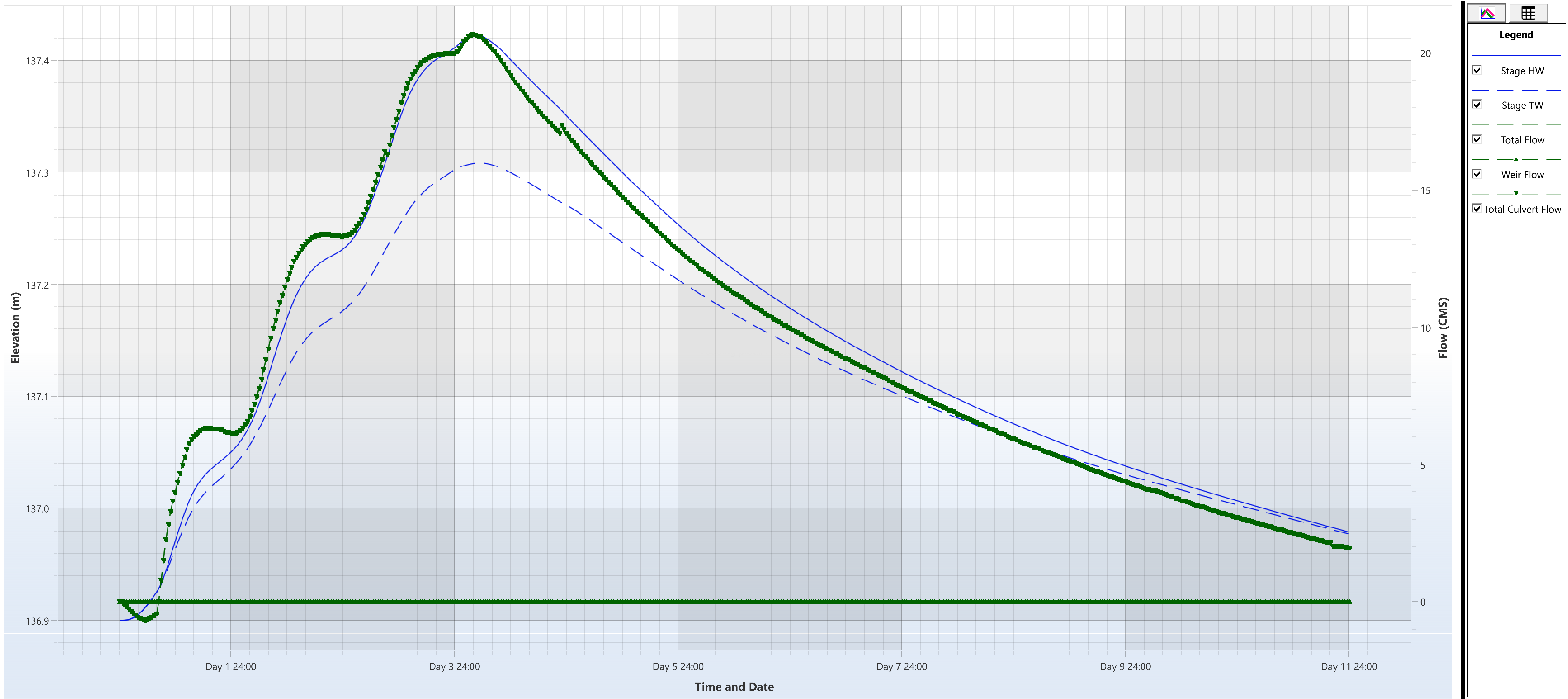



1% AEP Rainfall - Crossing 8 - Private Crossing, 7297 Hinchinbrooke Rd N
Elevation (m)
150
149.5
149
148.5
Flow (CMS)
35
30
25
20
15
10
5
0
Day 1 00:00
Day 2 00:00
Day 3 00:00
Day 4 00:00
Day 5 00:00
Day 6 00:00
Time and Date
Legend
☑ Stage HW
☑ Stage TW
☑ Total Flow
☑ Weir Flow
☑ Total Culvert Flow

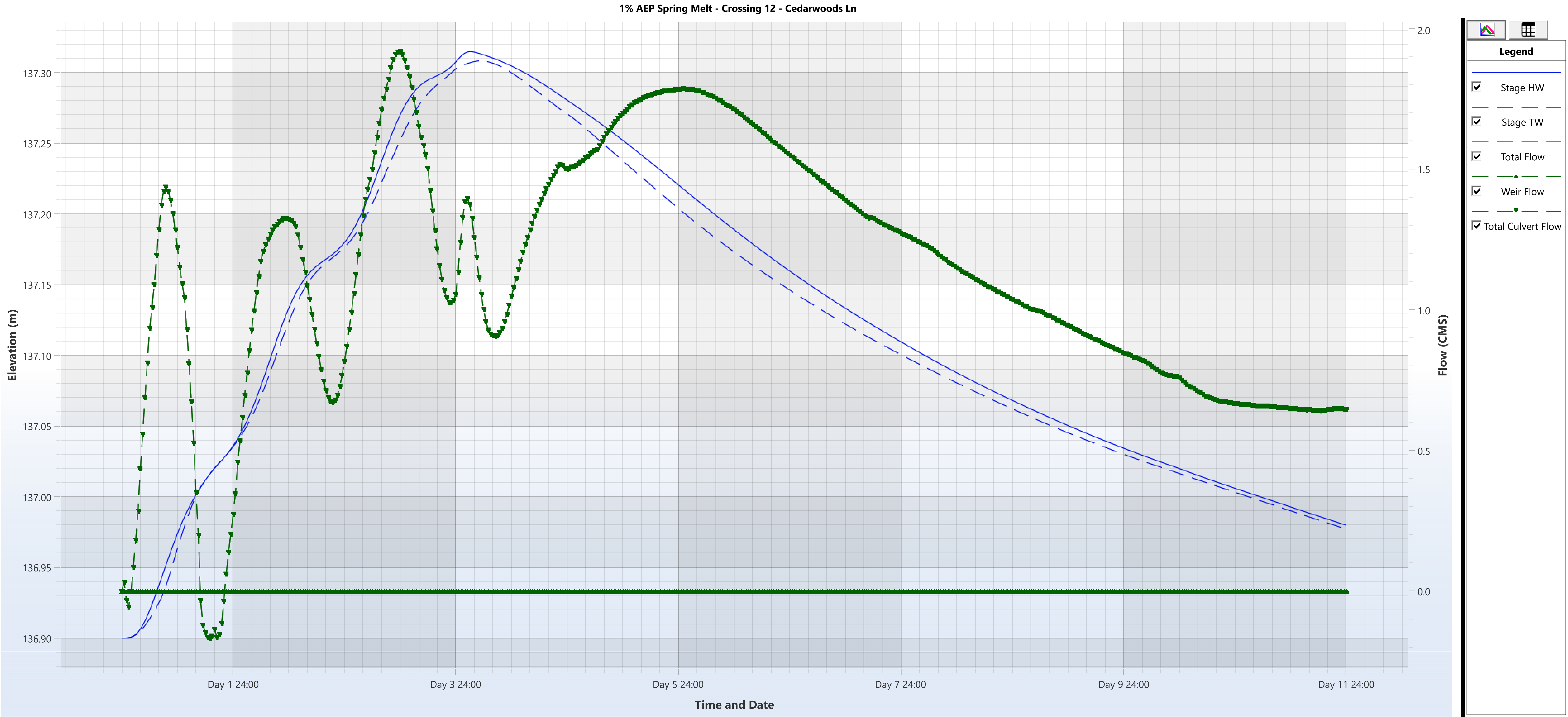

1% AEP Rainfall - Crossing 9 - Craig Rd
Elevation (m)
138.5
138
137.5
137
136.5
Flow (CMS)
15
10
5
0
Day 1 00:00
Day 2 00:00
Day 3 00:00
Time and Date
Legend
☑ Stage HW
☑ Stage TW
☑ Total Flow
☑ Weir Flow
☑ Total Culvert Flow

1% AEP Spring Melt - Crossing 10 - HWY 38 Near Howes Lake



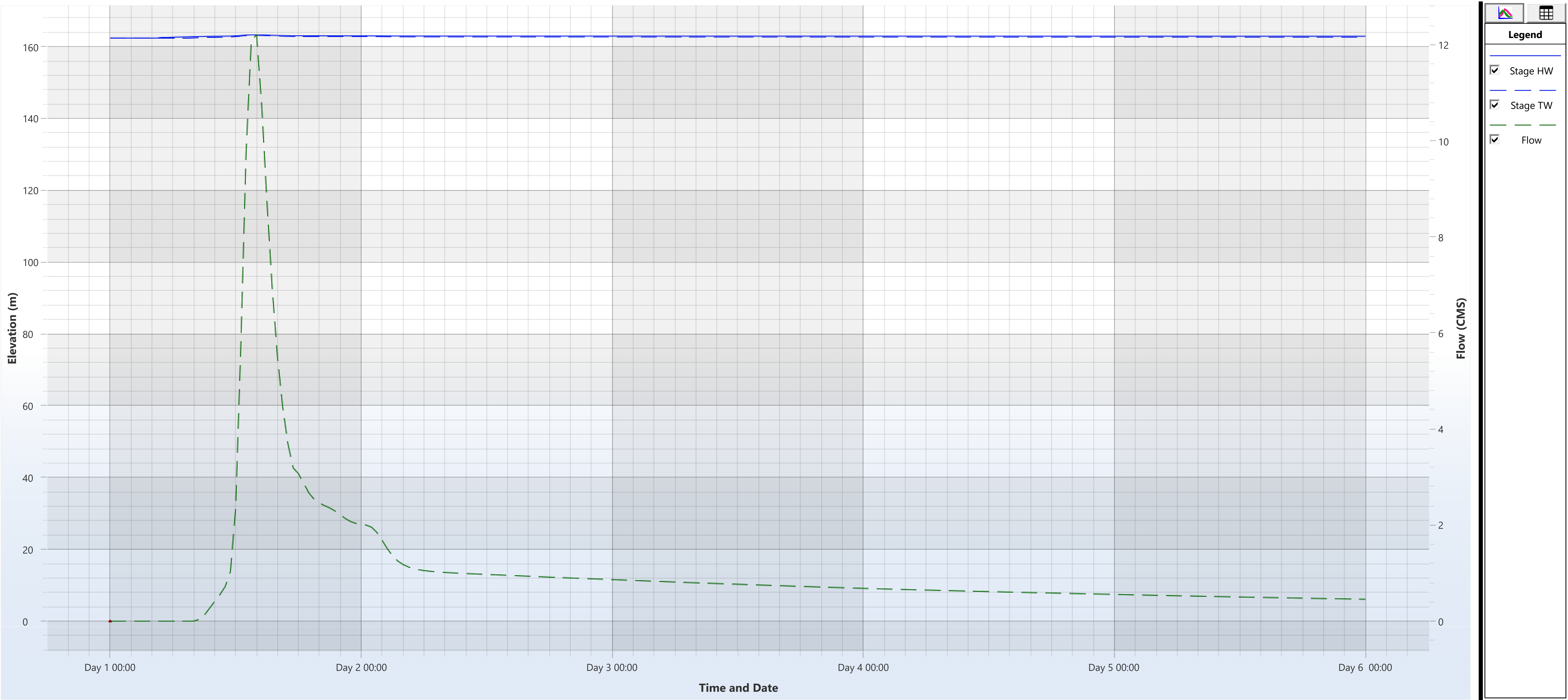


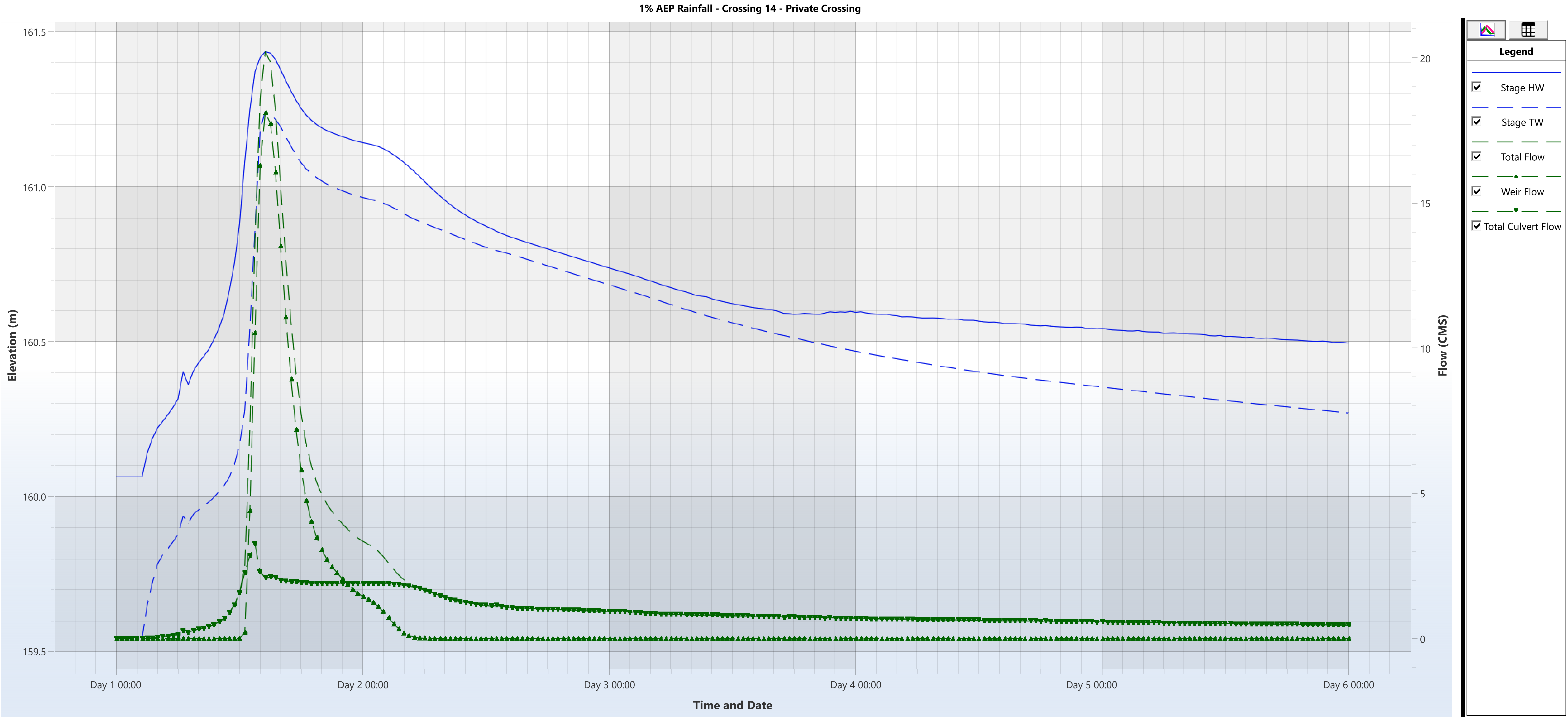
1% AEP Spring Melt - Crossing 11 - Desert Lk Rd



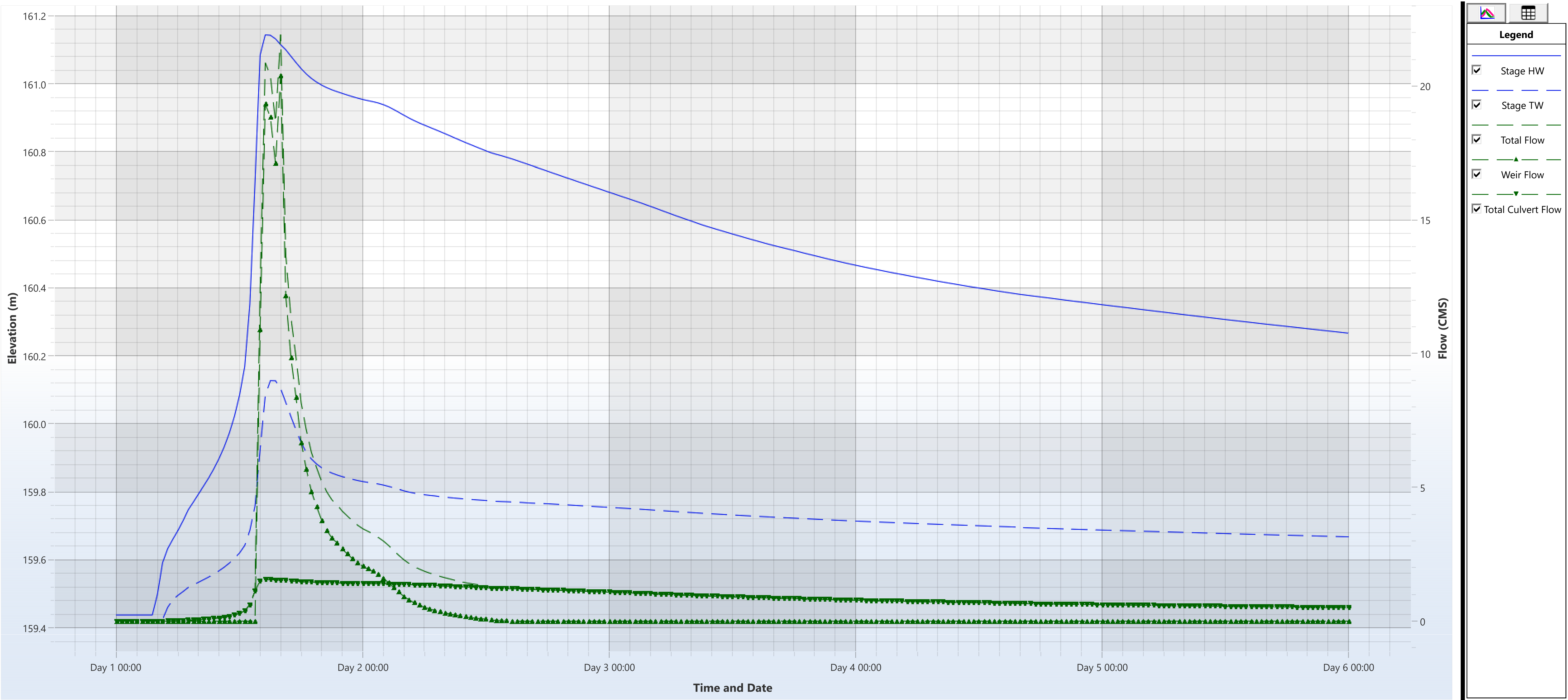
1% AEP Spring Melt - Crossing 12 - Cedarwoods Ln

1% AEP Rainfall - Crossing 13 - Buck Bay Rd

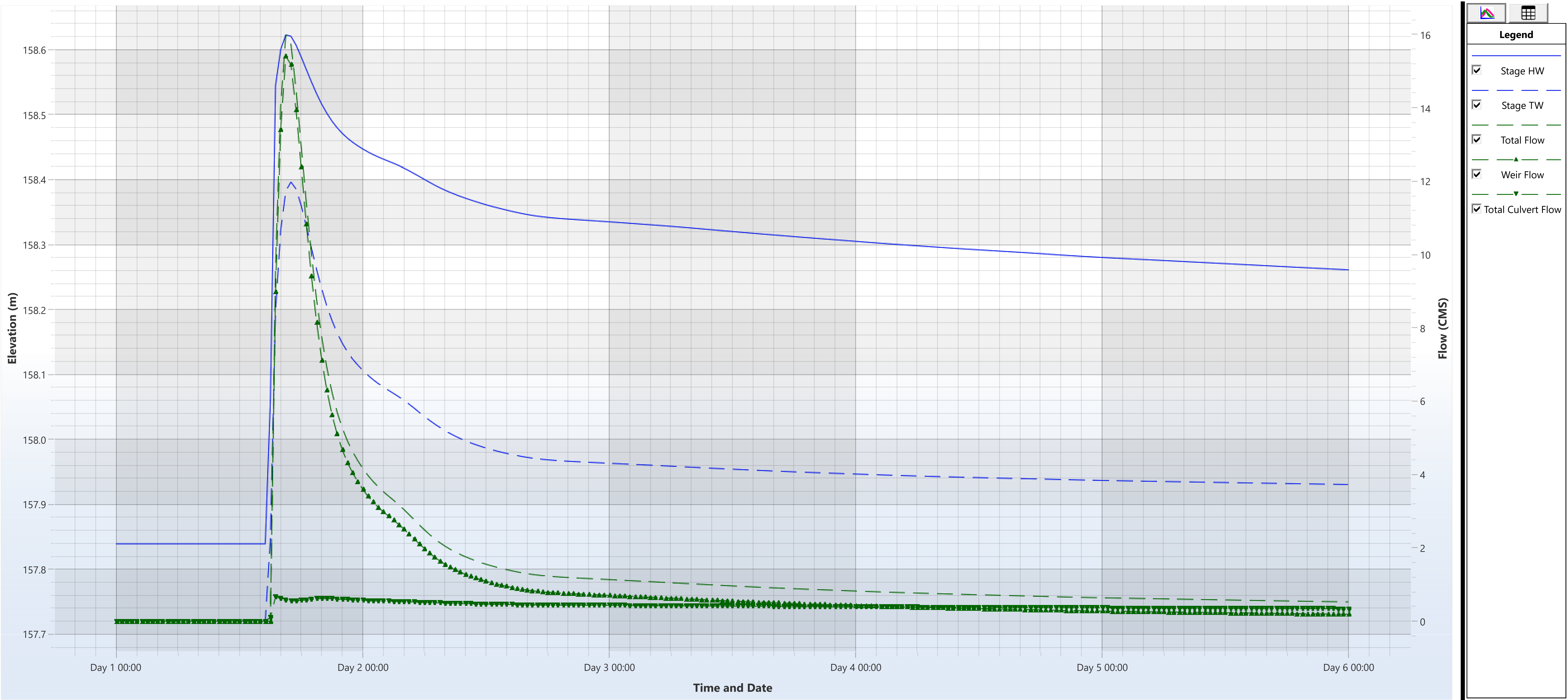


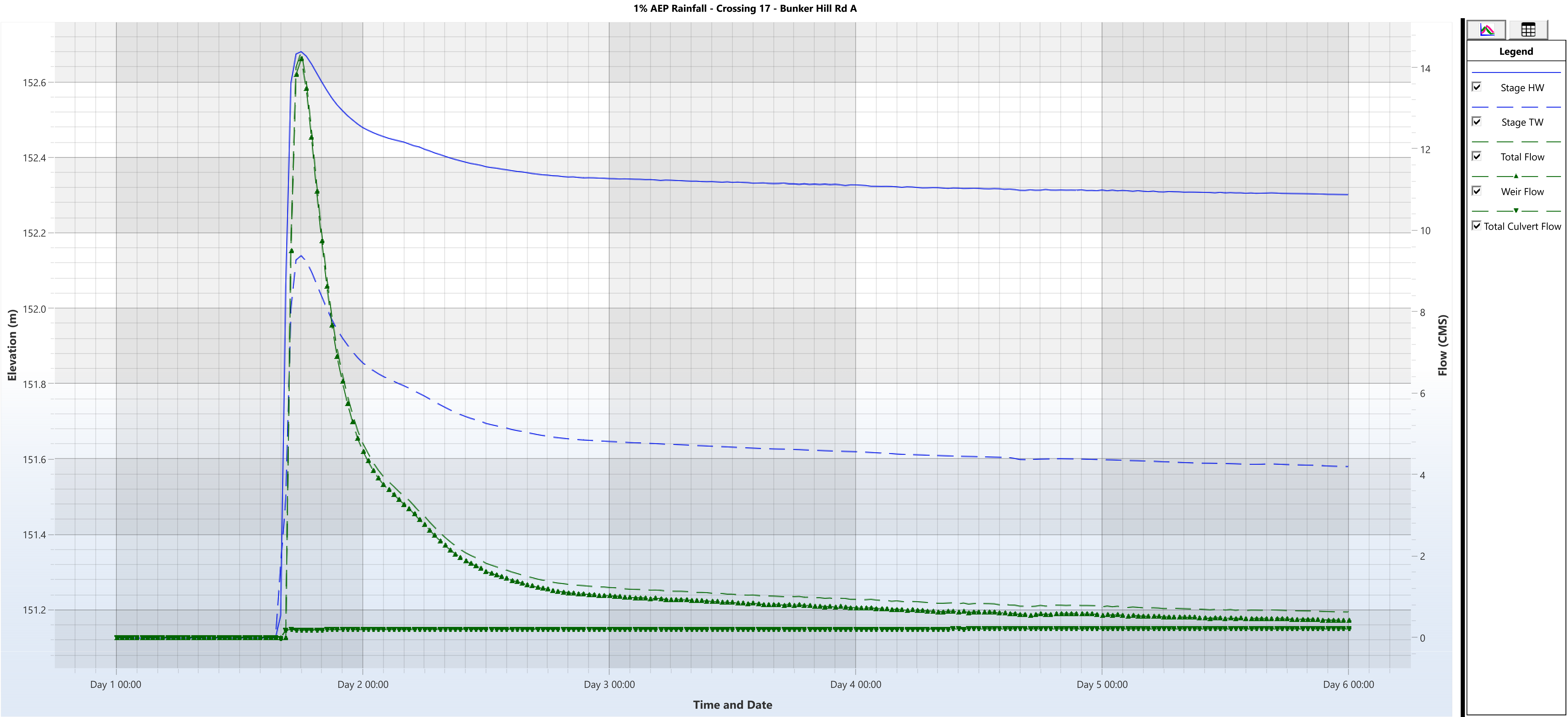

1% AEP Rainfall - Crossing 14 - Private Crossing
Elevation (m)
161.5
161.0
160.5
160.0
159.5
Flow (CMS)
20
15
10
5
0
Day 1 00:00
Day 2 00:00
Day 3 00:00
Day 4 00:00
Day 5 00:00
Day 6 00:00
Time and Date
Legend
☑ Stage HW
☑ Stage TW
☑ Total Flow
☑ Weir Flow
☑ Total Culvert Flow

1% AEP Rainfall - Crossing 15 - Westport Rd Near Glendower

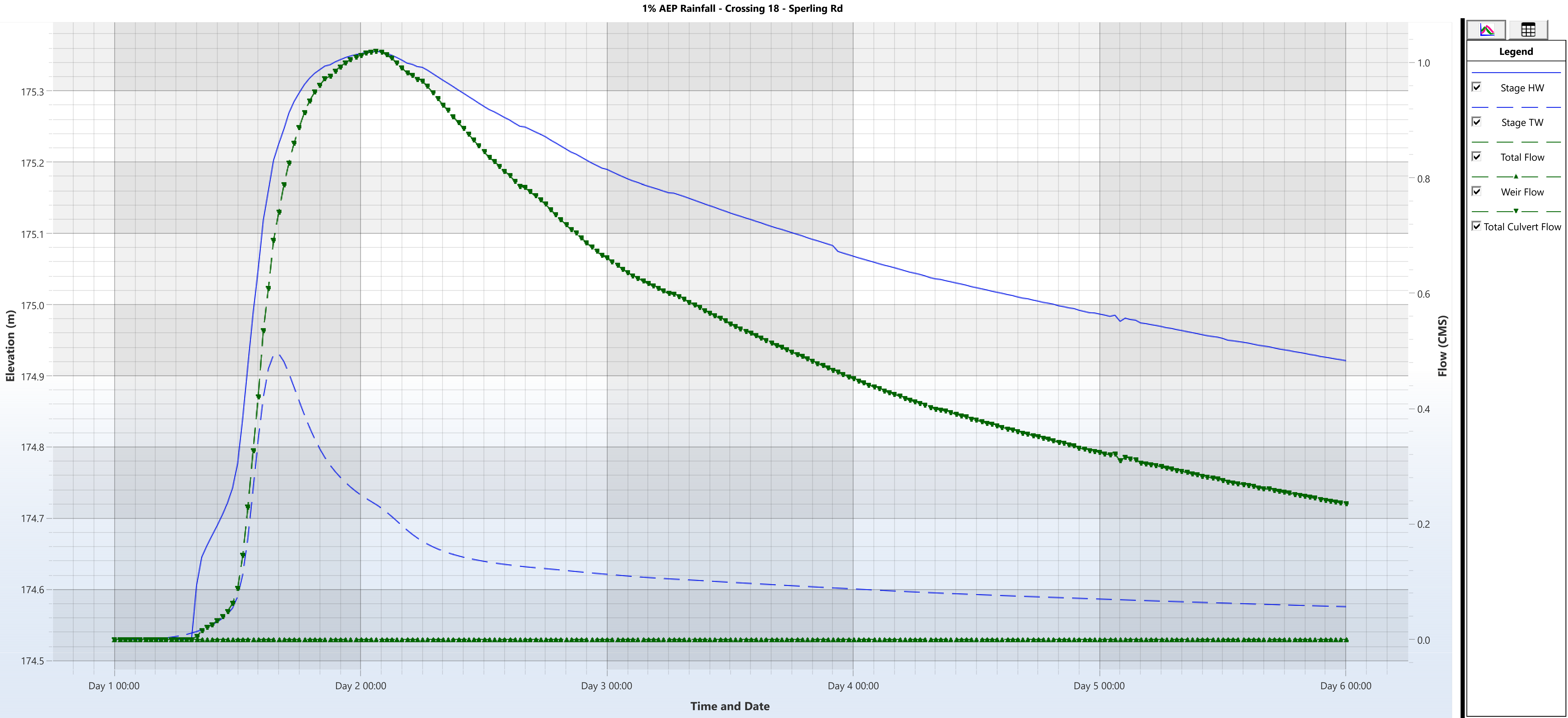


1% AEP Rainfall - Crossing 16 - Brooks Ln

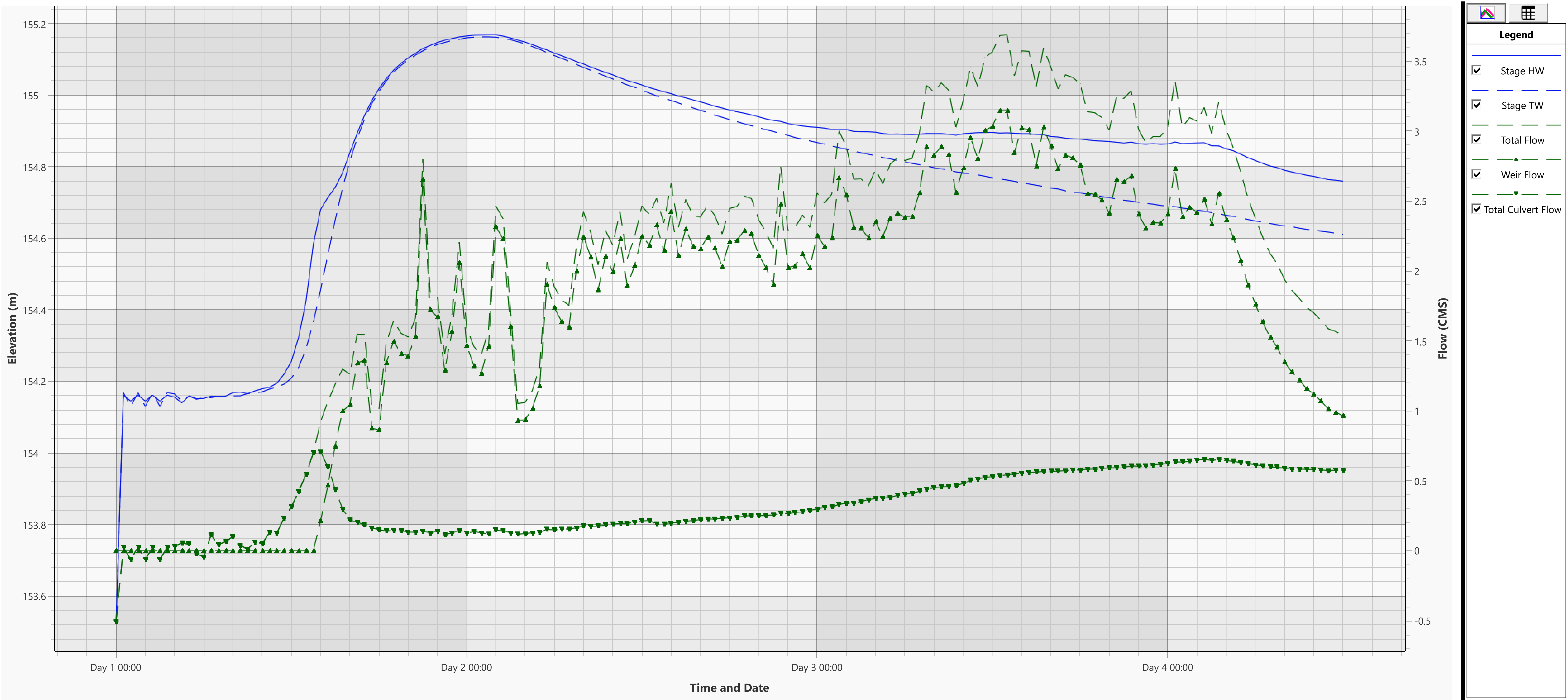




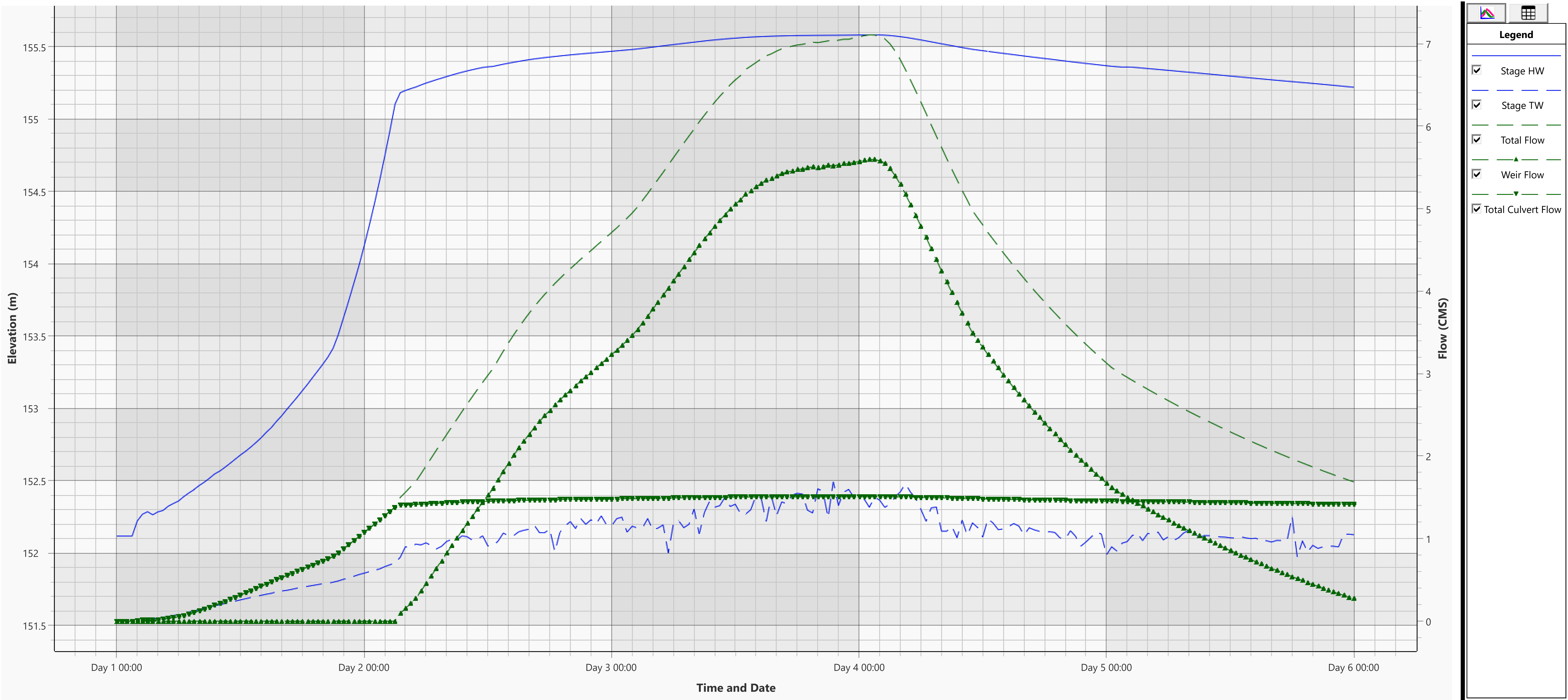
1% AEP Rainfall - Crossing 17 - Bunker Hill Rd A

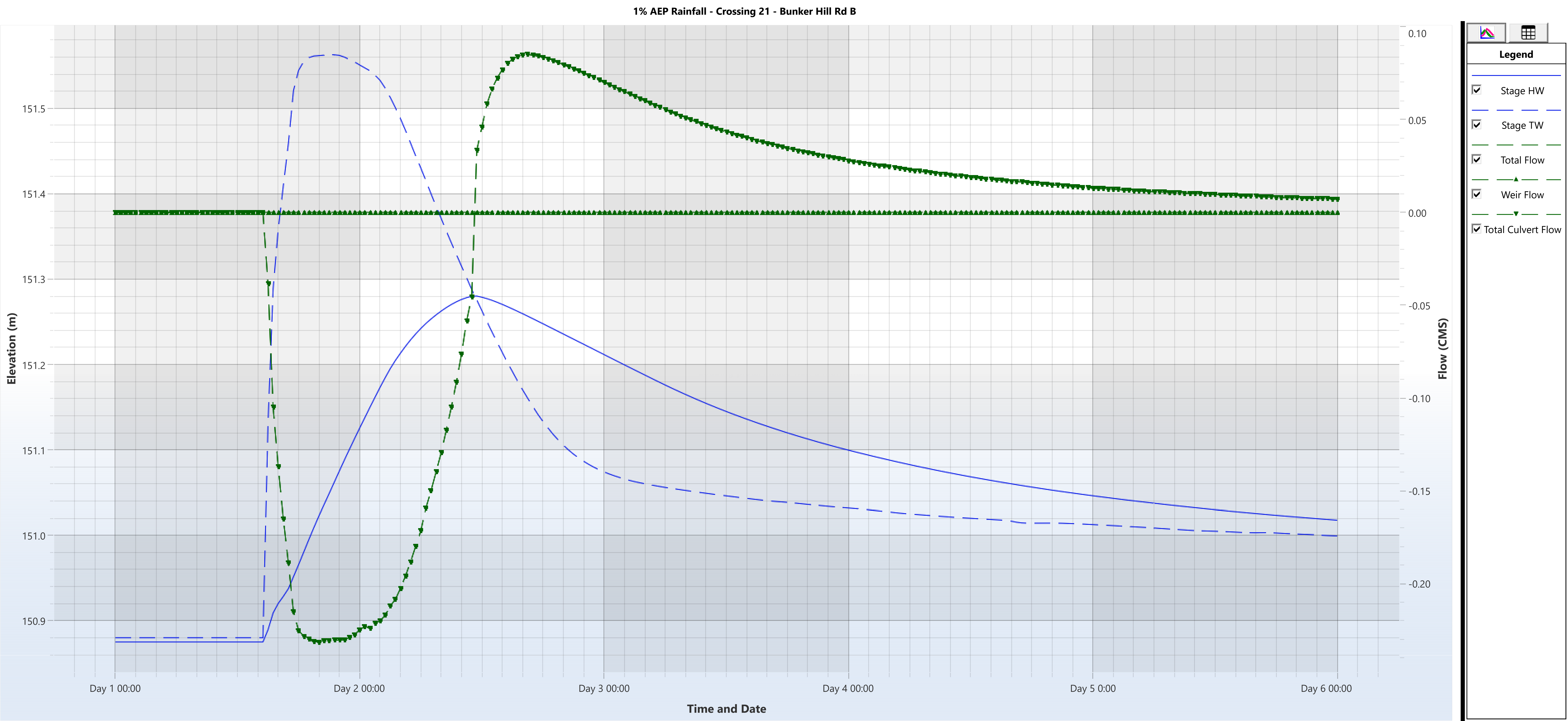

1% AEP Rainfall - Crossing 18 - Sperling Rd
Elevation (m)
175.3
175.2
175.1
175.0
174.9
174.8
174.7
174.6
174.5
Flow (CMS)
1.0
0.8
0.6
0.4
0.2
0.0
Day 1 00:00
Day 2 00:00
Day 3 00:00
Day 4 00:00
Day 5 00:00
Day 6 00:00
Time and Date
Legend
Stage HW
Stage TW
Total Flow
Weir Flow
Total Culvert Flow

1% AEP Spring Melt - Crossing 19 - McColl Ln

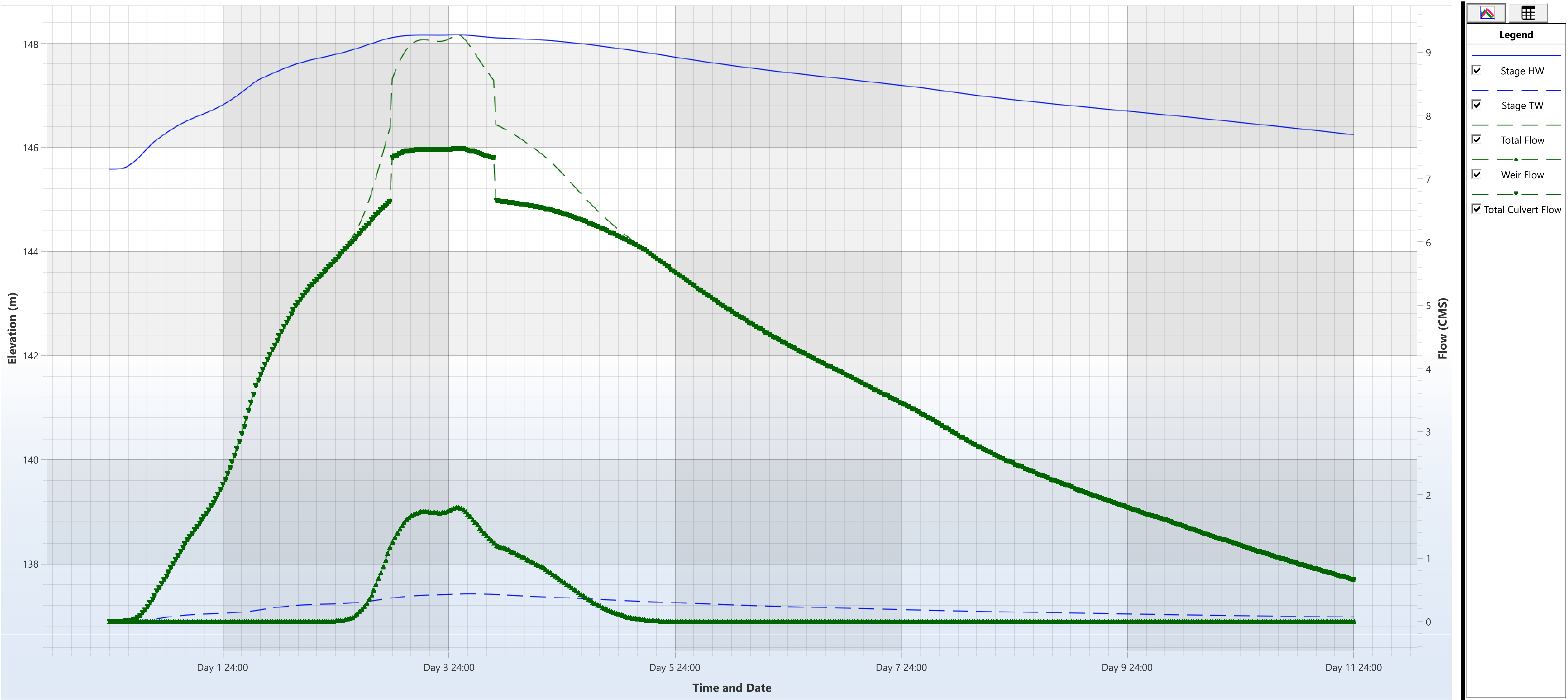


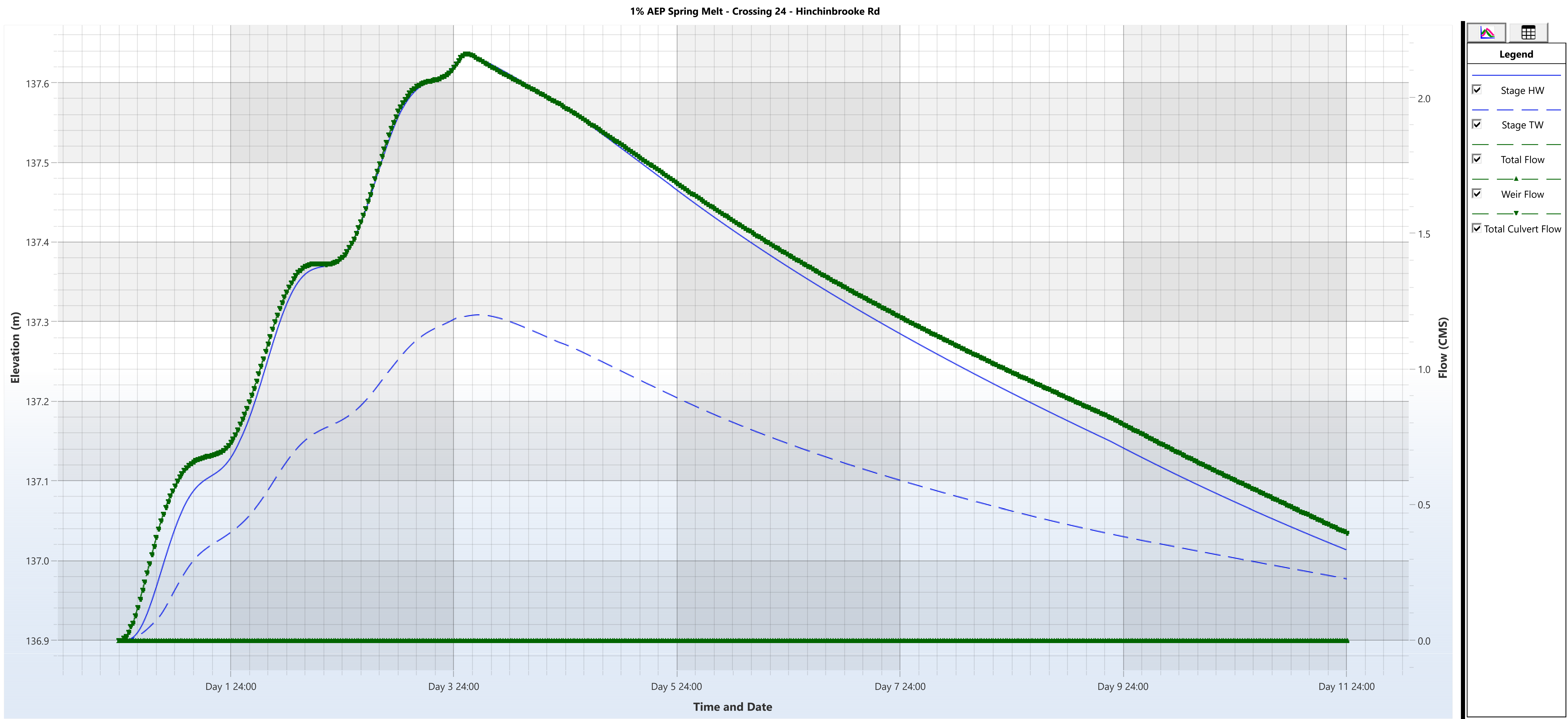
1% AEP Spring Melt - Crossing 20 - Private Crossing




1% AEP Rainfall - Crossing 21 - Bunker Hill Rd B
Elevation (m)
151.5
151.4
151.3
151.2
151.1
151.0
150.9
Flow (CMS)
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
Day 1 00:00
Day 2 00:00
Day 3 00:00
Day 4 00:00
Day 5 0:00
Day 6 00:00
Time and Date
Legend
☑ Stage HW
☑ Stage TW
☑ Total Flow
☑ Weir Flow
☑ Total Culvert Flow

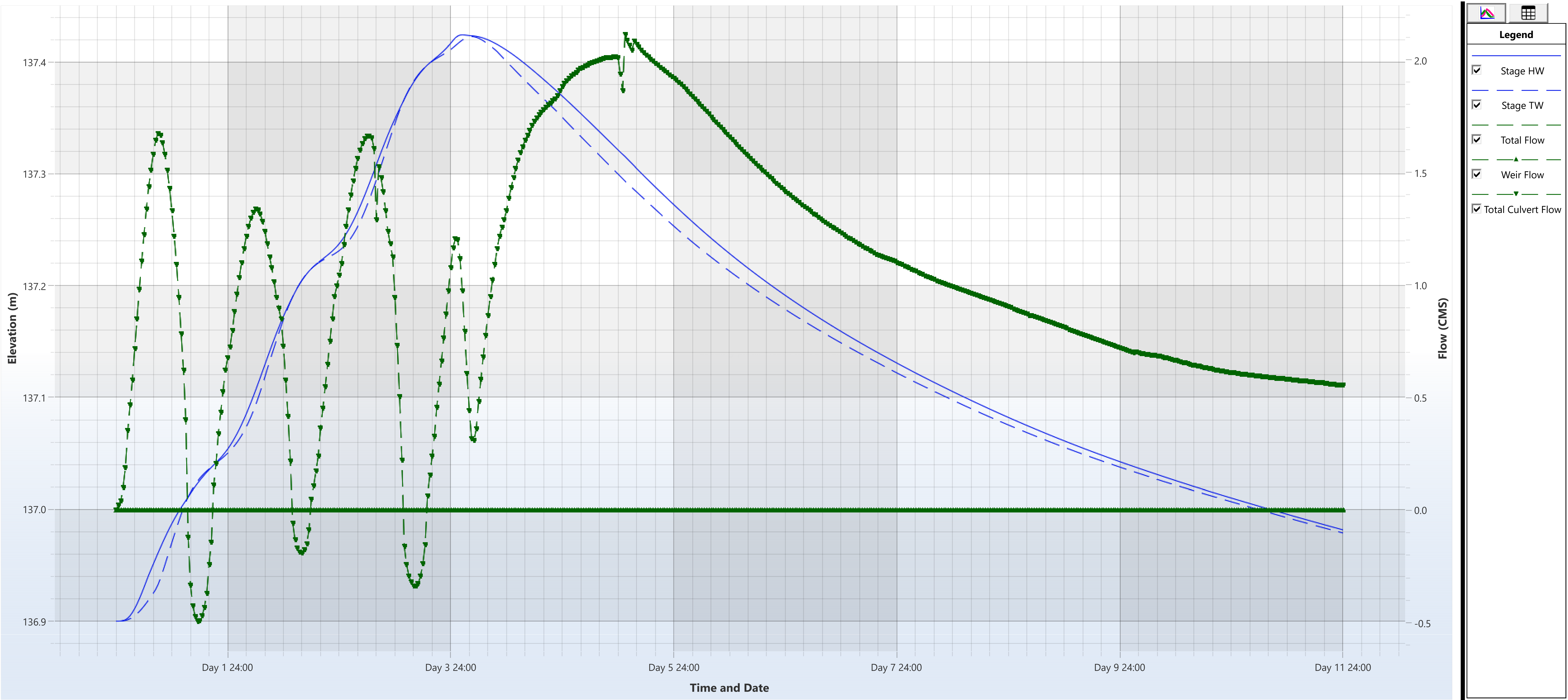
1% AEP Spring Melt - Crossing 23 - Hinchinbrooke Rd N





1% AEP Spring Melt - Crossing 24 - Hinchinbrooke Rd

1% AEP Springmelt - Crossing 25 - HWY 38 Near Verona



Appendix J:
Culvert & Bridge Data Sheets

CULVERT/BRIDGE DATA

Structure ID	1
Location	St. Andrews Lake Lane
UTM Coordinates	366964, 4938763
Type	Three HDPE Culverts
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	171.25	m
Invert	170.20	m
Number of Openings	3	
Low Point of Road	170.59	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	1.90	m³/s
HW_{peak}	170.85	m
TW_{peak}	170.85	m
ΔH_{peak}	0.00	m
Max. Relief Flow Depth	0.26	m

B. Photographic Presentation

C. Benchmark

Description	Swamp Bottom
Coordinates	366954.94, 4938763.24
Elevation	170.42

CULVERT/BRIDGE DATA

Structure ID	2
Location	K&P Trail near Cole Lake
UTM Coordinates	366876, 49338489
Type	Concrete Box Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	171.25	m
Invert	168.85	m
Number of Openings	1	
Low Point of Road	171.13	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	1.90	m³/s
HW_{peak}	170.84	m
TW_{peak}	170.77	m
ΔH_{peak}	0.07	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	Obvert of Culvert
Coordinates	366695.91, 4933879.69
Elevation	168.3

CULVERT/BRIDGE DATA

Structure ID	3
Location	Highway 38 near Cole Lake
UTM Coordinates	367020, 4938050
Type	Concrete Box Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	171.26	m
Invert	168.28	m
Number of Openings	1	
Low Point of Road	170.99	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	3.60	m^3/s
HW_{peak}	170.75	m
TW_{peak}	170.38	m
ΔH_{peak}	0.37	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	Obvert of Box Culvert
Coordinates	367022.21. 4938063.20
Elevation	171.02

CULVERT/BRIDGE DATA

Structure ID	5
Location	Highway 38 near Godfrey
UTM Coordinates	366665, 4933987
Type	Concrete Box Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	154.73	m
Invert	150.30	m
Number of Openings	1	
Low Point of Road	153.52	m
Governing 1% AEP Event	Rainfall	
Governing 1% AEP Q_{peak}	11.70	m^3/s
HW_{peak}	154.65	m
TW_{peak}	152.94	m
ΔH_{peak}	1.71	m
Max. Relief Flow Depth	1.13	m

B. Photographic Presentation

C. Benchmark

Description	South East Soffit
Coordinates	366666.36, 4933989.72
Elevation	152.36

CULVERT/BRIDGE DATA

Structure ID	6
Location	K&P Trail N
UTM Coordinates	366701, 4933876
Type	Bridge
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	154.39	m
Invert	150.06	m
Number of Openings	1	
Low Point of Road	154.28	m
Governing 1% AEP Event	Rainfall	
Governing 1% AEP Q_{peak}	11.70	m^3/s
HW_{peak}	152.74	m
TW_{peak}	152.66	m
ΔH_{peak}	0.08	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	top of conc culvert opening
Coordinates	366878.24, 4938488.39
Elevation	151.73

CULVERT/BRIDGE DATA

Structure ID	7
Location	Westport Road near Godfrey
UTM Coordinates	366673, 4933510
Type	CSP Arch Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	152.40	m
Invert	149.60	m
Number of Openings	1	
Low Point of Road	151.66	m
Governing 1% AEP Event	Rainfall	
Governing 1% AEP Q_{peak}	20.60	m³/s
HW_{peak}	152.47	m
TW_{peak}	152.11	m
ΔH_{peak}	0.36	m
Max. Relief Flow Depth	0.81	m

B. Photographic Presentation

C. Benchmark

Description	Obvert of Culvert, north side
Coordinates	366669.13, 4933513.28
Elevation	152.15

CULVERT/BRIDGE DATA

Structure ID	9
Location	Craig Road
UTM Coordinates	366850, 4930999
Type	CSP Arch Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	139.32	m
Invert	135.64	m
Number of Openings	1	
Low Point of Road	139.31	m
Governing 1% AEP Event	Rainfall	
Governing 1% AEP Q_{peak}	18.80	m³/s
HW_{peak}	138.67	m
TW_{peak}	138.14	m
ΔH_{peak}	0.53	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	Obvert of 4400 CSP
Coordinates	366855.43. 4930996.56
Elevation	138.51

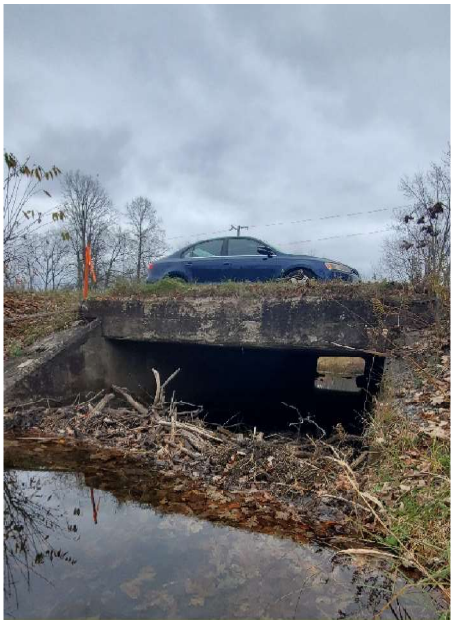
CULVERT/BRIDGE DATA

Structure ID	10
Location	Highway 38 near Howes Lake
UTM Coordinates	365712, 4928432
Type	Concrete Box Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	138.65	m
Invert	138.11	m
Number of Openings	1	
Low Point of Road	138.22	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	23.80	m^3/s
HW_{peak}	137.31	m
TW_{peak}	137.18	m
ΔH_{peak}	0.13	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation



C. Benchmark

Description	Top of conc. box culvert
Coordinates	365721.54, 4928405
Elevation	137.72

CULVERT/BRIDGE DATA

Structure ID	11
Location	Desert Lake Road
UTM Coordinates	366103, 4928059
Type	Bridge
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	139.25	m
Invert	135.50	m
Number of Openings	1	
Low Point of Road	139.16	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	20.70	m³/s
HW_{peak}	137.42	m
TW_{peak}	137.31	m
ΔH_{peak}	0.11	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	CL of Road
Coordinates	366105.11, 4928059.47
Elevation	139.5

CULVERT/BRIDGE DATA

Structure ID	12
Location	Cedarwoods Drive
UTM Coordinates	366021, 4926137
Type	Concrete Box Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	137.59	m
Invert	135.63	m
Number of Openings	1	
Low Point of Road	137.20	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	1.90	m³/s
HW_{peak}	137.31	m
TW_{peak}	137.31	m
ΔH_{peak}	0.00	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	CL of Steel Deck
Coordinates	366020.04, 4926135.68
Elevation	135.4

CULVERT/BRIDGE DATA

Structure ID	13
Location	Buck Bay Road
UTM Coordinates	370464, 4936882
Type	Bridge
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	162.89	m
Invert	162.50	m
Number of Openings	1	
Low Point of Road	162.74	m
Governing 1% AEP Event	Rainfall	
Governing 1% AEP Q_{peak}	12.20	m³/s
HW_{peak}	163.26	m
TW_{peak}	163.17	m
ΔH_{peak}	0.09	m
Max. Relief Flow Depth	0.52	m

B. Photographic Presentation

C. Benchmark

Description	BM cut cross top dam between north and middle logbay
Coordinates	369766.085, 4931605.917
Elevation	151.35

CULVERT/BRIDGE DATA

Structure ID	15
Location	Westport Road near Glendower
UTM Coordinates	370467, 4935677
Type	CSP Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	160.85	m
Invert	158.64	m
Number of Openings	1	
Low Point of Road	160.68	m
Governing 1% AEP Event	Rainfall	
Governing 1% AEP Q_{peak}	21.90	m³/s
HW_{peak}	161.14	m
TW_{peak}	160.13	m
ΔH_{peak}	1.01	m
Max. Relief Flow Depth	0.46	m

B. Photographic Presentation

C. Benchmark

Description	Obvert of 1800 CSP
Coordinates	370466.81, 4935672.82
Elevation	160.29

CULVERT/BRIDGE DATA

Structure ID	16
Location	Brooks Lane
UTM Coordinates	370892, 4935286
Type	CSP Arch Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	158.54	m
Invert	157.11	m
Number of Openings	1	
Low Point of Road	158.13	m
Governing 1% AEP Event	Rainfall	
Governing 1% AEP Q_{peak}	16.00	m³/s
HW_{peak}	158.62	m
TW_{peak}	158.40	m
ΔH_{peak}	0.22	m
Max. Relief Flow Depth	0.49	m

B. Photographic Presentation

C. Benchmark

Description	Soffit
Coordinates	370894.06, 4935290.12
Elevation	158.57

CULVERT/BRIDGE DATA

Structure ID	17
Location	Bunker Hill Road
UTM Coordinates	371226, 4934750
Type	CSP Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	152.90	m
Invert	150.34	m
Number of Openings	1	
Low Point of Road	152.22	m
Governing 1% AEP Event	Rainfall	
Governing 1% AEP Q_{peak}	14.40	m³/s
HW_{peak}	152.68	m
TW_{peak}	152.14	m
ΔH_{peak}	0.54	m
Max. Relief Flow Depth	0.46	m

B. Photographic Presentation

C. Benchmark

Description	1800 CSP Obvert
Coordinates	371230.56, 4934754.90
Elevation	152.48

CULVERT/BRIDGE DATA

Structure ID	18
Location	Sperling Road
UTM Coordinates	372984, 4938747
Type	CSP Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	176.24	m
Invert	174.53	m
Number of Openings	1	
Low Point of Road	175.41	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	1.00	m³/s
HW_{peak}	175.35	m
TW_{peak}	174.93	m
ΔH_{peak}	0.42	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	Obvert of 1600 CSP
Coordinates	372993.41, 4938736.61
Elevation	176.39

CULVERT/BRIDGE DATA

Structure ID	19
Location	McColl Lane
UTM Coordinates	372339, 4937417
Type	CSP Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	154.93	m
Invert	153.53	m
Number of Openings	2	
Low Point of Road	154.59	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	3.70	m³/s
HW_{peak}	155.17	m
TW_{peak}	155.16	m
ΔH_{peak}	0.01	m
Max. Relief Flow Depth	0.58	m

B. Photographic Presentation

C. Benchmark

Description	"good" Obvert of Culvert circle csp
Coordinates	372375.59, 4937441.71
Elevation	154.62

CULVERT/BRIDGE DATA

Structure ID	21
Location	Bunker Hill Road
UTM Coordinates	371480, 4934711
Type	CSP Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	151.90	m
Invert	150.20	m
Number of Openings	1	
Low Point of Road	151.84	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	0.10	m^3/s
HW_{peak}	151.56	m
TW_{peak}	151.56	m
ΔH_{peak}	0.00	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	Obvert of 1200 CSP
Coordinates	371483.02, 4934715.16
Elevation	151.66

CULVERT/BRIDGE DATA

Structure ID	22
Location	Hamilton Lane
UTM Coordinates	369758, 4931596
Type	Dam with three stoplog bays
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	151.70	m
Invert	150.18	m
Number of Openings	3	
Low Point of Road	151.40	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	8.10	m³/s
HW_{peak}	151.50	m
TW_{peak}	150.43	m
ΔH_{peak}	1.07	m
Max. Relief Flow Depth	0.10	m

B. Photographic Presentation

C. Benchmark

Description	Centerline Hamilton Lane
Coordinates	369702.38, 4931605.48
Elevation	152.03

CULVERT/BRIDGE DATA

Structure ID	23
Location	Hichinbrooke Road North
UTM Coordinates	367504, 4929867
Type	CSP Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	148.31	m
Invert	145.60	m
Number of Openings	1	
Low Point of Road	147.76	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	9.30	m^3/s
HW_{peak}	148.16	m
TW_{peak}	137.42	m
ΔH_{peak}	10.74	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

Upstream

Downstream

C. Benchmark

Description	Obvert of Culvert
Coordinates	367505.24, 4929866.03
Elevation	147.16

CULVERT/BRIDGE DATA

Structure ID	24
Location	Hichinbrooke Road
UTM Coordinates	367001, 4926814
Type	CSP Culvert
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	138.53	m
Invert	135.44	m
Number of Openings	1	
Low Point of Road	137.81	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	2.20	m³/s
HW_{peak}	137.40	m
TW_{peak}	137.31	m
ΔH_{peak}	0.09	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation (Coming)

C. Benchmark

Description	Obvert of Culvert
Coordinates	367010.43, 4926832.95
Elevation	138.18

CULVERT/BRIDGE DATA

Structure ID	26
Location	Highway 38 near Verona
UTM Coordinates	365713, 4928437
Type	Bridge
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	139.05	m
Invert	135.23	m
Number of Openings	1	
Low Point of Road	137.86	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	2.10	m³/s
HW_{peak}	137.42	m
TW_{peak}	137.42	m
ΔH_{peak}	0.00	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	CL of Road
Coordinates	365133.29, 4925571.37
Elevation	139.27

CULVERT/BRIDGE DATA

Structure ID	27
Location	K&P Trail near Verona
UTM Coordinates	365059, 4925559
Type	Bridge
Conversion to CGVD28	+0.33

A. Specifications

Top of Road Elevation at Structure	139.09	m
Invert	134.68	m
Number of Openings	1	
Low Point of Road	138.45	m
Governing 1% AEP Event	Spring melt	
Governing 1% AEP Q_{peak}	33.20	m³/s
HW_{peak}	136.48	m
TW_{peak}	136.48	m
ΔH_{peak}	0.00	m
Max. Relief Flow Depth	0.00	m

B. Photographic Presentation

C. Benchmark

Description	Centerline of top of bridge
Coordinates	365060.71, 4925558.19
Elevation	139.35

Appendix K:
Computational Mesh Spacing for 2D Flow Areas

FID	Name	Near Spacing	Near Repeats	Far Spacing
0	Reach 2 Creek 6	5	2	
1	Reach 2 Creek 7	5	1	
2	Reach 6 Creek 2	5	2	10
3	Reach 6 Creek 4	5	1	
4	Reach 6 Creek 6	10	1	
5	Reach 6 Creek 7	5	1	
6	Reach 6 Creek 9	5	2	20
7	Reach 6 Creek 10	5	1	
8	Reach 9 Creek 1	10	1	
9	Reach 9 Creek 2	10	1	
10	Reach 1 Creek 1	10	1	
11	Reach 1 Creek 2	5	2	
12	Reach 6 Creek 8	5	1	20
13	Reach 2 Creek 4	5	2	10
14	Cty Rd 38 CL	5	2	20
15	Private Crossing US Cole Lake	5	1	
16	Inflow Channel to Cole Lake	10	2	
17	Reach 2 Creek 2	5	2	
18	Cty Rd 38 CL2	5	2	10
19	Westport Rd CL	5	2	10
20	Private Driveawy CL	5	3	
21	Craig Rd CL	5	4	10
22	Reach 6 Creek 3	5	1	
23	Private Rd CL Off Dsrt Lk Rd	5	1	
24	Bunker Hill Rd CL	5	3	10
25	Breakline 4	3	2	10
26	Weir 10 CL	3	1	10
27	Breakline 44	5	1	
28	McColl Ln CL	5	2	
29	Sterling Rd CL	5	1	10
30	Breakline 46	1	1	
31	Breakline 50	5	1	
32	Breakline 55	5	1	10
33	Breakline 54	5	1	10
34	Buck Bay Rd CL	6	3	20
35	Bunker Hill Rd CL2	5	2	10
36	Brooks Ln CL	5	2	10
37	Bunker Hill Rd CL3	5	1	20
38	S Frontenac Rd 8 CL	5	3	10
39	Private Crossing 12 CL	5	1	10
40	Private Crossing 11 CL	5	1	
41	Private Crossing 9 CL	10	1	10
42	Reach 10 Crossing	5	2	20
43	Reach 1 Creek 3	2	2	
44	Breakline 28	5	1	
45	St Andrews Lake Ln CL	5	1	20
46	K&P Trail Near Cole Lake	5	1	20
47	Private Crossing DS White Lake	5	2	10
48	Breakline 58	3	3	
49	Bvr Dam DS Buck Bay Rd	10	1	10
50	Reach 6 Creek 5	10	1	20
51	Bvr Dam US 13 Isl Lk Inlet	5	1	10
52	Reach 6 Creek 11	5	1	10
53	Reach 2 Creek 1	5	2	
54	Reach 6 Creek 1	5	2	10
55	Breakline 86	10	1	
56	Reach 2 Creek 8	5	1	10
57	Breakline 21	5	1	
58	Breakline 42	10	3	
59	Breakline 45	10	1	
60	Reach 2 Creek 3	10	1	
61	Reach 3 Crossing 1		0	
62	Breakline 57	3	1	5
63	Reach 3 Crossing 2	5	3	20
64	14 Island Lake Weir	3	1	
65	K&P Trail near Godfrey2	2.5	3	10
66	13 Island Lk Dm	5	1	10
67	Breakline 34	3	3	10
68	Breakline 43	5	2	
69	Reach 2 Creek 5	10	2	
70	Old Mine Ln	4	3	
71	Private Crossing 9	4	3	
72	Breakline 72	3	2	
73	Breakline 74	3	2	
74	Breakline 78	5	3	
75	Breakline 79	10	4	
76	Breakline 9	2	1	
77	Breakline 6	2	1	
78	Breakline 26	2	1	
79	Breakline 36	2	1	
80	Breakline 39	1	1	
81	Breakline 13	1	1	
82	Breakline 81	1	1	
83	Breakline 11	2	1	
84	Breakline 12	2	1	
85	Reach 11 Breakline	1	1	
86	Breakline 2	2	1	