QUINTE CONSERVATION

Salmon River Upper Lakes Flood Hazard Mapping

Floodplain Mapping Report

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TABLE OF CONTENTS

List of Tables

List of Figures

STATEMENT OF LIMITATIONS AND CONDITIONS

Limitations

This report has been prepared for the Quinte Conservation in accordance with the agreement between KGS Group and Quinte Conservation (the "Agreement"). This report represents KGS Group's professional judgment and exercising due care consistent with the preparation of similar reports. The information, data, recommendations, and conclusions in this report are subject to the constraints and limitations in the Agreement and the qualifications in this report. This report must be read as a whole, and sections or parts should not be read out of context.

This report is based on information made available to KGS Group by Quinte Conservation and unless stated otherwise, KGS Group has not verified the accuracy, completeness, or validity of such information, makes no representation regarding its accuracy, and hereby disclaims any liability in connection therewith. KGS Group shall not be responsible for conditions/issues it was not authorized or able to investigate or which were beyond the scope of its work. The information and conclusions provided in this report apply only as they existed at the time of KGS Group's work.

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1.0 INTRODUCTION

1.1 Objectives of the Study

KGS Group was retained by Quinte Conservation (QC) to update the regulatory floodplain for the Salmon River Upper Lakes Watershed, from Kennebec Lake to the outlet of Crotch Lake. The study includes collection of topographic data through site inspection and surveying, hydrologic assessments, hydraulic modeling and analyses, and mapping of the Regulatory Floodplain.

A draft version of the floodplain maps was presented at a Public Information Centre (February 14, 2024 – Kennebec Hall, Arden, Ontario) to discuss and receive feedback from the public, that was taken into consideration for the preparation of the final version of the floodplain maps. Aspects discussed in that PIC included: the role of the Upper Arden Dam in the flows that occur downstream; the occurrence of beaver dams at some locations; areas prone to flooding and historic water levels at specific locations, including the area around Horseshoe Lake, Crotch Lake and near the Cranberry Lake Rd Bridge.

The study was conducted in accordance with the requirements outlined in the Ontario Ministry of Natural Resources and Forestry (MNRF), and the Flood Hazard Identification and Mapping Program (FHIMP) – Project Eligibility and Requirements. The technical guidelines used were the following:

- Natural Resources Canada Federal Flood Mapping Guidelines Series
- OMNR (2011) Technical Bulletins associated with the Lakes and Rivers Improvement Act (LRIA)
- OMNR Technical Guide – River & Stream Systems: Flooding Hazard Limit (2002)
- OMNR Technical Guide – River & Stream Systems: Erosion Hazard Limit (2002)
- USACE HEC-HMS and HEC-RAS User's Manual and Technical Reference Manual

Following guidance from Environment and Climate Change Canada (ECCC), in this study, recurrent events are referred to with both return periods and AEPs. This is to provide clarity to users of the report, and to the public, regarding the likelihood of a flood event happening in any given year. It highlights the fact that the event referred to as the 100-year flood has a 1% probability of occurring or being exceeded in any given year. The correspondence between return period and Annual Exceedance Probability (AEP) is provided in Table 1-1. The two nomenclatures are interchangeable in this report. This report describes the hydraulic analyses and modeling conducted as part of the study.

TABLE 1-1: RETURN PERIODS AND AEPS

Return Period	Annual Exceedance Probability (AEP)
2 years	50%
5 years	20%
10 years	10%
20 years	5%
25 years	4%
50 years	2%
100 years	1%
200 years	0.5%

Return Period	Annual Exceedance Probability (AEP)
500 years	0.2%

1.2 Previous Studies and Data Provided

KGS performed a background review of the data provided by QC which included:

- Previous Dam Safety Review (DSR) Studies:
  - Lower Arden Dam DSR (Hatch, 2009)
  - Upper Arden Dam DSR (Hatch, 2009)
  - Upper Arden Dam Break Analysis (AHYDTECH Geomorphic, 2017)
  - Middle Arden Dam DSR (Hatch, 2009)
- Dam Operations Manual (NRCA, 1994)
- 2019-2022 Arden Dams Inspection Photos
- Arden Dams Drawings
- Floodplain Maps (CCL, 1981)
- Ortho-imagery (Dated 2019)
- Elevation (Based on the Eastern Ontario LiDAR Acquisition Project, Dated 2021-2022)

Previous hydraulic studies that were identified in this project are:

- CCL (1981), Floodplain maps for certain lakes within the study area were created by Cumming-Cockburn & Associates Limited (CCL) in 1981; however, the associated studies or reports for these maps are currently unavailable.
- HATCH (2009), Dam Safety Reports (DSRs) for Upper Arden, Middle Arden, and Lower Arden Dams. As part of the study, the flood flows for the 100-year recurrent event (1% AEP) and other recurrent events were developed.
- AHYDTECH Geomorphic (2017), Upper Arden Dam Break Analysis. In this study 100-year flood and other recurrent events were simulated and included in an inundation map, for dam safety analysis.

KGS Group reviewed this background data to obtain useful information for developing the floodplain maps of the study area.

1.3 Topographic Data

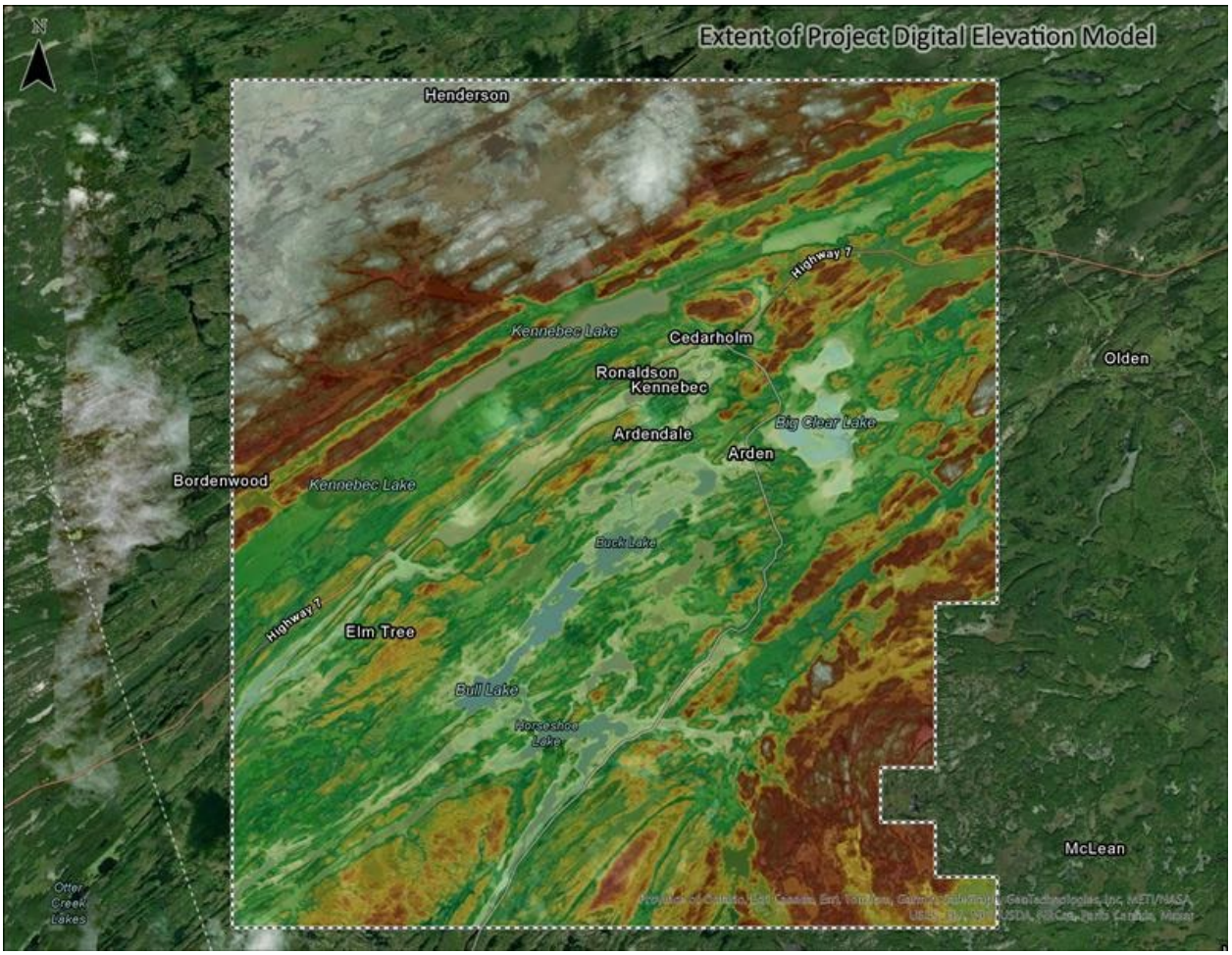
The project floodplain Digital Terrain Model DTM (Figure 1-1) that served as the basis for the study was developed based on the HRDEM (High Resolution Digital Elevation Model), collected by Natural Resources Canada (NRCAN) in 2022 as part of the as part of the Eastern Ontario LiDAR Acquisition Project of 2022. It was supplemented with bathymetric data at structures and crossings, collected by KGS Group, as well as information obtained from available Nautical Charts. The vertical datum in the DTM was set to CGVD2013.

The bathymetric survey was carried out by KGS Group in August 2023, as part of the Salmon River Upper Lakes Flood Hazard Mapping project. The survey focused on collecting bed elevation data at crossings and structures and at other locations along the lake system. The crossings were also surveyed to define their

dimensions and road elevations. A total of 10 locations were surveyed including 5 bridges, 2 culverts and 3 dam structures.

The Nautical Charts for the lakes were obtained from i-Boating website and were only available in image format. The depth data was extracted from the Nautical Charts at multiple locations within the lakes to create depth contours. The depth contours were converted to elevations, which were used to adjust the bottom of the lakes in the DTM. For sections of overlap between bathymetric data and nautical charts data, the bathymetric data was used as it was more accurate and easier to integrate.

FIGURE 1-1: EXTENT OF DIGITAL ELEVATION MODEL



1.4 Criteria for Flood Hazard Limit

The study area is located within Zone 2, in Ontario. Based on the "Technical Guide – River and Stream Systems: Flood Hazard Limit" (MNRF 2002), the Regulatory Flood for this watershed is the 100-year Flood (i.e. the flood with 1% AEP).

2.0 HYDROLOGY

2.1 General Description of the Watershed

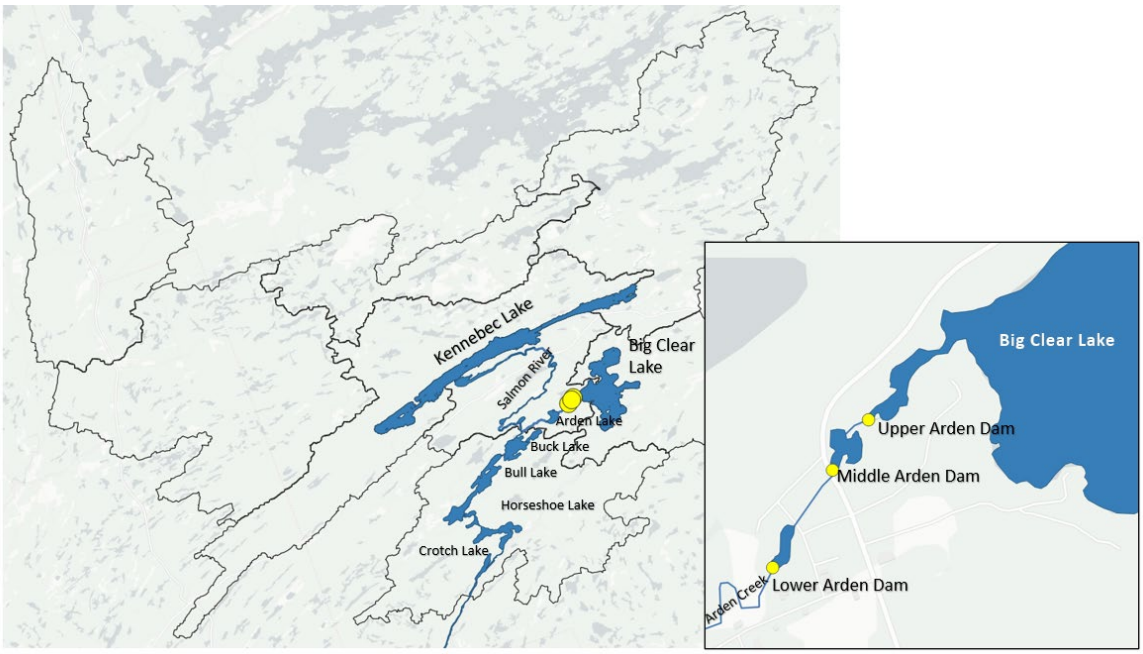
The Salmon River Upper Lakes are situated in the Township of Central Frontenac, including Kennebec Lake, Big Clear Lake, Arden Lake, Buck Lake, Bull Lake, Horseshoe Lake, Crotch Lake, and several other smaller lakes. The study area watershed (404 km^2) is shown in Figure 2-1.

Kennebec Lake (to the north of the study area) receives runoff from the upstream most portion of the watershed, approximately one-half of the watershed area (297 km^2). It drains through the Salmon River, which generally runs in the south direction, through flat terrain, to find, in that order, Buck Lake, Bull Lake, Horseshoe Lake and Crotch Lake.

Big Clear Lake receives the runoff from an eastern portion of the watershed (approximately 33 km^2 of drainage area) and drains through Arden Creek, a tributary of the Salmon River. The outflows from Big Clear Lake are controlled at the Upper Arden Dam. From there, Arden Creek flows towards the west, passing through the Middle Arden Dam, the Lower Arden Dam, and Arden Lake, to join the Salmon River (from the east) at Buck Lake.

The study area for this floodplain mapping project is from the shores of Kennebec Lake and Big Clear Lake, along the Salmon River and Arden Creek, to the outlet of Crotch Lake.

FIGURE 2-1: STUDY AREA SALMON RIVER AND UPPER LAKES



2.2 Hydrologic Analysis

Details of the hydrologic analyses carried out as part of this study are provided in KGS (2024a).

The study included hydrologic modeling and analysis using the program HEC-HMS to assess the magnitude of recurrent summer and spring flood events ranging from 2 to 500-year return periods (events with 50% to 0.2% AEP).

Several limitations were encountered while preparing a calibrated hydrologic model for this study. There are no hydrometric stations within the study watershed with measured flow data. Therefore, it was not possible to calibrate the model against observed flood events. To prepare a hydrologic model with reliable results to be used for floodplain mapping, the results obtained from RFFA were used to verify and refine the model parameters selected to represent the characteristics of the various sub-catchments within the watershed.

The Regulatory Flood in the study area is the 100-year flood (1% AEP) as indicated in the "Technical Guide – River and Stream Systems: Flooding Hazard Limit" (MNRF, 2002). The results presented in Table 2-1 show that the peak flows generated in the spring (rain plus snowmelt) are greater than their summer counterparts. Therefore, the flood generated by the 100-year rain-plus-snowmelt event was selected as the regulatory flood event in the study area and will be used for the definition of the floodplain for the Salmon River and Upper Lakes watershed.

As agreed in the scope of work, the 200-year (0.5% AEP) and the 500-year (0.2% AEP) spring floods were used for a sensitivity analysis used for climate change considerations.

TABLE 2-1: HYDROLOGIC MODEL RESULTS – SUMMER AND SPRING FLOWS AT THE OUTLET AND UPSTREAM OF KENNEBEC LAKE

Return Period	AEP	Winter/Spring Flow (m^3/s)			Summer/Fall Flow (m^3/s)		
		Study Area Outlet	Kennebec Lake	Big Clear Lake	Study Area Outlet	Kennebec Lake	Big Clear Lake
2	**50%**	26	17	2.3	7	4	0.4
5	**20%**	39	25	3.5	10	6	0.6
10	**10%**	47	31	4.3	12	7	0.8
25	**4%**	58	38	5.3	15	9	1.1
50	**2%**	67	43	6.1	17	10	1.3
100	**1%**	75	49	6.9	20	12	1.5
200	**0.5%**	82	54	7.6	23	14	1.8
500	**0.2%**	94	62	8.7	27	17	2.2

2.3 Hydrologic Analysis Outputs/Hydraulic Analysis Inputs

The input flows for the hydraulic analysis were the results obtained with the hydrologic model described in KGS (2024a). The corresponding 100-year spring flood hydrographs at different locations within the study area are provided in Figure 2-2.

Corresponding values were obtained from the hydrologic model and input to the hydraulic model for other recurrent flood events. Those are provided in KGS Group (2024a and 2024b). This report is focused on the

preparation of the floodplain maps with the Regulatory Flood. Table 2-2 shows the values that correspond to the 100-year (1% AEP) flood, which was adopted as the Regulatory Flood.

FIGURE 2-2: HYDROLOGIC INFLOWS 100-YEAR (1% AEP) FLOOD

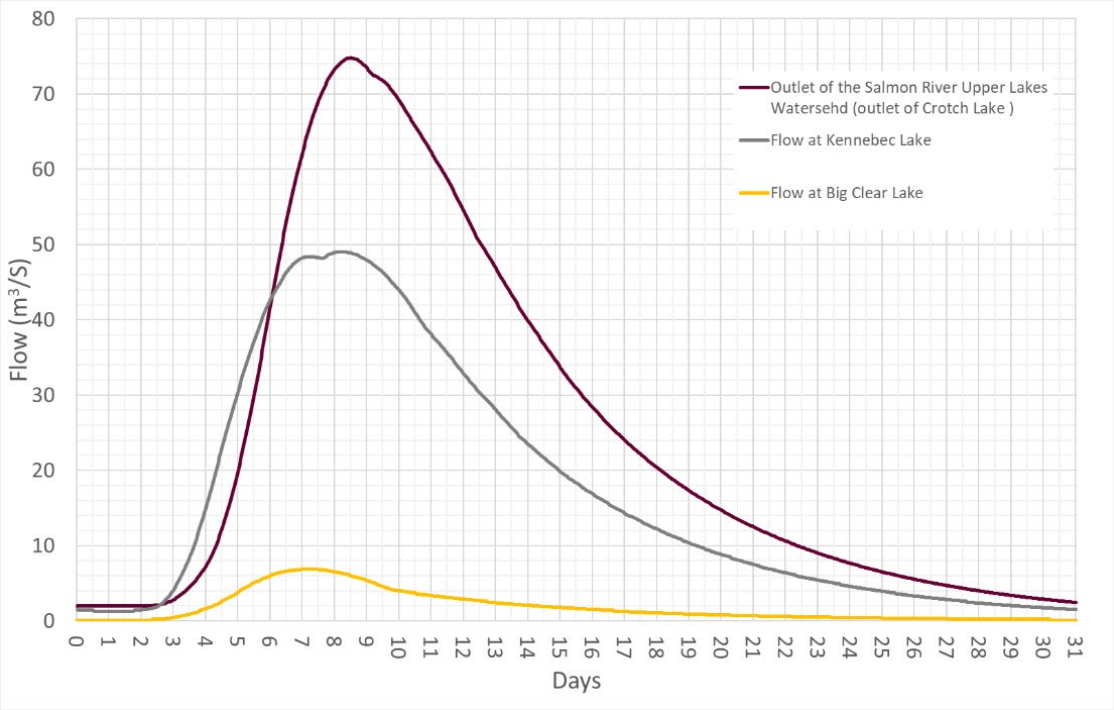


TABLE 2-2: ADOPTED FLOWS FOR HYDRAULIC MODEL

Hydrologic Model Output Location	Hydraulic Model Input Location	Peak Flow (m^3/s) 100-Year (1% AEP)
Junction 05	Inflows to Kennebec Lake from Cox's Lake (East of Kennebec)	20.5
Junction 03 and Subbasin Kennebec Lake	Inflows to Kennebec Lake from Beaver Creek (North of Kennebec)	31.1
Junction 07	Inflows to Big Clear Lake	8
Subbasin B11	Inflows to Horseshoe Lake	4.5
Subbasin B12	Inflows to Horseshoe Lake	2.4
Subbasin B08	Inflows to Buck Lake	7.2
Subbasin B09	Inflows to Arden Creek	1.6
Subbasin B06	Inflows to Salmon River at Garrison Lake	4.7

3.0 HYDRAULIC ANALYSIS

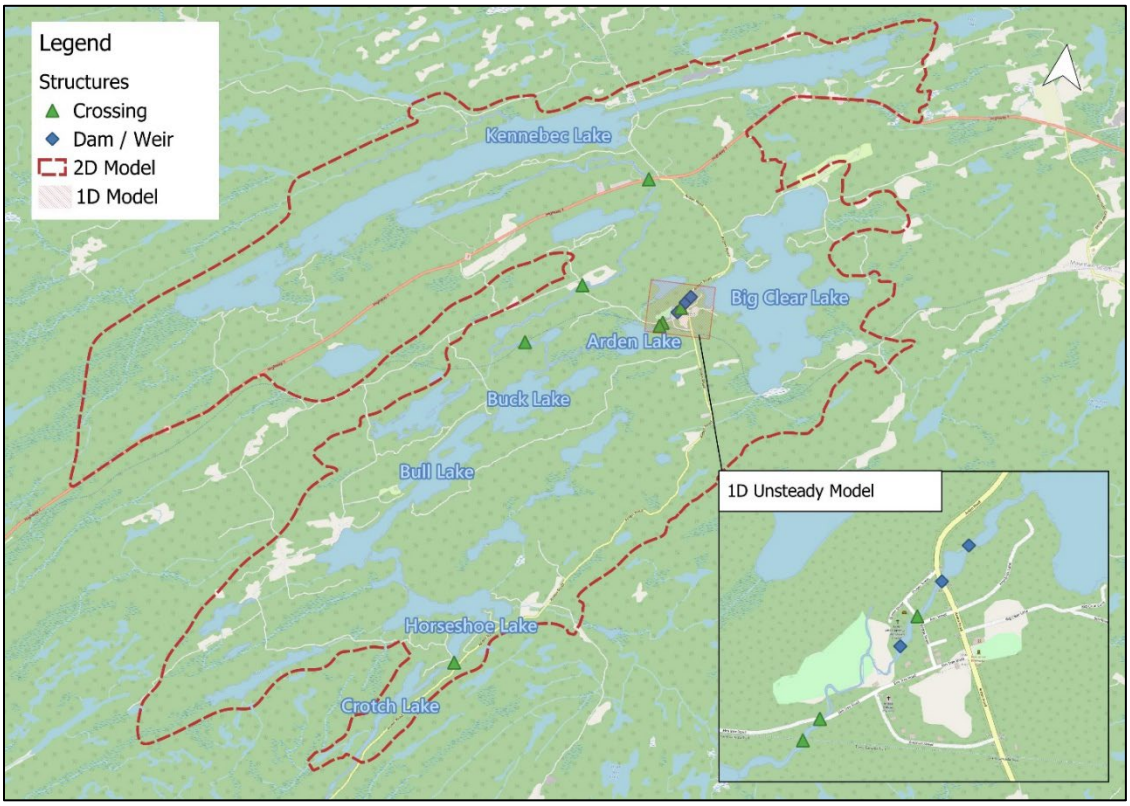
3.1 Hydraulic Analysis and Modelling

Details of the hydraulic analyses carried out as part of this study are provided in KGS (2024b). That report includes description of the hydraulic models used, and its various inputs, and assumptions made for the analysis.

After discussions with Quinte Conservation, two models (extents shown in Figure 3-1) were adopted for the definition of the floodplain and the assessment of various flood events in the study area:

- An all-encompassing 2D model was prepared with HEC-RAS, including the Salmon River and lakes from Kennebec Lake to Crotch Lake and the Arden Creek and lakes from Big Clear Lake to the confluence with the Salmon River. The results of this model were adopted for the entire domain of the Salmon River and for Arden Creek downstream of the Lower Arden Dam, in Arden.
- A hydrodynamic 1D model was prepared with HEC-RAS for Big Clear Lake and for Arden Creek from Big Clear Lake to Arden Lake. The results of this model were adopted for the domain from Arden Lake to upstream of the Lower Arden Dam, in Arden.

FIGURE 3-1: SALMON RIVER 2D AND 1D MODEL SECTIONS



3.2 Hydraulic Analysis Results

This section provides the results of the hydraulic model simulations for the Regulatory Flood (100-year or 1% AEP Flood) as well as for two scenarios (10 year or 10% AEP and 200-year or 0.5 % AEP) that were completed as a sensitivity analysis to assess potential changes due to climate change. Additional results for other flood scenarios discussed with Quinte Conservation are not included in this report. Table 3-1 and Table 3-2 show summaries of the results.

TABLE 3-1: SUMMARY OF RESULTS FROM THE 1D HYDRAULIC MODEL

Structure/Lake	Headwater Elevation (m, CGVD2013)			Overtopping Elevations (m, CGVD2013)
	10YR	100YR	200YR	
Big Clear Lake	196.53	196.67	196.70	
Upper Arden Dam	**196.48**	**196.58**	**196.61**	**196.30**
Middle Arden Dam	194.50	194.82	194.89	**195.50**
Post Office Bridge	190.36	190.74	190.83	**192.15**
Lower Arden Dam	189.71	189.87	189.91	**190.10**

Note: **Red** Highlighted Values indicate overtopping.

TABLE 3-2: SUMMARY OF RESULTS FROM THE 2D HYDRAULIC MODEL

Structure/Lake	Headwater Elevation (m, CGVD2013)			Overtopping Elevations (m, CGVD2013)
	10YR	100YR	200YR	
Fire Station Bridge	186.8	187.6	187.8	**188.1**
Railway Bridge (North of Arden Lake)	186.8	187.6	187.8	**189.0**
Garrison Bridge	189.8	190.4	190.5	**191.3**
Highway 7 Bridge	189.9	190.5	190.7	**192.2**
Trans-Canada Bridge (North of Buck Lake)	187.8	188.2	188.3	**192.4**

Structure/Lake	Headwater Elevation (m, CGVD2013)			Overtopping Elevations (m, CGVD2013)
	10YR	100YR	200YR	
Cranberry Lake Bridge	186.5	187.3	187.5	**188.2**
Kennebec Lake	198.8	199.3	199.4	
Garrison Lake	189.8	190.5	190.6	
Buck Lake	186.8	187.6	187.8	
Bull Lake	186.8	187.6	187.8	
Horseshoe Lake	186.6	187.4	187.5	
Crotch Lake	186.5	187.2	187.4	

Note: **Red** Highlighted Values indicate overtopping

4.0 FLOODPLAIN MAPPING

4.1 Public Information Centre

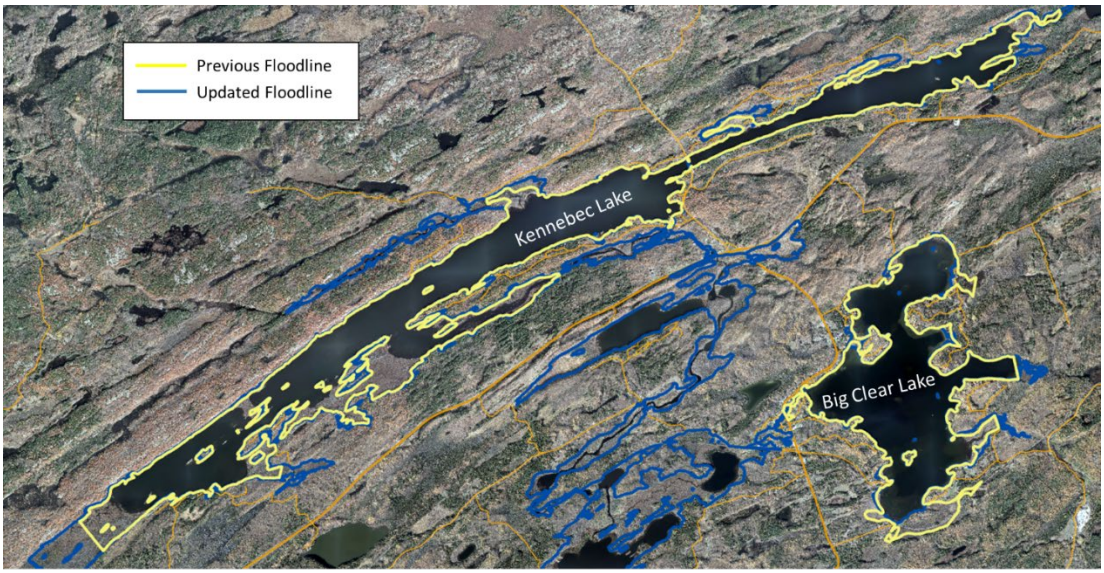
A draft version of the floodplain maps was presented at a Public Information Centre (February 14, 2024 – Kennebec Hall, Arden, Ontario) to discuss and receive feedback from the public, that was taken into consideration for the preparation of the final version of the floodplain maps. Aspects discussed in that PIC included: the role of the Upper Arden Dam in the flows that occur downstream; the occurrence of beaver dams at some locations; areas prone to flooding and historic water levels at specific locations, including the area around Horseshoe Lake, Crotch Lake and near the Cranberry Lake Rd Bridge.

4.2 Floodplain Mapping Definition

Floodplain maps were prepared using the results obtained from the simulation of the 100-year (1% AEP) Flood, which is the Regulatory Flood in this area of Ontario. The results showed that the flood is contained, in its majority, within the lake shoreline and within the banks of the channels that are connected to the lake system.

The previous regulatory floodline was defined for Kennebec Lake and Big Clear Lake and did not include the channels that interconnect the lakes nor the Arden Lake, Buck Lake, Bull Lake, Horseshoe Lake, and Crotch Lake. Figure 4-1 shows the previous regulatory floodline (delineated by a solid yellow line) and the updated regulatory floodline (delineated by a blue solid line). As shown in this figure, the updated floodline is similar to the previous floodline with some exceptions at the Kennebec Lake in which the updated floodline showed areas with more inundation along the north and east shoreline; the previous floodline showed an inundation area along the Big Clear Lake's south shoreline that was not flooded in the updated floodline.

FIGURE 4-1: PREVIOUS VS. UPDATED REGULATORY FLOODLINE AT KENNEBEC LAKE AND BIG CLEAR LAKE



4.3 Impacted Buildings

There are areas around Kennebec Lake, Buck Lake, Bull Lake, and Crotch Lake, and along Arden Creek that the analysis showed as flooded by the Regulatory Flood (100-year or 1% AEP flood). Based on the available imagery, there were close to 20 buildings identified within the floodplain, as well as some road sections and possibly one bridge. There were also some buildings that would be surrounded by flooding, for which access by road would be limited. These are discussed in the following sub-sections.

4.3.1 SHORELINE OF KENNEBEC LAKE

Along the north shoreline of Kennebec Lake, the study found some buildings and road segments within the floodplain. These are shown in Figure 4-2 (area near Bebris Rd) and in Figure 4-3 (area near Turner Way and the Baker Valley Airpark).

These areas were identified as part of the previous floodline; but the extent of the updated floodline is larger than the previous one in this part of the lake.

FIGURE 4-2: KENNEBEC LAKE NORTH SHORE NEAR BEBRIS RD

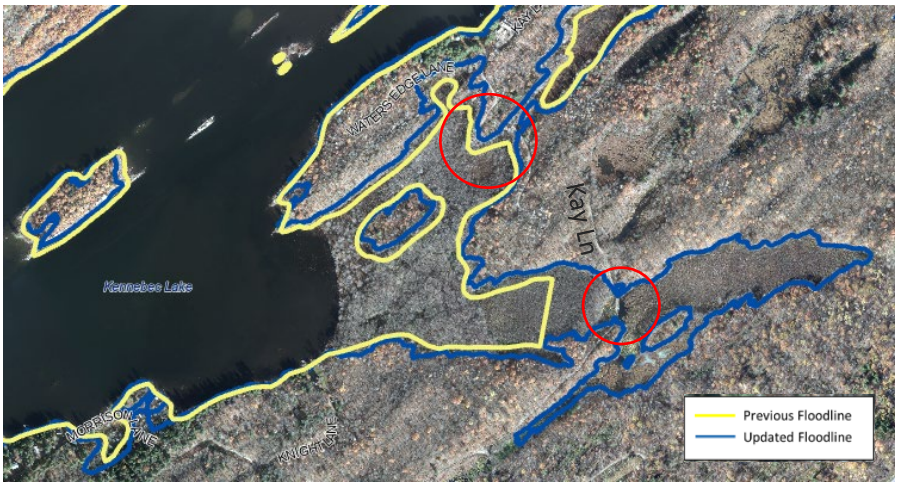
FIGURE 4-3: KENNEBEC LAKE NORTH SHORE NEAR TURNER WAY

There were also some areas on the south shoreline of Kennebec Lake in which buildings were found close to or surrounded by the floodplain line. These were near Wilkes Lane (Figure 4-4) and near Morrison Lane (Figure 4-5). Also, in that area Kay Lane was found to be flooded by the updated floodplain at various locations (Figure 4-6) that had not been included in the previous floodplain.

FIGURE 4-4: KENNEBEC LAKE SOUTH SHORE NEAR WILKES LANE

FIGURE 4-5: KENNEBEC LAKE SOUTH SHORE NEAR MORRISON LANE

FIGURE 4-6: KENNEBEC LAKE SOUTH SHORE ALONG KAY LN



4.3.2 HWY 7 AND ARDEN RD

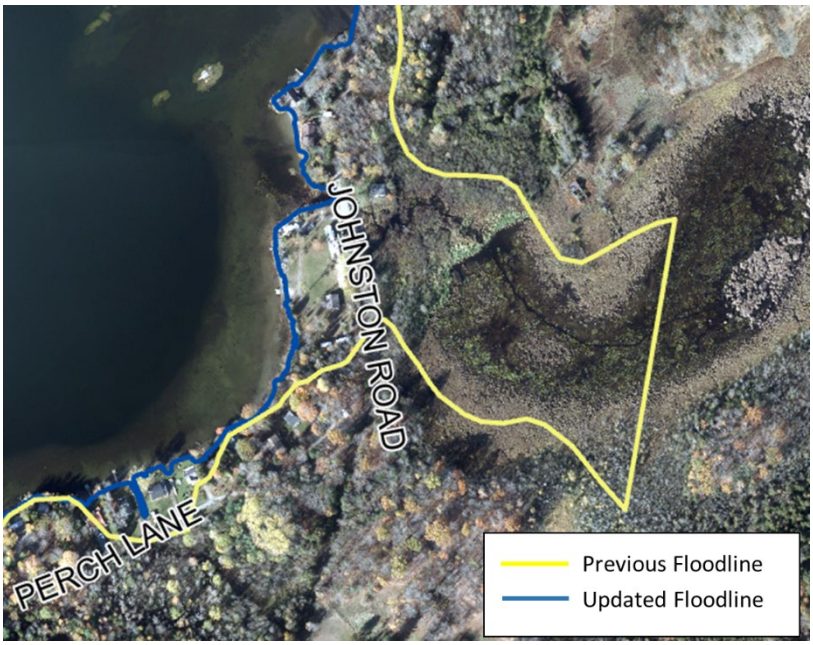
Downstream of Kennebec Lake, the flooding obtained for the Regulatory Flood did not overtop the Hwy7 Bridge, but it overtopped a small low portion of Arden Road near the intersection with Hwy 7 (Figure 4-7). This area had not been included in the previous floodplain delineation.

FIGURE 4-7: ARDEN RD NEAR HWY 7

4.3.3 BIG CLEAR LAKE

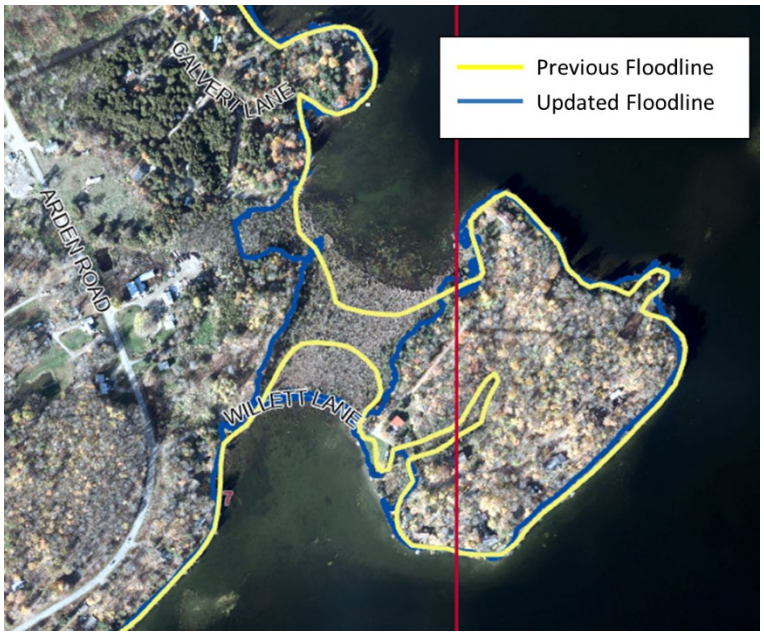
In general, the updated floodline around Big Clear Lake is very close to the previous floodline. There are some areas in which they differ. One such area (in the north-east shoreline of Big Clear Lake) is near Johnston Rd and Perch Lane (Figure 4-8). Some buildings in that area were located within the previous floodplain delineation; but are not included in the updated one.

FIGURE 4-8: JOHNSTON RD AND PERCH LANE AT BIG CLEAR LAKE



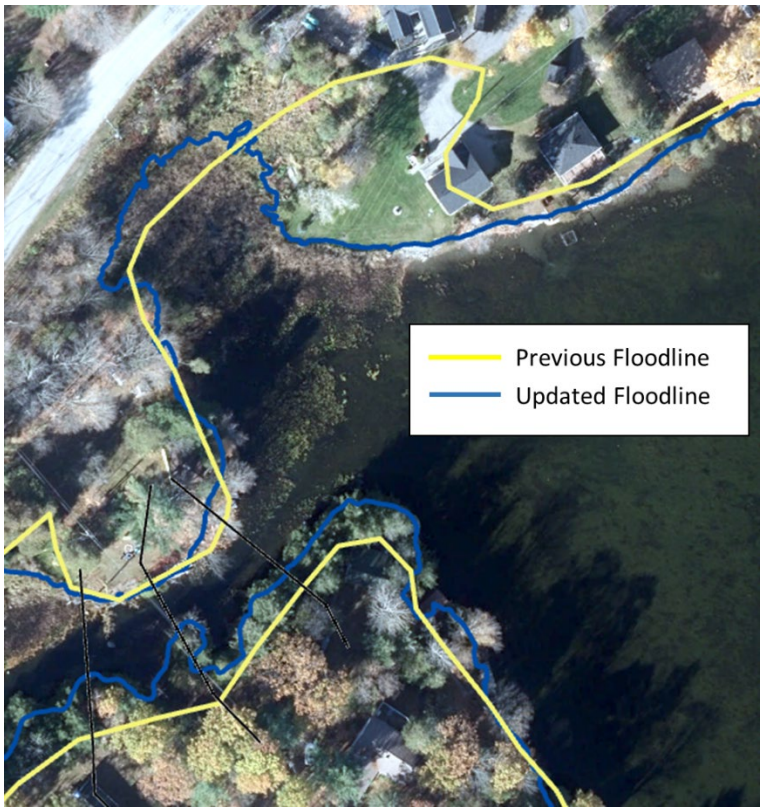
Along the west shore of Big Clear Lake, near Willett Lane, there is a small difference between the updated and previous floodline. The updated floodline does not show Willett Lane (Figure 4-9) as overtopped; but the areas on both sides of that road are low and would be within the floodplain.

FIGURE 4-9: NEAR WILLETT LANE AT BIG CLEAR LAKE



Along the west shore of Big Clear Lake, near the Upper Arden Dam, there is at least one building that was within the previous floodplain and would not be within the updated one, as shown in Figure 4-10.

FIGURE 4-10: NEAR UPPER ARDEN DAM AT BIG CLEAR LAKE



4.3.4 ARDEN CREEK

In Arden, along Arden Creek, some areas upstream of the Middle Arden Dam that were included in the previous floodplain delineation are not within the floodplain according to the updated floodline (Figure 4-11).

The operation of the dams is critical in this area. The Middle Arden Dam, generally would have eight logs in place during the spring, as per the winter set up, so that it would only be operating with a portion of its available spill capacity. The Upper Arden Dam would have four logs in, so it would also have additional spill capacity available. The operation of the dams would need to be coordinated so that releases from Upper Arden can be passed through Middle Arden as much as possible. Monitoring of floods is also important because while the Upper Arden Dam can sustain (and it has been subjected to) some degree of overtopping, the integrity of the dam must be taken into consideration to avoid endangering its stability during very extreme floods (beyond those considered for flood mapping). This requires proper flood operation and emergency planning.

Downstream of the Lower Arden Dam, the water levels, controlled by the levels on the Salmon River, further downstream, were found to overtop parts of Elm Tree Rd and some areas south of it, as shown in Figure 4-12.

FIGURE 4-11: ARDEN CREEK UPSTREAM OF LOWER ARDEN DAM

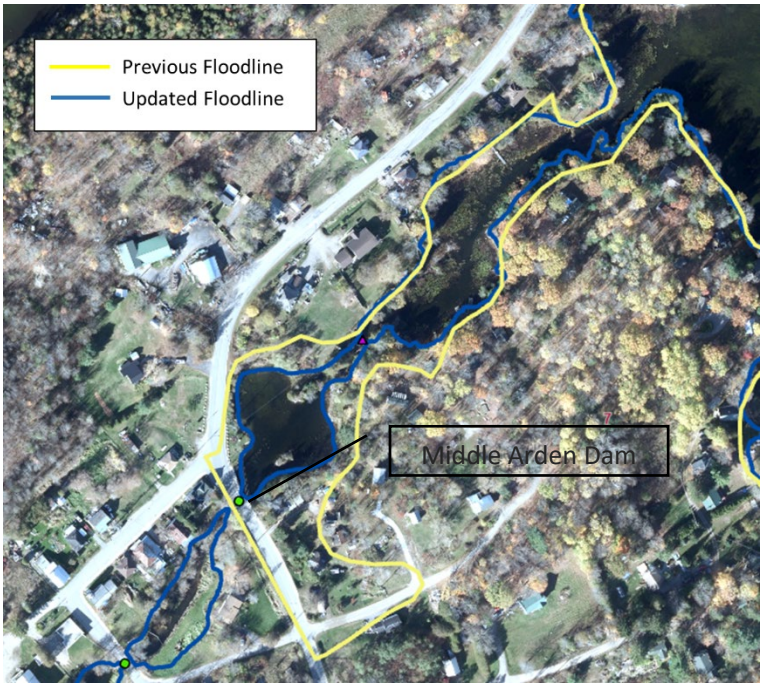
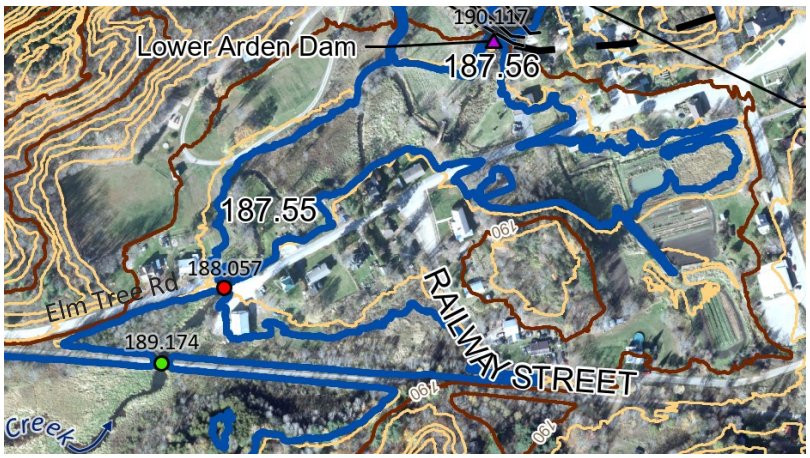


FIGURE 4-12: ARDEN CREEK DOWNSTREAM OF LOWER ARDEN DAM



4.3.5 GARRISON LAKE RD

In Garrison Lake Rd, south of the crossing over the Salmon River, the new floodline shows one building that would be within the floodplain (Figure 4-13). This area does not have previous floodplain delineation.

FIGURE 4-13: GARRISON LAKE RD

4.3.6 BUCK LAKE

At the northeast end of Buck Lake, the flooding during the Regulatory Flood (as simulated) overtopped the banks of Arden Creek so that there would be flows bypassing from Arden Lake, directly into Buck Lake (Figure 4-14). There are buildings on that end of Arden Lake, that would be close or within the new floodplain (Figure 4-15).

FIGURE 4-14: CONNECTION ARDEN LAKE - BUCK LAKE

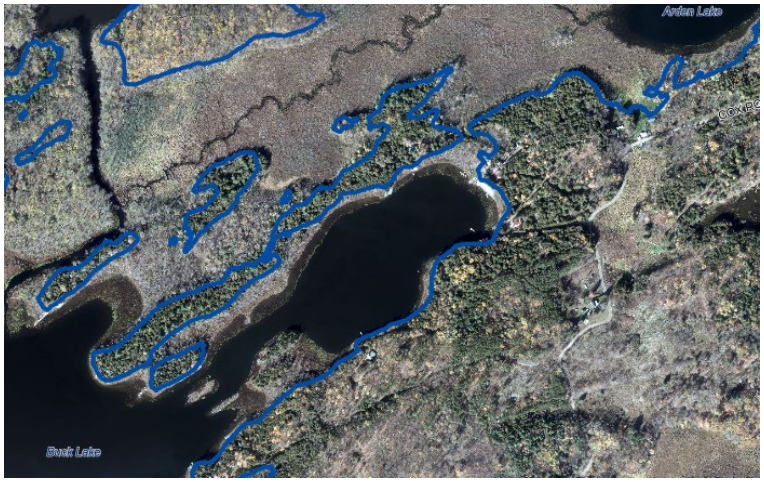


FIGURE 4-15: NORTHEAST END OF BUCK LAKE

Near the southwest end of Buck Lake, the new floodline shows buildings that would be surrounded by the floodplain limits (Figure 4-16).

FIGURE 4-16: SOUTHWEST END OF BUCK LAKE

4.3.7 BULL LAKE

Along the north shoreline of Bull Lake, near Hummingbird Lane, the new floodline shows buildings located in low areas that would be within the floodplain (Figure 4-17 and Figure 4-18). Portions of Woodland Park, on Hummingbird Ln, would be within the floodplain (Figure 4-19). Near the southwest end of Bull Lake, at Bull Lake Rd, there is at least one building that would be within the floodplain (Figure 4-20).

FIGURE 4-17: BULL LAKE AT HUMMINGBIRD LANE (AREA 1)

FIGURE 4-18: BULL LAKE AT HUMMINGBIRD LANE (AREA 2)

FIGURE 4-19: WOODLAND PARK AT BULL LAKE

FIGURE 4-20: BULL LAKE RD AT BULL LAKE

4.3.8 HORSESHOE LAKE

Near the northeast end of Horseshoe Lake, part of Clancy Lane was found to be within the floodplain (Figure 4-21). Also, at Horseshoe Lane, the boat launch and parking area would be within the floodplain. There is also a portion of Finch Ln that would be within the floodplain, limiting road access to the property located at the end of this road. (Figure 4-22).

FIGURE 4-21: CLANCY LN AT HORSESHOE LAKE

FIGURE 4-22: HORSESHOE LN AND FINCH LN AT HORSESHOE LAKE

4.3.9 CROTCH LAKE

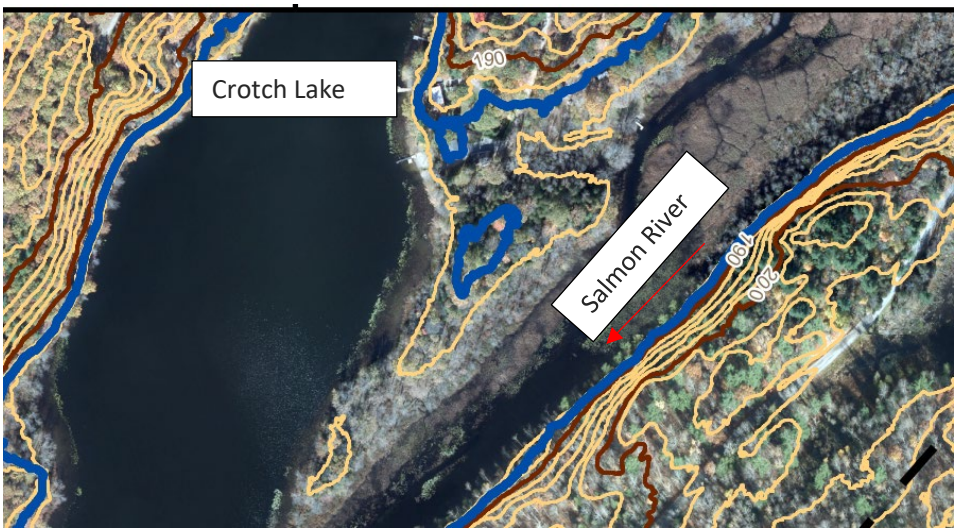
The area near the Cranberry Lake Rd crossing, between Horseshoe Lake and Crotch Lake, has been monitored for flooding by the Quinte Conservation. A low portion of the road just northwest of the bridge, experienced overtopping during the 2014 flood event. That part of the road would be overtopped as per the new floodline, and some buildings downstream of the bridge would be within the floodplain (Figure 4-23), with the water getting up to Arden Rd. Big Bay Drive was found to be not within the floodplain.

There is also a building on the north end of Crotch Lake within the floodplain (Figure 4-24). Some properties were also found to be in the floodplain, where the Salmon River enters Crotch Lake both on the river and the lake sides (Figure 4-25).

FIGURE 4-23: CRANBERRY LAKE RD AND ARDEN RD AT CROTCH LAKE

FIGURE 4-24: NORTH END OF CROTCH LAKE

FIGURE 4-25: SALMON RIVER AT CROTCH LAKE



4.4 Impacted Roads

The major local rural roads that were inundated are:

- Arden Rd. near HWY 7
- Elm Tree Rd. in Arden
- Cranberry Lake Rd. near Crotch Lake

There are a few road and trail segments that were found to be within the floodplain:

- Betris Rd. near Kennebec Lake
- Turner Way near Kennebec Lake
- Morrison Lane near Kennebec Lake

- Kay Ln. near Kennebec Lake
- Watersedge Ln near Kennebec Lake
- Trans-Canada Trail near Arden Lake
- Queen St near Arden Lake
- Gendron Rd. near Buck Lake
- Hummingbird Ln near Bull Lake
- Lake Rd. near Bull Lake
- Gardiners Rd. near Bull Lake
- Cranberry Lake Rd. near Horseshoe Lake
- Clancy Ln. near Horseshoe Lake
- Horseshoe Ln. near Horseshoe Lake
- Finch Ln. near Horseshoe Lake
- Winding Trail near Horseshoe Lake
- Big Bay Dr. near Crotch Lake

4.5 Impacted Structures

There were no bridges shown as overtopped for the Regulatory Flood. The bridge on Cranberry Lake Rd. would be close to overtopping.

4.6 Recommendations

The following recommendations are provided based on the findings of the study. They are general in nature since the main purpose of the study has been to characterize the overall flooding for definition of the flood hazard. The study did not focus on specific areas or on any detailed flood mitigation measures. The associated costs provided with these recommendations are only indicative.

4.6.1 ROADS

There are portions of three main roads in the floodplain that are shown within the floodplain. There are also a number of minor roads and trails within the floodplain. Some of them would affect access by land to buildings. These should be considered for emergency plans, and for prioritizing potential capital works to improve access and egress to areas and to residential buildings during emergencies.

The cost for addressing these potential overtopping would vary from site to site. A high-level cost estimate for raising a road is shown in Table 4-1. Consideration should be added at specific sites for road drainage.

TABLE 4-1: INDICATIVE COSTS FOR RAISING ROADS

Road Type	Height Raise	Cost Per Length
Two-lane road (~15 m wide) with asphalt surface treatment and realigned ditch profile (with general clearing and grubbing of vegetation)	Up to 0.3 m	$ 800 to $1,000 / m
	0.3 m to 0.9 m	$ 2,100 to $2,400 / m

4.6.2 FLOOD PROOFING

There are several buildings within the floodplain, along the shoreline of Kennebec Lake, Buck Lake, Bull Lake, and Crotch Lake. In these cases, of buildings already in the floodplain, the alternative would be floodproofing, of which multiple options are provided in Appendix 6 of the Ontario Flood Hazard Guidelines (MNRF, 2002). The options available range from restricted use of areas (i.e. basements) to structural measures to ensure building stability, and the cost varies on a site-specific basis.

New developments in these areas would be limited as per provincial policies and the directives of the various government and agency levels. Critical infrastructure (hospitals, fire stations, flood warning systems, power plants, water treatment plants) would not be permitted in these areas.

4.6.3 FLOOD OPERATION AND EMERGENCY PLANNING

Proper forecasting, management of resources and operation of structures are important during a flood, particularly in Arden Creek, where the operation of the dams can impact the conditions downstream and potentially up to the Salmon River. While the dams have adequate capacity to pass the Regulatory Flood, the typical operation of the dams only allows for part of that capacity to be available for the Upper Arden Dam and the Middle Arden Dam. That partial capacity, based on the findings of this study, is adequate to manage the floods without flooding areas in Arden. It is a balancing act requiring coordination of the operation of those two dams, and consideration for the areas downstream. A study to assess operation of the dams and operation capabilities during a flood, monitoring requirements, and also emergency preparedness and management is recommended (indicative cost 50 to 100 thousand dollars, based on specific scoping). The plans developed in such study would contribute to facilitating a clear public perception of the role of these dams during a flood, in the context of the overall watershed flooding condition.

Consideration should also be given to potential ice jam flooding (not investigated in this study) and beaver dam activity. Those would likely be site specific and were not part of this study scope.

5.0 REFERENCES

- KGS Group (2024a). Salmon River Upper Lakes Flood Hazard Mapping, Hydrology Report
- KGS Group (2024b). Salmon River Upper Lakes Flood Hazard Mapping, Hydraulics Report
- Ontario Ministry of Natural Resources, (OMNR 2002), River & Stream Systems: Flooding Hazard Limit Technical Guide
- Ontario Ministry of Natural Resources, (OMNR 2011), Lakes and Rivers Improvement Act Administrative Guide and Associated Technical Bulletins
- United States Army Corps of Engineers, (USACE, 2016), Hydraulic Reference Manual

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