Report

Flood Modifications Review Project

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1. Introduction and Scope

Water management within the Muskoka River Watershed (MRW) is complex and has evolved over many years to balance conflicting water demands. Starting in the 1800s, major changes were made to lake storage and connecting channels to facilitate navigation and stimulate industry growth. These changes, however, did not address flood mitigation. Within the last 12 years the watershed has experienced major flooding (specifically in 2008, 2013, 2016 and 2019) that caused significant damage to municipal infrastructure and private property.

The District Municipality of Muskoka (DMM) sought to reduce flood risk and address watershed health and has engaged the Province of Ontario for support to do so. In turn, DMM scoped 12 projects designed to describe the existing conditions within the watershed, and to inform a future integrated watershed management (IWM) approach to flood risk reduction. This integrated watershed management approach seeks to balance conservation and development while managing human activities and natural resources at a watershed scale. As part of this initiative, Hatch was retained by DMM to identify, describe, and evaluate potential structural options to mitigate flood risk within the DMM.

Work completed by Hatch is documented under the following two studies:

- *Structural Flood Mitigation Options*: the primary objective of this study was to identify 10 structural mitigation options amongst five priority areas in the MRW. That work was summarized in the Structural Flood Mitigation Options report delivered to DMM in September 2022.
- *Flood Modifications Review Project*: (this document) the primary objective of this study was to advance the 10 options identified in the Structural Flood Mitigation Options report to a conceptual design stage and determine the potential conjunctive benefit and costs associated with implementation of these options. The benefit analysis included a systems-based hydrologic/hydraulic modelling approach to determine the impacts of these 10 options on flood conditions in the watershed.

This report serves to document the work completed for the *Flood Modifications Review Project* (referred to herein as the Project). The scope of the Project included the following tasks:

- Background information collection/review (Section 2)
- Conceptual design of flood mitigation options (Section 5)
- Model evaluation of different mitigation option permutations at the MRW scale (including assessment of climate change aspects) (Section 6)
- Identification of potential environmental impacts and permitting requirements (Section 7)

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- Development of a Class 5 capital cost estimates for each flood mitigation option (Section 8)
- Identification of potential funding sources for option implementation (Section 9)
- Estimation of scope and costs for preliminary engineering design of the flood mitigation options (Section 10)
- Ranking of flood mitigation options and future work recommendations (Section 11).

The terms *Baseline Case* and *Mitigation Case* are used frequently throughout this report. Baseline Case refers to status-quo flood-impacted conditions congruent with the current state of the watershed, while Mitigation Case refers to flood-impacted conditions estimated to occur after the implementation of one or more specific flood mitigation options. Mitigation Case also extends to describe flood-impacted conditions in a future climate context. Definitions of these terms are revisited throughout the report where needed to provide clarity.

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2. Background Information

This section provides a brief description of the primary information sources collected and reviewed as part of the Project.

2.1 Guidelines, Reports, and Studies

- **Dam Operations Manual for Muskoka River Dams** (Ontario Ministry of Natural Resources, 1997 with updates) – The Dam Operations Manual (DOM) for Muskoka River Dams was provided by the Ministry of Natural Resources and Forestry (MNRF) and includes the physical dimensions and operational details for the various control structures throughout the MRW. This document is referred to throughout this report as the DOM (OMNR, 1997, updated in 2007).
- **Environmental Assessment of Big East River Dams** (OMNR, 2000) – this document provided pertinent details to support conceptual design of Option 1 (retrofit of Distress Dam; see Section 5.2).
- **Muskoka River Water Management Plan** (OMNR, et al, 2006 with amendments) – The Muskoka River Water Management Plan (MRWMP) provides information on the seasonal operating conditions and the storage characteristics of major lakes in the watershed.
- **Technical Report for Muskoka River Flood Plain Mapping Study** (H356689-00000-200-230-0002) (Hatch, 2020) – This report details the hydrologic and hydraulic analyses that produced the updated flood plain maps for select vulnerable areas in the Muskoka watershed. Select hydrologic and hydraulic models described in this report were adopted for the Project.
- **Interim Progress Report** (H366496-000-200-230-0001) (Hatch, 2022a) – This report details the hydrologic model developed for the flood plain mapping study and adopted for the Project reported herein.
- **South Muskoka – Fraserburg Reach Flood Plain Mapping Memo** (H366496-0000-200-030-0001) (Hatch, 2022b) - Memo dated June 10, 2022, issued to DMM by Hatch as part of the FPMS. This memo includes detailed information on the structure, set-up, and calibration of the hydrologic model adopted for the Project.
- **Flood Plain Mapping Technical Report** (H366496-0000-200-230-0002) (Hatch, 2022c) – This report[1] details the structure, set-up, and calibration of the hydrologic model adopted for the Project.
- **Musquash River Flood Plain Mapping Memo** (H366496-0000-200-030-0005_RevA) (Hatch 2022d) – Memo issued to DMM by Hatch documenting the structure, set-up and calibration of the Musquash River hydraulic model adopted for the Project.

[1] This report was under review by DMM when this Flood Modifications Review Project report was prepared.

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- **Moon River Flood Plain Mapping Memo** (H366496-0000-200-030-0005 – In Progress) (Hatch 2022e) - In-progress memo[1] to be issued to DMM by Hatch documenting the structure, set-up and calibration of the Moon River hydraulic model adopted for the Project.
- **Structural Flood Mitigation Options Report** (H367619-0000-2B1-066-0001) (Hatch 2022f) – Final report issued to DMM by Hatch, documenting the identification and localized assessment of 10 flood mitigation options amongst five priority areas in the MRW.
- **Hydraulic Structures** (Smith, 1995) – Guidance document on hydraulic structure design referenced during concept development of the retrofitted Distress Dam.
- **Hydraulic Design of Stilling Basins and Energy Dissipators – Engineering Monograph No. 25** (Peterka, 1984) – Guidance document on hydraulic structure design referenced during concept development of the retrofitted Distress Dam.
- **On the Relationship Between the 10,000 Year Flood and Probable Maximum Flood** (Zhou & Donnelly, 2008) – Research paper reference to inform estimation of the probable maximum flood (PMF) for conceptual design of the retrofitted Distress Dam.

2.2 Other Datasets

- **'Building_Footprint_2018' GIS Dataset** – These geospatial data include the footprints of structures within the District of Muskoka.
- **LiDAR Survey Data** – These topographic mapping data cover 1508.4 km² of the MRW and were collected as part of DMM's FPMS (Hatch, 2020). The 1-m grid datasets of Bare Earth and Hydroflattened digital elevation models (DEM) created from LiDAR data were employed to support conceptual design and other analyses.
- **Ontario Hydro Network (OHN) Data** – These geospatial data included watercourse outlines that were applied for mapping purposes to supplement available break line data that accompanies the *LiDAR Survey Data*.

2.3 Flood Plain Mapping Study (FPMS) Models

A hydrologic model and several hydraulic models were adopted for this study. These models were initially developed for the FPMS in the MRW (Hatch, 2020; 2022a; 2022b; 2022c; 2022d; 2022e).

All FPMS hydraulic models were created using HEC-RAS (Version 5.0.7). HEC-RAS is a modelling software developed by the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center and can facilitate development of both one-dimensional (1-D) or two-dimensional models (2-D). Models developed for the FPMS and adopted for this project included Big East, Huntsville Narrows, Baysville, Purbrook, Springdale and Bala Reach. A thorough description of these models is provided in the 2020 FPMS report (Hatch, 2020). Since 2020, additional hydraulic models have been developed as part of the FPMS for

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other areas in MRW. Three of these models have been adopted for the Project, including the Fraserburg (Hatch, 2022b), Musquash River (Hatch, 2022d) and Moon River (Hatch, 2022e) models.

The FPMS hydrologic model was developed using the USACE's Hydrologic Engineering Center Hydrologic Modelling System (HEC-HMS) software (Version 4.8). HEC-HMS is a standard tool for hydrologic modelling that is widely used in Canada. The model can represent snow accumulation and melt, snowmelt- and rainfall-runoff transformation, overland flow routing, groundwater outflow, and reservoir routing using a range of user-selected model processes. These features make the model suitable for simulating hydrologic conditions during the design events of the MRW, in addition to evaluating effects of climate change through adjustments to temperature and precipitation conditions. Further information on this model is provided in an interim report issued to DMM (Hatch, 2022a).

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3. Study Priority Areas

DMM is comprised of six municipalities, which include the towns of Gravenhurst, Bracebridge and Huntsville. These municipalities are located within the MRW, a basin which encompasses an area of approximately 5100 km^2 (including 78,000 ha of lakes). The watershed extends from headwaters along the western side of Algonquin Provincial Park and outlets to Georgian Bay via two rivers. The watershed features three distinct regions, specifically: North Branch Muskoka River (North Branch), South Branch Muskoka River (South Branch), and Lower Watershed (Lower Branch).

The North Branch and South Branch regions account for approximately two-thirds of the total MRW's drainage area. The North Branch and South Branch of the Muskoka River confluence near Bracebridge, and outlet as a single river into Lake Muskoka. The Lower Branch region features several large lakes – Lake Joseph, Lake Rosseau, and Lake Muskoka – where Lake Muskoka is the largest among them. Outflows from Lake Muskoka bifurcate into the Moon and Musquash Rivers, both of which flow to Georgian Bay. These rivers flow through Wahta Mohawk Territory before reaching Georgian Bay. Monitoring sites are located throughout the MRW (see Figure 3-1), which assist in characterizing hydrologic conditions throughout the year.

In recent historical years, the MRW has experienced several large flood events that caused extensive damages. Flood management in MRW is a challenging endeavor, driven in part by diverse water demands throughout the area. These water demands come from a variety of stakeholders, including Indigenous communities, hydropower operators, cottagers, and tourists/recreationalists. High densities of structures (e.g., homes, commercial buildings, etc) in flood plain areas present further challenges in the pursuit of flood mitigation. While comprehensive elimination of flooding is not possible for the MRW, targeted mitigations can be implemented to lessen the severity of flooding in local areas.

Hatch, DMM and the IWM Technical Working Group (TWG) collaborated together to identify five areas within the watershed for option identification and assessment. The selection of these locations was based on observational data collected during the 2013 and 2019 flood events and historical knowledge of the watershed. The general boundaries of these areas are identified in Figure 3-2 as *Priority Areas of Concern* and are referred to as follows—*Big East River* (North Branch Muskoka River), *Huntsville Narrows* (North Branch Muskoka River), *Springdale* (North Branch Muskoka River), *Baysville/Fraserburg/Purbrook* (South Branch Muskoka River), *Muskoka/Bala* (Lower Branch).

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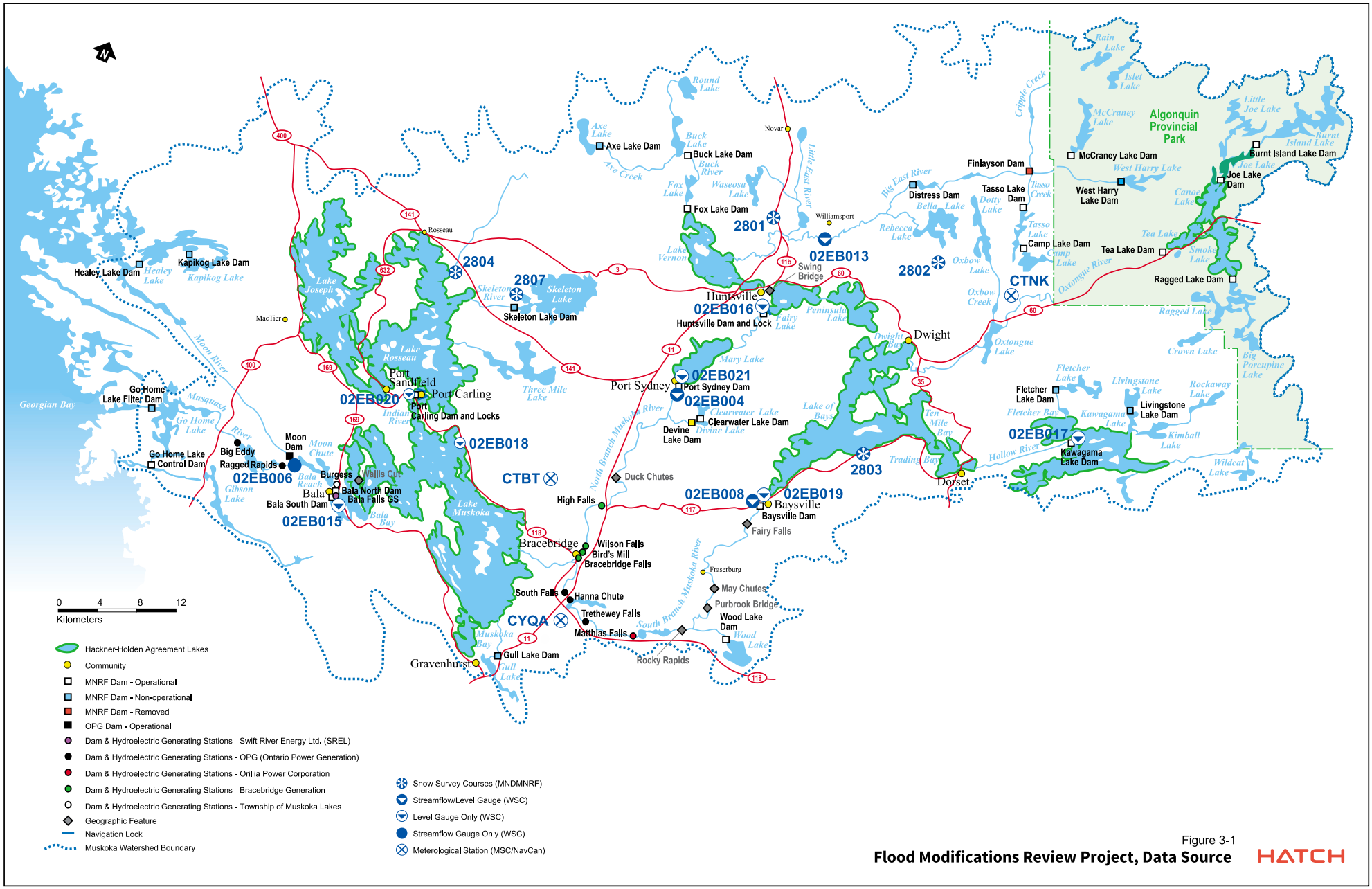

Figure 3-1

Flood Modifications Review Project, Data Source

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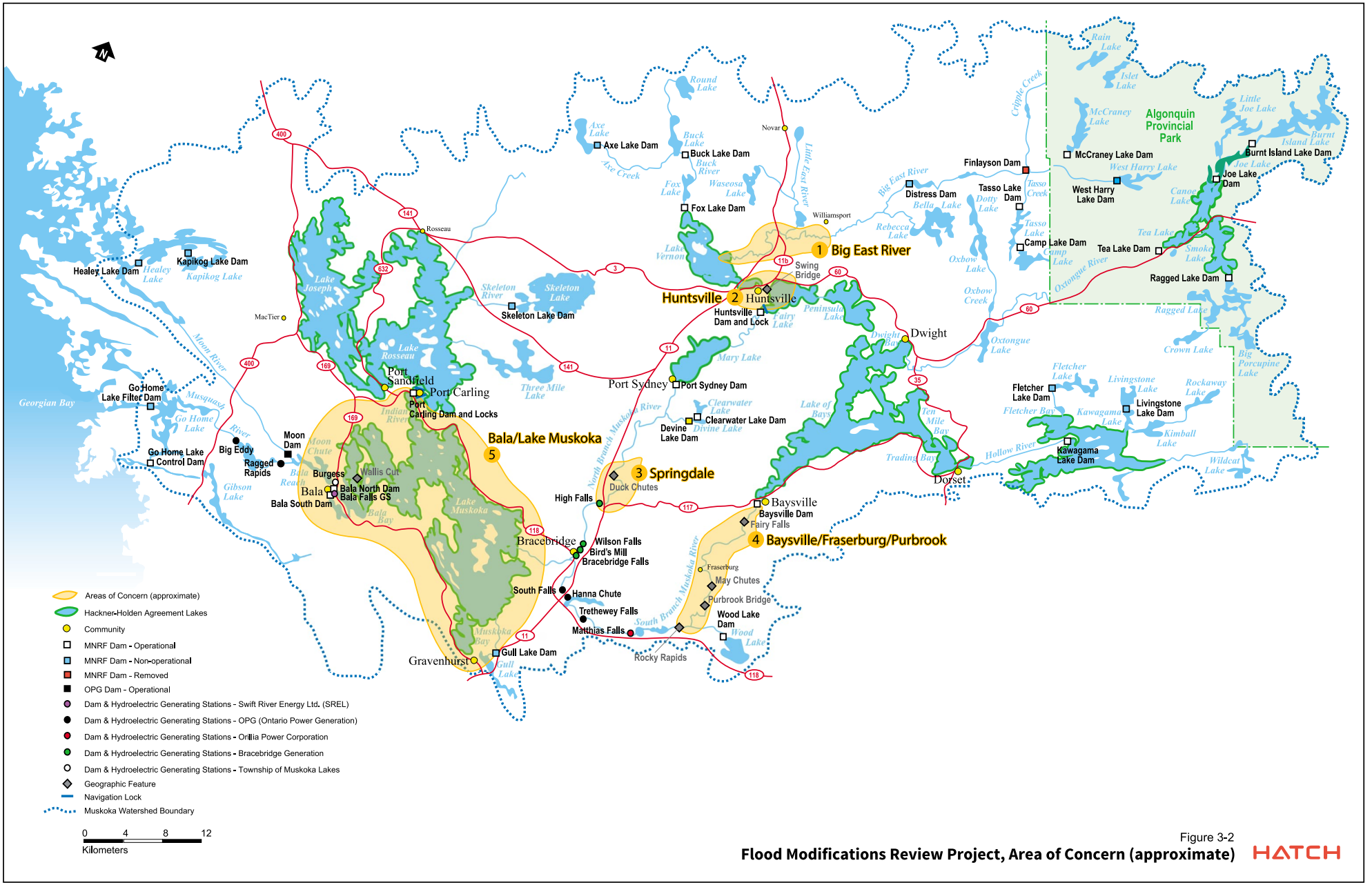

Figure 3-2

Flood Modifications Review Project, Area of Concern (approximate)

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4. Flood Event Hydrology

The two design flood events adopted as the basis for examining flood impacts in the MRW are those that occurred in 2019 and 2013. In April and May of those years, rain-on-snow events produced significant flooding and the highest flow rates ever recorded at the four main Water Survey of Canada (WSC) stations in the watershed. The 2019 event is the governing (most significant) design flood for the South Branch (downstream from Lake of Bays), North Branch (downstream from Fairy Lake) and Lower Branch regions. The 2013 event is the governing (most significant) design flood for the North Branch (upstream from Fairy Lake). A forensic analysis of these events is provided in numerous reports, including the *Technical Report for Muskoka River Flood Plain Mapping Study* (Hatch, 2020).

For the Project, evaluation of the impacts of different mitigation options on flood conditions throughout the MRW was only performed using the 2019 event (see Section 6). The rationale for selecting the 2019 event was that it served as the governing design flood event for most of the watershed, including Lake Muskoka. At the watershed-scale, Lake Muskoka is impacted by every one of the flood mitigation options, making it an important indicator for the analysis.

Baseline Case conditions in each priority area were established using the 2019 design event to assess and compare the impacts of each Mitigation Case. Flow data for these assessments were sourced from Water Survey of Canada (WSC) records, which were supplemented by simulated flows using the FPMS hydrologic model (Hatch, 2022a) to quantify the flow contributions of ungauged subbasins in the MRW. Baseline Case conditions in each priority area were established using the 2019 design event to assess and compare the impact of the flood mitigation Scenarios.

The main hydrologic input required for Mitigation Case assessments in the hydrologic models was flow (Q). These model datasets can be adjusted to reflect changes made to the watershed due to structural flood mitigations and are easily incorporated in hydrologic model simulations. The flow (Q) and water level (i.e., water surface elevation; WSE) output from the hydrologic models formed the main inputs required for the hydraulic model simulations of the Mitigation Case assessments. Flow data for design flood events were sourced from WSC records and were supplemented by simulated flows using the FPMS hydrologic model (Hatch, 2022a) to quantify the flow contributions of ungauged subbasins in the MRW. Water level data were mainly adopted from the results of the FPMS.

Design flood hydrographs and cumulative flow volume plots for each of the priority areas (and their respective reaches) are provided in Appendix A.

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5. Conceptual Design of Flood Mitigation Options

5.1 Overview

The 10 flood mitigation options identified in the Structural Flood Mitigation Options report (Hatch, 2022f) are summarized in Table 5-1.

Table 5-1: Flood Mitigation Options Identified in (Hatch, 2022f)

	Flood Mitigation Option	Priority Area
1	Retrofit of Control Structure at Distress Dam	Big East River
2	Berm Protection near Swing Bridge	Huntsville Narrows
3	Increase Fairy Lake Outflow via the Brunel Lift Locks	Huntsville Narrows
4	Retrofit of Control Structure at High Falls	Springdale
5	Channel Enlargement at May Chutes	Baysville/Fraserburg/Purbrook
6	Channel Enlargement at Rocky Rapids	Baysville/Fraserburg/Purbrook
7	Lower Head Pond Flood Levels at Matthias Generating Station	Baysville/Fraserburg/Purbrook
8	Channel Enlargement at Wallis Cut	Muskoka/Bala
9	Retrofit of Control Structure at Bala South Dam	Muskoka/Bala
10	Channel Enlargement at Moon Chutes	Muskoka/Bala

These 10 options are described in more detail throughout the following subsections. Information provided for each option includes a description of the mechanism of flood mitigation, conceptual design level details, and high-level estimates of design quantities (where relevant).

5.2 Option 1: Retrofit of Distress Dam

The water surface profile of Big East River is influenced both by Lake Vernon water surface elevation and the incoming flows from its subwatershed. Flows from the Big East River subwatershed are regulated by several upstream dams. The most downstream from these dams, Distress Dam (location shown in Figure 3-2), has a drainage area of 464 km^2. In 2000, Distress Dam was converted to a spill structure (as described in the DOM [OMNR, 1997 with 2007 updates]) and, in essence, functions as a weir to control flow and water levels. In its current state (Figure 5-1), the dam has limited ability for mitigating flooding.

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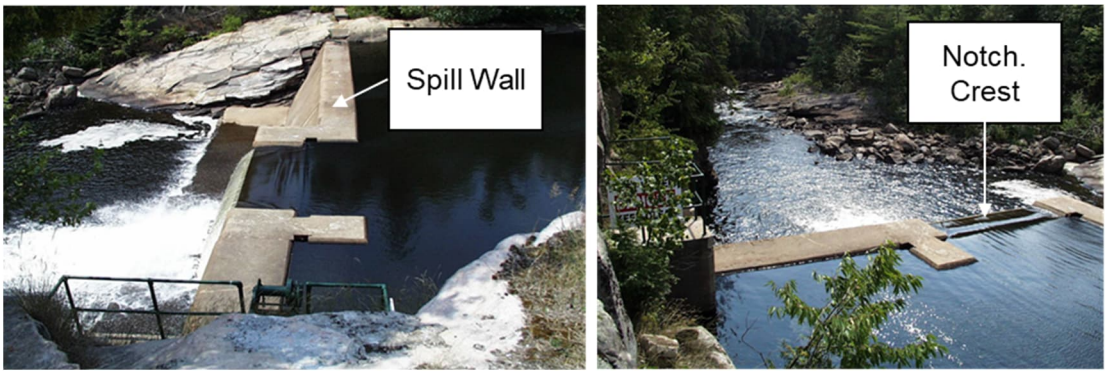

Figure 5-1: Existing control structure at Distress Dam upstream from the *Big East River* priority area (Source: the DOM [OMNR, 1997 with 2007 updates])

A retrofit of Distress Dam is required to increase its effectiveness in mitigating flooding. However, this retrofit would require construction of a new dam acknowledging that the position and size of the existing weir does not provide a meaningful amount of flood storage. The conceptual design of the retrofitted Distress Dam would decrease peak flows (downstream on the Big East River) through attenuation by means of flow impoundment using a large earthfill dam with a gated concrete spillway. A summary of the conceptual design attributes for the retrofitted Distress Dam are provided in Table 5-2, with conceptual design drawings included in Appendix B.

Table 5-2: Conceptual Design Attributes for Option 1 – Retrofit of Distress Dam

Attribute	Description or Value	Source
Bed Elevation of Reservoir (i.e., Upstream from Dam)	336.95 m	(OMNR, 2000) (OMNR, 1997 with 2007 updates)
Bed Elevation Downstream from Dam	336.95 m	Assumed due to lack of bathymetry data
Dam Crest Elevation (includes 1 m of freeboard above full supply level)	352 m	Full supply level set to achieve 50% peak flow reduction of the 2019 design flood event
Dam Height	15.05 m	Design selection
Design Flood (Probable Maximum Flood)	848 m^3/s	Flood frequency analysis using station 02EB013 and scaled based on findings of Zhou/Donnelly (2008)
Spillway Ogee Crest Elevation	340 m	Elevation set to match existing control structure invert elevation (Figure 5-1) to help maintain Baseline Case conditions under normal flow

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Attribute	Description or Value	Source
Stilling Basin Type	Type III	Suitable stilling basin type based on guidance in Peterka (1984) providing energy dissipation of released flows.
Mechanism of Flow Passage	Gate Underflow	Design selection
Gate Type	Vertical Lift Gate	Design selection
Number of Gates	Two	Design selection for redundancy (in the event of gate opening failure)
Gate Dimensions (Width x Height)	8.3 m x 6.9 m	Required size to pass design flood via gate underflow
Design Head	11 m	Design selection

The new Distress Dam would increase impoundment volume and enable the attenuation of flows from the North Branch region upstream from the dam through temporary storage. The proposed concept design would include a concrete spillway that has two gates approximately 8.3 m wide, separated by a 3 m wide pier. Flanking this concrete spillway on both sides will be earthfill embankments. Water spilled (or released) through the gates will flow into a stilling basin containing appurtenant structures designed to dissipate energy and reduce the erosive forces of the flow before this water travels downstream. Passage of the design flood (estimated as the probable maximum flood or 848 m^3/s) will be achieved via gate underflow with a design head of 11 m. Under normal operation, these gates would be fully raised, and streamflow would pass over the spillway weir as it currently does. During a flood condition, the gates will be lowered to regulate the flow, and ensure that a reduction in flow rate downstream to the Big East River is achieved. A dedicated stilling basin was deemed necessary at this stage of study. However, further investigation may indicate that this type of energy dissipation approach may be unnecessary depending on the nature of the local geology.

Conceptually, design of Distress Dam would achieve an approximately 50% reduction of the downstream peak flow rate, based on the magnitude 2013 design event and the impoundment volume upstream from the dam (Hatch, 2022f). Impounded storage would then be released gradually following the flood peak. More refined hydrologic modelling and additional study to determine an appropriate spill release strategy to ensure the desired flood attenuation is realized.

For this report, the 2019 design event was used as a basis to illustrate cumulative watershed benefits resulting from implementation of Distress Dam. Considering the 2019 design event

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was of a lower magnitude on the Big East River relative to the 2013 event, the results in Section 6 may not illustrate the full benefits of implementing Option 1.

Among the site-specific investigations or studies that may be required prior to implementation of this option are the following:

- More refined hydrologic modelling and additional study to determine an appropriate spill release strategy.
- Geotechnical survey to determine suitability of foundation. If the foundation is found to be competent bedrock, it may be possible to eliminate the structure's stilling basin, and thereby reduce cost.
- Field surveys to verify suitability of dam cross-section alignment.
- Numerical modelling to support design refinement of the spillway and energy dissipation components.
- Development of operational procedures to optimize flood control offered by the Distress Dam impoundment area.
- Environmental impact assessment to identify any potential impacts to the natural environment (see Section 7 for additional detail).

5.3 Option 2: Berm Protection near Swing Bridge

Option 2 includes installation of a berm to prevent flooding of commercial waterfront property in the Town of Huntsville. The Town of Huntsville's commercial area, located on the left bank of *Huntsville Narrows* (North Branch) and upstream from the Huntsville swing bridge, flooded in 2019. The area located between the intersections of John Street and Main Street (East) up to John Street and Cann Street was inundated.

The proposed flood protection berm would serve to reduce flood inundation severity. The concept includes an earthfill berm along most of the shoreline and a removable/mobile flood protection wall for a section of the shoreline that would continue to allow unobstructed view of the river during non-flood conditions. The horizontal alignment of the proposed berm is presented in Table 5-2. The concept design drawing for this option is provided in Appendix B.

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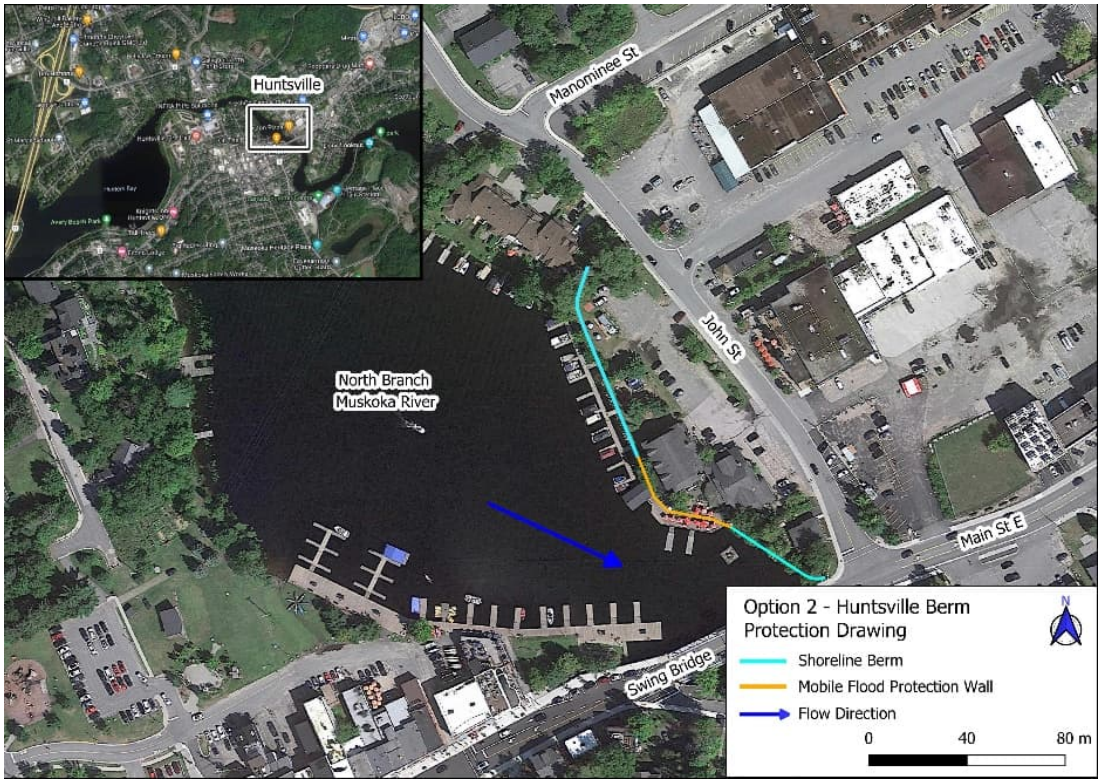

Figure 5-2: Approximate Alignment of Option 2

The earthfill berm would likely feature stairs to permit public access and a vehicle ramp to the parking lot to facilitate the annual removal and installation of the public and private docks along the water. A one-way valved stormwater drainage pipe will be needed to allow the local area to drain without allowing flood waters to flow up the drain. The slopes of the berm may be planted with decorative non-woody plantings to improve the aesthetics.

Where the two commercial buildings front the shoreline, a mobile flood protection system is proposed to allow access to the waterfront during non-flood conditions. An example of this type of mobile flood control is shown in Figure 5-3 and is composed of structural steel columns which are placed at regular intervals, with interlocking beams between them that create a watertight barrier when installed.

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Figure 5-3 Mobile Flood Protection Wall in River Seven in Bewdley, UK (Photograph by Deborah Hardiman, 2021)

The columns and beams are lightweight enough that a small team can assemble long stretches of the system in a short time. Preparation for the mobile flood protection wall would involve installing anchors and reinforced concrete foundations in the ground to support the columns and beams, which would have to be designed to withstand overturning loads from the barrier, as well as any other relevant loads. In conditions where the flood barrier is not required the components can be kept in storage, and the ground anchors supports for the columns are barely visible while not in use, with little to no aesthetic impact where installation is required. The mobile flood protection wall is estimated to have a length of approximately 70 m, with an estimated height of 2 m.

The total length of the proposed berm excluding the mobile flood control system is approximately 120 m. The height of the berm will vary but will be no higher than 2 m. Concrete abutments will be built between the mobile flood protection wall and the berm, allowing access to the patio while the wall is not in use. The berm will be composed of compacted soil but may require additional elements such as geosynthetic reinforcements or other materials. Material quantities for the protection system are listed in Table 5-3.

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Table 5-3: Conceptual Design Attributes for Option 2 – Berm Protection near Swing Bridge

Item	Quantities
Mobilization	1 Lump Sum (LS)
Earthfill Berm	1500 m^3
Concrete Work	85 m^3
Mobile Flood Protection	70 m

Flood mitigation benefits of implementing the shoreline berm and mobile flood protection wall are limited mainly to the commercial area adjacent to the site. Redirection of flow by the berm/wall implies that flood waters will be confined to the Huntsville Narrows main channel, which will reduce local flood plain storage but will not impact overall channel conveyance since the protected areas are outside of the main channel floodway. This flood plain storage was estimated to be much less than one percent of the peak design event flow volume in the Huntsville Narrows for the Baseline Case. As such, the loss of river and flood plain storage due to Option 2 will have no material effect on peak flow or water levels upstream or downstream from Huntsville Narrows.

Additional site-specific investigations or studies that may be required prior to implementation of this option include

- Geotechnical survey to suitability of foundation
- Check for any existing storm drainage features below grade that would affect this scheme
- Confirm berm extents relative to property lines
- Detailed site survey and development of site drainage plan
- Development of public access plan that includes dock management.

5.4 Option 3: Increase Fairy Lake Outflows Through Brunel Locks

Option 3 targeted the Huntsville Dam (specifically the Brunel Lift Locks) to increase outflow by modifying operations, both prior to and during the design flood. In the Baseline Case, Fairy Lake outflows during the design flow event are controlled by six gates at the Huntsville Dam. A seventh gate, which serves as an entrance leading to the Brunel Lift Locks, typically remains closed (with stoplogs) from winter through late-May (weather dependent) and thus is not active during the spring season or during passage of the design flood. The Huntsville Dam, Brunel Lift Locks and the locks channel are shown in Figure 5-4.

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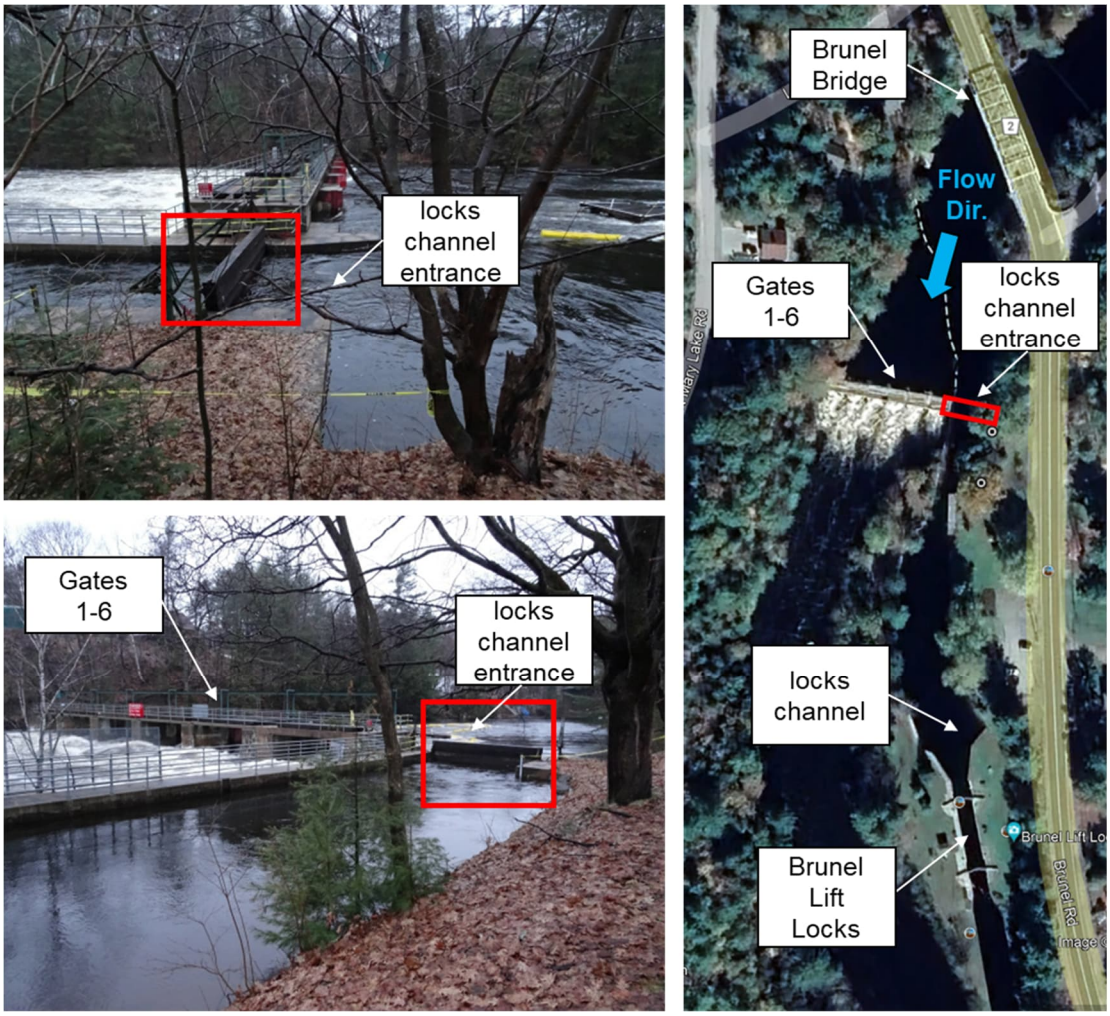

Figure 5-4: Huntsville Dam Site, including Gates 1 to 6, the Brunel Lift Locks, and the Locks Channel

The Brunel Lift Locks and channel facilitates boat passage via an upstream gate/door (which does not completely seal). According to the DOM (OMNR, 1997 with 2007 updates), the lock has a length of 27.2 m and a width of 6.25 m, with a normal water level difference of 3.1 m between the upper and lower sides of the lock. Therefore, the outlet capacity of the dam could be increased by opening the upstream and downstream lock gates and allowing additional flow to bypass the main spillway through the lock structure.

The increase in outflow capacity from Fairy Lake via the locks channel entrance was estimated using hydraulic structure information provided within the DOM (OMNR, 1997 with 2007 updates). The lock channel entrance has a width of 4.1 m and the sill elevation was assumed to have an elevation of 281.6 m (acknowledging that the lock entrance channel is not reported in the DOM [OMNR, 1997 with 2007 updates]). This elevation is the same as the

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sill elevation of the upper gate of the Brunel Lift Lock. Confirmation of the lock entrance sill will be required to confirm the findings summarized herein, as this information was not available for this study.

Option 3 would involve the draining of the lock and its approach channel for the winter season, then as-required removal of stop logs from the Brunel Lift Lock entrance prior to the design flood event to increase outflow capacity from Fairy Lake. This procedure may require modified/improved stoplog handling equipment. For the model evaluations of this option (see Section 6), the timing of removal was assumed to be April 1. The Mitigation Case stage-discharge relationship for Option 3 was calculated by adding the additional outflow through the locks channel entrance to the Baseline Case stage-discharge rating curve (Figure 5-5).

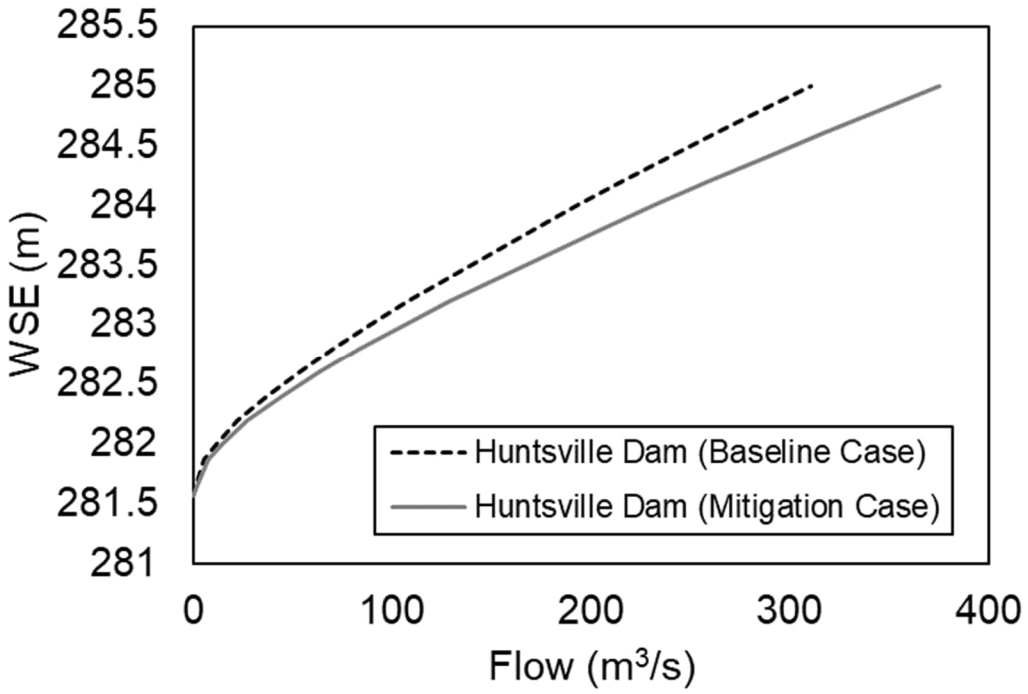

Figure 5-5: Water surface elevation (WSE; stage) – Discharge Rating Curve at Huntsville Dam for the Baseline Case and the Mitigation Case (i.e., Inclusion of Brunel Locks Outflow)

Areas that may experience flood mitigation benefits associated with implementing increased flow capacity at Fairy Lake (as per Option 3) include Fairy Lake, Peninsula Lake, Huntsville Narrows, Lake Vernon, and Big East River. Conversely, areas that may experience an increase in flood impacts resulting from these increased outflows include *priority areas of concern* of Springdale, Muskoka/Bala, Musquash River and Moon River. Evaluation of changing flood conditions in these areas is presented in Section 6.

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Increasing outflows from Fairy Lake (North Branch) via the Brunel Lift Locks is not anticipated to involve any structural alteration of the locks and only a change to operations. However, additional site-specific investigations or studies that may be required prior to implementation of this option include

- Completion of survey to confirm sill elevation of Brunel Life Locks entrance
- Completion of survey to determine bed geometry of the locks channel and calculation of water levels and flow velocities in the locks channel and its adjacent flood plain under design flood conditions
- Design of necessary erosion protection features (i.e., rip rap), if required, to protect the locks channel and adjacent flood plain during passage of the design flood
- Evaluate the need for modified/improved stoplog handling equipment that can fully remove (and reinstall) the lock channel stoplogs in flowing conditions
- Evaluation of any water retaining structures under the Lakes and Rivers Improvement Act guidelines, including stability analysis of structures under a new flood load.

5.5 Option 4: Retrofit of Control Structure at High Falls

Option 4 involves retrofitting aspects of the hydraulic structures at the High Falls Generating Station (GS), with the primary objective of reducing water levels in the Springdale priority area located upstream during flood events. Hydraulic structures at this site include a powerhouse (and accompanying approach channel), a vertical lift gate, and a free overflow spillway.

Under normal operating conditions flow is passed through the powerhouse and the vertical lift gate when spill is required. During high flow events, water levels rise when the capacity of the powerhouse and vertical lift gate is exceeded, and water begins to flow over the sill elevation of the free overflow spillway, as is the case for the design flood event conditions.

The proposed work consists of replacing existing flashboards and concrete sections of the free overflow spillway weir with two pneumatically actuated Obermeyer style gates that will be 3 m tall. These gates will be operable as opposed to the existing, fixed concrete spillway/weir. One gate will be adjacent to the existing lift gate and will be 28 m long extending to a new constructed pier/bulkhead on its east side. The second will be 18 m long and extend to the right bank. These bottom hinged gates are opened and closed using an inflatable air bladder, which simplifies installation and provides a lower maintenance solution relative to conventional gates. The conceptual design attributes for the retrofitted control structure at High Falls are illustrated on the design drawing in Appendix B.

The pneumatically actuated hinged design allows the gate to vary discharge based on flow conditions. During an extreme flood, the Obermeyer gates would be lowered (deflated) to increase spill flow and, in turn, lower the water level of the High Falls GS head pond. During normal flow conditions, the Obermeyer gates would be raised to match the crest elevation of

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the existing concrete spillway to maintain Baseline Case water levels characteristic of the upstream reach during non-flood conditions.

Flood mitigation benefits of installing and operating Obermeyer gates at High Falls are limited to the Springdale reach. Any influence from the High Falls head pond on upstream water levels in Springdale will terminate at Duck Chutes, as the chutes function as a hydraulic control ('choke point'). This control point means that Muskoka River North Branch water levels upstream from Duck Chutes are insensitive to water level changes resulting from Obermeyer operation at High Falls GS.

A reduction in reach water levels from the Baseline Case to Mitigation Case was determined to be equivalent to the removal of 195,138 m^3 of river and flood plain storage that would otherwise serve to attenuate flows at the peak of the design flood to downstream areas. An analytical approach was to determine the increase in peak flows.

The analytical approach was based on the premise that the change in storage volume can be converted to an increase in peak flow over a suitable time-period (Δt [days]). Considering that 1 day is the smallest time-period of measured hydrometric data applied for this study, selecting Δt equal to 1 day provides a conservative estimate of peak flow increase. A 1-day value for Δt was considered suitable based on an assessment of shape and response time in the hydrographs for other reaches of the Muskoka River North Branch. The estimation of Mitigation Case peak flow ($Q_{Peak(Mitigation)}\left[\frac{m^3}{s}\right]$) resulting from storage removal ($V_{storage}[m^3]$) is summarized in Equation 1:

$$Q_{Peak(Mitigation)}\left[\frac{m^3}{s}\right] = Q_{Peak(Baseline)} + \frac{V_{storage}}{\Delta t * \frac{24hour}{day} * 3600\frac{s}{hour}}$$

Equation 1

By applying Equation 1, this storage change was estimated to result in a design peak flow increase out of High Falls GS of 2 m^3/s (or an approximately 1% increase from the Baseline Case). This estimate assumes the removed storage volume will directly translate to this small 1-day peak flow increase, which is considered conservative.

Considering this small change in peak flow, removal of river and flood plain storage due to Option 4 is expected to have limited material change to peak water levels downstream from High Falls. Further, Option 4 is expected to have no material change to peak water levels upstream from the Duck Chutes due to the hydraulic control of Duck Chutes.

Additional site-specific investigations or studies that may be required to confirm the consequences of this option (prior to implementation) include

- Geotechnical survey to determine suitability of foundation
- Study investigating any effects of Obermeyer installation on High Falls GS operations

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- Detailed survey of the existing structures, downstream bathymetry, and head pond bathymetry to confirm or refine this option to achieve desired outflows.

5.6 Option 5: Channel Enlargement at May Chutes

Option 5 proposes to increase the conveyance through May Chutes (on the south branch of the Muskoka River) by excavating the channel, mainly by lowering the existing channel bed. The primary effect of this mitigation option will be the reduction of flood water levels in the Fraserburg reach. Option 5 involves the channel enlargement of the May Chutes cascades through widening, deepening or a combination of both (depending on location along the reach) to increase flow capacity. This change would lower water levels up to Slater Falls, as the falls function as a hydraulic control ('choke point'). Figure 5-3 below shows the proposed extent of excavation at May Chutes, with a total excavation length of approximately 700 m. A more detailed drawing of the site and proposed conceptual design is provided in Appendix B.

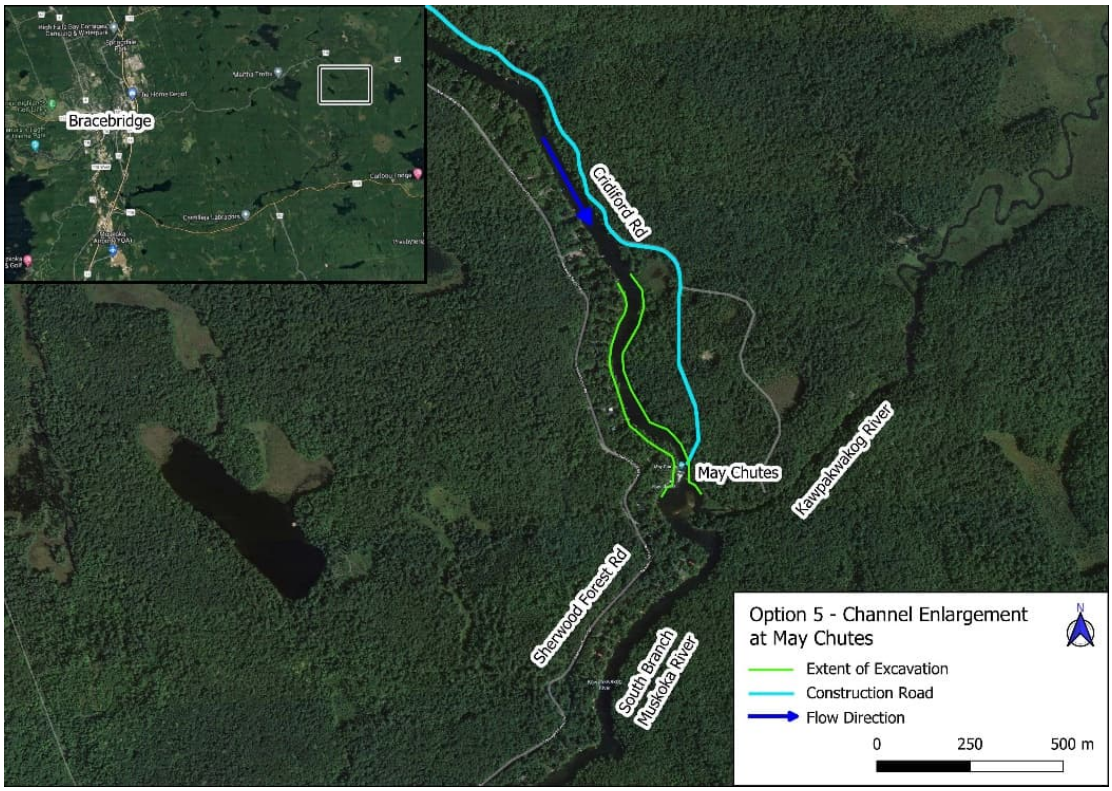

Figure 5-6: Extent of Excavation at May Chutes and Construction Road Access

Excavation in this area will likely be done underwater, from barges, due to longer construction times and challenges associated with dewatering or redirecting flow to allow for work in dry conditions. Based on bedrock geology made available by the Ontario Geological Survey (OGS), bedrock at this location is mapped as migmatitic rocks and gneisses (OGS, 1991), and excavation is expected to be undertaken from barges and require blasting to reach target depths. Both silt and blast curtains will need to be installed to reduce environmental impacts

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during excavation, and excavated material will require removal and transport off-site. Initial estimates of the excavation volume were obtained from the hydraulic model and confirmed through average end area volume calculations ('Trapezoidal Method') for the Baseline Case and Mitigation Case excavation cross sections. These calculations yielded a material excavation volume estimate of approximately 70,000 m^3 to reach target bed levels.

Two branching roads leading from Fraserburg Road, Cridiford Road and Sherwood Forest Road, lead to the near edge of the proposed excavation limits. The suitability of these roads for heavy machine traffic was uncertain. Therefore, a construction access road was included in the cost estimate to supplement the concept. To avoid disruption of the residential area on the west bank, this road should be built along the east bank leading down to May Chutes. Initial estimates suggest that the road will be approximately 3.0 km in length.

Flood mitigation benefits associated with excavating at May Chutes are limited mainly to the Fraserburg reach of Muskoka River South Branch. A reduction in reach water levels from the Baseline Case to Mitigation Case was determined using the Fraserburg hydraulic model and based on the removal 230,688 m^3 of river and flood plain storage that would otherwise serve to attenuate flows at the peak of the design flood to downstream areas. Using Equation 1 and the analytical approach described in Section 5.5 this storage change was estimated to result in a design peak flow increase out of the Fraserburg reach of 1.33 m^3/s (or an approximate 1% increase from the Baseline Case).

Additional site-specific investigations or studies that may be required prior to implementation of this option include

- Geotechnical survey to determine the material of the bed
- Detailed bathymetry survey
- Detailed numerical modelling to confirm intended hydraulic benefit of channel excavation and, if confirmed, optimize the excavation
- Investigation into effects of excavation on water levels during normal flow conditions
- Environmental impact assessment to identify any potential impacts to the natural environment (see Section 7 for additional detail).

5.7 Option 6 *and* 7: Channel Enlargement at Rocky Rapids *and* Lower Head Pond Flood Levels at Matthias GS

Options 6 and 7 both target flood mitigation for the Purbrook reach. While each option can be implemented individually, there is a synergistic benefit achieved by implementing both options together. For this reason, these options are presented together.

Option 6 proposes to increase the conveyance through Rocky Rapids by excavating the channel, resulting in a reduction in flood water levels upstream from Rocky Rapids to the Purbrook Bridge. Figure 5-7 shows the proposed extent of excavation at Rocky Rapids, with

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a total length of approximately 750 m of the rapids to be excavated. More detailed drawings of the site and proposed conceptual design is provided in Appendix B.

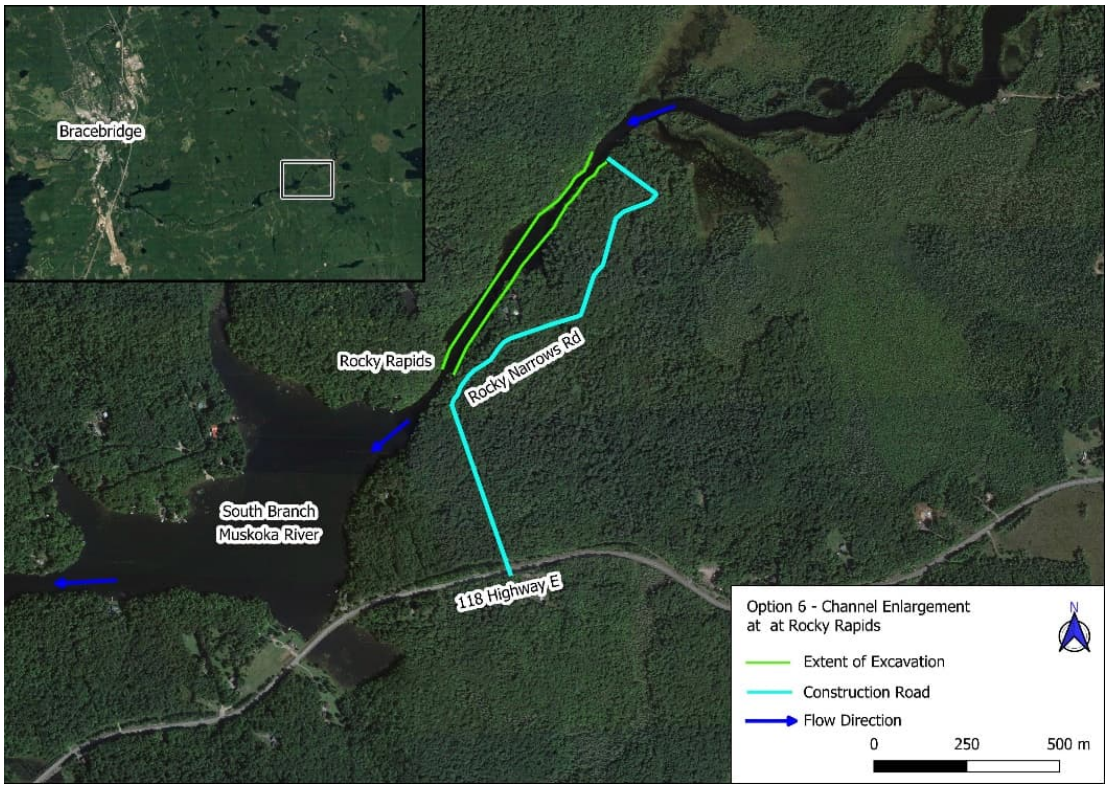

Figure 5-7: Extent of Excavation at Rocky Rapids and Construction Road Access

Excavation in this area will likely be done underwater due to longer construction times and challenges associated with dewatering or redirecting flow to allow for work in dry conditions. Based on bedrock geology made available by OGS, bedrock at this location is mapped as migmatitic rocks and gneisses (OGS, 2010). Excavation would be done from barges and require blasting to reach target depths. Silt curtains would be installed to reduce environmental impacts during excavation and excavated material would require removal and transport off-site. The excavation volume was estimated using the Purbrook hydraulic model and confirmed through average end area volume calculations ('Trapezoidal Method') of pre- and post-excavation cross sections. Approximately 71,000 m^3 of material would be excavated to reach target bed levels.

A branching road leading off from 118 Highway East, Rocky Narrows Road, leads to the near edge of excavation limits. However, there is uncertainty as to the suitability of this road for heavy machine traffic. Therefore, a construction access road was included as part of the implementation of this design and was estimated to be 1.6 km long.

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Option 7 proposes operating the existing Matthias GS at a lower head pond water level during the design flood event. Matthias GS is operated by Orillia Power and features three spillways and a large head differential from head pond to tailrace. Two of the three spillways have mechanized, bottom draw, steel gates, while the third has non-mechanized, panel gates. The third spillway is noted to only be used in the case of severe floods. The Matthias GS head pond has a maximum allowable elevation of 293.5 m, and during the 2019 design flood the head pond reached an elevation of 293.16 m, very close to the maximum allowable elevation.

The following analysis was conducted to determine required changes to gate openings at the two main spillways to pass the design flood event under a lower head pond elevation. For this analysis, no flood passage through the third spillway was assumed, and the gate opening heights of the main two main spillways were assumed to be equal. Using stage-discharge rating curves provided by Orillia Power and a head pond elevation of 293.16 m, the gate opening height required to pass the design flood under these assumptions was calculated.

Using the calculated gate opening estimated for the design flood event, the increase in gate opening required to pass the project design flood at a head pond elevation of 292 m was calculated to be 0.4 m for each gate. A head pond elevation of 292 m corresponds with the lower limit of the 'normal operating zone' for the Matthias head pond as outlined in the *MRWMP* (OMNR, et al, 2006 with 2019 updates). That is, if the gates were opened by an additional 0.4 m during this event, the upstream level can be lowered to 292 m.

It is expected that the dam has sufficient capacity and gate control to implement the mitigation details of Option 7. Therefore, this option requires no structural modifications at the Matthias GS.

Flood mitigation benefits associated with lowering the Matthias GS head pond water level are limited mainly to the Purbrook Reach from Matthias GS to Rocky Rapids. As discussed in the Structural Flood Mitigation Options Report (Hatch, 2022f), the full flood mitigation benefit of lowering Matthias GS head pond levels is only realized if the hydraulic control at Rocky Rapids is reduced (i.e., Option 6). By implementing Options 6 and 7 in tandem, design flood water levels from Matthias GS to Purbrook Bridge are significantly reduced.

A reduction in design flood levels in the Purbrook reach has the potential to increase peak flows from Purbrook to downstream areas. Changes in peak flows were estimated by comparing the change in peak storage (riverine and flood plain) between the Baseline Case and Mitigation Case (including both Options 6 and 7) for the Purbrook reach. Using the Purbrook hydraulic model, this change in storage was calculated to be 2.6 Mm^3. Applying Equation 1 and the analytical approach described in Section 5.6, this storage change was estimated to result in a design peak flow increase out of the Purbrook reach of 15 m^3/s (or an approximately 8% increase from the Baseline Case).

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Additional site-specific investigations or studies that may be required prior to implementation of this option include

- Geotechnical survey to determine the material of the bed
- Detailed bathymetry survey
- Detailed numerical modelling to confirm intended hydraulic benefit of channel excavation
- Investigation into effects of excavation on water levels during normal flow conditions
- Study investigating the any effects of channel enlargement at Rocky Rapids on Matthias GS operations
- Environmental impact assessment to identify any potential impacts to the natural environment (see Section 7 for additional detail).

5.8 Option 8: Channel Enlargement at Wallis Cut

Option 8 proposes the excavation of Wallis Cut, one of three flow constrictions at Bala Park Island that limits conveyance between Lake Muskoka and Bala Bay. The local impact of Option 8 is to reduce water levels in Lake Muskoka by allowing more flow to pass through this improved outlet channel.

As described in the Structural Flood Mitigation Options report (Hatch, 2022f), flow between Lake Muskoka and Bala Bay is influenced by three constrictions: Wallis Cut, Jannacks Narrows, and Coultier Narrows. Hydraulic simulations of design flood conditions showed that Wallis Cut passed the smallest proportion of total flow (7%) from Lake Muskoka to Bala Bay. This proportionally low flow through the reach means that installing a cofferdam to facilitate excavation may be a viable option in this area, since the associated increase in flow to Jannacks Narrows and Coultier Narrows during excavation is not expected to cause issues. For this high-level assessment, the excavations were assumed to take place underwater from barges rather than in a dewatered condition using cofferdams.

To effectively increase the flow capacity of Wallis Cut, bed material must be excavated within close proximity to the existing CN Rail Bridge. At this level of study, it was uncertain if the excavation could be undertaken without compromising the stability of the bridge supports. As such, relocation of the bridge may be necessary to reduce (or eliminate) this risk, but it is unknown at this time of this would be necessary.

Figure 5-8 presents the proposed excavation extent at Wallis Cut, with a total excavation length of approximately 150 m. Details associated with the conceptual design are provided in Appendix B.

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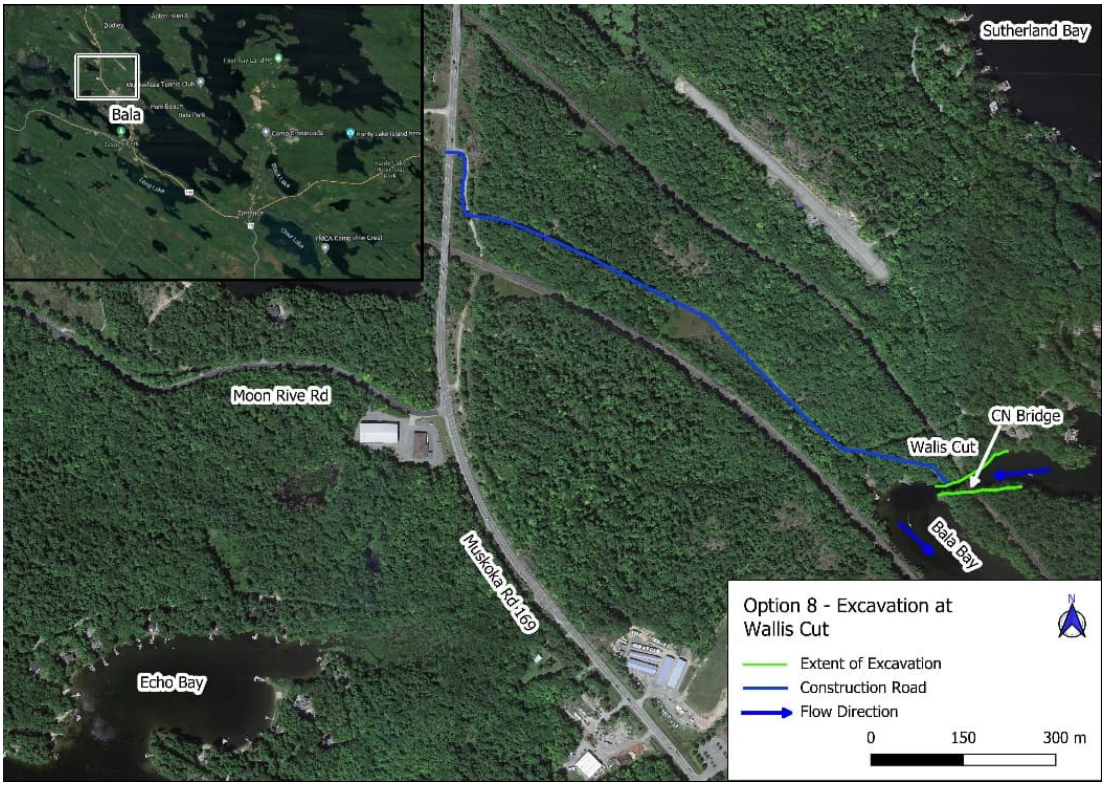

Figure 5-8: Extent of Excavation at Wallis Cut and Construction Road Access

Based on bedrock geology made available by OGS, bedrock at this location is mapped as migmatitic rocks and gneisses (OGS, 2010), excavation is expected to be undertaken from barges and require blasting to reach target depths. Blast and silt curtains will need to be installed to reduce environmental impacts during excavation, and excavated material will require removal and transport off-site. Initial estimates of the excavation volume were obtained with the hydraulic model and confirmed through average end area volume calculations ('Trapezoidal Method') of Baseline Case and Mitigation Case excavation cross sections. These calculations yielded a material excavation volume estimate of approximately 5,000 m^3 to reach target bed levels.

Satellite imagery shows a branching road leading off from Muskoka Road 169 that leads to the near edge of excavation limits. However, there is uncertainty as to the suitability of this road for heavy machine traffic. Therefore, a construction access road was included as part of the implementation of this design and was estimated to be 1.2 km long.

Hydraulic model simulations demonstrated that channel enlargement at Wallis Cut would increase flow conveyance from 7% of the design flood to 15%, with the remaining flow passing through either Coultier Narrows or Jannacks Narrows. A reduction in hydraulic restriction through Wallis Cut was estimated to lower Lake Muskoka design flood water levels by 0.14 m relative to the Baseline Case.

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A reduction in hydraulic resistance at Wallis Cut is expected to result in some increase to peak outflow rate from Lake Muskoka during the design flood. Analyses using numerical modeling of the Baseline and Mitigation cases, to produce a stage-discharge curve relating Lake Muskoka water level to Bala Bay outflow, indicated that excavation of Wallis Cut would increase the design flood peak outflow rate by 4 m^3/s. The rating curves (associated with both the Baseline and Mitigation cases is presented in Figure 5-9.

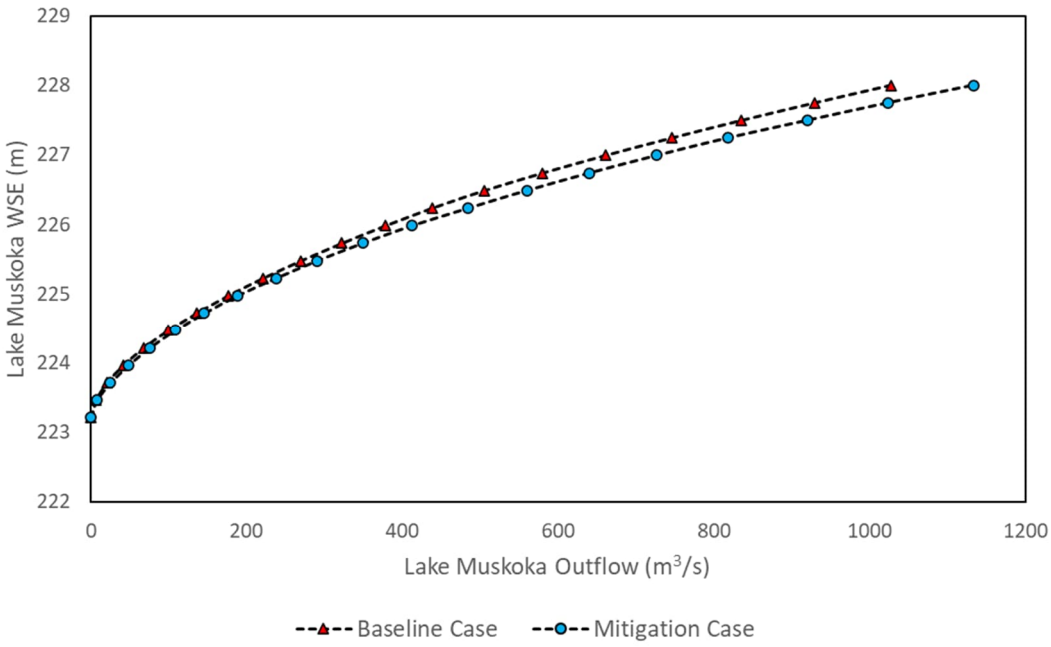

Figure 5-9: Stage-Discharge Rating Curve for Lake Muskoka for Baseline Case and Mitigation Case (Option 8)

While this approach provided a reasonable estimate, more detailed modelling may be warranted to confirm this estimate given the complicated nature of the hydraulics at Bala Park Island and compounding influence of Bala Dam on upstream water levels.

The curves in Figure 5-9 were further refined to include Option 9 (see Section 5.9 for details), as Options 8 and 9 have a cumulative effect on Lake Muskoka water levels and outflow.

Additional site-specific investigations or studies that may be required prior to implementation of this option include

- Geotechnical survey to determine the material of the bed
- Detailed bathymetry survey
- Options assessment to determine if cofferdamming is feasible and provides cost savings or other advantages

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- Detailed numerical modelling to confirm intended hydraulic benefit of channel excavation
- Study investigating any effects of channel enlargement at Wallis Cut on Bala Dam operations
- Environmental impact assessment to identify any potential impacts to the natural environment (see Section 7 for additional detail).

5.9 Option 9: Retrofit of Control Structure at Bala South Dam

Option 9 proposes bedrock excavation upstream from Bala South Dam to increase the outflow capacity of Bala South Dam. The sill elevations and widths of all eight bays of the South Bala Dam are 223.11 m and 4.3 m, respectively. A bedrock shelf (at an average elevation 0.3 m higher than the Bala South Dam gate sills, or 223.41 m) is located approximately 30 m upstream from the dam and constricts approach flow. Consequently, the DOM (OMNR, 1997 with 2007 updates) reports that, due to this obstruction, no significant outflow from Bala Bay occurs when the water level of Bala Bay is below 223.41 m, and similarly this bedrock limits dam outflow capacity when the water level is above 223.41 m.

This shelf of bedrock located upstream from the dam effectively acts as the sill of the structure. The proposed work at this location would be to excavate approximately 0.3 m (or more) off the bedrock shelf to allow flow control to shift back to the spillway and, therefore, increase the capacity of the Bala South Dam. The excavation quantity was estimated to be a minimum of 16.5 m3. Due to the location, it is not practicable to isolate and dewater the excavation area. Therefore, excavation must be done underwater. Based on bedrock geology made available by OGS, bedrock at this location is mapped as migmatitic rocks and gneisses (OGS, 2010), excavation would be done from barges and require blasting to reach target depths. Following the excavation, the dam could be operated with the stoplog bays fully open, such that the bedrock is no longer a limiting factor for the discharge capacity of the dam.

The impact of excavating the bedrock at Bala South Dam on outflow capacity was quantified by adjusting the Baseline Case stage-discharge rating curve for the dam (using data from the DOM [OMNR, 1997 with 2007 updates]). This adjustment involved reducing the effective sill elevation for all gates from 223.41 m to 223.11 m, which increases the outflow capacity across the entire range of operating levels for the station (Figure 5-10).

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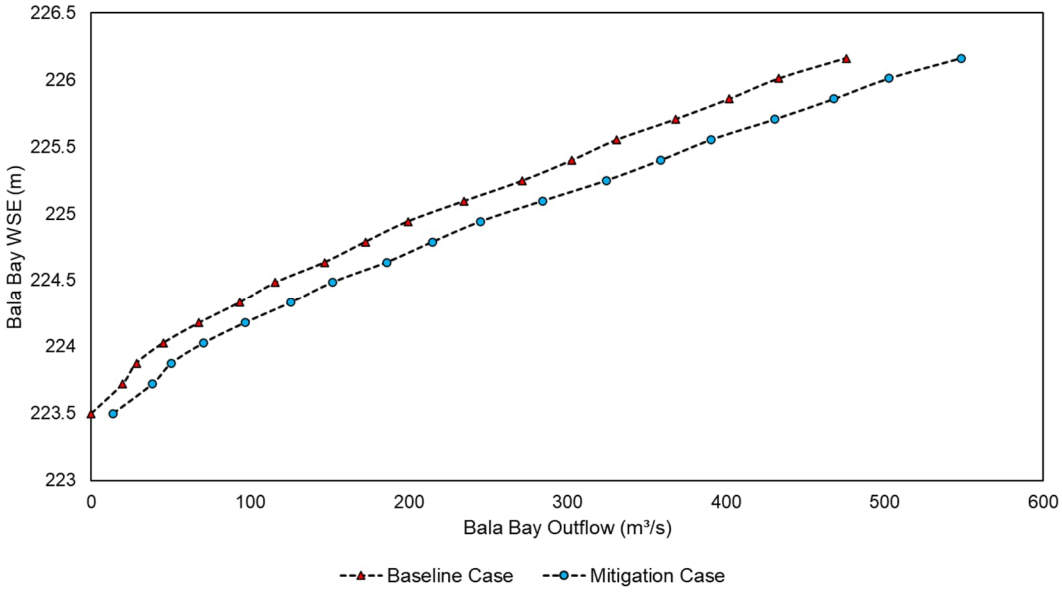

Figure 5-10: Stage-Discharge Rating Curve for Bala South Dam for Baseline Case and Mitigation Case

The rating curves shown in Figure 5-10 were incorporated into the hydraulic model. By representing both the Mitigation Case rating curve (Figure 5-10) and Wallis Cut excavation (Option 8) in the hydraulic model, a refined version of the Lake Muskoka rating curve shown in Figure 5-9 was developed. This rating curve (*Mitigation Case – Options 8 and 9*) is shown in Figure 5-11.

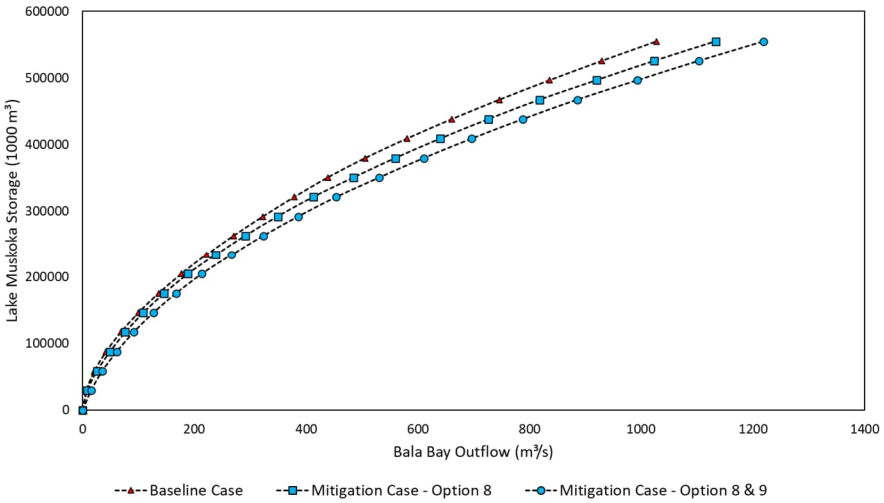

Figure 5-11: Storage-discharge rating curve for Lake Muskoka, for the *Baseline Case*, the *Mitigation Case* with Option 8 only, and the *Mitigation Case* with both Options 8 and 9

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The rating curves shown in Figure 5-11 were used in the hydrologic model to simulate the Lake Muskoka and Bala Bay water levels that would result during design flood conditions when various combinations of flood mitigation options (described in Section 6.1) are implemented. While Option 8 specifically results in lower Lake Muskoka water levels, Option 9 results in lower water levels for both Bala Bay and Lake Muskoka. Combining Option 8 and Option 9 result in even lower water levels for both Bala Bay and Lake Muskoka. This change also results in a small increase in outflow from Bala Dam to the downstream Bala Reach.

Additional site-specific investigations or studies that may be required prior to implementation of this option include

- Geotechnical survey to determine the material of the bed
- Detailed bathymetry survey
- Detailed numerical modelling to confirm intended hydraulic benefit of channel excavation
- Investigation into effects of excavation on water levels during normal flow conditions
- Study investigating the any effects of channel enlargement at Wallis Cut on Bala Dam operations
- Environmental impact assessment to identify any potential impacts to the natural environment (see Section 7 for additional detail).

5.10 Option 10: Channel Enlargement at Moon Chutes

In the Bala Reach, approximately 6.6 km downstream from the Bala Dam is a narrow strip of river called Moon Chutes. During regular flow conditions, the water level in the Bala reach is regulated by the Moon River Dam and Ragged Rapids GS. However, Moon Chutes becomes a significant hydraulic control point during periods of flooding. Option 10 was developed to increase conveyance through the Moon Chutes constriction by enlarging the channel through excavation, which will decrease its influence during periods of flooding. Figure 5-12 below shows the proposed extent of excavation at Moon Chutes, with a total length of approximately 300 m of the river proposed to be excavated.

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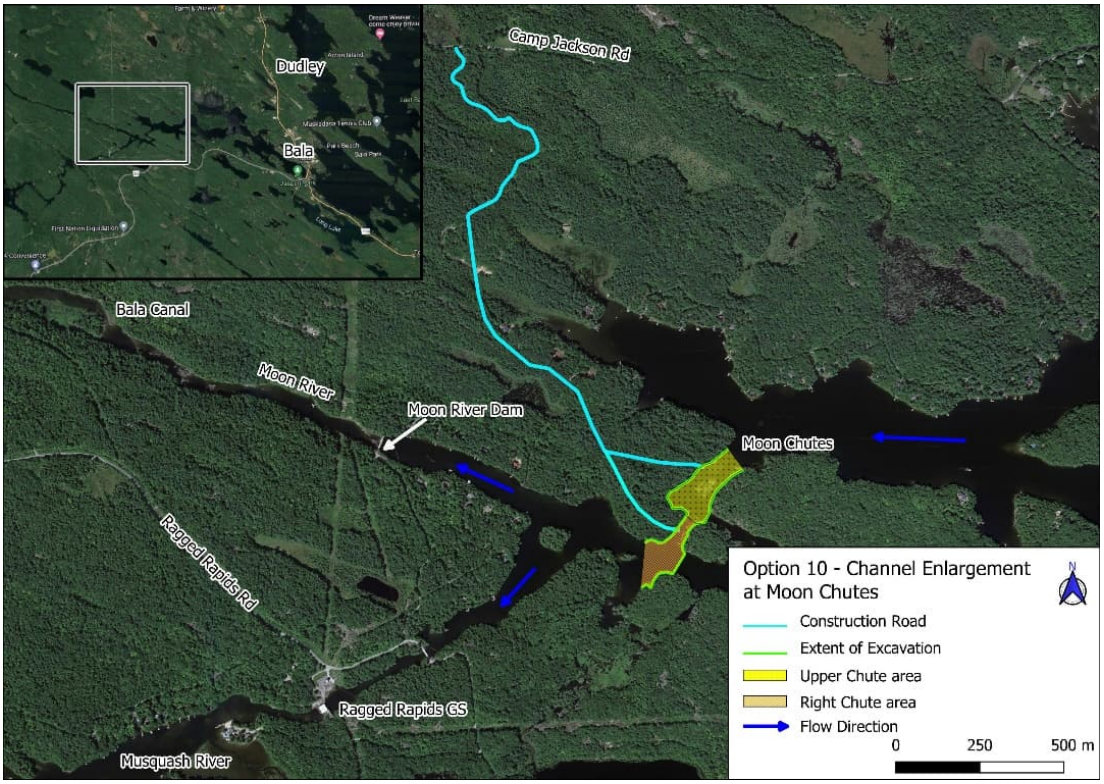

Figure 5-12: Extent of Moon Chutes Excavation and Construction Road Access

Hydraulic modeling of the area divided Moon Chutes into four sections, Upper, Right, Left and Lower Chutes. Excavation to reach target water levels would be necessary on Upper and Right Chutes, and initial estimates of the excavation volume were obtained from the hydraulic model and confirmed through average end area volume calculations ('Trapezoidal Method') of Baseline Case and Mitigation Case excavation cross sections. Approximately 32,100 m^3 of material would be excavated in the Upper Chutes section, and 11,000 m^3 would be excavated in the Right Chutes to reach target bed levels.

Excavation in the Upper Chute section is expected to be done underwater while excavation in the Right Chute section may be possible in dry conditions using cofferdams. Viability of this option is dependent on the capacity of the Left Chute to adequately cope with the increase in flow during construction. An optimum construction plan could be conceived at a future stage of development.

Based on bedrock geology made available by OGS, bedrock at this location is mapped as migmatitic rocks and gneisses (OGS, 2010), excavation is expected to be undertaken from barges and require blasting to reach target depths. Blast and silt curtains will need to be installed to reduce environmental impacts during excavation, and excavated material will require removal and transport off-site. Access to this site is limited. Therefore, a road must

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be added to facilitate construction. An initial estimate for the length of road construction is 2.5 km.

Flood mitigation benefits associated with excavation at Moon Chutes are limited to a reach that extends from Moon Chutes upstream to the Bala Dam. Any influence from the Moon Chutes excavation on upstream water levels in Bala Reach will obviously terminate at Bala Dam. A comparison of the Baseline and Mitigation Option stage-discharge curves for Bala Reach, generated using the hydraulic model, is shown in Figure 5-13. This figure illustrates the expected extent by which water levels can be lowered during large flood events.

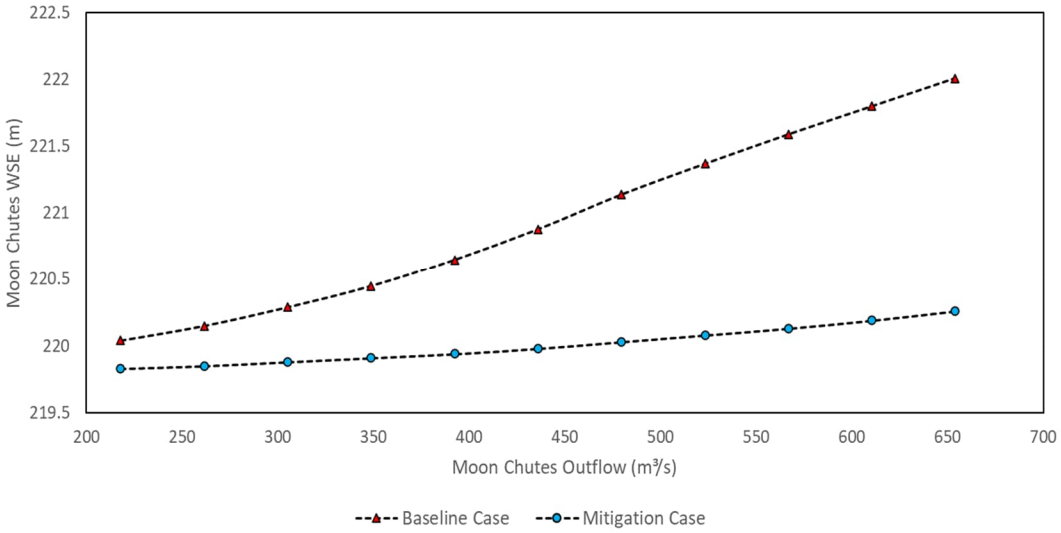

Figure 5-13: Stage-Discharge Rating Curves for the Bala Reach for Baseline Case and Mitigation Case (i.e., Option 10)

The reduction in water level in this reach will result in a slight increase in outflow to downstream reaches during a large flood event. A level-pool routing technique was used to estimate this impact. This refined approach was warranted to best estimate the immediate flood impacts of Moon Chutes excavation on important downstream areas like Moon River and Musquash River. Using an initial condition of inflow to Bala Reach and storage for Bala Reach, the level-pool routing approach employs Equation 2:

$$\frac{S_{j+1} - S_j}{t_{j+1} - t_j} = \frac{I_j - I_{j+1}}{2} + \frac{O_j - O_{j+1}}{2}$$

Equation 2

where j is the timestep in the calculation (hours), S is the storage in Bala Reach (m^3), I is the inflow to Bala Reach (m^3/s), and O is the outflow from Moon Chutes. The level-pool approach uses the finite difference method to covert an inflow (I) time-series to Bala Reach to an outflow (O) hydrograph while accounting for available riverine and flood plain storage (S).

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With the reduction in storage for the Mitigation Case relative to the Baseline Case, the level-pool routing approach yielded an increase in peak flow of 3 m^3/s. It should be noted that due to the complicated nature of excavating the chutes, more detailed modelling may be required to refine the flow estimates for future studies.

Additional site-specific investigations or studies that may be required prior to implementation of this option include

- Geotechnical survey to determine the material of the bed
- Detailed bathymetry survey
- Detailed numerical modelling to confirm intended hydraulic benefit of channel excavation
- Investigation into effects of excavation on water levels during normal flow conditions
- Study investigating the any effects of channel enlargement at OPG's Ragged Rapids GS and the Moon River Dam
- Environmental impact assessment to identify any potential impacts to the natural environment (see Section 7 for additional detail).

5.10.1 Assumed Flow Split Between Moon River and Musquash River

Downstream from Lake Muskoka, the flow splits from Moon Chutes to the Moon River and the Musquash River. The Moon River is hydraulically controlled by the Moon Dam and the Musquash River is hydraulically controlled at Ragged Rapids. The Moon River is characterized by steep banks and has greater flow conveyance than the Musquash River. To ensure no additional flooding caused by the upstream flood mitigation options, the maximum flow rate in the Musquash River is limited to 113 m^3/s, as per the MRWMP which states that the 'maximum flow into Go Home Lake [downstream from Ragged Rapids] is 113 m^3/s to avoid flooding/high flow conditions on the lake' (OMNR et al., 2006 with amendments).

These limiting flow rates were adopted in the hydraulic models of the flood mitigation scenarios, and any additional flows were routed through the Moon River. This means that changes in outflows from Moon Chutes resulting from any options are assumed to primarily affect Moon River, while Musquash River downstream from Ragged Rapids GS remains unaffected.

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6. Muskoka River Watershed Flood Mitigation Scenarios

The impact of each flood mitigation option presented in Section 5 was evaluated locally for their governing flood event (i.e., 2013 or 2019) in the Structural Flood Mitigation Options report (Hatch, 2022f). The Flood Modification Review Project instead focused on evaluating the effect of the flood mitigation options on the greater MRW. This section presents the details of evaluation, including

- Derivation of mitigation scenarios that consist of combinations of options presented in Section 5
- High-level description of the evaluation approach for each scenario
- Analyses and presentation of model results via summary infographics.

For all scenarios, the 2019 design event was selected for analysis. As noted in Section 4, the rationale for this selection is that the 2019 design event was the governing flood for most priority areas. One exception is the North Branch upstream from Fairy Lake, where 2013 design event peak flow rates were higher than those in 2019.

Flood mitigation scenarios were assessed with hydrologic and hydraulic models, using models adopted from the FPMS (Hatch, 2020; 2022a, 2022b; 2022c, 2022d, 2022e; see Section 2.3). The main objective of modelling flood mitigation scenarios was to quantify the relative impact of each scenario on flood conditions in the MRW. This objective was achieved by analyzing the flow rates, water levels, number of impacted structures, and flood inundation areas.

6.1 Scenario Selection

Six flood mitigation scenarios were defined by combining subgroups of the ten flood mitigation options identified in Section 5. Option selection for each scenario considered the following attributes of each option: proximity to priority areas of interest, magnitude of local flood mitigation benefits, and potential for flood impacts to upstream and downstream areas of the MRW.

A summary of included options, as well as impacted priority areas and major water bodies for each scenario, is provided in Table 6-1.

Scenario 1 includes only Option 1 (see Section 5.2) due to the relatively large impact that adding significant storage at Distress Dam is expected to have on the MRW. Scenario 2 combines flood mitigation options impacting Muskoka River North Branch (downstream from Distress Dam), while Scenario 3 combines options impacting Muskoka River South Branch. Scenario 4 includes flood mitigation options at or downstream from Lake Muskoka.

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Table 6-1: Flood Mitigation Scenarios

Scenario	Impacted MRW Branch(es)	Impacted Priority Area(s)	Major Water Bodies Assessed for Flood Impacts	Flood Mitigation Option(s)
1	North Branch Lower Branch	Big East River Huntsville Narrows Springdale Muskoka/Bala[1]	Muskoka River North Branch[2] Lake Vernon Fairy Lake & Peninsula Lake Mary Lake Lake Muskoka Bala Bay Bala Reach Moon River Musquash River	Option 1
2				Option 2, Option 3, Option 4
3	South Branch Lower Branch	Fraserburg/Purbrook Muskoka/Bala[1]	Muskoka River South Branch[3] Lake Muskoka Bala Bay Bala Reach Moon River Musquash River	Option 5, Option 6, and 7
4	Lower Branch	Muskoka/Bala[1]	Lake Muskoka Bala Bay Bala Reach Moon River Musquash River	Option 8, Option 9, Option 10
5a	North Branch South Branch Lower Branch	Big East River Huntsville Narrows Springdale Fraserburg/Purbrook	Muskoka River North Branch[2] Muskoka River South Branch[3] Lake Vernon Fairy Lake and Peninsula Lake	Options 1 through 10 (inclusive)

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Scenario	Impacted MRW Branch(es)	Impacted Priority Area(s)	Major Water Bodies Assessed for Flood Impacts	Flood Mitigation Option(s)
5b		Muskoka/Bala[1]	Mary Lake Lake Muskoka Bala Bay Bala Reach Moon River Musquash River	Options 2 through 10 (inclusive)

Notes:

1. Muskoka/Bala priority area includes consideration of Moon River and Musquash River.
2. Assessed reaches of the Muskoka River North Branch were limited to priority areas of Big East River, Huntsville Narrows and Springdale.
3. Assessed reaches of the Muskoka River South Branch were limited to priority areas of Fraserburg and Purbrook. None of the options in Section 5 are expected to impact the Baysville priority area.

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Scenario 5a combines Scenarios 1 to 4 to evaluate the total impact of implementing all ten flood mitigation options simultaneously. Scenario 5b combines Scenarios 2 to 4, thereby excluding Scenario 1. The rationale for including Scenario 5b (exclusion of Option 1) is the acknowledgement that Option 1 will have an appreciably complex design considerations relative to the other options, which may pose exceptional barriers to implementation.

6.2 Scenario Evaluation

Flood conditions for each scenario were evaluated using a combination of hydrologic and hydraulic models. The hydrologic and hydraulic models were adopted from the FPMS (Hatch, 2020; 2022a; 2022b; 2022c; 2022d; 2022e) and modified as described in Section 2.3.

Six sets of model simulations were run to develop Mitigation Case conditions for each scenario, which were compared with Baseline Case conditions. The purpose of these relative comparisons was to assess the potential benefit associated with the conjunctive implementation of the flood mitigation options conceived as part of this project. This potential benefit is illustrated by changes to peak flow rate, the number of impacted structures, and either peak water level or flood inundation area.

6.2.1 Hydrologic Model

Several changes were made to the hydrologic model adopted from the FPMS (Hatch, 2022a; discussed in Section 2.3) to facilitate analyses of all scenarios. At a high level, these changes are categorized as follows:

- **Adjustment of hydrologic model subwatershed boundaries**: The hydrologic model domain encompasses a network of subwatersheds that comprise the much larger MRW. To properly assess Option 1 in the hydrologic model, a subwatershed for Distress Dam was added to the model using subwatershed properties derived using the *Ontario Flood Assessment Tool* (OMNR, 2022).
- **Estimation of the effects of options on river reach peak inflows and outflows:** Analytical approaches were required to estimate the effects of several options on changes to peak inflows and outflows to rivers in select subwatersheds. The estimated peak flow increases derived through analytical approaches were applied to scale-up outflow hydrographs for subwatersheds Distress Dam, High Falls and Matthias. This approach accounted for the changes to peak flows resulting from Options 1, 4, 5, 6 and 7. Analytical approaches were required due to limitations associated with the one-way modelling coupling between the hydrologic and hydraulic models, and the simplified representation of rivers in the hydrologic model.
- **Modification of lake outlet rating curves and relevant model settings:** Several of the mitigation options include updating lake storage-outflow curves (Options 3, 8, and 9). Hydrologic simulations where Mitigation Case storage-outflow curves were applied also required updates to model settings. For all scenarios, it was assumed that Baseline Case storage-outflow curves would apply from October to March, and that Mitigation Case

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storage-curves would be activated on April 1. This represents the full effect of Options 3, 8 and 9 immediately prior to design flood conditions.

6.2.2 Hydraulic Models

Several changes were made to the hydraulic models adopted from the FPMS (Hatch, 2020; 2022d; 2022e; 2022f; discussed in Section 2.3) to facilitate analyses of all scenarios. Most of these changes are documented in the Structural Flood Mitigation Options report (Hatch, 2022f) and include boundary expansion of the Muskoka/Bala model to Bala Park Island and application of unsteady model simulation settings. A detailed summary of all adopted hydraulic models is shown in Table 6-2.

The hydraulic models in were used in conjunction with GIS tools (including application of LiDAR based topographic data) to evaluate flood inundation area and the number of impacted structures.

6.2.3 Model Selection for Assessing Peak Water Level and Flood Inundation Area

To facilitate the watershed-scale evaluation, both the hydrologic and hydraulic models were used in combination. A limitation of these models is the absence of two-way model coupling, meaning that the hydrologic and site-specific hydraulic models do not exchange information back-and-forth during model simulations. Each scenario was instead evaluated using one-way model coupling, whereby information is passed between models after the completion of a model simulation.

The evaluation approach taken for each scenario was done so to produce conservative, yet reasonable, estimates of flood impacts in the MRW resulting from options implementation. As discussed in Section 6.2.1, inflows and outflows of each water body were generally determined by the hydrologic model and supplemented by analytical approaches. The hydrologic model was also directly applied to determine differences between Baseline Case and Mitigation Case peak water levels for the following lakes:

- Fairy Lake and Peninsula Lake
- Mary Lake.

Simulated flows from the hydrologic models were applied to hydraulic models to determine differences between Baseline Case and Mitigation Case peak water levels for the following river reaches:

- North Branch Muskoka River (Big East River, Huntsville Narrows, Springdale)
- South Branch Muskoka River (Fraserburg, Purbrook)
- Lower Branch Muskoka River (Bala Reach)
- Moon River
- Musquash River.

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Table 6-2: Hydraulic Model Details

MRW Branch	Priority Area	Reach(es)	Upstream Model Boundary	Downstream Model Boundary	Upstream Boundary Condition	Downstream Boundary Condition	Steady or Unsteady Simulation Settings	Original Model Source
North Branch	Big East River	Upper Big East River	Williamsport	Big East River at Highway 11	Flow Hydrograph	Rating Curve	Unsteady[1]	(Hatch, 2020)
			Little East River		Flow Hydrograph			
		Lower Big East River	Big East River at HWY 11	Lake Vernon	Flow Hydrograph	Constant Water Level (WSE)	Unsteady[1]	(Hatch, 2020)
				Local Inflow	Flow Hydrograph			
	Huntsville Narrows			Huntsville Narrows	Lake Vernon	Fairy Lake	Flow Hydrograph; Constant Water Level (WSE)	Unsteady[1]; (Hatch, 2020)
	Springdale			Springdale	Duck Chutes	High Falls GS Head Pond	Flow Hydrograph; Constant Water Level (WSE)	Unsteady[1]; (Hatch, 2020)
South Branch	Baysville[3]/ Fraserburg/ Purbrook	Baysville		Baysville Dam	Fairy Falls	Q-WSE Critical Depth Rating Curve[1]	Unsteady[1]	(Hatch 2020)
				Fraserburg	Fairy Falls	Purbrook Bridge	Normal Depth	Normal Depth; Steady[2]; (Hatch, 2022b)
				Purbrook	Purbrook Bridge	Matthias GS Head Pond	Flow Hydrograph; Constant Water Level (WSE)	Unsteady[1]; (Hatch, 2020)
Lower Lakes	Bala	Lake Muskoka, Bala Bay, Bala Reach	U/S of Bala Park Island[1]	Moon Chutes	Varies throughout reach	Q-WSE Critical Depth Rating Curve[1]	Steady[2]	(Hatch, 2020)
	Musquash River	Musquash River (d/s of Bala Reach)	Moon Chutes	Go-Home Lake	Normal Depth Known Water Level (WSE)	Known Water Level (WSE)	Steady[2]	(Hatch, 2022d)
	Moon River	Moon River (d/s of Bala Reach)	Moon Chutes	D/S of Ragged Rapids	Normal Depth	Known Water Level (WSE)	Steady[2]	(Hatch, 2022e)

Notes:
1. Model developed in FPMS changed to facilitate Baseline Case and Mitigation Case simulations.
2. The presence of numerous hydraulic controls with Fraserburg, Muskoka/Bala, Musquash River, and Moon River models posed constraints for applying unsteady simulation settings.
3. None of the flood mitigation options are expected to impact Baysville. However, application of the Baysville model was relevant for the climate change assessment.

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Differences between Baseline Case and Mitigation Case peak water levels for the remaining major lakes (Lake Vernon, Lake Muskoka, Bala Bay) were assessed using hydraulic models. These hydraulic models (Table 6-2) properly account for the hydraulic controls that influence the peak water levels.

6.3 Scenario Results

Infographics were created to illustrate the results of each flood mitigation scenario in Sections 6.3.1 to 6.3.6. Each infographic presents a comparison of key indicators for both the Baseline Case and Mitigation Case including

- simulated water level and flood inundation area differences for lakes
- simulated flood inundation area differences for rivers
- simulated peak inflow and outflow for rivers and lakes
- the number of impacted structures for rivers and lakes.

The left-hand side of the infographics includes a schematic of the MRW, with relevant hydrologic and hydraulic components highlighted. Differences in peak water level are included for lakes impacted under a particular scenario. Tables include summaries of flood conditions for both the Baseline Case and Mitigation Case.

The right-hand side of the infographic includes the simulated water level hydrographs (for select lakes), as well as a table of peak flow rates sourced from the hydrologic model. These tables include information for the following areas: North Branch, Lake Vernon, Fairy Lake, Mary Lake, South Branch, and Lake Muskoka. North Branch inflows represent North Branch Muskoka River conditions immediately downstream from Distress Dam, and outflows represent conditions immediately upstream from the confluence between the North Branch Muskoka River and Lake Muskoka. South Branch Muskoka River inflows were taken as the flow from Lake of Bays, and outflows represent conditions immediately downstream from Matthias GS.

Any grayed text accompanied with '*n/a*' in the infographic indicates that the area is not expected to change because of the flood mitigation options active in that scenario. Green text and red text indicate an increase or decrease, respectively, in flooding severity as a result of options implementation.

Infographics for all scenarios are presented in Figure 6-1 through Figure 6-6, and are discussed in the following sections. Comprehensive results summary tables are also provided in Section 6.3.7.

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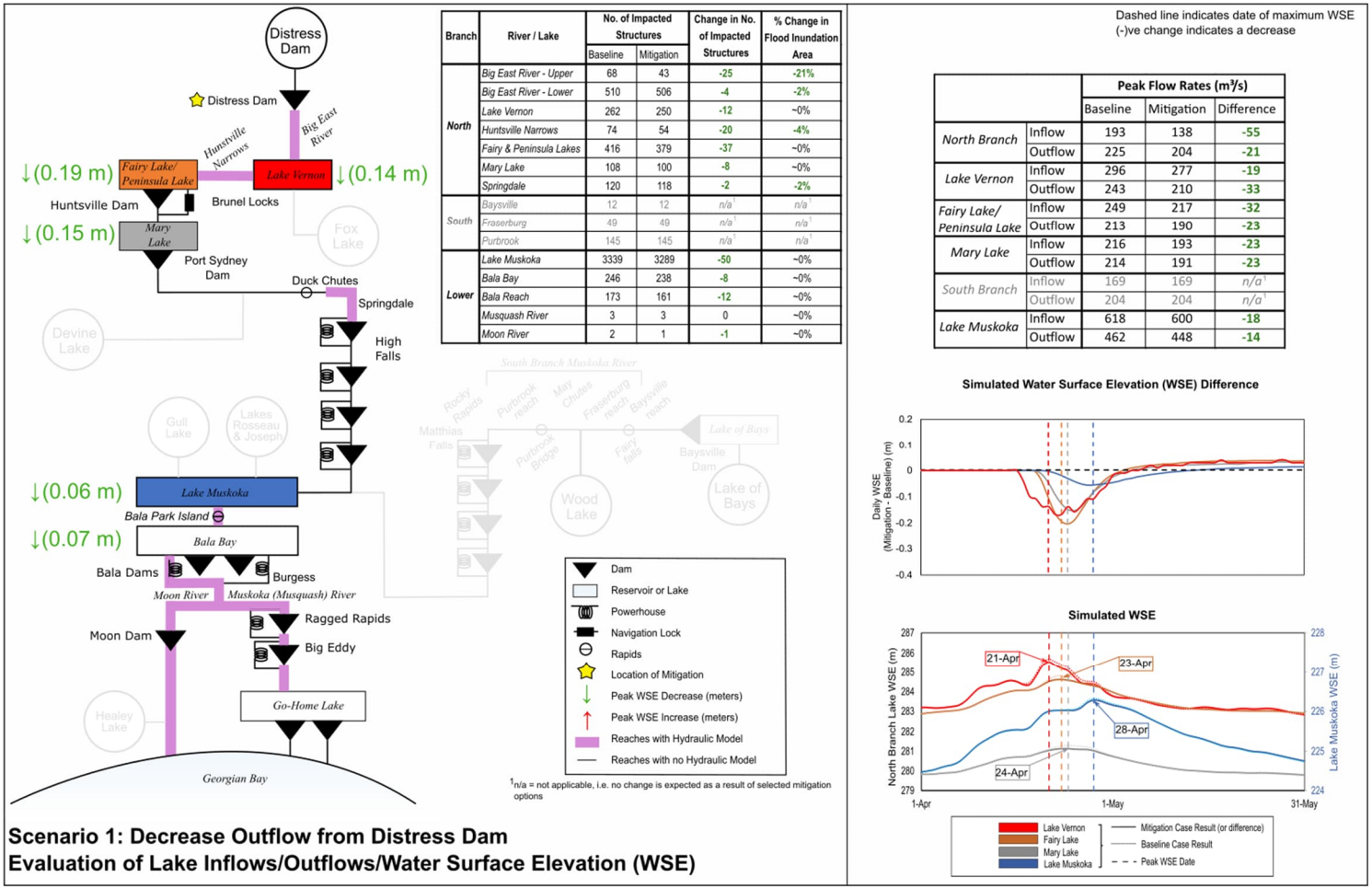

Branch	River / Lake	No. of Impacted Structures		Change in No. of Impacted Structures	% Change in Flood Inundation Area
		Baseline	Mitigation		
North	Big East River - Upper	68	43	-25	-21%
	Big East River - Lower	510	506	-4	-2%
	Lake Vernon	262	250	-12	~0%
	Huntsville Narrows	74	54	-20	-4%
	Fairy & Peninsula Lakes	416	379	-37	~0%
	Mary Lake	108	100	-8	~0%
	Springdale	120	118	-2	-2%
South	Baysville	12	12	n/a[1]	n/a[1]
	Fraserburg	49	49	n/a[1]	n/a[1]
	Purbrook	145	145	n/a[1]	n/a[1]
Lower	Lake Muskoka	3339	3289	-50	~0%
	Bala Bay	246	238	-8	~0%
	Bala Reach	173	161	-12	~0%
	Musquash River	3	3	0	~0%
	Moon River	2	1	-1	~0%

		Peak Flow Rates (m³/s)		
		Baseline	Mitigation	Difference
North Branch	Inflow	193	138	-55
	Outflow	225	204	-21
Lake Vernon	Inflow	296	277	-19
	Outflow	243	210	-33
Fairy Lake/ Peninsula Lake	Inflow	249	217	-32
	Outflow	213	190	-23
Mary Lake	Inflow	216	193	-23
	Outflow	214	191	-23
South Branch	Inflow	169	169	n/a[1]
	Outflow	204	204	n/a[1]
Lake Muskoka	Inflow	618	600	-18
	Outflow	462	448	-14

Figure 6-1: Scenario 1 Infographic of Hydrologic and Hydraulic Model Results

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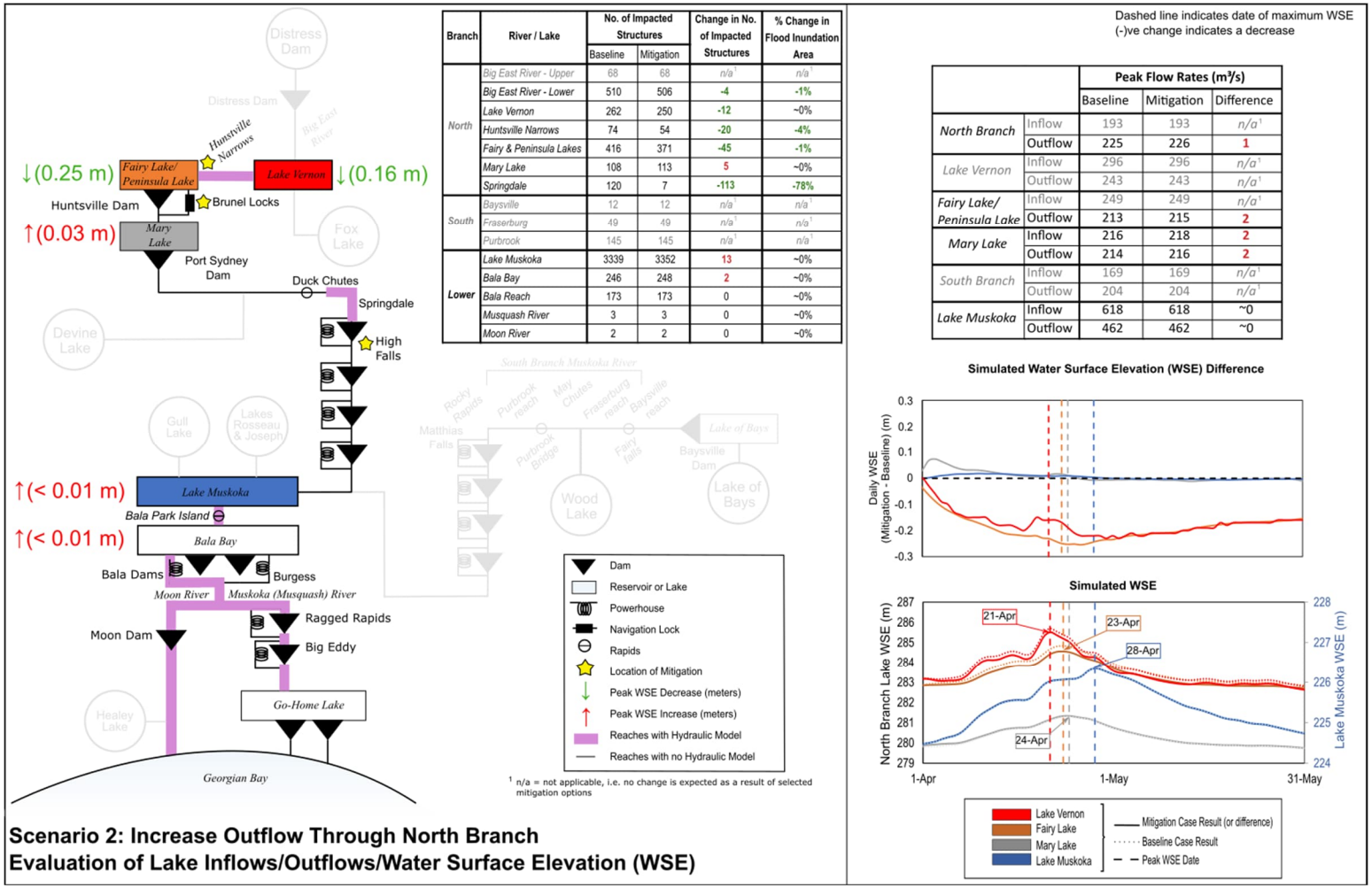

Branch	River / Lake	No. of Impacted Structures		Change in No. of Impacted Structures	% Change in Flood Inundation Area
		Baseline	Mitigation		
North	Big East River - Upper	68	68	n/a[1]	n/a[1]
	Big East River - Lower	510	506	-4	-1%
	Lake Vernon	262	250	-12	~0%
	Huntsville Narrows	74	54	-20	-4%
	Fairy & Peninsula Lakes	416	371	-45	-1%
	Mary Lake	108	113	5	~0%
	Springdale	120	7	-113	-78%
South	Baysville	12	12	n/a[1]	n/a[1]
	Fraserburg	49	49	n/a[1]	n/a[1]
	Purbrook	145	145	n/a[1]	n/a[1]
Lower	Lake Muskoka	3339	3352	13	~0%
	Bala Bay	246	248	2	~0%
	Bala Reach	173	173	0	~0%
	Musquash River	3	3	0	~0%
	Moon River	2	2	0	~0%

		Peak Flow Rates (m³/s)		
		Baseline	Mitigation	Difference
North Branch	Inflow	193	193	n/a[1]
	Outflow	225	226	1
Lake Vernon	Inflow	296	296	n/a[1]
	Outflow	243	243	n/a[1]
Fairy Lake/ Peninsula Lake	Inflow	249	249	n/a[1]
	Outflow	213	215	2
Mary Lake	Inflow	216	218	2
	Outflow	214	216	2
South Branch	Inflow	169	169	n/a[1]
	Outflow	204	204	n/a[1]
Lake Muskoka	Inflow	618	618	~0
	Outflow	462	462	~0

Figure 6-2: Scenario 2 Infographic of Hydrologic and Hydraulic Model Results

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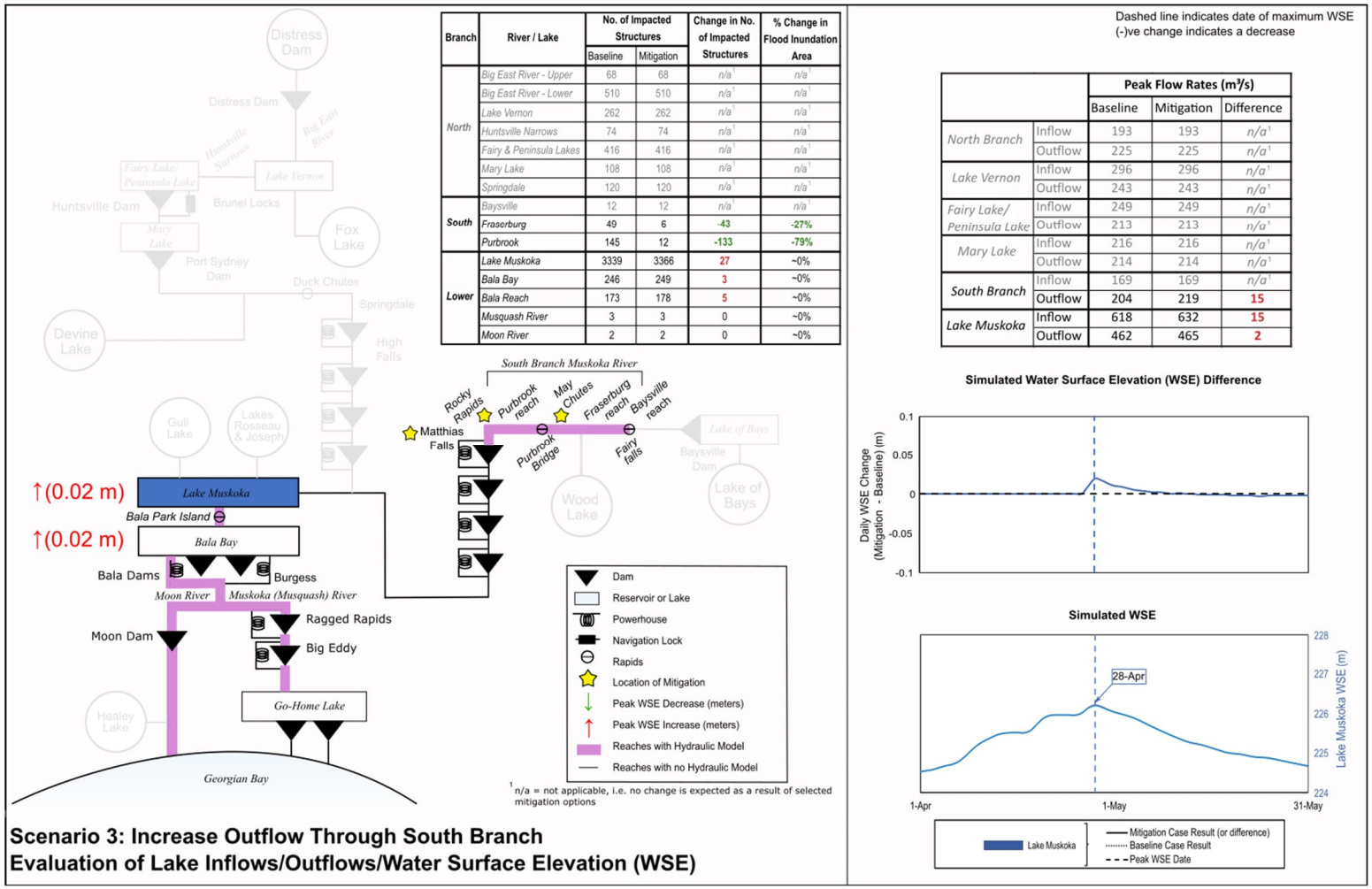

Branch	River / Lake	No. of Impacted Structures		Change in No. of Impacted Structures	% Change in Flood Inundation Area
		Baseline	Mitigation		
North	Big East River - Upper	68	68	n/a[1]	n/a[1]
	Big East River - Lower	510	510	n/a[1]	n/a[1]
	Lake Vernon	262	262	n/a[1]	n/a[1]
	Huntsville Narrows	74	74	n/a[1]	n/a[1]
	Fairy & Peninsula Lakes	416	416	n/a[1]	n/a[1]
	Mary Lake	108	108	n/a[1]	n/a[1]
	Springdale	120	120	n/a[1]	n/a[1]
South	Baysville	12	12	n/a[1]	n/a[1]
	Fraserburg	49	6	-43	-27%
	Purbrook	145	12	-133	-79%
Lower	Lake Muskoka	3339	3366	27	~0%
	Bala Bay	246	249	3	~0%
	Bala Reach	173	178	5	~0%
	Musquash River	3	3	0	~0%
	Moon River	2	2	0	~0%

		Peak Flow Rates (m^3/s)		
		Baseline	Mitigation	Difference
North Branch	Inflow	193	193	n/a[1]
	Outflow	225	225	n/a[1]
Lake Vernon	Inflow	296	296	n/a[1]
	Outflow	243	243	n/a[1]
Fairy Lake/ Peninsula Lake	Inflow	249	249	n/a[1]
	Outflow	213	213	n/a[1]
Mary Lake	Inflow	216	216	n/a[1]
	Outflow	214	214	n/a[1]
South Branch	Inflow	169	169	n/a[1]
	Outflow	204	219	15
Lake Muskoka	Inflow	618	632	15
	Outflow	462	465	2

Figure 6-3: Scenario 3 Infographic of Hydrologic and Hydraulic Model Results

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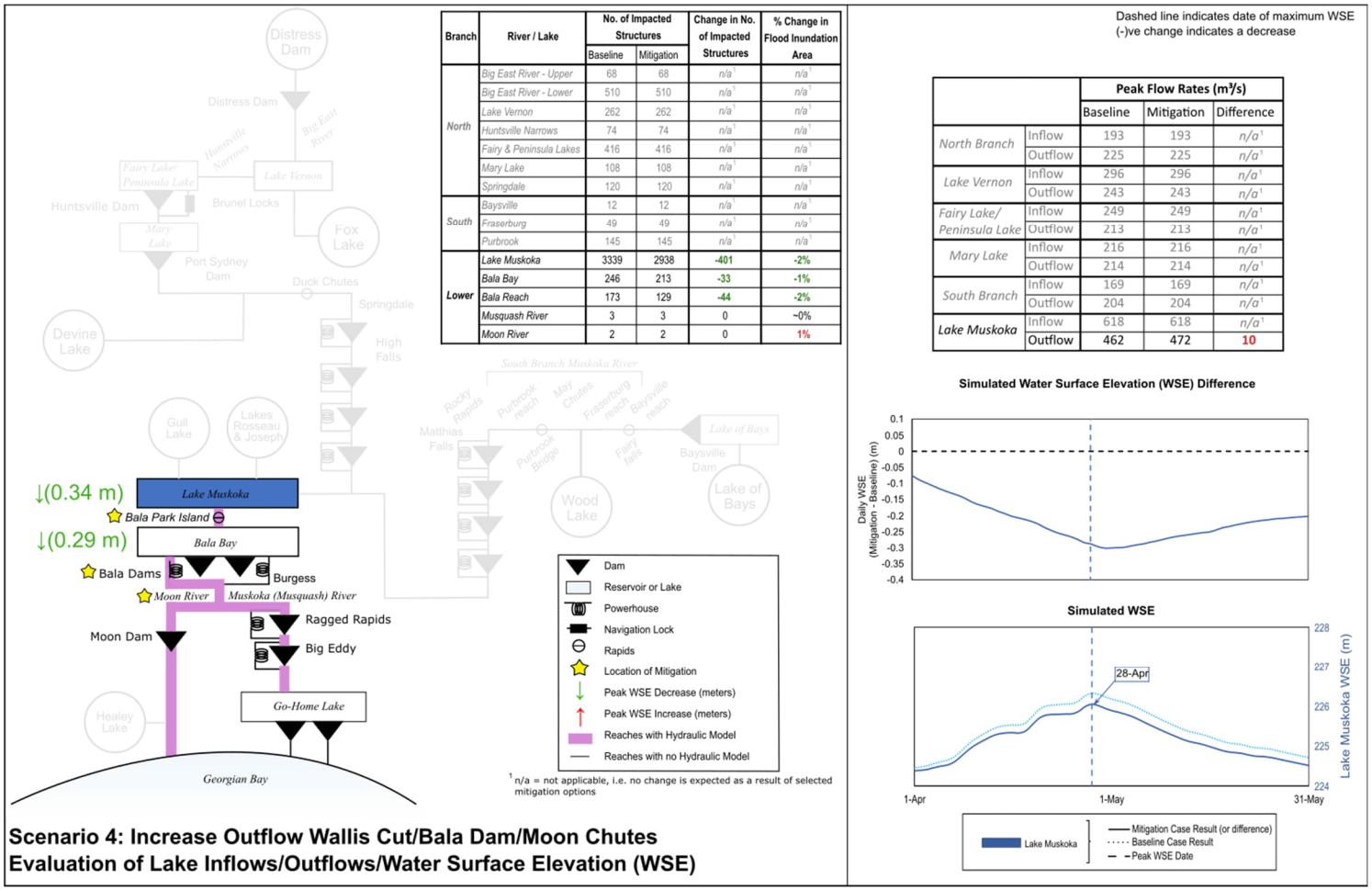

Branch	River / Lake	No. of Impacted Structures		Change in No. of Impacted Structures	% Change in Flood Inundation Area
		Baseline	Mitigation		
North	Big East River - Upper	68	68	n/a[1]	n/a[1]
	Big East River - Lower	510	510	n/a[1]	n/a[1]
	Lake Vernon	262	262	n/a[1]	n/a[1]
	Huntsville Narrows	74	74	n/a[1]	n/a[1]
	Fairy & Peninsula Lakes	416	416	n/a[1]	n/a[1]
	Mary Lake	108	108	n/a[1]	n/a[1]
	Springdale	120	120	n/a[1]	n/a[1]
South	Baysville	12	12	n/a[1]	n/a[1]
	Fraserburg	49	49	n/a[1]	n/a[1]
	Purbrook	145	145	n/a[1]	n/a[1]
Lower	Lake Muskoka	3339	2938	-401	-2%
	Bala Bay	246	213	-33	-1%
	Bala Reach	173	129	-44	-2%
	Musquash River	3	3	0	~0%
	Moon River	2	2	0	1%

		Peak Flow Rates (m³/s)		
		Baseline	Mitigation	Difference
North Branch	Inflow	193	193	n/a[1]
	Outflow	225	225	n/a[1]
Lake Vernon	Inflow	296	296	n/a[1]
	Outflow	243	243	n/a[1]
Fairy Lake/ Peninsula Lake	Inflow	249	249	n/a[1]
	Outflow	213	213	n/a[1]
Mary Lake	Inflow	216	216	n/a[1]
	Outflow	214	214	n/a[1]
South Branch	Inflow	169	169	n/a[1]
	Outflow	204	204	n/a[1]
Lake Muskoka	Inflow	618	618	n/a[1]
	Outflow	462	472	10

Figure 6-4: Scenario 4 Infographic of Hydrologic and Hydraulic Model Results

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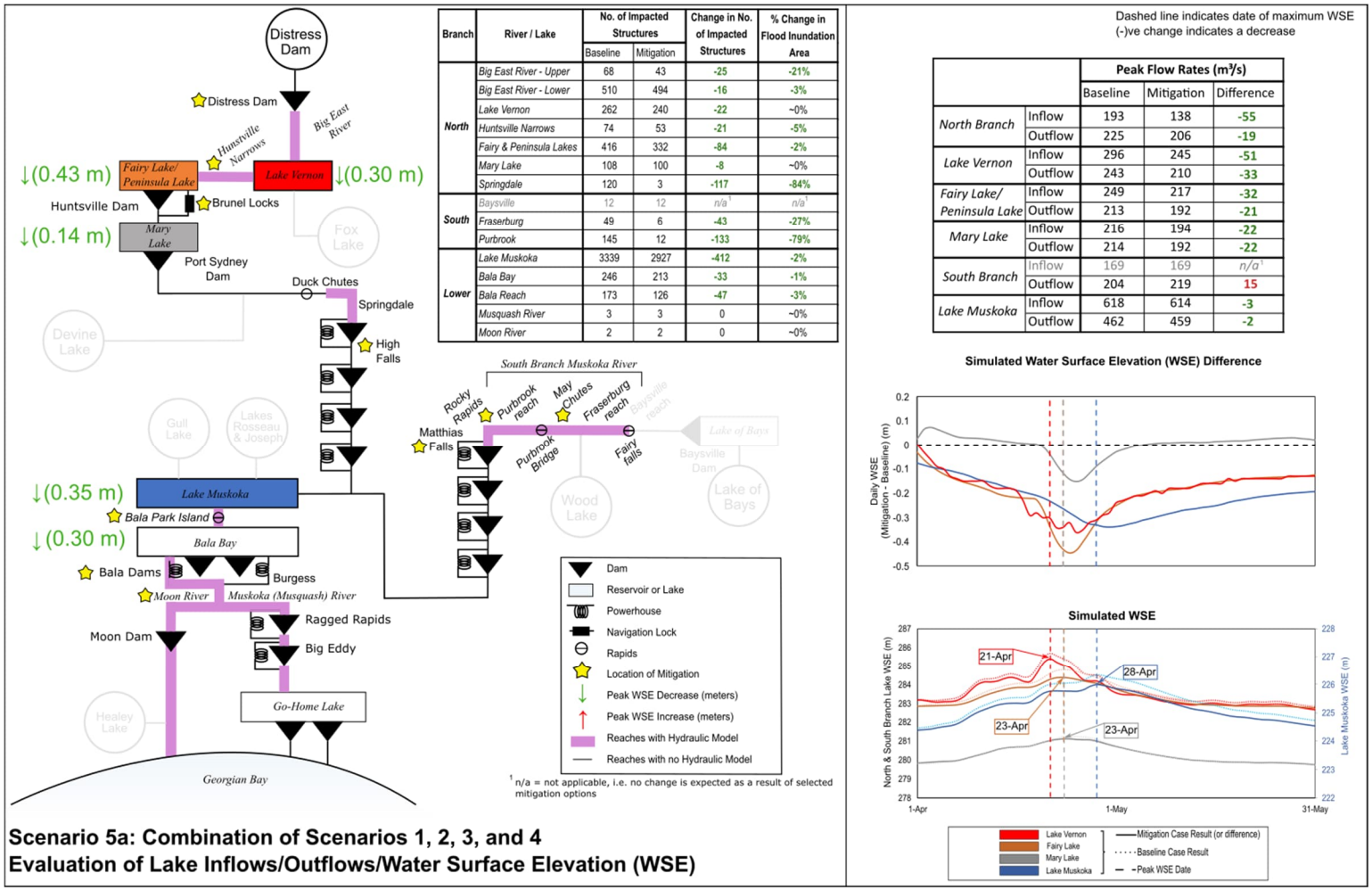

Branch	River / Lake	No. of Impacted Structures		Change in No. of Impacted Structures	% Change in Flood Inundation Area
		Baseline	Mitigation		
North	Big East River - Upper	68	43	-25	-21%
	Big East River - Lower	510	494	-16	-3%
	Lake Vernon	262	240	-22	~0%
	Huntsville Narrows	74	53	-21	-5%
	Fairy & Peninsula Lakes	416	332	-84	-2%
	Mary Lake	108	100	-8	~0%
	Springdale	120	3	-117	-84%
South	Baysville	12	12	n/a[1]	n/a[1]
	Fraserburg	49	6	-43	-27%
	Purbrook	145	12	-133	-79%
Lower	Lake Muskoka	3339	2927	-412	-2%
	Bala Bay	246	213	-33	-1%
	Bala Reach	173	126	-47	-3%
	Musquash River	3	3	0	~0%
	Moon River	2	2	0	~0%

		Peak Flow Rates (m^3/s)		
		Baseline	Mitigation	Difference
North Branch	Inflow	193	138	-55
	Outflow	225	206	-19
Lake Vernon	Inflow	296	245	-51
	Outflow	243	210	-33
Fairy Lake/ Peninsula Lake	Inflow	249	217	-32
	Outflow	213	192	-21
Mary Lake	Inflow	216	194	-22
	Outflow	214	192	-22
South Branch	Inflow	169	169	n/a[1]
	Outflow	204	219	15
Lake Muskoka	Inflow	618	614	-3
	Outflow	462	459	-2

Figure 6-5: Scenario 5a Infographic of Hydrologic and Hydraulic Model Results

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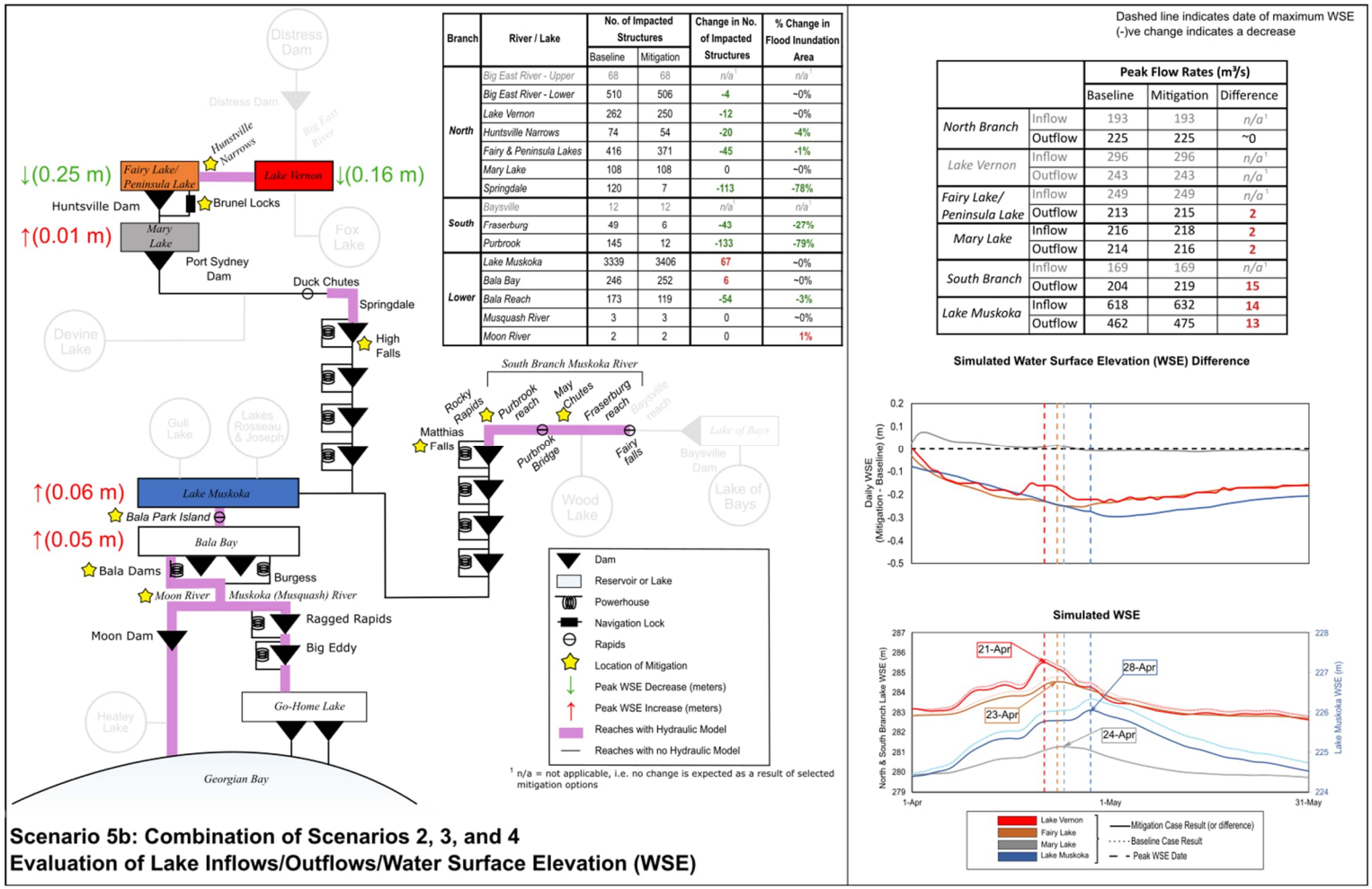

Branch	River / Lake	No. of Impacted Structures		Change in No. of Impacted Structures	% Change in Flood Inundation Area
		Baseline	Mitigation		
North	Big East River - Upper	68	68	n/a[1]	n/a[1]
	Big East River - Lower	510	506	-4	~0%
	Lake Vernon	262	250	-12	~0%
	Huntsville Narrows	74	54	-20	-4%
	Fairy & Peninsula Lakes	416	371	-45	-1%
	Mary Lake	108	108	0	~0%
	Springdale	120	7	-113	-78%
South	Baysville	12	12	n/a[1]	n/a[1]
	Fraserburg	49	6	-43	-27%
	Purbrook	145	12	-133	-79%
Lower	Lake Muskoka	3339	3406	67	~0%
	Bala Bay	246	252	6	~0%
	Bala Reach	173	119	-54	-3%
	Musquash River	3	3	0	~0%
	Moon River	2	2	0	1%

		Peak Flow Rates (m^3/s)		
		Baseline	Mitigation	Difference
North Branch	Inflow	193	193	n/a[1]
	Outflow	225	225	~0
Lake Vernon	Inflow	296	296	n/a[1]
	Outflow	243	243	n/a[1]
Fairy Lake/ Peninsula Lake	Inflow	249	249	n/a[1]
	Outflow	213	215	2
Mary Lake	Inflow	216	218	2
	Outflow	214	216	2
South Branch	Inflow	169	169	n/a[1]
	Outflow	204	219	15
Lake Muskoka	Inflow	618	632	14
	Outflow	462	475	13

Figure 6-6: Scenario 5b Infographic of Hydrologic and Hydraulic Model Results

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6.3.1 *Scenario 1: Distress Dam*

Scenario 1 includes only Option 1 (retrofit of Distress Dam as described in Section 5.2). Scenario 1 results in Figure 6-1 indicate that Option 1 greatly reduces flood severity in the North Branch and Lower Branch of the MRW, with no effect on flood conditions in the South Branch. The flood mitigation impact of Scenario 1 is relatively small in many of the lakes, mainly due to their large storage volumes relative to river reaches that see more impact. The upper Big East River, directly downstream from Distress Dam, enjoys the greatest percent reduction in flood inundation area at 21%.

In the Lower Branch, 71 flood mitigated structures (i.e., structures no longer affected by flood waters as a result of implementing the flood mitigation options) are observed, however the flood inundation area remains virtually unchanged between the Baseline Case and the Mitigation Case. This again is due to the large storage volume of the Lower Branch, and the high density of structures along the inundation boundary. The total number of 179 flood mitigated structures in the MRW is estimated to result from implementation of Distress Dam.

6.3.2 *Scenario 2: North Branch Muskoka River*

Scenario 2 includes a combination of three options: Options 2, 3 and 4. Scenario 2 results are illustrated in Figure 6-2 and indicate that these options reduce flood levels in the North Branch, with small increases in flood levels in the Lower Branch of the MRW, and no effect on flood conditions in the South Branch.

Flooding is primarily reduced in the North Branch, especially in the Springdale region (113 flood mitigated structures) due to reduced water levels resulting from Obermeyer gate control at High Falls. Option 3 increases peak outflows from Fairy Lake, resulting in peak flow increases to Mary Lake. Subsequently, higher peak outflows from Mary Lake result in higher peak inflows to Springdale. The increased capacity at High Falls resulting from Option 4 exceeds the increased peak outflow from Mary Lake, which results in a net reduction of peak water levels in Springdale for Scenario 2.

Scenario 2 resulted in fewer structures affected by flood waters on the lower Big East River, Lake Vernon, the Huntsville Narrows, Fairy and Peninsula Lakes, and Springdale. However, more structures were affected by flood water at Mary Lake, Lake Muskoka, and Bala Bay. Collectively, there was a net total of 174 flood mitigated structures.

6.3.3 *Scenario 3: South Branch Muskoka River*

Scenario 3 includes a combination of three options: Options 5, 6, and 7, all of which are located on the Muskoka River South Branch. Scenario 3 results are presented in Figure 6-3 and indicate that these options reduce flood levels in the South Branch but increase in flood levels at the Lower Branch.

Flooding is primarily reduced in the South Branch where the largest percentage reductions in flood inundation area were observed for the Fraserburg reach upstream from May Chutes

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(27%) and the Purbrook reach upstream from Rocky Rapids (79%). Despite an increase in peak inflows into Lake Muskoka, the Lower Branch shows a marginal increase in the number of impacted structures and virtually no change to the inundation areas. This minor change is due to the natural flow attenuation of the relatively large Lake Muskoka, where a 15 m^3/s peak inflow increase translates to a small rise (0.02 m) in peak water levels.

Scenario 3 resulted in fewer structures affected by flood waters at Fraserburg and Purbrook. However, more structures were affected by flood water at Lake Muskoka, Bala Bay, and the Bala Reach. Collectively, there was a net total of 141 less structures affected by flood waters.

6.3.4 Scenario 4: Lower Branch

Scenario 4 includes a combination of three options: Options 8, 9, and 10, all of which are located downstream from Lake Muskoka. Scenario 4 results are illustrated in Figure 6-4 and indicate that these options reduce flood levels in the Lower Branch area, with small increases to flood levels for the Moon River.

Scenario 4 precipitates the greatest change to lower lakes where Lake Muskoka, Bala Bay, and Bala Reach inundation areas reduce by up to 2% relative to the Base Case. Despite these seemingly modest reductions in flood inundation area, the total number of flood mitigated structures is 478. As indicated by the analysis completed for the *Structural Flood Mitigation Options Report* (Hatch, 2022f), a number of these structures are boathouses. In this report, implementation of Option 8 (Wallis Cut) was estimated to result in 156 flood impacted structures, of which four percent were classified as boathouses. Further study of the conceptual options should consider the classification of structures (including 'boathouses'), in flood mitigation areas.

Analysis of Scenario 4 demonstrates that the small increase in flood inundation area on the Moon River results in no change to the number of flood-impacted structures in that area. As discussed in Section 5.10, changes to peak outflows from Bala Reach (spawned by any option summarized herein) are assumed to primarily affect Moon River, meaning that flood conditions on the Musquash River (downstream from the Ragged Rapids head pond) remain unaffected. The small changes to flood inundation area on the Moon River is owed to its relatively steep riverbanks.

6.3.5 Scenario 5a: Combination of Scenario 1, 2, 3, and 4

Scenario 5a is a combination of Scenarios 1, 2, 3, and 4. That is, all flood risk mitigation options implemented simultaneously. This scenario affects flood waters in all three branches (to varying degrees), as shown in Figure 6-5.

The North Branch is exclusively impacted by the implementation of Options 1, 2, 3, and 4. These options collectively hold back water at Distress Dam while facilitating better movement of water down the North Branch to Lake Muskoka and, in essence, reduce flood levels throughout this area. Collectively, these result in 293 flood mitigated structures.

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The South Branch is exclusively impacted by the implementation of Options 5, 6, and 7. The changes to flooding prompted by implementation of these options are similar to the changes in Scenario 3. That is, 176 flood mitigated structures while the peak outflow increases by 15 m^3/s.

The net result of decreased peak outflow from the North Branch and increased peak outflow from the South Branch is a 3 m^3/s net reduction in Lake Muskoka peak inflow. This reduction in peak inflow combined with implementation of Options 8 and 9 result in a relatively significant drop in peak water level for Lake Muskoka (0.35 m) and Bala Bay (0.30 m). This drop is accompanied by a reduction in flood inundation area and 492 flood mitigated structures in the Lower Branch.

6.3.6 Scenario 5b: Combination of Scenario 2, 3, and 4

Scenario 5b is identical to Scenario 5a except for the exclusion of Option 1 (Distress Dam). Infographics for Scenario 5a (Figure 6-5) and Scenario 5b (Figure 6-6) shows the net reduction in structures for each case is 961 and 351, respectively, a difference of 610 structures. Noteworthy is that 610 flood mitigated structures is greater than the flood mitigated structures for Scenario 1 (179). This shows that implementing Option 1 helps to offset part of the flood risk introduced to both the North Branch and Lower Branch by implementing other options.

Without the implementation of Option 1, there is a net increase in flows in the North Branch. Option 3 (i.e., increase outflows from Fairy Lake, see Section 5.4) increases flows into Mary Lake, causing the peak water level of Mary Lake to increase by 0.01 m. The configuration of Mary Lake allows for a greater volumetric discharge of water at lower water surface elevations, compared to Fairy Lake, such that the additional flow during the spring freshet period has minimal impact on Mary Lake's inundation area.

In the Lower Branch, there is a marginal increase to flooding in Lake Muskoka, Bala Bay, and Moon River. Options 8 and 9 mostly counteract the increase to Lake Muskoka inflows by eliminating any downstream flow constrictions at the Lake Muskoka outlet. There is a small increase to flood inundation area in Lake Muskoka, though only 67 additional structures are impacted. Bala Bay is almost completely unaffected, while Bala Reach has a net reduction in flood inundation area and impacted structures. The Musquash River remains unaffected by any of the upstream flood mitigation options. Moon River has a small increase to flood inundation area (+1%) and no change to number of impacted structures.

6.3.7 Summary Tables

The following summary tables are provided key results from all scenario infographics (Figure 6-1 through Figure 6-6):

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- Number of impacted structures (Table 6-3)
- Percentage change in flood inundation area (Table 6-4)
- Value and percentage change in peak flow rate (Table 6-5).

The following general observations are made from these tables:

- **Scenario 1** reduces peak flow rates throughout the North Branch and Lower Branch. When implemented concurrently with other scenarios, Option 1 can help offset the increased flood risk that results from other options. The net number of flood mitigated structures for Scenario 1 is 179.
- **Scenario 2** results in significant reductions in flood inundation areas for select areas of the North Branch (e.g., Springdale), with small increases in flood risk for the Lower Branch. The net number of flood mitigated structures for Scenario 2 is 174.
- **Scenario 3** has the greatest average reduction in flood inundation area amongst all Scenarios. However, the flood mitigation benefits of this scenario are limited to the South Branch, with small increases in flood risk for the Lower Branch. The net number of flood mitigated structures for Scenario 3 is 141.
- **Scenario 4**, which exclusively reduces flood risk for the Lower Branch, has the second highest number of flood mitigated structures. A small increase in flood risk for the Moon River is observed with no increases to impacted structures in that area. The net number of flood mitigated structures for Scenario 4 is 478.
- **Scenario 5a** has the greatest number of flood mitigated structures. This is largely due to the combined effects of retrofitting Distress Dam and increasing flow conveyance downstream from Lake Muskoka. Scenario 5a has the greatest overall reduction in flood inundation areas, which results in 961 net flood mitigated structures.
- **Scenario 5b** implements all flood mitigations apart from the retrofit of Distress Dam and has the third highest net number of flood mitigated structures (351). However, Scenario 5b marginally increases the number of impacted structures in Lake Muskoka due to the additional inflow sourced primarily from the South Branch. Scenario 5b also results in the greatest increase to Lake Muskoka's flood inundation area.

6.3.8 Limitations of Model Results

There are several limitations of the hydrologic and hydraulic models employed to provide the results presented throughout Section 0. These limitations include the following:

- **Uncertainty in Model Predictions:** Despite the industry-standard practices followed to develop hydrologic and hydraulic models, uncertainty in model predictions persists. This uncertainty is attributed to model representation of watershed hydrology and riverine

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Table 6-3: Summary of Number (No.) of Impacted Structures for Baseline Case and Mitigation Case Scenarios

Branch	River/Lake	No. of Impacted Structures[1,2] and Change from Baseline Case											
		Baseline Case	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5a		Scenario 5b	
North Branch	*Big East River – Upper*	68	43	***(-25)***	68	*(n/a)*	68	*(n/a)*	68	*(n/a)*	43	***(-25)***	68	*(n/a)*
	Big East River – Lower	510	506	***(-4)***	506	***(-4)***	510	*(n/a)*	510	*(n/a)*	494	***(-16)***	506	***(-4)***
	Lake Vernon	262	250	***(-12)***	250	***(-12)***	262	*(n/a)*	262	*(n/a)*	240	***(-22)***	250	***(-12)***
	Huntsville Narrows	74	54	***(-20)***	54	***(-20)***	74	*(n/a)*	74	*(n/a)*	53	***(-21)***	54	***(-20)***
	Fairy & Peninsula Lakes	416	379	***(-37)***	371	***(-45)***	416	*(n/a)*	416	*(n/a)*	332	***(-84)***	371	***(-45)***
	Mary Lake	108	100	***(-8)***	113	***(+5)***	108	*(n/a)*	108	*(n/a)*	100	***(-8)***	108	*(n/a)*
	Springdale	120	118	***(-2)***	7	***(-113)***	120	*(n/a)*	120	*(n/a)*	3	***(-117)***	7	***(-113)***
South Branch	*Baysville*	12	12	*(n/a)*	12	*(n/a)*	12	*(n/a)*	12	*(n/a)*	12	*(n/a)*	12	*(n/a)*
	Fraserburg	49	49	*(n/a)*	49	*(n/a)*	6	***(-43)***	49	*(n/a)*	6	***(-43)***	6	***(-43)***
	Purbrook	145	145	*(n/a)*	145	*(n/a)*	12	***(-133)***	145	*(n/a)*	12	***(-133)***	12	***(-133)***
Lower Branch	*Lake Muskoka*	3339	3289	***(-50)***	3352	***(+13)***	3366	***(+27)***	2938	***(-401)***	2927	***(-412)***	3406	***(+67)***
	Bala Bay	246	238	***(-8)***	248	***(+2)***	249	***(+3)***	213	***(-33)***	213	***(-33)***	252	***(+6)***
	Bala Reach	173	161	***(-12)***	173	*(n/a)*	178	***(+5)***	129	***(-44)***	126	***(-47)***	119	***(-54)***
	Musquash River	3	3	*(n/a)*	3	*(n/a)*	3	*(n/a)*	3	*(n/a)*	3	*(n/a)*	3	*(n/a)*
	Moon River	2	1	***(-1)***	2	*(n/a)*	2	*(n/a)*	2	*(n/a)*	2	*(n/a)*	2	*(n/a)*
Total		5527	5348	***(-179)***	5353	***(-174)***	5386	***(-141)***	5049	***(-478)***	4566	***(-961)***	5176	***(-351)***

Notes:

1. Grey text, accompanied with (n/a), indicate that no change is expected due to the selected mitigation options.
2. The change to the number of impacted structures is presented in the parentheses as *(+/- ###).* Green text indicates a net decrease, red text indicates a net increase to the number of impacted structures.

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Table 6-4: Summary of Percentage Change in Flood Inundation Area for Baseline Case and Mitigation Case Scenarios

Branch	River/Lake	Baseline Case Flood Inundation Area (km^2)	Percentage Change in Flood Inundation Area from Baseline Case[1,2;]					
			Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5a	Scenario 5b
North	*Big East River – Upper*	1.9	**-21%**	*(n/a)*	*(n/a)*	*(n/a)*	**-21%**	*(n/a)*
	Big East River – Lower	6.9	**-2%**	**-1%**	*(n/a)*	*(n/a)*	**-3%**	**~0%**
	Lake Vernon	18.0	**~0%**	**~0%**	*(n/a)*	*(n/a)*	**~0%**	**~0%**
	Huntsville Narrows	1.2	**-4%**	**-4%**	*(n/a)*	*(n/a)*	**-5%**	**-4%**
	Fairy & Peninsula Lakes	16.7	**~0%**	**-1%**	*(n/a)*	*(n/a)*	**-2%**	**-1%**
	Mary Lake	11.0	**~0%**	**~0%**	*(n/a)*	*(n/a)*	**~0%**	**~0%**
	Springdale	0.6	**-2%**	**-78%**	*(n/a)*	*(n/a)*	**-84%**	**-78%**
South	*Baysville*	0.5	*(n/a)*	*(n/a)*	*(n/a)*	*(n/a)*	*(n/a)*	*(n/a)*
	Fraserburg	2.0	*(n/a)*	*(n/a)*	**-27%**	*(n/a)*	**-27%**	**-27%**
	Purbrook	4.4	*(n/a)*	*(n/a)*	**-79%**	*(n/a)*	**-79%**	**-79%**
Lower	*Lake Muskoka*	122.5	**~0%**	**~0%**	**~0%**	**-2%**	**-2%**	**~0%**
	Bala Bay	4.8	**~0%**	**~0%**	**~0%**	**-1%**	**-1%**	**~0%**
	Bala Reach	3.4	**~0%**	**~0%**	**~0%**	**-2%**	**-3%**	**-3%**
	Musquash River	3.9	**~0%**	**~0%**	**~0%**	**~0%**	**~0%**	**~0%**
	Moon River	2.9	**~0%**	**~0%**	**~0%**	**+1%**	**~0%**	**+1%**

Notes:
1. Grey text, accompanied with (n/a), indicate that no change is expected due to the selected mitigation options.
2. The percent change in inundation area is presented in the parentheses as *(+/- ###)*. Green text indicates a net decrease, red text indicates a net increase, and black text indicates marginal change to the flood inundation areas.

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Table 6-5: Summary of Change in Peak Flow Rates (Value and Percentage) for Baseline Case and Mitigation Case Scenarios

Major Water Body	Inflow or Outflow	Baseline Case	Peak Flow Rate (m^3/s)[1;2;3] and Percentage Change from Baseline Case					
			Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5a	Scenario 5b
North Branch	Inflow	193	138 ***(-28%)***	193 *(n/a)*	193 *(n/a)*	193 *(n/a)*	138 ***(-28%)***	193 *(n/a)*
	Outflow	225	204 ***(-9%)***	226 ***(~0%)***	225 *(n/a)*	225 *(n/a)*	206 ***(-8%)***	225[3] ***(~0%)***
Lake Vernon	Inflow	296	277 ***(-6%)***	296 *(n/a)*	296 *(n/a)*	296 *(n/a)*	245 ***(-17%)***	296 *(n/a)*
	Outflow	243	210 ***(-14%)***	243 *(n/a)*	243 *(n/a)*	243 *(n/a)*	210 ***(-14%)***	243 *(n/a)*
Fairy & Peninsula Lakes	Inflow	249	217 ***(-13%)***	249 *(n/a)*	249 *(n/a)*	249 *(n/a)*	217 ***(-13%)***	249 *(n/a)*
	Outflow	213	190 ***(-11%)***	215 ***(+1%)***	213 *(n/a)*	213 *(n/a)*	192 ***(-10%)***	215 ***(+1%)***
Mary Lake	Inflow	216	193 ***(-11%)***	218 ***(+1%)***	216 *(n/a)*	216 *(n/a)*	194 ***(-10%)***	218 ***(+1%)***
	Outflow	214	191 ***(-11%)***	216 ***(+1%)***	214 *(n/a)*	214 *(n/a)*	192 ***(-10%)***	216 ***(+1%)***
South Branch	Inflow	169	169 *(n/a)*	169 *(n/a)*	169 *(n/a)*	169 *(n/a)*	169 *(n/a)*	169 (n/a)
	Outflow	204	204 *(n/a)*	204 *(n/a)*	219 ***(+7%)***	204 *(n/a)*	219 ***(+7%)***	219 ***(+7%)***
Lake Muskoka	Inflow	618	600 ***(-3%)***	618[3] ***(~0%)***	632 ***(+2%)***	**618 *(n/a)***	614 ***(~0%)***	632 ***(+2%)***
	Outflow	462	448 ***(-3%)***	462[3] ***(~0%)***	465 ***(~0%)***	472 ***(+2%)***	459 ***(~0%)***	475 ***(+3%)***

Notes:
1. Grey text, accompanied with (n/a), indicate that no change is expected due to the selected mitigation options.
2. The change to the peak flow rate is presented in the parentheses as *(+/- ###).* Green text indicates a net decrease, red text indicates a net increase, and black text indicates marginal change to the flood inundation areas.
3. The change to the peak flow rate is less than 0.5 m^3/s, such that the peak flow rate rounded to the nearest whole number is equal to the baseline.

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processes; exclusion of certain physical processes (e.g., wind set-up); calibration approach; and assumptions required during model set-up and scenario design.

- **Simplified Hydraulic Routing in Hydrologic Model:** The hydrologic model transfers flows between water bodies in a manner that simplifies the hydraulic routing processes of lakes and rivers in the MRW. As described in Section 6.2.3, the constraint of limited representation of hydraulic routing in the hydrologic model was overcome using a methodical process of one-way model coupling to establish flood conditions for all water bodies of interest.
- **Hydrologic Model Calibration:** The hydrologic model adopted from FPMS (Hatch, 2022a; 2022c) was calibrated to the peak flood conditions. Therefore, the model results are limited to the peak flows and water levels. In future studies, it may be worthwhile to evaluate the effects of the flood mitigation options throughout the year to ascertain any operational changes required.
- **Bathymetry Availability for Option Evaluation:** In several priority areas – particularly Bala Reach, Bala Bay and Fraserburg – limited bathymetric data were available for design and model evaluation of channel enlargement options. Future collection of detailed bathymetry data is recommended as part of any site-specific study to further advancement of the options outlined in this report.
- **MRW Gaps in Assessment of Flood Conditions:** Selection of specific priority areas allowed study efforts to pursue targeted development of site-specific options. As part of this, the scenario evaluation provided in this report is not considered comprehensive for the MRW, as several North Branch and South Branch reaches were not assessed.

6.4 Effects of Climate Change on Design Flood Conditions

Applied Weather Associates (AWA) was retained by Hatch Ltd to support the climate change component of the Flood Modifications Review Project Report. AWA developed climate scaling factors that were applied to hydrologic model inputs to assess the resilience of Scenario 5b in a future climate scenario.

AWA (2022) developed climate scaling factors for two Shared Socioeconomic Pathways (SSP): SSP 4.5 and SSP 8.5. SSPs are defined by the Intergovernmental Panel for Climate Change (IPCC) to represent potential future climate conditions based on the volume of greenhouse gas emissions, to the year 2100. SSP 4.5 represents the climate change pathway where some human-caused emissions are eliminated and is considered the most likely outcome (the ‘4.5’ means that radiative forcing stabilizes at 4.5 W/m^2). SSP 8.5 represents the most severe climate change pathway where little to no human-caused emissions are eliminated or restricted and is considered a less likely outcome (the ‘8.5’ means that radiative forcing stabilizes at 8.5 W/m^2).

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A statistically downscaled Regional Climate Model (RCM) was used in the climate projection analysis, such that the spatial and temporal resolutions were higher for the Lake Muskoka basin (AWA, 2022). The scaling factors were determined by comparing future projections of temperature and precipitation data to current and historical data (1950-2014). The scaling factors, presented in Table 6-6, are the median values from 26 different model projections.

Table 6-6: Scaling Factors (AWA, 2022) for Temperature (Temp) and Precipitation (PPT) for Three Future Time-Periods

	SSP 4.5			SSP 8.5		
Parameter	2025-2050	2050-2075	2075-2100	2025-2050	2050-2075	2075-2100
1-day Winter PPT	1.13	1.22	1.33	1.25	1.38	1.35
2-day Winter PPT	1.14	1.16	1.18	1.18	1.30	1.37
3-day Winter PPT	1.08	1.15	1.26	1.18	1.24	1.34
4-day Winter PPT	1.02	1.15	1.24	1.14	1.24	1.30
5-day Winter PPT	1.02	1.16	1.17	1.17	1.26	1.30
October Monthly PPT	1.03	0.98	1.04	1.07	1.04	1.07
November Monthly PPT	1.14	1.10	1.16	1.06	1.17	1.21
December Monthly PPT	1.11	1.16	1.14	1.14	1.16	1.30
January Monthly PPT	1.14	1.20	1.25	1.20	1.25	1.30
February Monthly PPT	1.08	1.15	1.25	1.14	1.23	1.28
March Monthly PPT	1.14	1.21	1.22	1.14	1.23	1.35
April Monthly PPT	1.11	1.14	1.13	1.08	1.18	1.24
October Monthly Temp (°C)	2.1	2.8	2.5	2.6	4.0	6.3
November Monthly Temp (°C)	1.8	1.9	2.3	1.6	2.8	5.2
December Monthly Temp (°C)	2.4	3.0	4.1	2.9	4.4	6.3
January Monthly Temp (°C)	3.1	4.3	5.6	3.5	6.1	8.6
February Monthly Temp (°C)	2.7	4.1	5.7	3.3	5.5	8.8
March Monthly Temp (°C)	1.3	2.9	5.2	1.3	4.2	6.8
April Monthly Temp (°C)	1.2	2.7	5.0	1.4	3.6	6.8

The scaling factors in Table 6-6 have a ±20% level of uncertainty due to the inherently uncertain nature of climate projection modelling. To assess the climate resilience of the flood mitigation Scenario 5b, the scaling factors were applied to the temperature and precipitation data inputs of the hydrologic model.

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6.4.1 Application of Scaling Factors

The climate change assessment was performed using the 2019 design event as a basis. These factors were applied to scale the precipitation and temperature data that serve as input to the hydrologic model. The precipitation and scaling approaches are summarized as follows.

6.4.1.1 Precipitation Scaling

- Daily precipitation inputs to the hydrologic model were multiplied by a corresponding Monthly PPT factor in Table 6-6 to produce a scaled daily precipitation time-series. This treatment accounts for the predicted trend of greater precipitation volumes in future years.
- An alternate scaling approach was used for a 5-day window that centered around a high rainfall event in April that precipitated the 2019 design flood event. Within this 5-day window, 1-day through 5-day Winter PPT factors were applied instead of Monthly PPT factors. This treatment accounts for the potential for climate change to result in more severe and extreme storm events.

6.4.1.2 Temperature Scaling

- Average daily temperatures inputs to the hydrologic model were increased by the corresponding Monthly Temp factors in Table 6-6 to produce a scaled daily temperature time-series. This treatment accounts for the predicted trend of warmer temperatures in future years.

6.4.2 Climate Change Evaluation

Four climate change cases were evaluated in the hydrologic model to characterize potential impact of climate change to the MRW after implementing the flood mitigation options from Scenario 5b. The cases evaluated include SSP 4.5 2025 – 2050, SSP 4.5 2075 – 2100, SSP 8.5 2025 – 2050, and SSP 8.5 2075 – 2100.

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Historical (i.e., Baseline Case) and associated scaled April 2019 datasets are provided in

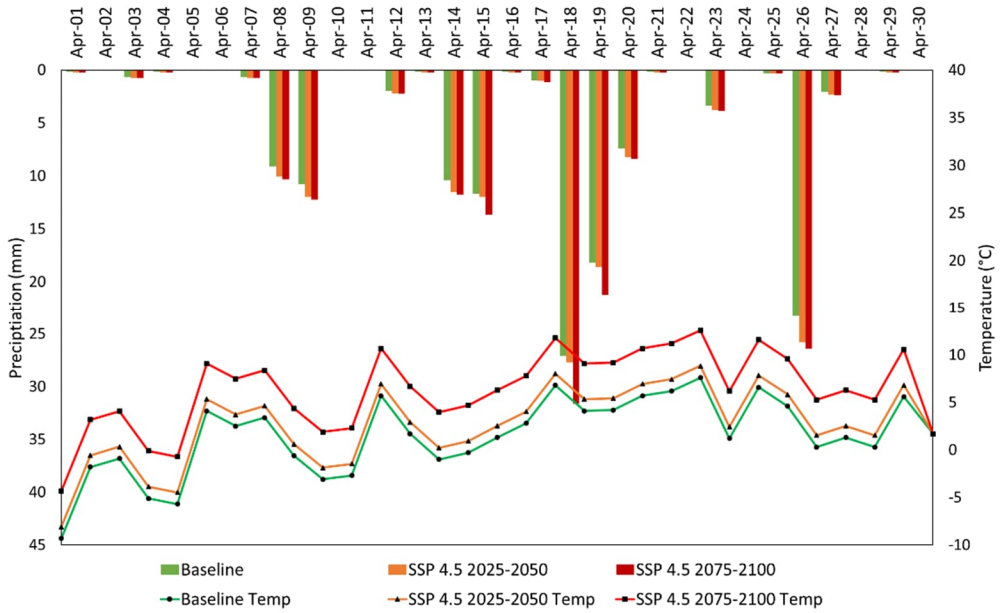

Figure 6-7 to Figure 6-10 for weather stations Algonquin Park East Gate (APEG) and Beatrice, which provide precipitation and temperature inputs to the hydrologic model.

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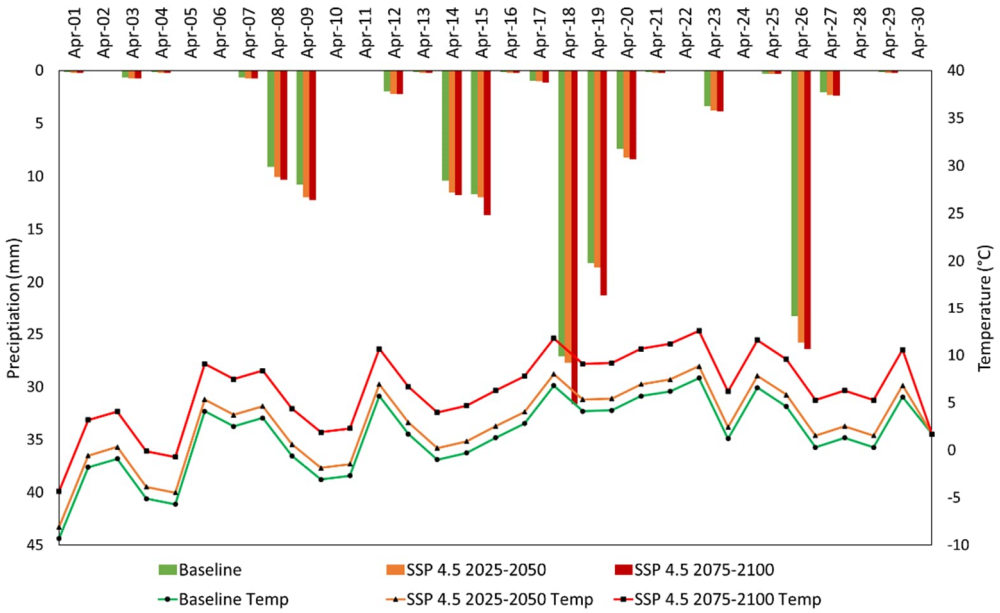

Figure 6-7: Precipitation and Temperature Trends for SSP 4.5 Climate Cases at Algonquin Park East Gate Weather Station

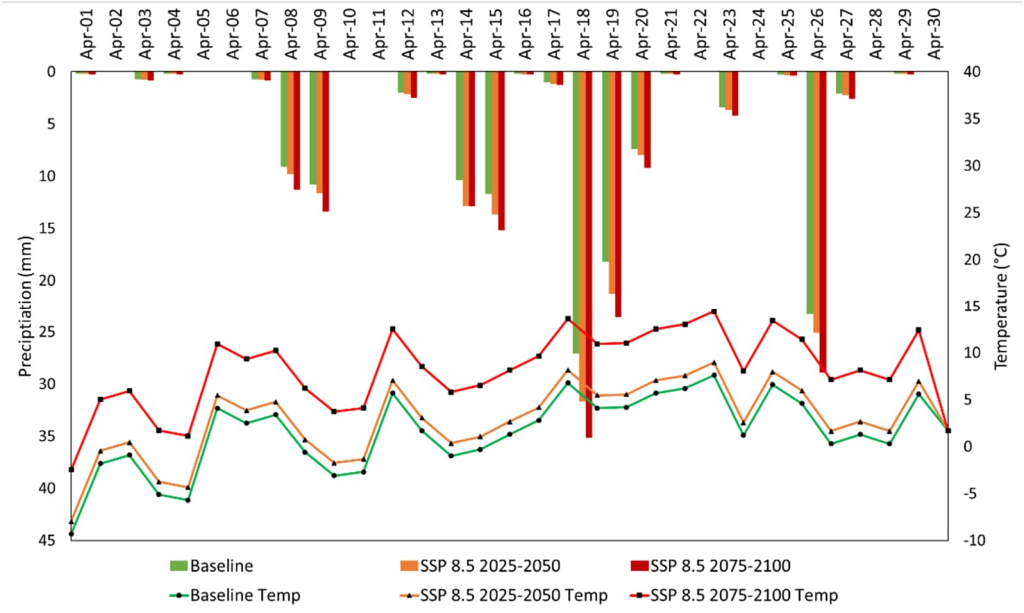

Figure 6-8: Precipitation and Temperature Trends for SSP 8.5 Climate Cases at Algonquin Park East Gate Weather Station

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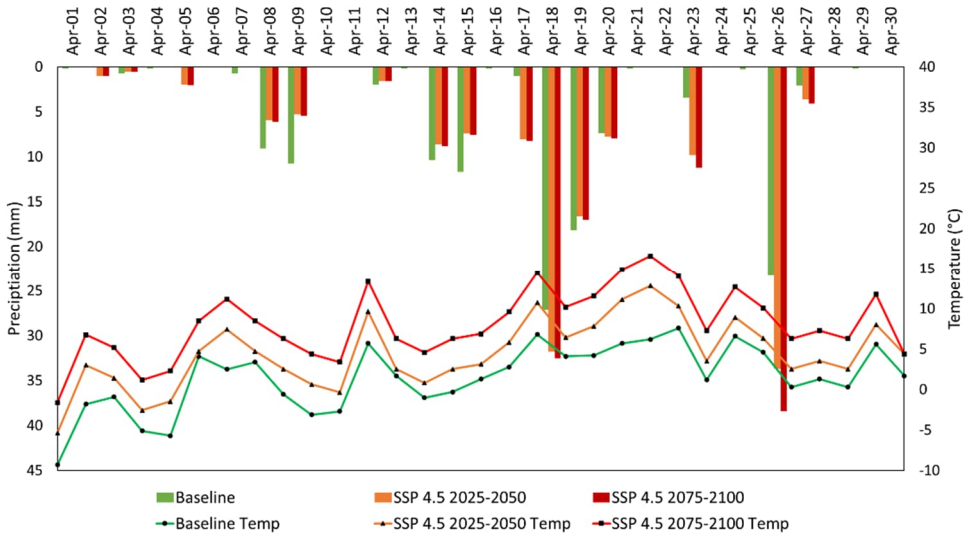

Figure 6-9: Precipitation and Temperature Trends for SSP 4.5 climate cases at the Beatrice weather station

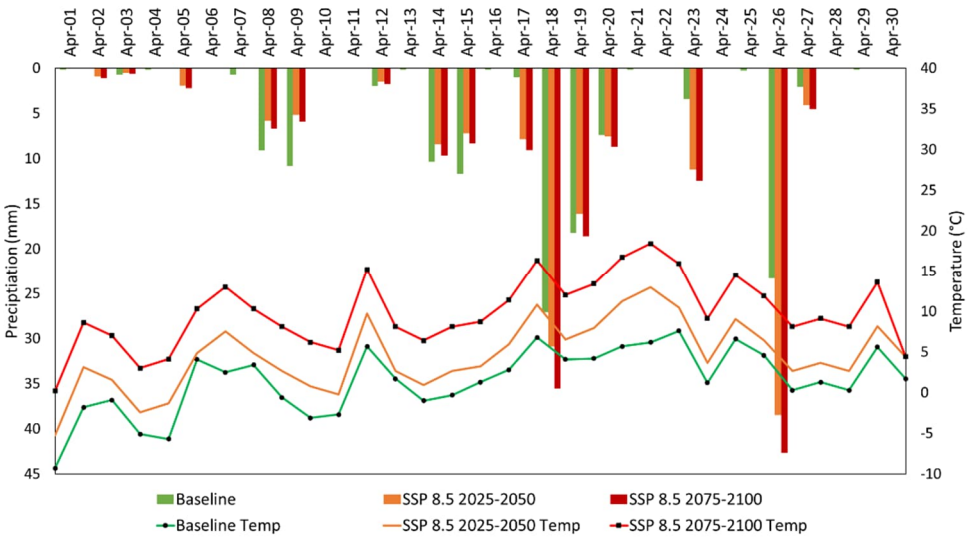

Figure 6-10: Precipitation and Temperature Trends for the SSP 8.5 Climate Cases at the Beatrice Weather Station

Temperature and precipitation are both expected to increase in each climate change case evaluated. However, the mean annual precipitation is not expected to change drastically, though the frequency of short duration storm events is likely to increase (AWA, 2022). This trend indicates there will be less snowfall and an increase in rainfall and runoff throughout the winter period.

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To further explore the implications of this trend, the hydrologic model of the MRW was applied to simulate snow water equivalent (SWE) depths and direct runoff for the Lake Rosseau Basin (closer to the Beatrice station) and the Oxtongue Lake Basin (closer to the Algonquin Park East Gate station) under each climate change case. SWE and cumulative runoff results are presented in Figure 6-11 and Figure 6-12 for the October 15 to June 30 period (with 2018/2019 as the baseline).

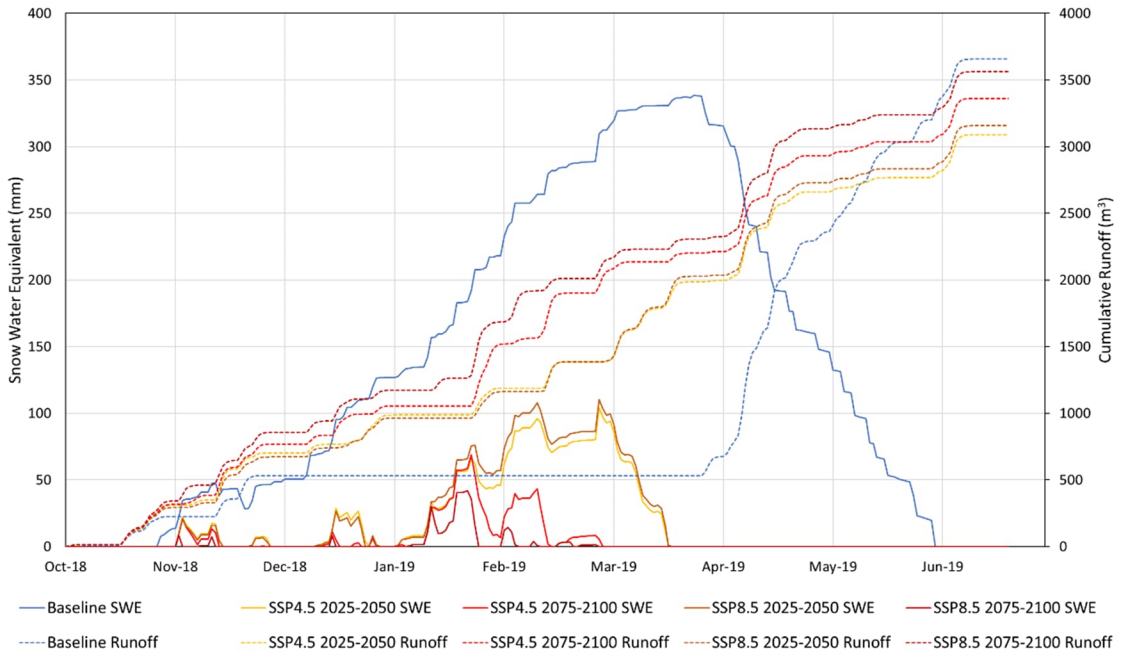

Figure 6-11: SWE depth and cumulative runoff at the Lake Rosseau Basin, from the four climate change cases and the *Baseline Case* (i.e., no climate change)

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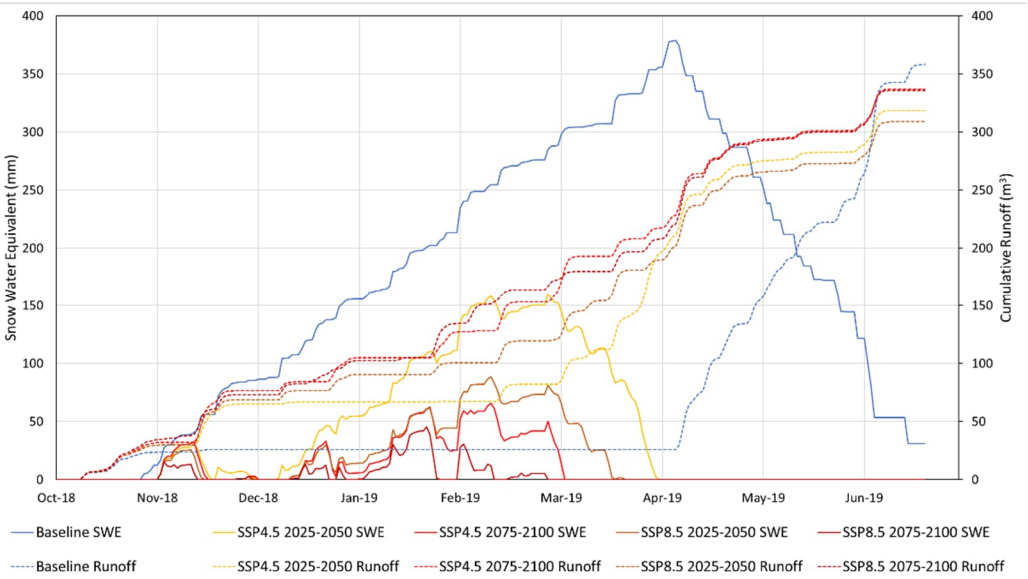

Figure 6-12: SWE depth and cumulative runoff at the Oxtongue Lake Basin, from the four climate change cases and the *Baseline Case* (i.e., no climate change)

As shown in both Figure 6-11 and Figure 6-12, SWE is greatly reduced in all climate change cases. There is less total cumulative runoff in the climate change cases compared to the Baseline Case, despite an increase in precipitation. Less cumulative runoff results from higher air and ground temperatures which, in turn, promotes greater infiltration losses in the climate change cases.

6.4.3 Climate Change Results

6.4.3.1 Increasing Mid-Winter Flood Risk

Hydrologic model simulations illustrate the potential effects of climate change on SWE and resulting subwatershed runoff. Results in Figure 6-11 and Figure 6-12 illustrate SWE and runoff trends for subwatersheds Lake Rosseau and Oxtongue Lake, which are assigned input data from Beatrice and APEG stations, respectively. As shown in both Figure 6-11 and Figure 6-12, snow accumulation and associated SWE is greatly reduced in all climate change cases. Also shown in these figures is the trend of snow accumulation and associated SWE greatly reduced in all climate change cases.

Case SSP 8.5 2075-2100 pathway has the smallest maximum SWE, which is due to the overall warmer temperatures. Also evident is the presence of increasing mid-winter melt events, which contribute to a steady rise of cumulative runoff during the winter months (i.e., January to April). In contrast, Baseline Case cumulative runoff plateaus through winter and rises quickly at the onset of the spring freshet. An increase in the frequency of mid-winter melt events may contribute to increases in winter flood risk. A resulting increase in winter water levels is expected to occur, which may require modifications to current operating rules.

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6.4.3.2 *Resilience of Flood Mitigation Options in a Future Climate*

The hydrologic model was applied to assess the resiliency of Options 2 to 10 (i.e., Scenario 5b) and the flood conditions of the MRW. The same methodology to assess Scenario 5b (see Section 6.3.6) was employed, except with scaled temperature and precipitation inputs.

Table 6-8 presents changes in the number of impacted structures and flood inundation area for SSP 4.5 2075-2100, as this is considered a higher likelihood future climate trajectory. These results indicate that flood risk associated with the spring freshet is expected to decrease in future years, because of a more gradual melt of the snowpack throughout the winter compared to current years.

In general, a reduction in peak flow rates is observed under future climate conditions for all examined areas in the MRW. While a decrease in peak flow contributes to a reduction in flood severity during the freshet, a rise in the frequency and severity of mid-winter flooding is also expected. As discussed in Section 6.4.1, more mid-winter melt events and greater runoff volumes are expected for all future climate cases, which is a driving factor behind changing mid-winter flood conditions

These results suggest that the 10 options developed as part of this study will be adequate to address freshet flooding in a future climate, as peak water levels are predicted to decrease. However, further assessment should be completed as part of future work to evaluate the performance of these options in mitigating mid-winter flooding. Other complicating factors during winter, such as mid-winter ice jams and challenges with structural operations under ice-affected conditions, should be included in this work.

The climate change assessment presented in this report is limited to the 2019 design event. Analyses of other flood years may be beneficial to complement report findings, particularly for areas that may have been affected more during other design events (i.e., upper areas of the North Branch in 2013).

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Table 6-7: 2018-2019 Peak Flow Rates For Baseline Case and Climate Change Cases

		Peak Flow Rate (m^3/s)[1] and Percentage Change from Scenario 5b (w/ Baseline Climate)					
Major Water Body	**Inflow/ Outflow**	**Baseline Case (w/ Baseline Climate)**	**Scenario 5b (w/ Baseline Climate)**	**Scenario 5b (w/ SSP 4.5 2025-2050 Climate)**	**Scenario 5b (w/ SSP 4.5 2075-2100 Climate)**	**Scenario 5b (w/ SSP 8.5 2025-2050 Climate)**	**Scenario 5b (w/ SSP 8.5 2075-2100 Climate)**
North Branch[2]	Inflow	193	193	123 ***(-36%)***	121 ***(-37%)***	120 ***(-37%)***	129 ***(-33%)***
	Outflow	225	225	183 ***(-36%)***	193 ***(-14%)***	205 ***(-9%)***	203 ***(-10%)***
Lake Vernon	Inflow	296	296	255 ***(-14%)***	251 ***(-15%)***	251 ***(-15%)***	263 ***(-11%)***
	Outflow	243	243	202 ***(-17%)***	197 ***(-19%)***	198 ***(-19%)***	207 ***(-15%)***
Fairy Lake	Inflow	249	249	209 ***(-16%)***	204 ***(-18%)***	204 ***(-18%)***	215 ***(-14%)***
	Outflow	213	215	177 ***(-18%)***	170 ***(-21%)***	173 ***(-20%)***	178 ***(-17%)***
Mary Lake	Inflow	216	218	180 ***(-17%)***	174 ***(-20%)***	177 ***(-19%)***	183 ***(-16%)***
	Outflow	214	216	191 ***(-12%)***	182 ***(-16%)***	194 ***(-10%)***	200 ***(-7%)***
South Branch[3]	Inflow	169	169	105 ***(-38%)***	83 ***(-51%)***	111 ***(-34%)***	92 ***(-46%)***
	Outflow	204	219	154 ***(-30%)***	136 ***(-38%)***	159 ***(-27%)***	147 ***(-33%)***
Lake Muskoka	Inflow	618	550	616 ***(-13%)***	550 ***(-13%)***	594 ***(-6%)***	582 ***(-8%)***
	Outflow	462	379	430 ***(-20%)***	351 ***(-26%)***	387 ***(-19%)***	370 ***(-22%)***

Notes:

1. The change to the peak flow rate due to climate change is presented in the parentheses as *(+/- ###)*.
2. North Branch refers to the North Branch Muskoka River from immediately downstream of Distress Dam to Lake Muskoka, as described in Section 0.
3. South Branch refers to the South Branch Muskoka River from Lake of Bays to immediately downstream of Matthias GS, as described in Section 0.

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Table 6-8: Comparison of Baseline Case, Scenario 5b (Baseline Climate), and Scenario 5b (SSP 4.5 2075-2100 Climate)

Branch	River/Lake	No. of Impacted Structures	No. of Impacted Structures (Change from Baseline Case w/ Baseline Climate)				Flood Inundation Area (km^2)	Percentage Change in Flood Inundation Area from Baseline Base w/ Baseline Climate	
		Baseline Case w/ Baseline Climate	Scenario 5b w/ Baseline Climate		Scenario 5b w/ SSP 4.5 2075-2100 Climate		Baseline Case w/ Baseline Climate	Scenario 5b w/ Baseline Climate	Scenario 5b w/ SSP 4.5 2075-2100 Climate
North	*Big East River – Upper*	68	68	*(n/a)*	36	**(-32)**	1.9	*(n/a)*	**-37%**
	Big East River – Lower	510	506	***(-4)***	475	**(-35)**	6.9	**~0%**	**-6%**
	Lake Vernon	262	250	***(-12)***	221	**(-41)**	18.0	**~0%**	**-1%**
	Huntsville Narrows	74	54	***(-20)***	43	**(-31)**	1.2	**-4%**	**-8%**
	Fairy & Peninsula Lakes	416	371	***(-45)***	285	**(-131)**	16.7	**-1%**	**-2%**
	Mary Lake	108	108	*(n/a)*	94	**(-14)**	11.0	**~0%**	**-1%**
	Springdale	120	7	***(-113)***	0	**(-120)**	0.6	**-78%**	**-93%**
South	*Baysville*	12	12	*(n/a)*	1	**(-11)**	0.51	*(n/a)*	**-15%**
	Fraserburg	49	6	***(-43)***	2	**(-47)**	2.01	**-27%**	**-57%**
	Purbrook	145	12	***(-133)***	1	**(-144)**	4.36	**-79%**	**-127%**
Lower	*Lake Muskoka*	3339	3406	***(+67)***	2479	**(-860)**	122.48	**~0%**	**-4%**
	Bala Bay	246	252	***(+6)***	186	**(-60)**	4.79	**~0%**	**-3%**
	Bala Reach	173	119	***(-54)***	69	**(-104)**	3.43	**-3%**	**-10%**
	Musquash River	3	3	*(n/a)*	0	**(-3)**	3.86	**~0%**	**-118%**
	Moon River	2	2	*(n/a)*	1	**(-1)**	2.90	**+1%**	**-8%**
Total		**5527**	**5119**	***(-392)***	3893	**(-1634)**	**N/A[1]**	**N/A[1]**	**N/A[1]**

Notes:

1. *(n/a)* = not applicable

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7. Mitigation Scenarios Environmental Impact Assessment

Potential environmental impacts of the selected options were reviewed in the *Structural Flood Mitigation Options* report (Hatch, 2022f). These generally included impacts to the following:

- Woodlands
- Wetlands
- Fish and Fish Habitat
- General Wildlife Habitat
- Species at Risk and their habitats.

Many of the potential impacts of each of the options are related to the following:

- Flood water levels result in inundation of habitats that may not normally be inundated under normal flood conditions. Habitats that are not regularly flooded may be impacted through loss of vegetation that does not tolerate flooded conditions. However, these impacts are related to how long an area would be flooded. Some habitats may tolerate short-term flooding as impacts related to high water levels may take more than a week for impacts to occur.
- Direct impacts where habitats need to be permanently altered (i.e., deepening or widening channels). Options that require permanent alteration to habitats may result in the loss of habitat if the alteration changes the habitat's form and function (i.e., deepening a channel that may result in water depths and flow velocities unsuitable for fish spawning).
- If the option alters flows under normal conditions (i.e., normal spring freshet, summer low flow). Any options that may alter flows under normal conditions may impact habitats through lower water levels under normal spring conditions or lower water levels during the low flow period in the summer. These changes may reduce habitats such as wetlands that rely on the spring freshet to replenish water levels in the spring prior to slowly lowering over the summer, or flooded vegetation that may support spawning and nursery areas for fish in the spring. Altered summer flows may result in habitats such as wetlands drying out causing the habitat to change to another habitat type that may not support wetland dependent species. Lower water levels may also impact fish species' normal migration patterns if the depth no longer allows fish to easily move between habitats.
- Impacts during construction. Construction impacts may result from removal of vegetation during access to the site and releases of deleterious substances such as silt and sediment to adjacent habitats.

Options 5, 6, 7, 8, and 10 require permanent alteration to the channel and therefore will result in alterations to terrestrial and aquatic habitats. These impacts include loss of riparian

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vegetation, and alteration to fish habitats. The extent of these impacts will depend on habitat that is present within the proposed area of alteration and the species that may utilize these habitats. Site-specific terrestrial surveys to document habitats that will be altered during construction should be carried out during future phases of the project to fully understand the extent of impacts. Fish and fish habitat assessments should be carried out within the proposed work area, along with upstream and downstream, to identify the extent and significance of impacts from the project.

Table 7-1 provides a broad and high-level summary of the anticipated alteration to water levels under normal flows and the anticipated time for the flood waters to return to normal levels. This summary is based only on the details presented in Section 5 interpreted with professional judgement, however further study is required to verify or adjust these predictions.

Table 7-1:Summary of Time to Return to Normal Water Levels and Changes to Normal Flow

Option	Approximate Time for Water Levels to Return to Pre-Flood Conditions after Flood	Severity Changes to Water Levels Under Normal Flow Conditions
Option 1 – Distress	Days	**Low Severity** – Distress is designed to maintain water levels similar to Baseline Case
Option 2 – Huntsville Berm	N/A	**No changes expected**
Option 3 – Brunel Locks	Days	**No changes expected** - Brunel locks are already used during normal water level conditions
Option 4 – High Falls retrofit	Hours	**Low Severity** – Obermeyers are designed to maintain water levels similar to Baseline Case
Option 5 – May Chutes	Days	**Moderate Severity –** more study needed
Option 6 and 7 – Rocky Rapids and Matthias GS (implemented together)	Days (some uncertainty given the large size of inundation area at Purbrook)	**Moderate Severity –** more study needed
Option 8 – Wallis Cut	Days	**Moderate Severity –** more study needed
Option 9 – Bala Dam retrofit	Days	**Low Severity** – stop logs can be used at dam to maintain
Option 10 – Moon Chutes	Days	**Moderate Severity –** more study needed

While many of the options have the potential to inundate areas not normally inundated (i.e., woodlands), the inundation is anticipated to be short-term and is not considered to be a significant impact. While the preliminary assessment suggests that the inundation in these

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areas will be only a few days, the time to return to normal flows should be confirmed during future phases of the project.

Options 2 and 3 are predicted to have no changes to permanent water levels and therefore are not anticipated to result in alterations to any habitats. Options 1, 4, and 9 are predicted to have limited alterations to water levels and are unlikely to result in significant impacts to adjacent habitats. Options 5, 6, 7, 8, and 10 are anticipated to have moderate changes to water levels and may result in some impacts to habitats under normal flow conditions. These water level changes should be confirmed during future phases of the project to confirm the severity of impact and if the impacts could permanently alter habitats following implementation of the selected options.

Construction impacts to the terrestrial environment are likely to be limited to vegetation removal along access routes and temporary work areas required for construction. Many of the impacts to terrestrial ecosystems can be mitigated through limiting the size of work area to limit vegetation removal, removing vegetation during the non-sensitive period for species that utilize the habitats present on site, and replacing lost vegetation through replanting following construction. Site-specific surveys will be required to identify if any sensitive vegetation communities or species at risk habitat is present along the access routes or within the work areas.

Construction impacts to aquatic resources will include temporary access to construct or alter water control structures (i.e., Options 1, 4 and 9) and in-water works related channel alterations (i.e., Options 5, 6, 7, 8, and 10). In-water works that require the work area to be isolated during construction will also result in impacts to fish and fish habitat including potential for the death of fish or temporary loss of access to habitats. The full extent of construction impacts should be refined during future design phases of the project where construction methods and extent of work areas are finalized.

The following sections discuss potential impacts under each scenario due to each option. It should be noted that detailed terrestrial surveys should be completed for each scenario to confirm if there may be permanent or temporary impacts to species at risk and their habitats due to construction access and project footprints. Table 7-2 provides a summary of potential environmental impacts for each scenario.

7.1 Scenario 1 (Big East River)

7.1.1 Option 1: Retrofit Distress Dam

Mitigation efforts would likely see the temporary inundation of previously un-inundated woodland and wetland areas (Hatch, 2022f); however, it is expected that water levels would return to pre-flood conditions after no more than a few days (Table 7-1). Further, the primary effect(s) on MRW outside of the immediate priority area for Option 1 is expected to be a reduction in peak water levels (WSE) in the Huntsville Lakes. However, as it is expected that the extent of inundation would only persist for a maximum of a few days, no permanent

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change to water levels is expected in the Huntsville Lakes. Thus, environmental impacts resulting from Option 1 are expected to be of low severity or non-existent.

7.2 Scenario 2 (North Branch – Huntsville Narrows)

Under flood conditions, it is expected that the primary effect(s) on MRW outside of the immediate priority area for all the options under Scenario 2 would result in the increase of peak water levels (WSE) in Lake Muskoka.

7.2.1 Option 2: Huntsville Narrows Berm

Mitigation efforts would be unlikely to alter the baseline impacts (i.e., no inundation) to woodland and wetland areas with Option 2 (Hatch, 2022f; Table 7-1). Thus, no permanent environmental impacts are expected with Option 2.

7.2.2 Option 3: Increase Outflow Through Fairy Lake (Brunel Lift Locks)

Mitigation efforts would be unlikely to alter the baseline impacts (i.e., no inundation) to woodland and wetland areas with Option 3 (Hatch, 2022f) as the Brunel Lift Locks are already utilized during normal water-level conditions. If inundation occurs, it is anticipated that water levels in Lake Muskoka would return to pre-flood conditions within a few days (Table 7-1). Thus, potential impacts are expected to be of low severity, and no permanent environmental impacts are expected with Option 3.

7.2.3 Option 4: Retrofit Obermeyer at High Falls Dam (Springdale)

Mitigation efforts for Option 4 have the potential to eliminate the inundation of woodland areas but would be unlikely to reduce or eliminate inundation impacts to adjacent wetland areas (Hatch, 2022f). However, expected impacts to water levels in Lake Muskoka and inundated areas are expected to persist for no longer than a few hours as the Obermeyer is designed to maintain water levels similar to baseline conditions (Table 7-1). Thus, potential impacts are expected to be of low severity, and no permanent impacts are expected with Option 4.

7.3 Scenario 3 (South Branch – Baysville, Fraserburg, Purbrook)

There are no mitigation options available for the Baysville subreach. Additionally, under flood conditions, it is expected that the primary effect(s) on MRW outside of the immediate priority area for all the options identified under Scenario 3 would result in the increase of peak water levels (WSE) in Lake Muskoka. As a result, no impacts are anticipated for Scenario 3.

7.3.1 Option 5: Excavate May Chutes (Fraserburg)

Mitigation efforts for Option 5 have the potential to eliminate the inundation of woodland areas as well as to reduce (but not eliminate) the inundation of wetland areas (Hatch, 2022f). Further, mitigation efforts under Option 5 are expected to bring down the water surface profile within the Fraserburg subreach. However, under this option, the time required for water levels to return to pre-flood conditions is expected to be no longer than a few days.

Given the nature of excavation activity, however, construction works associated with Option 5 have the potential to adversely affect fish habitat including permanent alterations to the depth, water flow velocity, and water levels in May Chutes (Hatch, 2022f). Additionally, excavation

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works have the potential to adversely impact fish behaviour and welfare, including permanent impacts to fish movement due to increased velocities and temporary impacts from movement restrictions, noise, and vibration impacts during construction activity. As a result, detailed fish and fish habitat assessments are required to confirm severity of impacts under Option 5.

7.3.2 Option 6: Excavate Rocky Rapids (Purbrook) and Option 7: Lower Matthias Generating Station Headpond Level During Flood (Purbrook)

Mitigation efforts are likely to reduce, but not eliminate, inundation of woodland and wetland areas under Options 6 and 7 (Hatch, 2022f). Additionally, under Option 7, water availability in impacted wetlands within the Purbrook subreach are likely to decrease due to lower headpond levels (Hatch, 2022f). The time expected for headpond levels and Lake Muskoka water levels to return to pre-flood conditions is roughly a few days, with some uncertainty given the large size of the potential inundation area (Table 7-1).

Additionally, as discussed in Option 5, excavation works have the potential to adversely affect fish habitat including permanent alterations to the depth, water flow velocity, and water levels; this is applicable in Rocky Rapids under Option 6, an area particularly sensitive to increased depths as fish likely use the shallow rapids for life processes (Hatch, 2022f). Additionally, excavation works have the potential to adversely impact fish behaviour and welfare, including permanent impacts to fish movement due to increased velocities and temporary impacts from movement restrictions, noise, and vibration impacts during construction activity. As a result, detailed fish and fish habitat assessments are required to confirm severity of impacts under Option 6.

7.4 Scenario 4 (Lower Branch – Muskoka/Bala)

Under flood conditions, the primary expected effect(s) of MRW outside of the immediate priority area for all the options identified under Scenario 4 are an increase in peak water levels in Bala Bay and a reduction in peak water levels in Lake Muskoka.

7.4.1 Option 8: Excavate Wallis Cut and Option 10: Excavate Moon Chutes

Like the excavation impacts discussed for Options 5 and 6 under Scenario 3, excavation works at Wallis Cut and Moon Chutes have the potential to adversely affect fish habitat, such as permanently altering water levels in Lake Muskoka, which may expose (and therefore result in the loss of) shallow fish spawning habitat. Additionally, increased water levels in Bala Bay resulting from flood events has the potential to impact water quality from flood drawdown along areas of Bala Bay (Hatch, 2022f).

Excavation works further have the potential to adversely impact fish behaviour and welfare, including permanently impacting fish movement (e.g., increased velocities from channel widening) and temporary impacts from movement restrictions, noise, and vibration impacts during construction activity (Hatch, 2022f). As a result, detailed fish and fish habitat assessments are required to confirm severity of impacts under Option 8.

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Table 7-2: Summary of Potential Environmental Impacts of Each Scenario

Scenario	Priority Area	Flood Mitigation Option(s)	Primary Effect(s) on MRW Outside of Immediate Priority Area	Impacts				
				Woodland Inundation	Wetland Inundation	Fish/Fish Spawning Habitat	Potential to Impact Species at Risk	General Wildlife Impacts
1	Big East River	• Option 1: Retrofit Distress Dam	Reduced peak water level (WSE) in Huntsville Lakes	Temporary inundation of previously un-inundated woodlands; no permanent impacts anticipated.	Temporary inundation of previously un-inundated wetlands; no permanent impacts anticipated.	No permanent impacts expected. May be temporary impacts during construction of the dam retrofit.	Potential for impacts during construction if SAR habitat is removed for access or construction areas. Detailed surveys are required during detailed design to confirm species and habitat presence.	Potential to temporarily inundate late wintering area for Moose; no permanent impacts anticipated.
2	North Branch (Huntsville Narrows)	• Option 2: Huntsville Narrows Berm • Option 3: Increase Outflow Through Fairy Lake (Brunel Lift Locks)	Increase peak water level (WSE) in Lake Muskoka	Unlikely to alter baseline conditions (i.e., no inundation). Therefore, no impacts anticipated.	Unlikely to alter baseline conditions (i.e., no inundation). Therefore, no impacts anticipated.	No permanent impacts anticipated. May be temporary impacts during construction of the Huntsville Narrows berm.	Potential for impacts during construction if SAR habitat is removed for access or construction areas. Detailed surveys are required during detailed design to confirm species and habitat presence.	Unlikely to alter baseline conditions (i.e., no impact) to Stratum 2 deer overwintering habitat.
		• Option 4: Retrofit Obermeyer at High Falls Dam (Springdale)		Potential to eliminate baseline inundation of woodland areas. Therefore, no impacts anticipated.	Unlikely to alter baseline inundation impacts to wetland areas. Therefore, no impacts anticipated.	No permanent impacts anticipated. May be temporary impacts during construction of Obermeyer at High Falls.	Potential for impacts during construction if SAR habitat is removed for access or construction areas. Detailed surveys are required during detailed design to confirm species and habitat presence.	Potential to reduce or eliminate baseline inundation impacts to Stratum 2 deer overwintering habitat.
3	South Branch (Baysville)	• None		No options available for this subreach.				
	South Branch (Fraserburg)	• Option 5: Excavate May Chutes		Potential to eliminate baseline inundation of woodland areas. Therefore, no impacts anticipated.	Potential to reduce baseline inundation of wetland areas. May also temporarily bring down water surface profile. Therefore, no impacts anticipated.	Potential temporary effects: • Impacts to fish movement (due to movement restrictions from construction works). • Impacts to fish welfare (due to construction work noise and vibration impacts). • Potential impacts during construction due to blasting. Potential permanent effects: • Impacts to fish habitat, including permanent alterations to channel depth, water flow velocity, and water levels (particularly relevant to Option 6). • Impacts to fish movement (due to increased water velocity). • Potential for loss of spawning and nursery habitat	Potential for impacts during construction if SAR habitat is removed for access or construction areas. Detailed surveys are required during detailed design to confirm species and habitat presence.	Potential to reduce baseline inundation impacts to Stratum 2 deer overwintering habitat, a Mixed Wader Nesting Colony, and the adjacent Colonial Waterbird Nesting Area.
	South Branch (Purbrook)	• Option 6: Excavate Rocky Rapids		Potential to reduce baseline inundation of woodland areas. Therefore, no impacts anticipated.	Potential to reduce baseline inundation of wetland areas. Therefore, no impacts anticipated.			
		• Option 7: Lower Matthias Generating Station Headpond Level During Flood			Potential to reduce baseline inundation of wetland areas. Water availability in impacted wetlands likely to decrease due to lower headpond levels. Therefore, no impacts anticipated.	No permanent impacts identified.	Potential for impacts during construction if SAR habitat is removed for access or construction areas. Detailed surveys are required during detailed design to confirm species and habitat presence.	

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Scenario	Priority Area	Flood Mitigation Option(s)	Primary Effect(s) on MRW Outside of Immediate Priority Area	Impacts: Woodland Inundation	Impacts: Wetland Inundation	Impacts: Fish/Fish Spawning Habitat	Impacts: Potential to Impact Species at Risk	Impacts: General Wildlife Impacts
4	Lower Branch (Muskoka / Bala)	• Option 8: Excavate Wallis Cut • Option 10: Excavate Moon Chutes	Increase peak water level (WSE) in Bala Bay and reduce peak water level (WSE) in Lake Muskoka. No impacts anticipated due to short term peak increase.	Unlikely to alter baseline inundation impacts on woodland areas. Therefore, no impacts anticipated.	Unlikely to alter baseline inundation impacts to wetland areas. Therefore, no impacts anticipated.	Potential temporary effects: • Impacts to fish movement (due to movement restrictions from construction works). • Impacts to fish welfare (due to construction work noise and vibration impacts). • Potential impacts during construction due to blasting. Potential permanent effects: • Impacts to fish habitat, including permanent alterations to channel depth, water flow velocity, and water levels (particularly relevant to Options 8 and 10). • Impacts to fish movement (due to increased water velocity). • Potential for loss of spawning and nursery habitat	Potential for impacts during construction if SAR habitat is removed for access or construction areas. Detailed surveys are required during detailed design to confirm species and habitat presence.	Unlikely to alter baseline impacts to Stratum 2 deer overwintering habitat, a Mixed Wader Nesting Colony, and the adjacent Colonial Waterbird Nesting Area.
		• Option 9: Increase Outflow at Bala Dam / Bala Dam Retrofit			Potential to decrease water levels for wetlands adjacent to Lake Muskoka while saturating wetlands adjacent to Bala Bay due to increased outflow. Therefore, no impacts anticipated.	Potential temporary effects: • Impacts to fish movement (due to movement restrictions from construction works). • Impacts to fish welfare (due to construction work noise and vibration impacts). • Potential impacts during construction due to blasting. Potential permanent effects: • Impacts to fish habitat, including permanent alterations to channel depth, water flow velocity, and water level.	Potential for impacts during construction if SAR habitat is removed for access or construction areas. Detailed surveys are required during detailed design to confirm species and habitat presence.	

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7.4.2 Option 9: Increase Outflow at Bala Dam / Bala Dam Retrofit

Mitigation efforts would be unlikely to impact the inundation impacts on woodland areas within this subreach. Additionally, mitigation efforts would be unlikely to reduce or eliminate inundation impacts to wetland areas; increasing outflow at Bala Dam may instead decrease water levels for wetlands adjacent to Lake Muskoka while saturating wetlands adjacent to Bala Bay. However, under Option 9, water levels are expected to revert to pre-flood conditions within a few days. Furthermore, it is expected that stop logs can be utilized at the dam to maintain appropriate water levels during flood conditions (Table 7-1). Thus, potential impacts are expected to be of low severity, and therefore, Option 9 is not anticipated to result in permanent impacts.

7.5 Combination of Scenarios 1 to 4

As discussed above, detailed fish and fish habitat assessments will be required to confirm temporary and permanent impacts.

7.6 Combination of Scenarios 2 to 4

As discussed above, detailed fish and fish habitat assessments will be required to confirm temporary and permanent impacts.

7.7 Permitting (Constraints/Requirements)

Based on the preliminary assessment of the impacts of each scenario to natural heritage features, the following is a list of environmental permits and approvals that may be required to support the implementation of each scenario. This list should be reviewed and refined during future phases of design when the baseline and targeted environmental investigations/surveys are completed, the temporary and permanent footprint of each scenario has been finalized, and the relevant agencies have been consulted.

7.7.1 Federal

***Species at Risk Act*, 2002:** This Act provides a framework to ensure the survival of wildlife species and the protection of natural heritage in Canada (Species at Risk Act, S.C. 2002, c. 29 2002). Under SARA, the Federal government has responsibility for wildlife as follows: Wildlife on Federal lands, aquatic species; and Migratory birds protected by the *Migratory Birds Convention Act* (MBCA) (Migratory Birds Convention Act, S.C. 1994, c. 22 1994). Species listed under SARA are defined as Species At Risk (SAR) of disappearing from Canada. Specifically, SARA contains prohibitions against the killing, harming, harassing, capturing, taking, possessing, collecting, buying, selling or trading of individuals of Endangered, Threatened and Extirpated Species listed in Schedule 1 of the Act. The Act also contains a prohibition against the damage or destruction of their residence (e.g., nest or den).

Applicability: The appropriate authority for consideration of a permit application under SARA depends on the species affected by the proposed activity and its location. A desktop screening was completed in order to compile a list of provincially listed SAR and was cross referenced with SARA Schedule 1 to determine the potential presence of SARA species within the Study Area. Federal lands or aquatic species listed on Schedule 1 were not

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identified during the desktop screening, however the individuals and nests of birds listed on Schedule 1 of SARA and listed on the *Migratory Birds Convention Act* (1994) are protected.

Fisheries Act, 1985: The Federal *Fisheries Act* was established in 1985 with amendments that came into effect on August 28, 2019. This Act provides protection to fish and fish habitat such that:

"No person shall carry on any work, undertaking or activity other than fishing that results in the death of fish" (Section 34.4 (1))."

"No person shall carry on any work, undertaking or activity that results in harmful alteration, disruption or destruction of fish habitat." (Section 35(1))."

Fish habitat is defined by the Act as "water frequented by fish and any other areas on which fish depend directly or indirectly to carry out their life processes, including spawning grounds and nursery, rearing, food supply and migration areas". The *Fisheries Act* requires that any development project avoid causing the death of fish, or a Harmful Alteration, Disruption or Destruction (HADD) of fish habitat unless authorized by the Minister of Fisheries and Oceans. This applies to any works being undertaken in or near waterbodies that supports fish habitat as defined in the act. If mitigation measures cannot be applied, and residual effects will cause death to fish, or result in a HADD, then a Request for Review must be submitted to DFO. If DFO identifies that the project is likely to result in the death of fish or a HADD of fish habitat, an Authorization (i.e., approval) for the Project will be required and as a result, an Offsetting Plan may be required.

Applicability: Any waterbody or watercourse that contains fish, or indirectly supports fish, as described in the *Fisheries Act*, is provided protection under the Act. All Priority Areas contain watercourses/waterbodies that are known to contain fish and several critical habitat features including spawning shoals, and as such the Project must comply with the *Fisheries Act*. Should any of the scenarios be anticipated to result in a significant impact to the resident fish population, a Request for Project Review should be submitted to DFO to determine if the project may result in a HADD. If DFO determines that the work would result in a HADD, typically an Offsetting Plan would be developed in consultation with the District of Muskoka and DFO, or in cases where DFO determines that HADD is significant, a more onerous Fisheries Act Authorization may be required. The following provides a summary of the recommended approach to receiving DFO approvals:

- **Scenario 1** may require in-water works to complete the alterations at Distress Dam. These impacts are likely to be temporary and are unlikely to result in a HADD. However, once the final design and construction footprint have been developed, the project may require submission of a Request for Project Review to DFO.
- **Scenario 2** may require in-water works to construct the berm for Option 2 and the control structure retrofit for Option 4. These impacts are likely to be temporary and are unlikely to

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result in a HADD. However, once the final design and construction footprint have been developed, the project may require submission of a Request for Project Review to DFO.

- **Scenario 3** includes channel alterations for Options 5, 6, and 7. These alterations have the potential to result in a HADD. Once the final design and construction footprint have been developed, a Request for Project Review should be submitted to DFO to determine the likelihood of the project resulting in a HADD. Should DFO determine that the project may result in a HADD, an Offsetting Plan can be developed in consultation with DFO.
- **Scenario 4** includes channel alterations for Options 8 and 10. These alterations have the potential to result in a HADD. Once the final design and construction footprint have been developed, a Request for Project Review should be submitted to DFO to determine the likelihood of the project resulting in a HADD. Should DFO determine that the project may result in a HADD, an Offsetting Plan can be developed in consultation with DFO.
- **Scenarios 5a and 5b** include channel alterations in Scenarios 3 and 4. These alterations have the potential to result in a HADD. Once the final design and construction footprint have been developed, a Request for Project Review should be submitted to DFO to determine the likelihood of the project resulting in a HADD. Should DFO determine that the project may result in a HADD, an Offsetting Plan can be developed in consultation with DFO.

Migratory Birds Convention Act, 1994. The Migratory Birds Convention Act (MBCA) was passed in 1917 and updated in 1994. The MBCA protects migratory bird populations by regulating potentially harmful anthropogenic activities. The MBCA (1994) and the Migratory Bird Regulations (MBR) are federal legislative requirements that are binding on members of the public and all levels of government, including federal and provincial governments.

Bird species protected are listed under Article I of the MBCA, and are native or naturally occurring in Canada, and are species that are known to occur regularly in Canada. The legislation protects certain species, controls the harvest of others, and prohibits commercial sale of all species. As described in Section 6 of the associated MBR:

Subject to subsection 5(9), no person shall:

- *Disturb, destroy or take a nest, egg, nest shelter, Eider Duck shelter or duck box of a migratory bird, or*
- *Have in his possession a live migratory bird, or a carcass, skin, nest or egg of a migratory bird except under authority of a permit therefore.*

The “incidental take” of migratory birds and the disturbance, destruction or taking of the nest of a migratory bird is prohibited. “Incidental take” is the killing or harming of migratory birds due to actions, such as economic development, which are not primarily focused on taking migratory birds. No permit can be issued for the incidental take of migratory birds or their nest or eggs as a result of economic activities. These prohibitions apply throughout the year.

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Environment and Climate Change Canada (ECCC) and the Canadian Wildlife Service (CWS) have compiled nesting calendars that show the variation in nesting intensity by habitat type and nesting zone, within broad geographical areas distributed across Canada. While this does not mean nesting birds will not nest outside of these periods, the calendars can be used to greatly reduce the risk of encountering a nest. It is noted that ECCC advises that avoidance is the best approach.

The MBCA applies to all of Canada. As such, the MBCA is applicable to the entire Study Area. Therefore, if a species or their nest, that are listed under the MBCA are encountered during Project works, they must comply with the Act. As vegetation removal is part of future construction works, it is recommended that it occur outside of the core breeding time-period identified by the ECCC which takes place from April 1 to August 31 in any given year for this area. It is important to note, the core breeding time calendar developed by ECCC is a guideline for the peak breeding activity and that the MBCA protects birds year-round.

7.7.2 Provincial

Endangered Species Act, 2007: The Ontario Endangered Species Act, 2007 (ESA) was passed into law in 2007 and came into effect on June 30, 2008. Under the ESA, there are more than 200 species in Ontario that are identified as Extirpated (EXP), Endangered (END), Threatened (THR), or of Special Concern (SC). Section 9 of the ESA generally prohibits the killing or harming of a Threatened or Endangered species. Section 10 of the ESA prohibits the damage or destruction of the habitat of species listed as Endangered and Threatened. Habitat is broadly characterized within the ESA as the area prescribed by a regulation (O. Reg. 242/08) as the habitat of the species or an area on which the species depends directly or indirectly, to carry on its life processes, including reproduction, rearing of young, hibernation, migration or feeding.

Applicability: To better understand the absence/presence of the SAR and their habitats in each of the scenarios, baseline surveys are recommended to refine the potential for species to be utilizing habitats within the impacted areas and if the impacts would trigger a permit. Should potential SAR habitat be identified, then targeted surveys should be conducted to further confirm habitat presence and use by SAR. The results of these surveys will inform the need for the Project to obtain permits under the ESA 2007 and/or its regulatory exemptions under the Act for Threatened/Endangered species. Since the intent of these projects is work that will be completed to protect against flooding, some scenarios may be exempt under Section 23.18 of O.Reg. 242/08.

Should any impacts to SAR habitat be identified during future stages of the project, the project should be reviewed for application of Section 23.18 of O.Reg. 242/08. Should Section 23.18 of O.Reg. 242/08 not be applicable to the project, the results of the surveys along with the proposed project design and construction details, should be submitted to the MECP in an Information Gathering Form (IGF) to confirm permitting requirements.

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Ontario Water Resources Act, 1990 and Environmental Protection Act, 1990: In-water work are required during construction activities, and therefore dewatering may be required to create an isolated dry work area. If dewatering is over 50,000 L/day but under 400,000 L/day a registration on the Environmental Activity and Sector Registry (EASR) system would be required. If dewatering exceeds 400,000 L/day, a Permit to Take Water (PTTW) would be required. Final dewatering rates should be confirmed during detailed design phase of the project.

Any water pumped during dewatering activities will need be discharged to the appropriate area and would require an approval of one or a combination of the following:

- MECP Environmental Compliance Approval (OWRA, Section 53); and/or
- Municipal Discharge Permits.

The need for these permits will be determined during future phases of the project.

Conservation Authorities Act, 1990: The priority areas of the Project do not fall within a regulated area of a conservation authority. Therefore, no permit under Ontario Regulation 166/06 is anticipated.

Lake and Rivers Improvement Act, 1990: The Lake and Rivers Improvement Act (LRIA), originally passed into law in 1927, was revised in 1990 to reflect changes in management philosophies (Stork & Chang, 1990). Under the LRIA, the Minister of Natural Resources and Forestry is given the legislative authority to govern dam design, construction, operation, maintenance, and safety in Ontario (OMNRF, 2017). It is also applicable to channel modifications, including modifications that alter flows and/or water levels (OMNRF, 2017).

Applicability: LRIA approval is required for various works, including works on dams, river channels, and water crossings. Specifically, approval must be obtained to modify a dam to raise water levels, control flooding via the creation of reservoirs, or divert the flow of water (OMNRF, 2017). Channelization also requires LRIA approval when the work takes place outside of a conservation authority and has the potential to adversely impact fish habitat or movement (OMNRF, 2017). To best understand LRIA applicability, the OMNRF recommends submitting an application for review and requesting a scoping meeting so that they are able to review and provide feedback (OMNRF, 2017).

It is anticipated that LRIA approval will be required for every scenario. Once the detailed design phase has progressed to a point where the permanent and temporary construction footprint is known, along with any potential environmental impacts, an application for LRIA approval should be submitted to the MNRF to begin the permitting process.

Fish and Wildlife Conservation Act, 1997: The Fish and Wildlife Conservation Act (FWCA) allows the MNRF to regulate and conserve fish and wildlife within Ontario. Under the FWCA, licenses and permits can be issued for the collection of fish and wildlife for various uses including sustenance and scientific studies.

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Applicability: Project that require work areas to be isolated from water or surrounding habitats will require that fish and wildlife trapped within the work area be captured and released unharmed into habitat outside of the work area. This work will likely be required for many of the scenarios. Once construction has been scheduled, applications for a License to Collect Fish for Scientific Purposes and/or a Wildlife Collector's Permit should be submitted to the MNRF for review and approval prior to starting construction.

7.7.3 Municipal

Upper and Lower-Tier Municipal Tree By-Laws: In the event the project requires the removal or injury of trees, the local municipal tree by-laws should be reviewed to confirm tree permitting requirements.

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8. Capital Cost Estimates and Construction Schedule

A Class 5[2] conceptual screening cost estimate for each of the flood risk mitigation options summarized in this report is presented in Table 8-1. The total cost includes construction, engineering[3], and contingency. These order of magnitude estimates were informed by the concept designs illustrated in Appendix B are considered to have an accuracy range of +100/-50%.

- As per standard industry practice, as well as historical data from Hatch's experience, a contingency of 30% of total construction costs was included to account for design uncertainties at this level.
- Engineering costs were estimated as a percentage of the construction cost. This percentage varied to account for the specific nature of work with consideration for quantities and schedule duration. Engineering costs included site data collection (e.g., topographic and bathymetric surveys), preliminary and final design, preparation of tender documents, preparation of design drawings, procurement, review of contractor's submissions in regard to technical compliance, on-site monitoring of contractors' activities and quality plan.

8.1 General Exclusions

The following elements are excluded from the provided estimates:

- Estimated duration of potential for work stoppage of any kind
- Cost escalation
- Risk allowance
- Bonding and insurances
- Owner's costs and reserves
- Goods and services tax (GST), sales tax and import duties unless specifically included
- Schedule acceleration costs
- Schedule delays and associated costs, such as those caused by unexpected site conditions, unidentified ground conditions, labour disputes
- Force majeure.

[2] AACEI Cost Estimate Classification System Guidelines

[3] Includes all phases of Project Lifecycle Process (see Section 10) including preliminary engineering design costs described in Table **10-1** .

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Table 8-1: Class 5 Capital Cost Estimates for Select Options

Option		Schedule[2] (Months)	Cost (CAD $ 2022)				
			Construction	Engineering	Subtotal	Contingency	Total
Option 1 (Distress Dam)		36	$29,700,000	$2,970,000	$32,670,000	$8,910,000	$41,580,000
Option 2 (Berm)		4	$1,000,000	$200,000	$1,200,000	$300,000	$1,500,000
Option 3 (Brunel Locks)		N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Option 4 (High Falls)		6	$7,000,000	$700,000	$7,700,000	$2,100,000	$9,800,000
Option 5 (May Chutes)		56	$35,800,000	$1,790,000	$37,590,000	$10,740,000	$48,330,000
Option 6 (Rocky Rapids)		56	$35,200,000	$1,760,000	$36,960,000	$10,560,000	$47,520,000
Option 7 (Matthias GS)		N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Option 8[3] (Wallis Cut)	Excavation	11	$4,900,000	$490,000	$5,390,000	$1,470,000	$6,860,000
	Realign Rail bridge	12	$8,560,000	$490,000	$9,050,000	$2,568,000	$11,618,000
Option 9 (Bala Dam)		2	$300,000	$100,000	$400,000	$90,000	$490,000
Option 10 (Moon Chutes)		40	$23,600,000	$1,180,000	$24,780,000	$7,080,000	$31,860,000

Notes:
1. N/A = no costs are associated with this option
2. Excludes shutdowns or work stoppage of any kind.
3. If the rail bridge must be realigned, then total cost for Option 8 includes both riverbed excavation and rail realignment.

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8.2 General Assumptions

General assumptions and inclusions adopted for, and limitations associated with, the cost estimate include the following:

- For all options, the work schedule was assumed to be 5 days per week, with 8-hour shifts
- Adequate workforce of skilled laborers and construction material available during construction work.

8.3 Specific Option Considerations

- Option 1 (Distress Dam) – Construction sequence was assumed to include the following major steps:
  - Excavate bypass channel (assumed to be 10 m deep and 10 m wide) between the existing Distress Dam and the new dam site to allow river water to flow around the location of the concrete spill structure.
  - Build bottom portion (substructure) of concrete spillway structure.
  - Realign bypass channel to allow river water to flow in natural channel and over the partially completed spillway (sub) structure.
  - Build embankments and concrete spillway superstructure.

    All excavation was assumed to be in rock. Embankment material for the dam was assumed to be locally available. Distress Dam Road was assumed to be sufficient to serve as a construction access road. A 250 m road extension starting at the existing Distress Dam and terminating at the new dam site was included to provide construction access to the new site.
- Option 2 (Berm) includes clearing, grubbing, and grading. No additional components, such as sheet piles, were assumed to be necessary as part of design/construction. Sourcing of the flood wall barrier was assumed to be in Ontario. Quantities for formwork, rebar, concrete, anchors, and steel supports for the flood wall were estimated based on drawings provided by the supplier.
- Construction estimates for Option 4 (High Falls) include dewatering of the site, demolition of specified existing concrete sections from barges, as well as excavation for footings. Some of the work was assumed to be done underwater, and mobilization for specialized divers was included. Coring for the installation of dowels and anchors between the existing and new concrete sections are included as well, as are formwork, rebar, concrete, as was backfilling new foundations and patching and finishing concrete surfaces. Proposed bladder gates and necessary mechanical and electrical work have been included.
- Options 5 (May Chutes), 6 (Rocky Rapids), 8 (Wallis Cut) and 10 (Moon Chutes) – Limited information was available for road construction and location where needed.

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Possible construction access routes were assumed for each option and the length was scaled from maps/drawings. Costs included clearing and grubbing, backfilling, grading, and landscaping for these access roads.

- Option 9 (Bala Dam) – Construction access were assumed to not be required.
- All excavations for Options 5, 6, 8, 9, and 10 were assumed to be in rock. The rock excavation will require drilling and blasting, followed by removal by excavator onto barges. Costs associated with transporting excavated rock off-site were based on 75 km haul distance. Recovery cost of saleable material was not included in the estimates. Silt curtains and blast curtains were assumed to be required for minimizing environmental impacts caused by excavation. Given this method of removal, quantities for coffer dams are not included in provided estimates but an alternate method of removal could be considered in subsequent stages of study.
- Option 8 (Wallis Cut) – This option requires excavating within the vicinity of the rail bridge supports. Drilling and blasting near these supports could pose a risk to the stability of these supports and its foundation. The information available during this study prohibited an estimate of the potential success of employing stability schemes as part of the Construction. Should stability techniques be inadequate to ensure the bridge supports are not compromised, consideration must be given to a realignment of the rail bridge to a new location. Acknowledging the uncertainty associated with ensuring stable bridge supports at the existing bridge during construction, a cost estimate was generated for moving the bridge prior to excavating Wallis Cut, explicitly included in Table 8-1 as a portion of the total cost associated with Option 8.

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9. Potential Funding Sources

Municipalities often face challenges in meeting their constituents' needs for investment in many types of critical infrastructure and programs. This section identifies select funding tools to facilitate the implementation of the structural mitigation measures conceived as part of this Project. In all, five potential sources of funding (two federal sources, two provincial sources, and one private source) were identified. Grouping the funding tools will enable DMM to coordinate and prioritize key stakeholders that may be willing to provide political or monetary support more readily. The completion of the analysis of the six scenarios listed above will serve as a basis for the decision-making process towards achieving flood risk reduction and will help justify funding for the implementation of the flood mitigation options selected during future phases of the project. The following sections describe funding sources that were reviewed and their applicability to the flood mitigation options summarized herein.

9.1 Funding and Financing Approaches

To hone the Municipality's ability to secure funds and financing for the proposed flood mitigations described above, this section summarizes three categories of major funding and financing tools: Federal, Provincial, and Public-Private Partnerships. Grouping the tools enables the Municipality to coordinate and prioritize key stakeholders that could be willing to provide monetary, political, or other support for implementation more readily.

9.1.1 Federal Funding Opportunities

The following sections provide an overview of the eligibility requirements and application processes for potential federal funding sources that may apply to the proposed flood mitigation options described above.

9.1.1.1 National Disaster Mitigation Program

The Canadian National Disaster Mitigation Program (NDMP) was developed by the Ministry of Public Safety and Emergency Preparedness with the intention of reducing the impact of natural disasters by investing in areas with significant, recurring flood risk and costs, and advancing work to facilitate private residential insurance for overland flooding. Muskoka was previously approved for funding under the NDMP for the District flood plain mapping in 2021.

Stream 4 of the NDMP funding applies to the proposed flood mitigation options, as it includes investments in small scale structural mitigation projects. These projects must improve flood resilience by proactively preventing or mitigating damages and losses. Other funding streams available under the NDMP include risk assessments, flood mapping, and mitigation planning. The NDMP operates through an (up to) 50% federal and 50% provincial funding model for provinces. If the Municipality chooses to stack additional federal funding programs, the maximum level of assistance from all federal institutions must not exceed 50% of the total eligible project costs for province[4].

[4] Note that the NDMP and DMAF programs cannot be stacked.

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NDMP projects are cost-shared with the provinces by up to 50%. Provincial and territorial governments may collaborate with and redistribute the funding to eligible entities, including municipal/local governments. A separate application must be submitted for each of the options individually. However, confirmation from Public Safety Canada regarding the grouping of projects was pending at the time of publishing this report.

The NDMP funding period closed on March 31, 2022. However, it is expected that a new funding period will be opened in 2023 and DMM should confirm this expectation. It should be noted that for the period of 2021-2022 proposals, only non-structural mitigation projects were being accepted. It is currently not known whether this same limitation will be implemented for the next NDMP application period.

9.1.1.1.1 Eligibility

To be eligible for Stream 4 (described above), applicants must demonstrate that they have completed the tasks described in Streams 1 to 3, including a risk assessment, valid flood map and a mitigation plan for the geographic area of the proposal[5]. Additionally, a risk assessment information template must be completed for the geographic area of the project.

The Merit Criteria Assessment must include the following information:

- Copy of up-to-date NDMP risk assessment information template
- List of community stakeholders who will be engaged in the project implementation process
- Description of how the proposed project aligns with the goals, objectives and key activities identified in the mitigation plan
- Prioritized list of all projects proposed for the Mitigation Program stream.

Small-scale structural mitigation projects will only be considered if the applicant can demonstrate that the project cannot be funded under other existing federal funding programs. Projects that are already funded by the Provincial government or have received funding from another Federal program at any time are not eligible to be funded under the NDMP.

Eligible costs for small-scale structural flood mitigation measures include, but are not limited to, physical measures, such as

- Construction of new permanent structural measures designated to mitigate the impacts of flooding (e.g., channel improvement, floodways and dykes, flow regulation/diversion, creating upstream storage, flood protection measures, reinforcing or raising homes to minimize vulnerability to floods and others)
- Improvement or modernization of existing permanent structural measures

[5] Under certain conditions, the Province may submit non-structural projects for Stream 4 funding without having met the requirements of Streams 1 to 3.

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- Post-flood finishing costs for measures undertaken within the eligible period
- Consultant fees
- Measures taken to protect primary residences only
- Other permanent structural flood mitigation measures and costs related to post-flood finishing measures implemented or undertaken during the eligible time periods.

Additionally, incremental costs incurred by the province that are not part of regulator operating costs including, but are not limited to,

- Exceptional salary costs, benefits, and incidentals
- Exceptional administrative costs
- Materials
- Facilities
- Exceptional transportation costs
- Other costs incurred by provinces or territories that are directly attributed to the implementation of permanent structural and non-structure flood mitigation measures in their respective jurisdictions during the eligible time periods that are not a part of regular operating costs.

The Minister of Public Safety and Emergency Preparedness is the final authority regarding eligibly of costs and expenditures, including amounts of payments made through this program.

9.1.1.1.2 Application Process

Proposals for Stream 4 projects must clearly demonstrate how the applicant has met the requirements of the first three funding streams. Since Stream 4 funding is for the actual implementation of a specific mitigation program, the proposal must include a detailed implementation plan which includes applicable resources, time, costs, agreements, materials, and other factors that will contribute to the completion of the project.

Stream 4 projects are assessed based on the following screening criteria:

- **Risk Rating** – Applicants must complete the risk assessment information template to generate a new risk rating for their proposal area. This rating will be used to assess the highest risk communities which will benefit from the implementation of the project.
- **Stakeholder Engagement** – The proposal should demonstrate the involvement of a diversity of stakeholders who have agreed to participate in the mitigation process.
- **Return on Investment (ROI)** – The application should clearly demonstrate how the project will result in reduced losses due to future natural disaster(s). The ROI may be

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calculated by assessing the cost of damages during the asset life cycle (i.e., biodiversity loss, impact to wildlife, etc.) over the total eligible project costs.

- **Disaster Mitigation Plan Alignment** – The applicant should demonstrate the degree of alignment with their disaster mitigation plan.
- **Provincial Priority Rank** – The province will assign a rank to its disaster mitigation priority projects as part of the NDMP application process.
- **Project Summary** – The proposal should provide a qualitative project summary for each of the criteria listed above.

All NDMP proposals that meet the screening criteria are evaluated by an assessment committee consisting of provincial representatives and officials from federal departments and agencies responsible for emergency management, mitigation, flooding, and other relevant areas. The committee will rank each project in relation to all other projects within the same funding stream. After the committee has ranked the projects, a list of recommended projects (in order of priority ranking) will then be submitted to the Minister of Public Safety and Emergency Preparedness for consideration.

9.1.1.1.3 Program Status

The most recent application period for the April 1, 2021, to March 31, 2022, funding period was closed on January 28, 2021. At this time Hatch cannot confirm that this program will continue with another assessment period. Hatch recommends contacting the Ontario Ministry of Municipal Affairs and Housing to determine if there will be future funding available.

9.1.1.2 Disaster Mitigation and Adaptation Fund

The Disaster Mitigation and Adaptation Fund (DMAF) is a $3.375 billion national merit-based program run by Infrastructure Canada intended to support public infrastructure projects designed to mitigate current and future climate-related risks and disasters triggered by climate change. The DMAF supports Canadian communities wherein a risk of infrastructure failure could result in threats to health and safety; threats to critical infrastructure, including interruptions in essential services; significant disruptions in economic activity; and/or increasingly high costs for recovery and replacement.

As of 2021, the DMAF funding was split between two streams with $670M allocated to small-scale projects (Projects with total eligible costs between $1M to $20M) and the remaining allocated to large-scale projects (Projects with total eligible costs of $20M or more).

The maximum federal contribution from all sources of the total eligible expenditures (including contingencies) for a given project is up to 40% for municipalities. For grouped projects, cost-sharing will be applied based on the owner of the assets in each subproject.

For reference, similar projects which have previously received funding from the DMAF include

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- Flood Mitigation, Control and Improvements in the Junction Creek Watershed
  Canada will help reduce the impacts of flooding for Sudbury residents - Canada.ca;
- Community Flood Mitigation Project for the City of Thunder Bay
  Canada helps Thunder Bay build climate change resilience by reducing the impact of flooding - Canada.ca;
- City of Markham's Flood Control Project
  Canada helps protect communities across the Greater Toronto Area from flooding and storms - Canada.ca;
- Chatham-Kent Flood Mitigation Along Thames & Sydenham Rivers
  Canada helps protect Chatham-Kent from flooding - Canada.ca;
- Improvements for the Downtown Brampton Flood Protection project
  Investing in flood protection for Brampton's historic downtown core - Canada.ca.

9.1.1.2.1 Eligibility

Eligible infrastructure projects under DMAF include construction of public infrastructure and/or modification or reinforcement of existing public infrastructure including natural infrastructure that prevents, mitigates or protects against the impacts of climate change. Projects must be focused on reducing the socio-economic, environmental and cultural impacts triggered by natural hazards and extreme weather events. Natural hazards include erosion and flooding.

Individually, Options 1, 5, 6, and 10 summarized herein (See Section 5) classify as "large-scale" projects based on their projected cost, while the rest classify as small-scale projects. However, this classification may vary depending on how the options are combined as a flood risk mitigation solution.

The minimum eligibility requirements are as follows:

- the organization is an eligible Recipient under the DMAF
- the organization owns or will own the asset(s) or it has, or will have, secured all necessary rights and interest in the asset(s) Infrastructure Canada funds
- the submission is for a project to expand, improve or build new public infrastructure that prevents, mitigates, or protects against the impacts of climate change on Canadian communities, with the exclusion of emergency services infrastructure and man-made disasters
- the total eligible cost for the project is at least $1M
- the project is not solely for land acquisition
- the project will be substantially completed no later than December 31, 2032.

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Applicants eligible to apply for funding include

- A province or territory; or a municipal or regional government established by – or under – provincial or territorial statute.
- A public sector body that is established by – or under – provincial or territorial statute or by regulation; or is wholly-owned by a province, territory, municipal or regional government.
- When working in collaboration with a municipality, a Canadian public or not-for-profit institution that is authorized, under the terms of a Canadian provincial, territorial or federal statute; or Royal Charter, to deliver post-secondary courses or programs that lead to recognized and transferable post-secondary credentials.
- A private sector body, including for-profit organizations and not-for-profit organizations. In the case of for-profit organizations, they will need to work in collaboration with one or more of the entities referred to above or an Indigenous Recipient listed below.

By combining the flood risk mitigation options summarized herein there is potential to promote cumulative benefits that are more effective than the individual benefits associated with each option on their own. As such, under the DMAF program, multiple projects can be grouped together (to include multiple “subprojects”) so long as it can be demonstrated that each of the investments systematically work together as a unit to reduce the same risk within the same period.

For projects which include bundled subprojects, cost-sharing is applied based on the owner of the assets in each subproject. If all the subprojects will be owned entirely by the Municipality, the program will provide a maximum federal contribution of 40% from all sources of the total eligible expenditure.

9.1.1.2.2 Application Process

Prior to applying, the Municipality must ensure that the proposed project meets the minimum eligibility requirements (described in the previous section). The DMAF application form, submitted via the INFC online Application Portal, will assess applications against eligibility and merit criteria, and will help determine potential Indigenous consultation and environment assessment (EA) requirements. The application period typically remains open for 4 to 5 months.

Evaluation of applications is based on the following criterion:

- **Natural Hazard Risk Assessment** – Considers the likelihood of hazard risk and the socio-economic impacts of the hazard risk. Applications should provide quantitative data related to the potential risk which the project intends to mitigate, including the loss of lives/missing people; percentage of people directly affected; percentage of local economic costs; and percentage of population without essential services.

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- **Community Resilience** – The application should demonstrate how the project will result in substantial improvement to the resilience of the community and decrease the potential socio-economic impacts on the populations impacted by the natural hazard risk. It is recommended that the applicant provides studies and/or Indigenous Traditional Knowledge to support claims.
- **Return on Investment (ROI)** – The application should clearly demonstrate how the project will result in reduced losses due to future natural disaster(s). The ROI may be calculated by assessing the cost of damages during the asset life cycle (i.e., biodiversity loss, impact to wildlife, etc) over the total eligible project costs.
- **Innovation** – Demonstrating an innovative solution or approaches to reducing the socio-economic impact of natural hazard risks, such as partnerships, knowledge transfer, natural infrastructure, and innovative management processes to respond to the future effects of climate changes.
- **Natural Hazard Risk Transfer** – The upstream and downstream impacts of the natural hazard risk should be considered in the application.
- **Strategic Alignment** – The project should align with Ontario's and the Municipality's applicable mitigation plans, strategies, frameworks, policies, and related asset management and land-use plans. Noncompliant projects will not be considered.
- **Project Co-Benefits** – Projects which provide compounding benefits to communities are preferred, such as addressing multiple hazards, greenhouse gas reduction, protection of cultural resources, improved recreational opportunities, and employment opportunities.

The application should provide an estimate of the total cost of the project throughout, rounded up to the nearest dollar value, including both eligible and ineligible costs. It should be noted that cost increase or cost overruns will not be covered by the funding, so it is important that contingency is built into this cost estimate.

Once applications have been reviewed, Infrastructure Canada submits recommendations to the Minister of Infrastructure and Communities, and an Approval-in-principal letter will be issued for successful applicants which will include information regarding securing the funding as well as Indigenous consultation and EA requirements, where applicable. If the project is awarded funding, the Municipality will be required to submit regular reports to Infrastructure Canada outlining the implementation progress and financial management. Additionally, eligible recipients will be required to report annually on the Community Employment Benefits, where applicable.

9.1.1.2.3 Program Status

The last application period for the DMAF program closed on October 15, 2021, for large-scale projects and November 15, 2021, for small-scale projects. On November 24, 2022, the Canadian government announced the launch of the National Adaptation Strategy, wherein

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$1.6 billion will be allocated over five years to fund projects which the DMAF in addition to other projects that improve disaster response and protect Canadians from extreme heat and health effects.

9.1.2 Provincial Funding Opportunities

The following sections provide an overview of the eligibility requirements and application processes for potential provincial funding sources that may apply to the proposed flood mitigation options described above.

9.1.2.1 Investing in Canada Infrastructure Program

The Investing in Canada Infrastructure Program (ICIP) is administered through a bilateral agreement with the province of Ontario. The agreement was initially signed in 2016 to invest more than $2 billion in federal funding for the rehabilitation, repair, and modernization of existing infrastructure. In 2018, a second agreement was signed to provide more than $11 billion in federal funding over the next decade for long-term infrastructure projects through four streams: Public Transit Infrastructure, Green Infrastructure, Community, Cultural and Recreational Infrastructure, and Rural and Northern Infrastructure. Through the ICIP, projects are cost-shared with the province, municipalities, Indigenous communities, and other partners to help create healthy and sustainable communities.

9.1.2.1.1 Eligibility

The Green Infrastructure funding stream under the 2018 agreement includes projects that support climate change preparedness, including projects to improve adaptation and resilience to climate change and provide climate-related disaster mitigation. The first intake for the Green Infrastructure stream was in 2021, with Ontario investing more than $40 million and Canada investing more than $100 million under the first intake.

Based on the previously approved projects under the 2021 intake of the Funding Stream, the flood mitigation options which involve the enhancement to existing infrastructure (i.e., retrofitting) or the construction of new infrastructure (i.e., construction of new berm structures) may qualify for the Green Infrastructure funding stream under the ICIP.

9.1.2.1.2 Application Process

To apply for ICIP funds, the Municipality must submit their project to the province for review. The province will prioritize project during the intake period and submit to Infrastructure Canada for review. Once Infrastructure Canada has validated the eligibility, they will seek ministerial approval and funding will begin once costs are incurred.

9.1.2.1.3 Program Status

Provincial intake for the Green Infrastructure funding stream opened on October 25, 2019, and closed January 22, 2020. The next intake period has not yet been disclosed. Currently there are no active projects under review. Hatch is not aware of the start date for the next application period and recommends that former managers of the fund be contacted to determine if there will be future funding available.

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9.1.2.2 Ontario Community Infrastructure Fund

The Ontario Community Infrastructure Fund (OCIF) launched in 2022 to provide funding for small, rural, and northern communities to develop and renew their infrastructure. The purpose of ECIF is to help eligible communities invest in local infrastructure and asset management planning to address their specific priority needs.

In 2022, OCIF provided approximately $400 million to 424 communities across the province for the implementation of core infrastructure projects. The funding scheme is intended to be flexible, allowing municipalities to choose how they use their funds based on the specific needs of their community. This flexibility gives municipalities the ability to accumulate their funding for a period of up to 5 years to address larger infrastructure projects if required. The minimum grant size is $100,000, and municipalities with a higher infrastructure index will be eligible to receive a proportionally larger grant per $100,000 of core infrastructure.

9.1.2.2.1 Eligibility

The following municipalities are eligible for funding under the OCIF:

- Small municipalities (population less than 100,000)
- Northern municipalities
- Rural municipalities.

The population used for grant eligibility is based on 2016 census data for the 2021-2022 grants. Per the 2016 census data Muskoka has an approximate population of 60,599 people, qualifying it under the definition of a “small municipality”. Municipalities in Parry Sound-Muskoka received funding during the 2021 intake of the OCIF program.

This program is intended to contribute to capital expenditures for the construction of core infrastructure projects. Core infrastructure projects include assets which generates income or incur equity, such as toll roads, bridges, and water and wastewater assets (e.g., sanitary and stormwater facilities) that are part of an asset management plan. Some of the proposed structural flooding mitigation measures summarized herein, including the proposed berm at the swing bridge at Huntsville Narrows, addresses a health and safety concern. As such, the Ministry may consider it a core infrastructure project. Additionally, when submitting planning documents (described in the following section), the project must demonstrate that it is consistent with Ontario’s land-use planning framework per applicable provincial and municipal plans.

9.1.2.2.2 Application Process

Municipalities do not need to apply for funding under this program but will be required to provide applicable planning and reporting documents to the Ministry of Infrastructure (MOI) as requested. These documents include, but are not limited to,

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- A comprehensive asset management plan, covering at least core infrastructure assets, and including all the information and analysis described in O. Reg. 588/17: *Asset Management Planning for Municipal Infrastructure*
- A form presenting information on how the funds were or will be used on eligible expenditures
- All other reporting requested by the Ministry
- Annual Financial Information Return (FIR) for their previous years to the Ministry of Municipal Affairs and Housing via Smart FIR.

9.1.2.2.3 Program Status

Funds received by OCIF in 2022 are to be allocated for the period between 2023 and 2026. The next intake period has not yet been disclosed. Currently Hatch is not aware of the start date for the next application period and recommends that former managers of the fund be contacted to determine if there will be future funding available.

9.1.3 Other (Private) Funding Opportunities

The following sections provide an overview of the eligibility requirements and application processes for potential private funding sources that may apply to the proposed flood mitigation options described above.

9.1.3.1 Municipal Climate Resiliency Grants

For over a decade, the Intact Foundation has supported more than 90 projects through the Climate Adaptation Grants program. In 2021, Intact Entities and Intact Financial Corporation (collectively referred to as “Intact”) launched the Municipal Climate Resiliency Grants (MCRG) to help municipalities adapt to the impacts of climate change. Intact invested $1 million in 10 communities across Canada facing challenges related to flooding and wildfire risks, with the goal of increasing community resilience against the impacts of climate change. Intact is willing to fund up to $100,000 toward project costs and prioritizes projects that implement natural infrastructure solutions.

9.1.3.1.1 Eligibility

Intact focuses its investments on projects that increase resiliency against flooding and wildfire related risks. Due to limited funds, only 10 projects out of 144 applicants were accepted for the 2022 grant cycle.

Applications for funding must adhere to the following criteria:

- Be submitted by a municipality within Canada, NGO, Indigenous group, or other public body performing a function of the government of Canada
- Impact a community that is vulnerable to the impacts of flooding and wildfire risks
- Ready to begin implementation within 1 to 2 years of application (“shovel ready”)

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- Support projects that have measurable outcomes and indicators of success
- Support one of the following focus areas:
  - "Shovel ready" natural infrastructure solutions such as culverts, berms, and dykes; natural water management systems; naturalized spaces that reduce water runoff; and planting trees and native plants to improve resiliency
  - Climate mitigation tools
  - Readiness research feasibility assessments
  - Awareness and education
- Support projects that can be scaled across the community
- Only submit one application per municipality
- The grant amount cannot exceed $100,000 (CAD).

Muskoka would be more likely to receive funding for the construction of the berm, as it is identified as a natural infrastructure option. Less complex options that utilize the existing environment may also be considered, such as the channel enlargement proposed at Rock Rapids, Wallis Cut, May Chutes and Moon Chutes.

9.1.3.1.2 Application Process

Applicants must submit the MCRG application form which must include the following information about the project:

- Proof of eligibility
- Contact information
- Organization profile
- Project profile
- Additional projects details, including, but not limited to,
  - The challenge and solution
  - Anticipated start/end date
  - Which of the focus areas is applicable to the project
  - Three defined objectives and the methods of measuring success
  - Capability to be scaled
  - Potential collaborative opportunities with charitable organizations and/or the Intact Centre on Climate Adaptation

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- Describe how Intact could provide labour or skill-based volunteering (remotely)
- Any supporting documentation, including recommendation letters, project budget, etc.

Grant applications go through a three-step process which includes initial screening by a member of the social impact team, secondary screening by a grants review committee, and a final approval by the Intact Foundation. The application should clearly identify which "focus area" it supports and demonstrate the expected timeframe of the project.

9.1.3.1.3 Program Status

The most recent grant cycle was Fall 2022. Intact has not yet disclosed whether another grant cycle will open for this program.

9.2 Funding Summary and Recommendations

Six potential funding sources were identified that could possibly fund some or all of the flood mitigation options summarized herein. These sources include the National Disaster Mitigation Program, the Disaster Mitigation and Adaptation Fund, Investing in Canada Infrastructure Program, Ontario Community Infrastructure Fund, and the Municipal Climate Resiliency Grant program. The following table provides a summary of which flood mitigation options are eligible for each of the funding programs discussed in this report.

Table 9-1 Summary of Project-Specific Funding Eligibility

	Federal		Provincial		Other
Flood Mitigation Options	NDMP	DMAF	ICIP	OCIF	MCRG
1 Retrofit of Control Structure at Distress Dam	✓	✓	✓		
2 Berm Protection near Swing Bridge	✓	✓		✓	✓
3 Increase Fairy Lake Outflow via the Brunel Lift Lock[6]					
4 Retrofit of Control Structure at High Falls	✓	✓	✓		
5 Channel Enlargement at May Chutes	✓	✓			✓
6 Channel Enlargement at Rock Rapids	✓	✓			✓
7 Lower Head Flood Levels at Matthias GS[7]					
8 Channel Enlargement at Wallis Cut	✓	✓			✓
9 Retrofit of Control Structure at Bala South Dam	✓	✓	✓		
10 Channel Enlargement at Moon Chutes	✓	✓			✓

[6] Operational change and not eligible
[7] Operational change and not eligible.

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The information requirements for the funding sources discussed in this section are relatively similar and will require some level of progress in terms of planning and design.
Figure 9-1 provides a high-level 'next steps' guide that will help prepare for the next intake of the funding streams. All six steps provide a fundamental basis that will help frame the project(s) in a way which justifies funding under all five of the programs.

All the funding programs can be stacked except for the two federal funding programs (NDMP and DMAF). Hatch recommends that the District begins compiling applicable technical reports and other information required in preparation for the 2023 intake of the DMAF program as soon as possible. If certain projects are not selected for the DMAF program, Hatch recommends that the District uses the information presented in the DMAF application for the next intake of the NDMP, which requires applicants to demonstrate that they are unable to receive funding from any other federal programs.

As stated in 'Step 1' above, it is highly recommended that the District begin to build a relationship with each of the agencies/organization (if not already done so) and alert them of the initiative, and communicate the alignment of the project(s) (or options) with the goals of each of the respective programs. Hatch has an existing rapport with the federal and provincial agencies and can provide further insight on the best methods of engagement.

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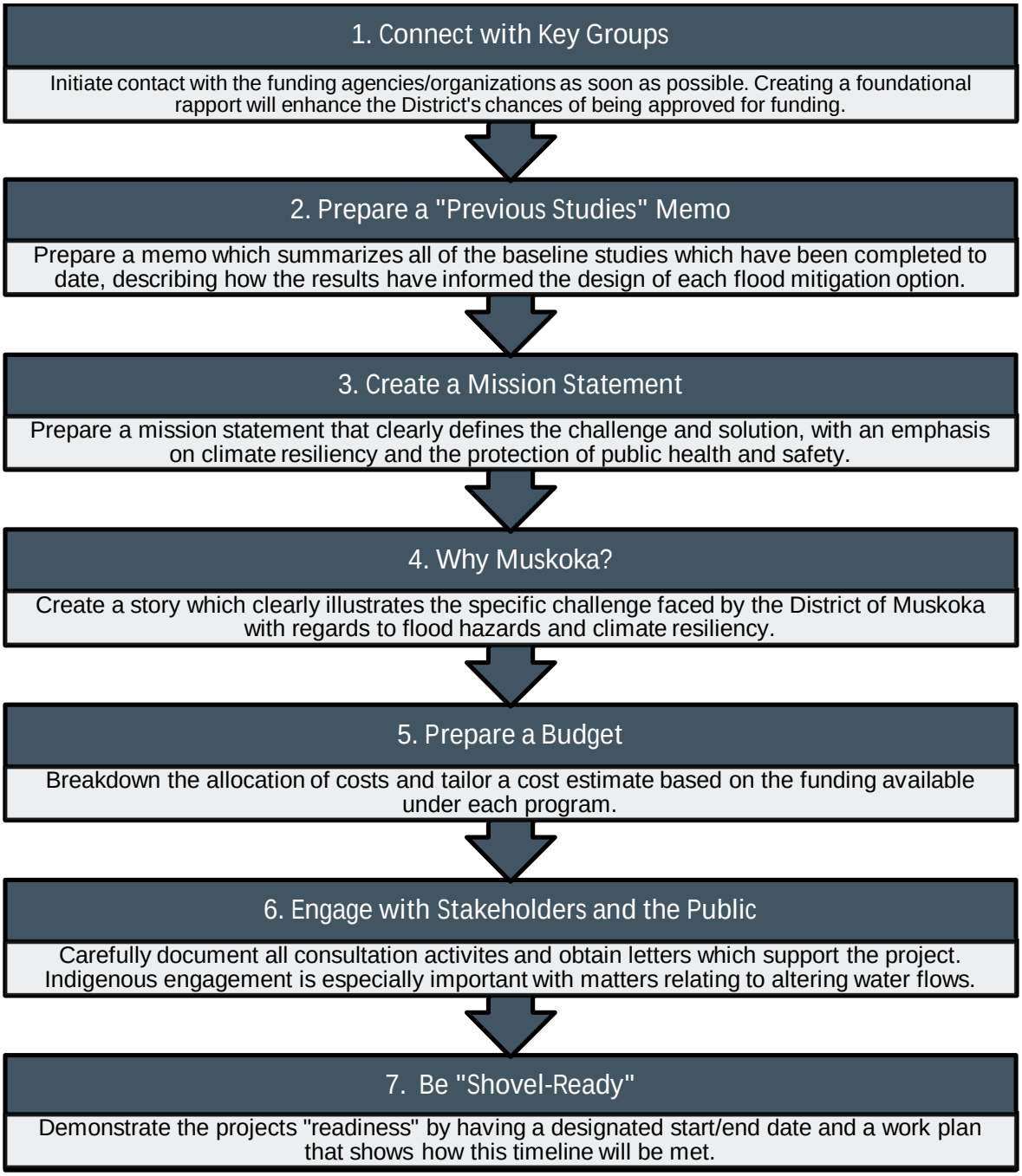

Figure 9-1: Recommended Next Steps for Funding Acquisition

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10. Preliminary Design Scope and Cost Considerations

The Project Life-Cycle Process is a proven internationally recognized project delivery methodology adopted as a best practice by some of the largest and most successful organizations in the world, including Hatch. The process serves to divide project development into four distinct and sequential phases, each with its own specific focus areas and deliverables, and each separated by a Gate Review.

The phases leading up to the execution or construction stage of a project are normally referred to as the "Front End Loading" or FEL Phases of the project, as this is where all the front-end work or planning takes place. Each FEL phase is set-up and executed as one (or more) distinct project(s) which includes its own initiation (context setting), planning (setup), execution, monitoring, and close-out. The close-out is followed by a Gate Review that serves as a check point to determine, using pre-determined criteria, if project objectives can still be achieved. If so, the project will advance to the next FEL phase. These phases are illustrated in Figure 10-1.



Figure 10-1: Front-End Loading (FEL) Stages

A summary of the scope associated with FEL1 and FEL2, which are applicable to this stage of the flood risk mitigation study of the MRW, are defined below.

- FEL1 – Conceptual Study Phase
  - This phase develops and assesses options towards project objectives. In terms of flood risk reduction in the Muskoka River watershed, much of the work executed by DMM to date falls into this phase including the flood plain mapping studies, the Operational Adjustments and Scoping Study[8], the Structural Flood Mitigation Options Study[9], and this Flood Modifications Review Project reported herein.

[8] *Operational Adjustments and Scoping Study for the Muskoka River Water Management Plan*. Phase 1 Report. Hatch, Ltd. August 2022. Phase 2 Report. Hatch, Ltd. November 2022. Doc. No. H367618-0000-2B2-066-0001 and H367618-0000-2B2-066-0002.
[9] *Structural Flood Mitigation Options*. Hatch, Ltd. September 2022.

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- FEL2 – Pre-feasibility Phase
  - This phase proceeds after successfully passing through Gate 1 Review and addresses the viability of selected options. The primary objective of the FEL2 Phase is to follow-up on the recommended options identified in the FEL1 Phase, by advancing options to preliminary engineering level, with the purpose of selecting a single option for project definition. The FEL2 Phase will be the next step in the evaluation, and also validates whether the selected options will achieve intended objectives and, if not, may result in no subsequent phases being actioned.

For each of the flood mitigation options (Section 5), high-level estimates of scope and cost requirements to advance the option to a preliminary engineering design (or FEL2 stage) was derived. These estimates were initially provided in the *Structural Flood Mitigation Options* report (Hatch, 2022f). These estimates have been re-evaluated as part of this report and have been deemed to be still representative of the scope and costs required to advance conceptual options to a preliminary engineering stage.

The general scope requirements for the preliminary engineering design are similar for all options, and include the following activities and tasks:

- Project Management (Project governance, coordination, meetings, and reporting)
- Background Review and Site Visit (Collection and review of pertinent data to better inform the design, followed by a site visit by select team members, where necessary)
- Field Investigation (Collection of site topographic surveys, bathymetric surveys, and/or geotechnical investigations to allow the team to refine the overall construction effort)
- Preliminary Design (Engineering design of each component, including hydrotechnical, structural, geotechnical, and mechanical input)
- Environmental Review (Environmental review, including constraints mapping, species at risk reviews, and permitting input)
- Cost Estimate (Class 3) to support full project funding requests. This cost will be based on refined estimates of material quantities and earthworks requirements
- Stakeholder Engagement (Support to the District in soliciting and managing stakeholder input e.g., public consultation)
- Deliverable Preparation (Preparation of all drawings and a final summary report).

While these major activities will be common to all options, within these general scope requirements there are unique features for each option that require consideration and will influence the cost estimates for individual options. For example, the excavation of Wallis Cut will require a rail study to evaluate potential options for relocation or modification of the existing railway bridge. These unique requirements (discussed throughout Section 5) were

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factored into the initial estimate of costs for preliminary engineering design to the extent possible at this early phase of study. Additionally, these costs (Table **10**-1) were estimated based on perceived design effort; environmental constraints and construction requirements (among other factors). The costs in Table 10-1 are also included as part of Table 8-1.

Table 10-**1: Costs for Preliminary Design Engineering Services**

Flood Mitigation Option	Examples of Unique Project Scope Requirements	Approximated Range of Costs for Preliminary Engineering Services (2022 $CAD)
Option 1: Retrofit of Distress Dam	Dam Classification Study Dam Design Increased permitting effort	400,000 – 600,000
Option 2: Berm Protection near Swing Bridge	Public Impacts Study Architectural Services Dam Safety Review	150,000 – 350,000
Option 3: Increase Fairy Lake Outflows through the Brunel Lift Locks	Public Impacts Study and Operational Review Architectural Services 3D Flow Assessment	100,000 – 200,000
Option 4: Retrofit of Control Structure at High Falls	Obermeyer Gate Design Bathymetric Surveys Hydropower Impacts Study	150,000 – 350,000
Option 5: Channel Enlargement at May Chutes	Public Safety Evaluation Detailed Bathymetric Surveys Low flow Operational Review	200,000 – 400,000
Option 6: Channel Enlargement at Rocky Rapids	Public Safety Evaluation Detailed Bathymetric Surveys Low Flow Operational Review	200,000 – 400,000
Option 7: Lower Head Pond Flood Levels at Matthias GS	Hydropower Impacts Study	50,000 – 100,000
Option 8: Channel Enlargement at Wallis Cut	Public Safety Evaluation Detailed Bathymetric Surveys Rail Impact Study	200,000 – 300,000
Option 9: Retrofit of Control Structure at Bala South Dam	Hydropower Impacts Study Detailed Bathymetric Surveys	100,000 – 200,000

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Flood Mitigation Option	Examples of Unique Project Scope Requirements	Approximated Range of Costs for Preliminary Engineering Services (2022 $CAD)
Option 10: Channel Enlargement at Moon Chutes	Public Safety Evaluation Hydropower Impacts Study Detailed Bathymetric Surveys Alternative Excavation Options Study	300,000 – 400,000

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11. Evaluation Ranking Matrix of Flood Mitigation Options

Flood mitigation options were compared using an evaluation ranking matrix. Qualitative evaluation criteria were defined to help understand the potential challenges, benefits, and risks to each option as associated with their constructability, environmental impact, and flood mitigation performance. A score between 0 and 3 was assigned to each criterion where 0 represents the least favorable and 3 represents the most favorable. The evaluation criteria and levels are summarized in Table 11-1 and consist of the following categories:

- **Cost:** The expected total implementation cost for each option as guided by the cost estimates summarized in Section 8 and Section 10.
- **Potential to Encounter Hurdles for Constructability or Timely Implementation:** Will construction be challenging, or is there potential for relatively long schedules, or delays? Relatively technically challenging projects are more likely to require longer durations to implement. For example, options that require significant in-water work will need various permits which may be preceded by relatively long approval processes prior to work proceeding. Operationally based options will score high in this category because operational changes do not require materials acquisition, construction planning, or other potential challenges specific to construction.
- **Potential for Adverse Local Environmental Impacts:** In this context “local” refers to the associated area. Will the project result in significant local environmental impacts that may need to be mitigated? These impacts may include the potential to generate high Total Suspended Load plumes during construction, affect local fish species or other area wildlife (either in the short-term or the long-term), or to generate water levels lower than historical during non-flood conditions.
- **Net Potential for Adverse Environmental Impacts in the MRW:** Similar to above but on a watershed wide basis (i.e., outside the associated priority area). Can the flood option result in adverse environmental impacts to other areas of the watershed?
- **Potential for Adverse Local Impacts to Residents:** Could local residents suffer unintended affects to option implementation? For example, will the water level be reduced during normal flow periods? Will the option be aesthetically acceptable?
- **Potential for Adverse Effects to Downstream Stakeholders:** Could the project negatively affect downstream stakeholders on the watershed? For example, is it possible the residents downstream from the mitigative option experience higher flows/water levels if storage is reduced on the upstream basin?
- **Effectiveness of Reducing Local Impacts to Flooded Structures:** How effective is the option in reducing flood damage to local structures?
- **Net Effectiveness of Reducing Impacts to Flooded Structures in the MRW:** How effective is the option in reducing flood damage to structures in other areas of the MRW?

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Does it increase, reduce, or result in no change to flood damage in other areas of the watershed?

Every evaluation attribute associated with each flood risk mitigation option was assigned a score. This score was based on the perceived merit of the option being examined relative to the perceived merit of the other nine options. The summation of the attribute scores for each option yielded a total score for that option and, in turn, facilitated that ability to rank the options in terms of overall benefit. A higher total score indicated a potentially more attractive flood mitigation option. The evaluation ranking matrix and resulting scores are presented in Table 11-1. These scores suggest the following, in order of their overall total score:

- Options 2, 3, and 4 all have very similar total scores and appear to be the most attractive options, and also offer the smallest cost per flood mitigated structure. Collectively, these options serve to reduce flood risk on the North Branch and are reasonably cost effective while providing significant local flood relief, particularly in Springdale (as evidenced by the flood analysis associated with Scenario 2). All three options are good candidates for advancement.
- Options 8 and 9, which involve channel improvements at Wallis Cut and immediately in front of the Bala Spillway, were the top ranked options for the Muskoka/Bala Reach. Both options would provide flood relief to Lake Muskoka, which showed a significant drop in flood affected structures in Scenario 4, while promoting little incremental impact to lower reaches. Both options may be good candidates for advancement.
- Option 10, which involves channel improvements at Moon Chute, has a total score just below that of Options 8 and 9. Although the flood relief offered by this option is significant, its cost is also relatively high should in-water excavation be required. As such, this option is considered attractive but less so than Options 8 and 9.
- Option 1, which involves an upgrade of the Distress Dam to better function as a flood management facility, offered the one of the best watershed wide benefits of all options that were considered. However, development of this option is expected to be relatively expensive and will require the most involved construction and regulatory attention. Therefore, this option is also considered attractive but less so than Options 8 and 9.
- Options 5 and 6, which involve very large excavations at strategic locations on the South Branch, all result in relatively low total scores. These excavations require very long construction schedules and were consequently estimated to be expensive. This long schedule enhances the perceived risk of potential environmental impacts. Therefore, Options 5 and 6 appear to be less attractive options compared to the others conceived in this project.
- Option 7, which involves lowering of the headpond at Matthias GS, could be higher if paired with Option 6 (excavation at Rocky Rapids). Lowering the headpond of Matthias GS under flood conditions promotes a limited flood risk reduction between Matthias and

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Rocky Rapids. However, excavation at Rocky Rapids coupled with a lower head pond at Matthias GS significantly reduces flood risk. As such, the relative unattractiveness of Option 6 lowers the perceived attractiveness of Option 7.

- Option 4 and 7 involve reducing head pond levels at two power stations during the spring freshet. This reduction implies lower energy production for the power generators. As such, power generators may need to be compensated for any potential revenue loss associated with this operational modification, or their support may be difficult to obtain.

The foregoing assessment helps to categorize option development attractiveness by river reach. In this case, the order of attractiveness may be the North Branch, followed by the lower watershed, followed by the South Branch. This ranking is based on a relatively sparse dataset with the quality and quantity of reference information inconsistent for each option. This fact facilitated a semi-subjective evaluation of the relative merits of each option. As such, the results presented herein should be regarded as a high-level screening of potential flood risk reduction options and should be revisited once additional data becomes available. Acknowledging that funding is limited, embarking on a data collection exercise that is necessary to advance the next level of study can be guided by the ranking presented herein.

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Table 11-1: Evaluation Ranking Criteria and Levels

Ranking (0 – 3)	Description of Ranking							
	Cost	Potential for Hurdles to Constructability and Timely Implementation	Potential for Adverse Local Environmental Impacts	Net Potential for Adverse Environmental Impacts in the MRW	Potential for Adverse Local Impacts to Residents	Potential for Adverse Effects to Downstream Stakeholders	Effectiveness of Reducing Local Impacts to Flooded Structures	Net Effectiveness of Reducing Impacts to Flooded Structures in the MRW
0	High Cost	High Potential	High Potential	High Potential	High Potential	High Potential	Minimal Effectiveness	Minimal Effectiveness
1	Moderate Cost	Moderate Potential	Moderate Potential	Moderate Potential	Moderate Potential	Moderate Potential	Low Effectiveness	Low Effectiveness
2	Low Cost	Low Potential	Low Potential	Low Potential	Low Potential	Low Potential	Moderate Effectiveness	Moderate Effectiveness
3	Minimal Cost	Minimal Potential	Minimal Potential	Minimal Potential	Minimal Potential	Minimal Potential	High Effectiveness	High Effectiveness

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Table 11-2: Evaluation Ranking Matrix for Flood Mitigation Options in the MRW

MRW Branch	*Option Number*	*Option Descrip.*	Total Score	Ranking (0 – 3; where 3 is the best ranking)							
				Cost	Potential for Hurdles to Constructability and Timely Implementation	Potential for Adverse Local Environmental Impacts	Net Potential for Adverse Environmental Impacts in the MRW	Potential for Adverse Local Impacts to Residents	Potential for Adverse Effects to MRW Stakeholders	Effectiveness of Reducing Local Impacts to Flooded Structures	Net Effectiveness of Reducing Impacts to Flooded Structures in the MRW
North	*4*	*High Falls*	21	2	3	3	3	3	2	3	2
North	*3*	*Brunel Locks*	20	3	3	3	2	3	2	2	2
North	*2*	*Huntsville Berm*	19	3	3	3	3	2	3	2	0
Lower	*9*	*Bala Dam*	17	3	2	2	2	3	3	2	2
South	*7*	*Matthias*	17	3	3	3	3	3	2	0	0
Lower	*8*	*Wallis Cut*	16	2	1	2	2	3	3	3	2
Lower	*10*	*Moon Chute*	16	1	1	1	2	3	3	3	2
North	*1*	*Distress Dam*	15	1	0	1	2	2	3	3	3
South	*6*	*Rocky Rapids*	9	0	1	1	2	1	1	2	1
South	*5*	*May Chutes*	8	0	1	1	2	1	1	2	1

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12. Summary and Future Work

Ten flood risk mitigation options were identified in a previous study titled *Structural Flood Mitigation Options* (Hatch, 2022f). These ten options were evaluated for their effectiveness within a local context relative to five priority areas collectively identified by DMM, the Technical Working Group, and Hatch. These priority areas included Big East River, Huntsville, Springdale, Baysville/Fraserburg/Purbrook, and Bala/Lake Muskoka.

The study reported herein served to refine these 10 options and produce concept level designs and costs[10] for implementation. These options were combined, in various ways, to examine their potential effectiveness to reduce flood risk from a watershed perspective. Six flood risk reduction scenarios were conceived and evaluated to determine their merits (relative to Base Case conditions) in terms of flood inundation area, peak water level, and flood-impacted structures. A ranking matrix was used to summarize and compare the beneficial and detrimental effects and identify a potential path forward toward reducing flood risk in the MRW.

The sections that follow outline key summary points resulting from this project.

12.1 Priority Study Areas and Hydrology

- DMM municipalities are located within the MRW basin, which encompasses a drainage area of 5,100 km². The MRW features three regions – South Branch, North Branch, and Lower Branch – and at least one of the five priority areas is located within each region.
- Hatch, DMM and the IWM Technical Working Group (TWG) collaborated to identify five priority areas within the watershed, based on observational data collected during the 2013 and 2019 flood events and historical knowledge of the watershed. These Priority Areas of Concern include Big East River (North Branch Muskoka River), Huntsville Narrows (North Branch Muskoka River), Springdale (North Branch Muskoka River), Baysville/Fraserburg/Purbrook (South Branch Muskoka River), Muskoka/Bala (Lower Watershed).
- The design flood event adopted for evaluating net impacts in the MRW priority areas, in terms of flood risk, was the flood that occurred in 2019. The 2019 flood event was the governing flood for the majority of the MRW, apart from the North Branch upstream from Fairy Lake.

12.2 Conceptual Design of Flood Mitigation Options

- Conceptual designs of the ten flood mitigation options identified and selected in the *Structural Flood Mitigation Options* study were developed and presented in Appendix B of this report.

[10] Class 5 of the AACE International Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction.

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- A list of recommended studies to advance these options towards a preliminary design stage was also provided. See Section 6.

12.3 Muskoka River Watershed Flood Mitigation Scenarios

Six flood mitigation scenarios were selected by combining any number of the flood mitigation options, as described in this report. The selection for each scenario considered immediate local impacts, magnitude of flood mitigation, and potential impacts to upstream and downstream priority areas.

Impacts to flooding were assessed in each priority area, for each flood mitigation scenario, using hydrologic and hydraulic models adopted from the DMM FPMS (Hatch, 2020; 2022c, 2022d, 2022e) and the *Structural Flood Mitigation Options* study (Hatch, 2022f). These models were used in combination and were modified as needed to achieve study objectives, including updating model boundary conditions.

The concurrent implementation of six different combinations of flood mitigation options resulted in flood reduction in select regions of the MRW and, in the case of implementing all ten flood mitigation options, reduced flooding in all regions of the MRW.

Climate change effects were evaluated to better understand the performance of flood mitigation Scenario 5b in the future. Climate change is expected to reduce peak flows and water levels yet increase the likelihood and severity of mid-winter floods. At the peak flood date, climate change reduced flooding for Scenario 5b.

Future work should be completed to evaluate operational and structural changes that may be required to mitigate potential increases to mid-winter flooding risk.

12.4 Environmental Impact Assessment

- Conduct hydrology studies to determine if the mitigation option will result in habitat impacts under normal flows, including a normal spring freshet and summer low flow conditions.
- Conduct field surveys to confirm presence of species at risk and their habitat in areas where temporary and permanent alterations are required.
- Conduct fish and fish habitat assessments in areas where temporary and permanent changes to fish habitat are required.
- Conduct detailed assessment of impacts based upon permanent and temporary footprints of scenarios.
- Prepare Environmental Impact Assessment Report for project to confirm impacts of the project.

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12.5 Preliminary Design Scope and Cost Considerations

- For each of the flood mitigation options, a refined estimate of costs and scope requirements for preliminary engineering design was derived. These cost and scope requirements considered unique features of all ten options.

12.6 Evaluation Ranking Matrix of Flood Mitigation Scenarios

- Each flood mitigation option design was ranked using mostly qualitative criteria. The ranking matrix was refined and expanded upon, based on the original rankings developed for the *Structural Flood Mitigation Options* workshop (June 24, 2022) with the DMM.
- Evaluation of the ranking matrix helped to categorize prioritize option development relative to river reach. The priority order may be the North Branch, followed by the lower watershed, followed by the South Branch.
- The results derived herein should be regarded as a high-level screening of potential flood risk reduction options and should be revisited once additional data becomes available. Acknowledging that funding is limited, embarking on a data collection exercise that is necessary to advance the next level of study can be guided by the ranking suggested in the bullet above.

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Appendix A
Design Flood Hydrographs

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Design Flood Hydrographs

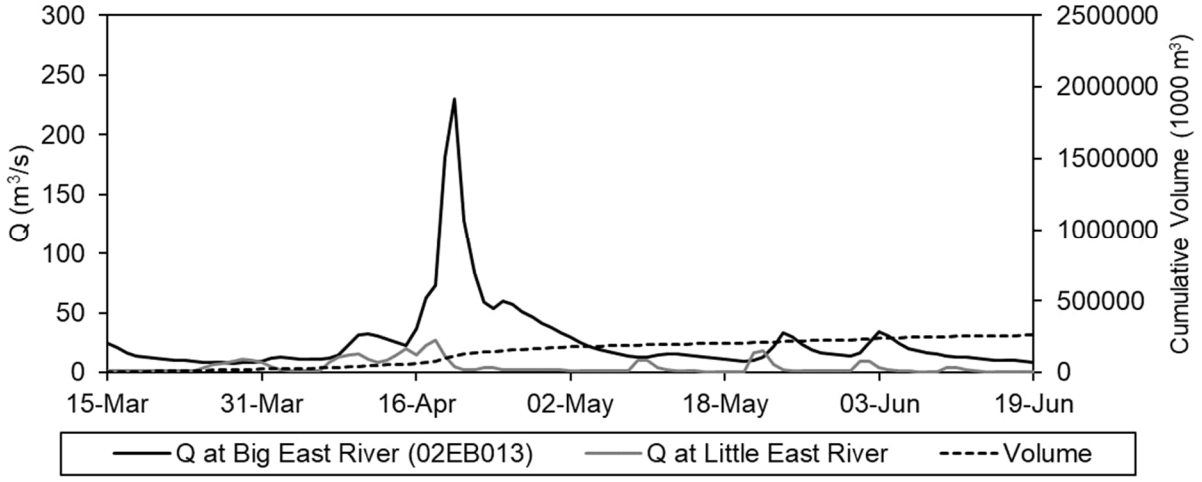

Figure A-1: Design flood hydrographs to the *Upper Big East River* reach (Year 2013)

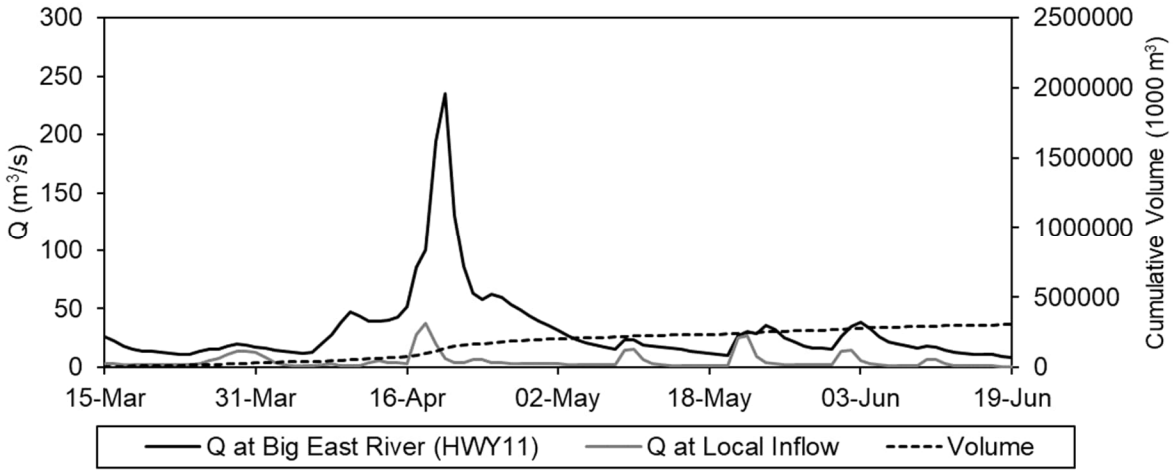

Figure A-2: Design flood hydrographs to the *Lower Big East River* reach (Year 2013)

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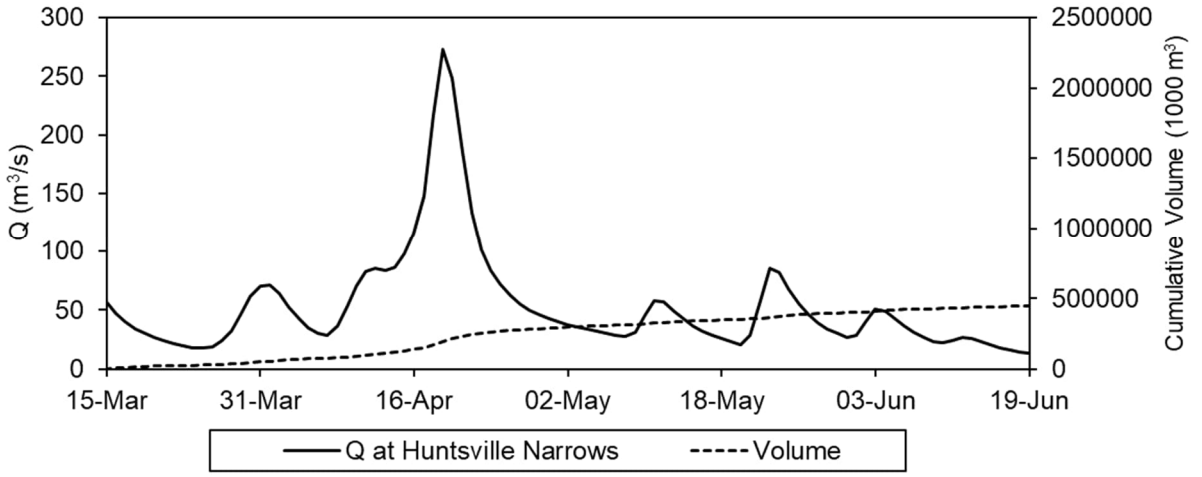

Figure A-3: Design flood hydrograph to the *Huntsville Narrows* reach (Year 2013)

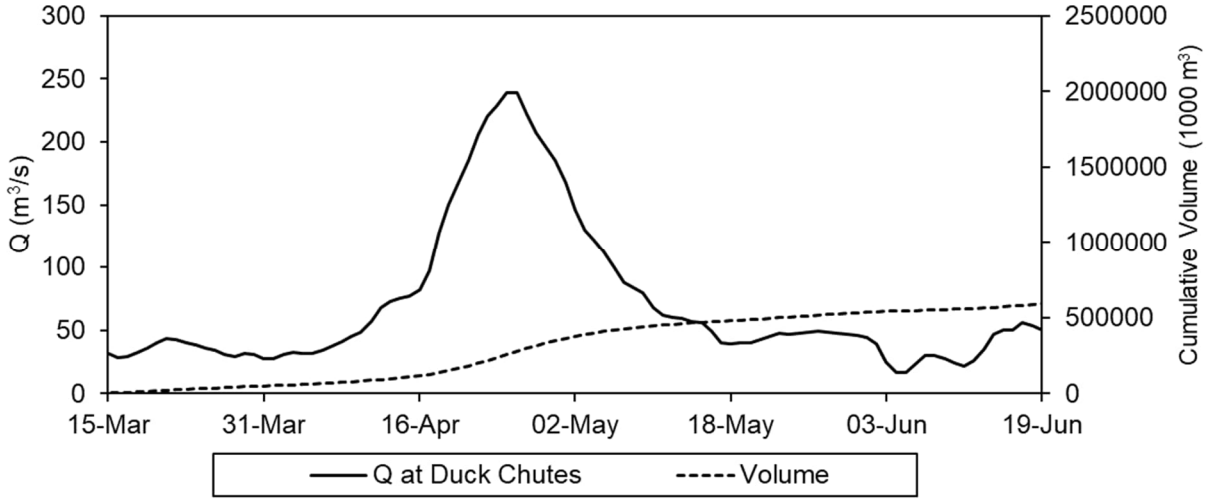

Figure A-4: Design flood hydrograph to the *Springdale* reach (Year 2019)

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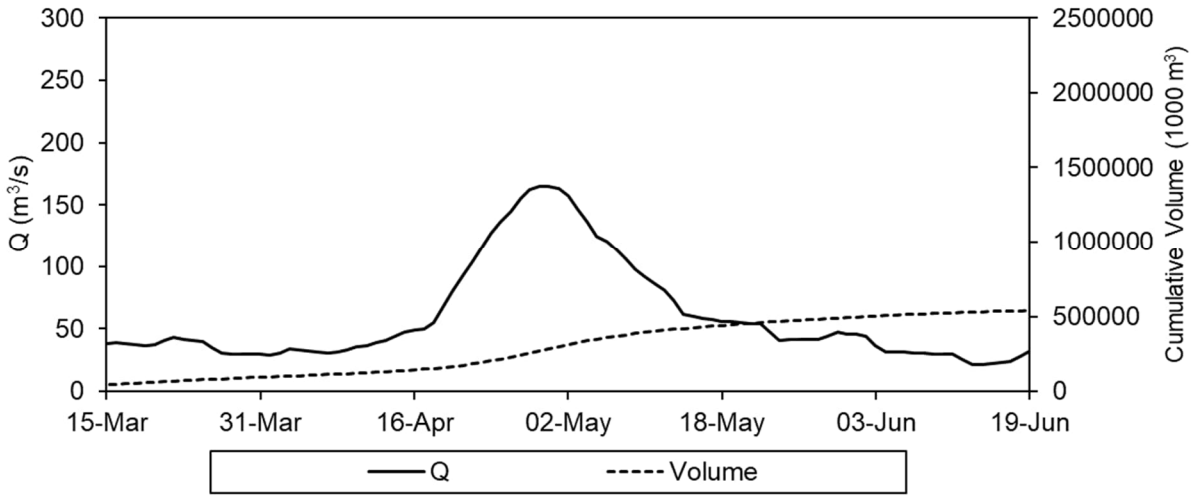

Figure A-5: Design flood hydrograph to the *Baysville* and *Fraserburg* reaches (Year 2019)

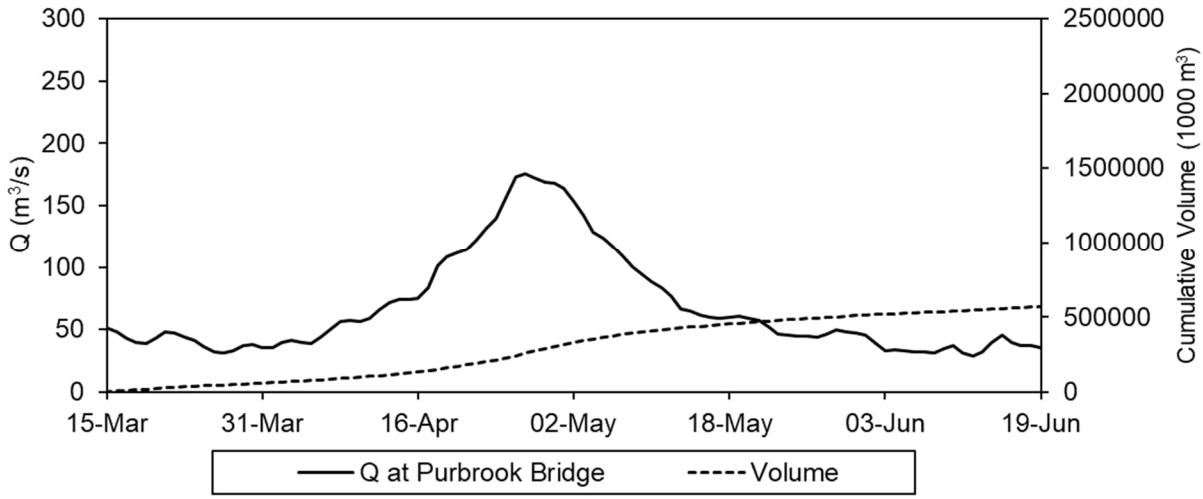

Figure A-6: Design flood hydrograph to the *Purbrook* reach (Year 2019)

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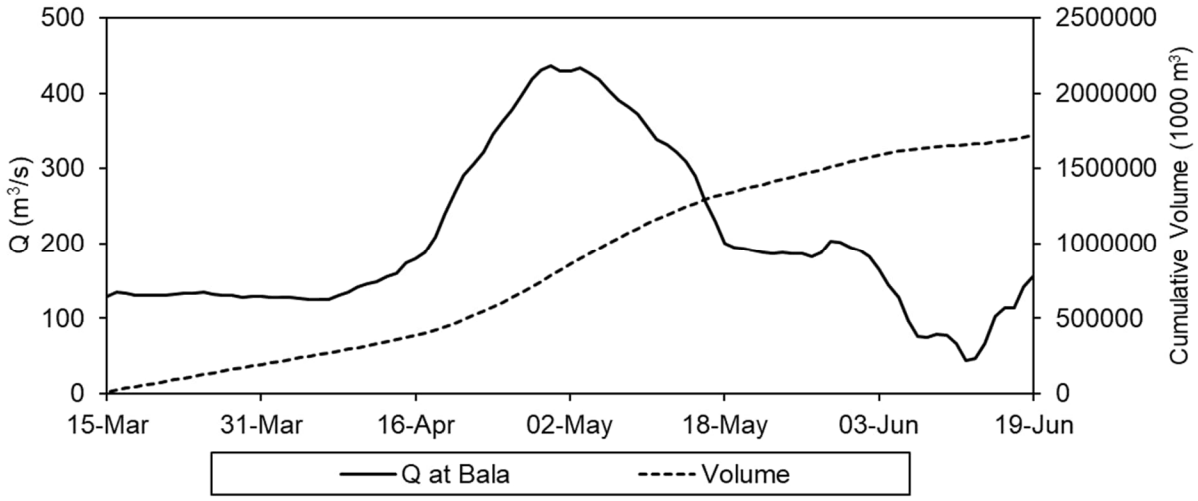

Figure A-7: Design flood hydrograph to the *Muskoka/Bala* reaches (Year 2019)

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Appendix B
Drawings

H367619-0000-220-270-0001: Overall Site Plan
H367619-0000-220-270-0010: Option 1 - Distress Dam Retrofit
H367619-0000-220-270-0020: Option 2 - Huntsville Berm Protection
H367619-0000-220-270-0040: Option 4 - High Falls
H367619-0000-220-270-0050: Option 5 - May Chutes Excavation
H367619-0000-220-270-0060: Option 6 - Rocky Rapids Excavation
H367619-0000-220-270-0080: Option 8 - Wallis Cut Excavation
H367619-0000-220-270-0090: Option 9 - Bala Dam
H367619-0000-220-270-0100: Option 10 - Moon Chute Excavation

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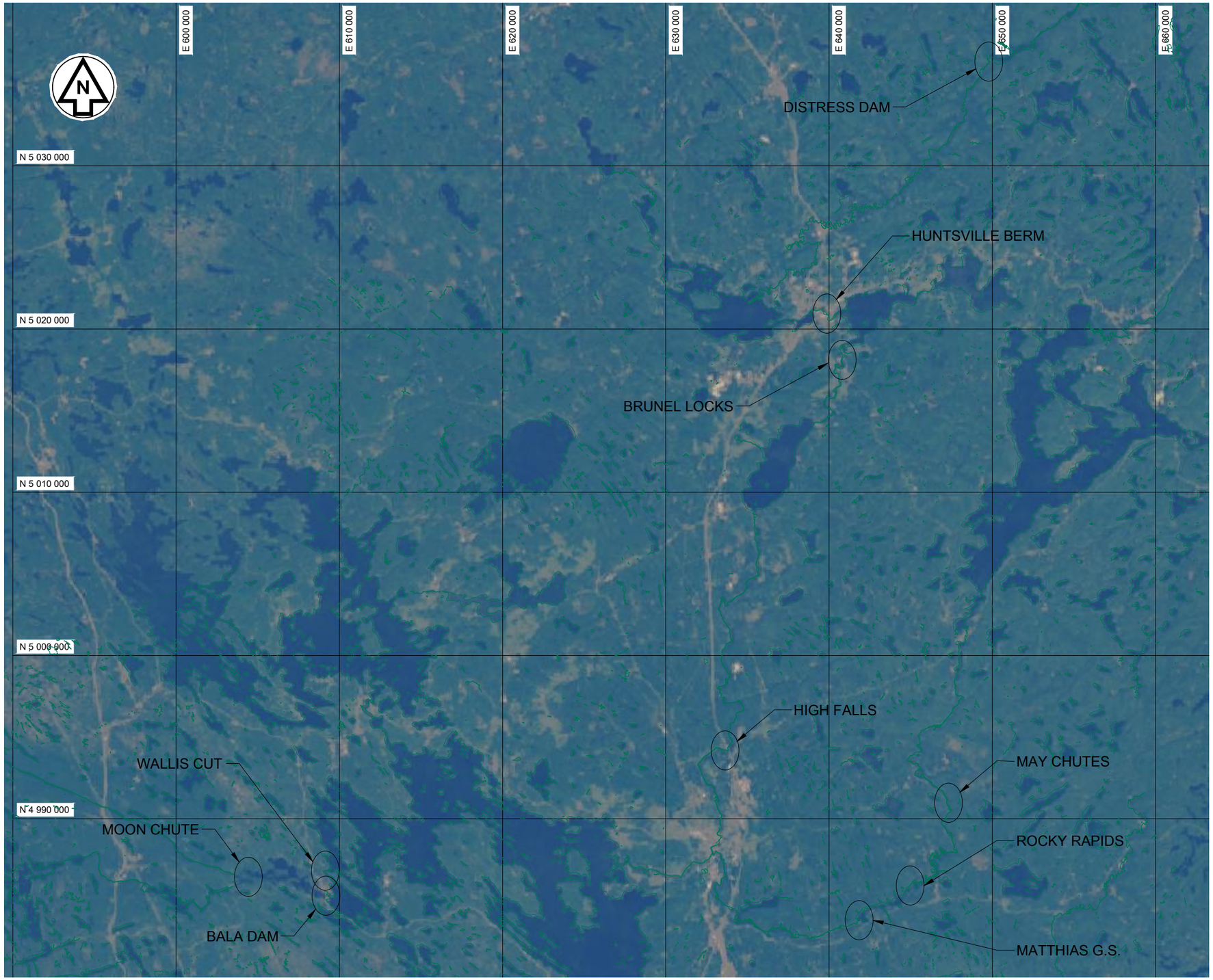

0 2 4 6 8 KM

SCALE: 1:250 000

PRELIMINARY

NOT FOR CONSTRUCTION

Figure No.H367619-0000-220-270-0001

OVERALL PLAN OF FLOOD MITIGATION

SCALE 1:250 000

NOTES:

1. COORDINATES ARE IN UTM NAD 83 ZONE 17.

THE DISTRICT MUNICIPALITY OF MUSKOKA

FLOODS MODIFICATIONS REVIEW

OVERALL SITE PLAN

HATCH

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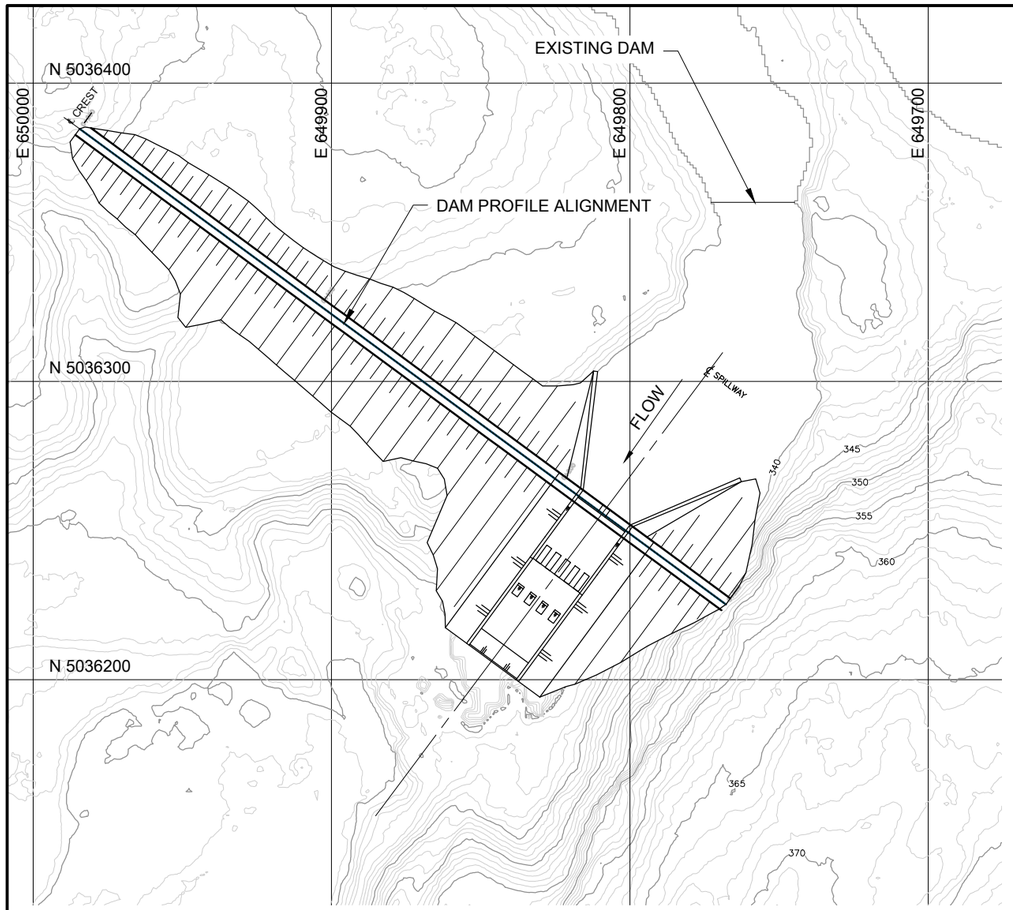
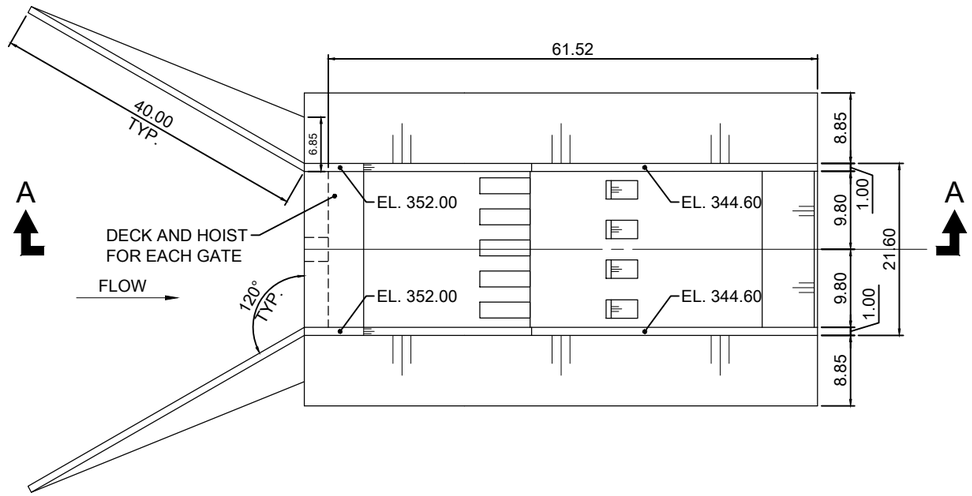


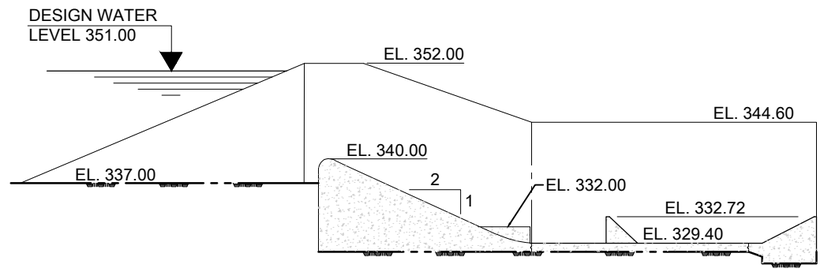
PLAN VIEW OF DISTRESS DAM

SCALE 1:2000



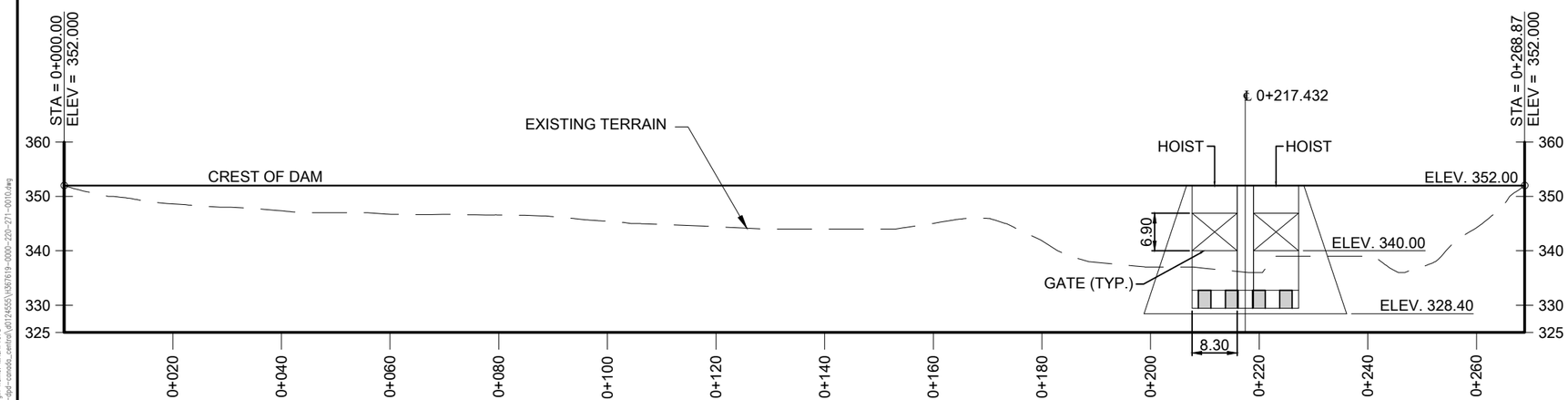
PLAN VIEW OF WING WALLS AND SPILLWAY

SCALE 1:750



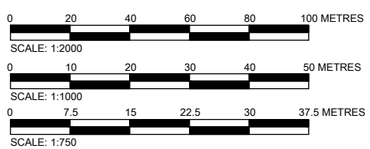
SECTION A-A

SCALE 1:750



PROFILE VIEW - LOOKING UPSTREAM

SCALE 1:1000



NOTES:

1. ALL DIMENSIONS ARE IN METERS.
2. COORDINATES ARE IN UTM NAD 83 ZONE 17.

Figure No. H367619-0000-220-271-0010

THE DISTRICT MUNICIPALITY OF MUSKOKA

FLOOD MODIFICATIONS REVIEW

OPTION 1 - DISTRESS DAM RETROFIT

HATCH

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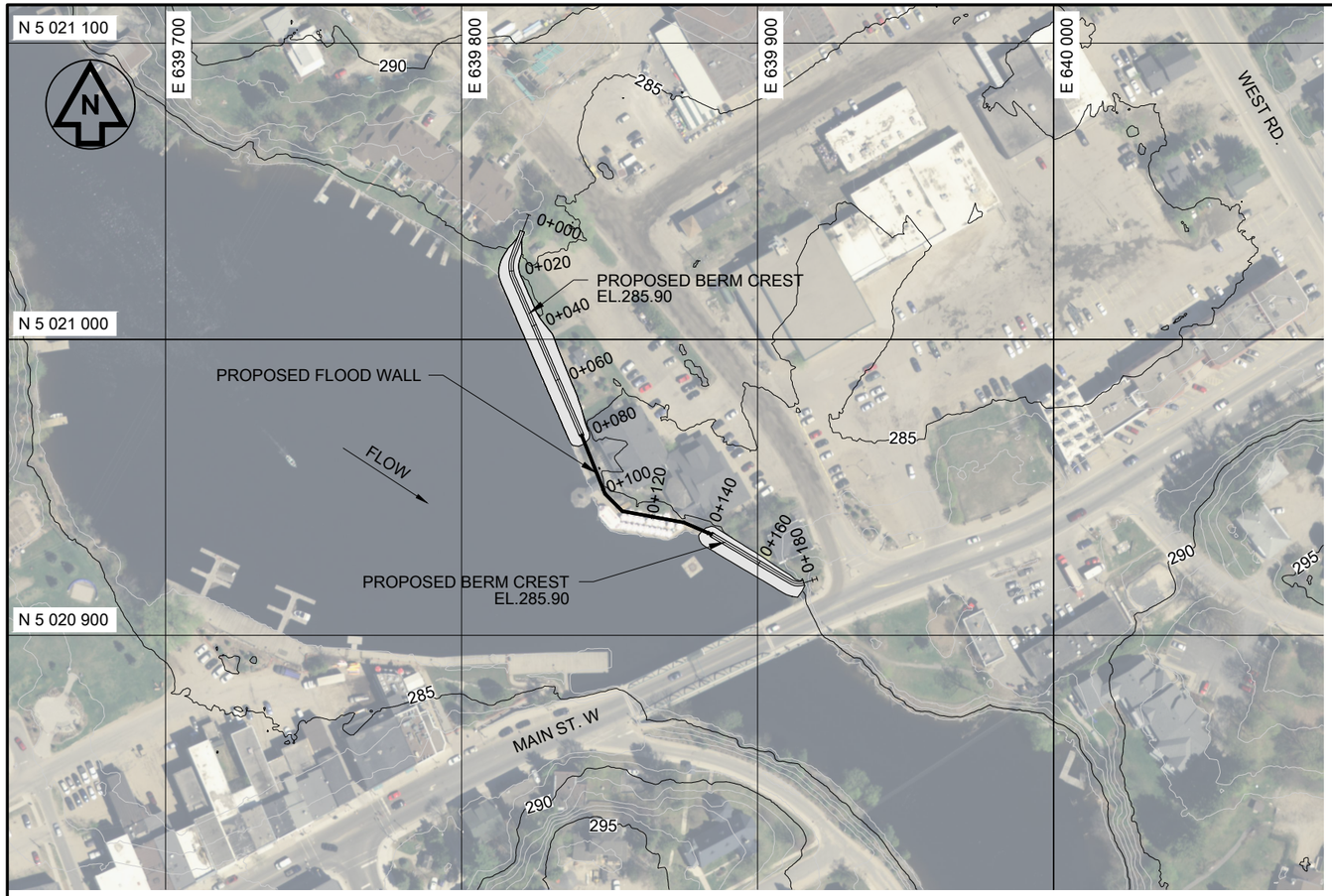


PLAN OF BERM AND FLOOD WALL

SCALE 1:2000



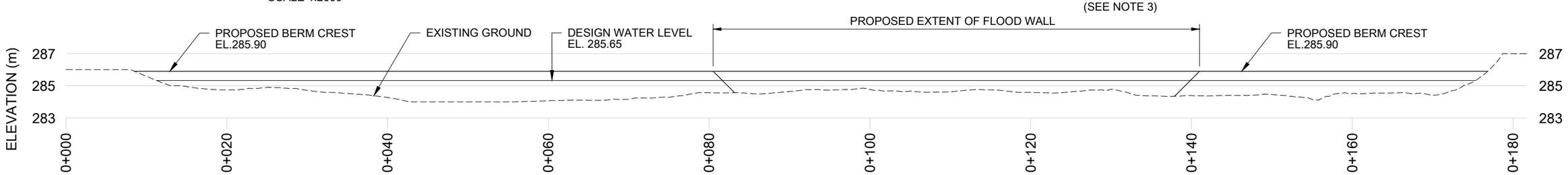
REMOVABLE FLOOD WALL (T.B.D.) - ASSEMBLED

SCALE: N.T.S.
(SEE NOTE 3)



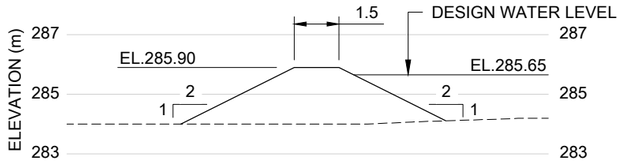
REMOVABLE FLOOD WALL (T.B.D.) - IN ASSEMBLY

SCALE: N.T.S.
(SEE NOTE 3)



PROFILE OF BERM AND FLOOD WALL

SCALE HOR.1:500
SCALE VER.1:250



TYPICAL SECTION OF BERM

SCALE 1:200

0 20 40 60 80 100 METRES
SCALE: 1:2000

0 5 10 15 20 25 METRES
SCALE: 1:500

0 2.5 5 7.5 10 12.5 METRES
SCALE: 1:250

0 2 4 6 8 10 METRES
SCALE: 1:200

NOTES:

1. ALL DIMENSIONS ARE IN METERS.
2. COORDINATES ARE IN UTM NAD 83 ZONE 17.
3. SPECIFIC DESIGN FEATURES OF FLOOD WALL WILL BE DETERMINED IN A FUTURE DESIGN PHASE.

PRELIMINARY
NOT FOR CONSTRUCTION

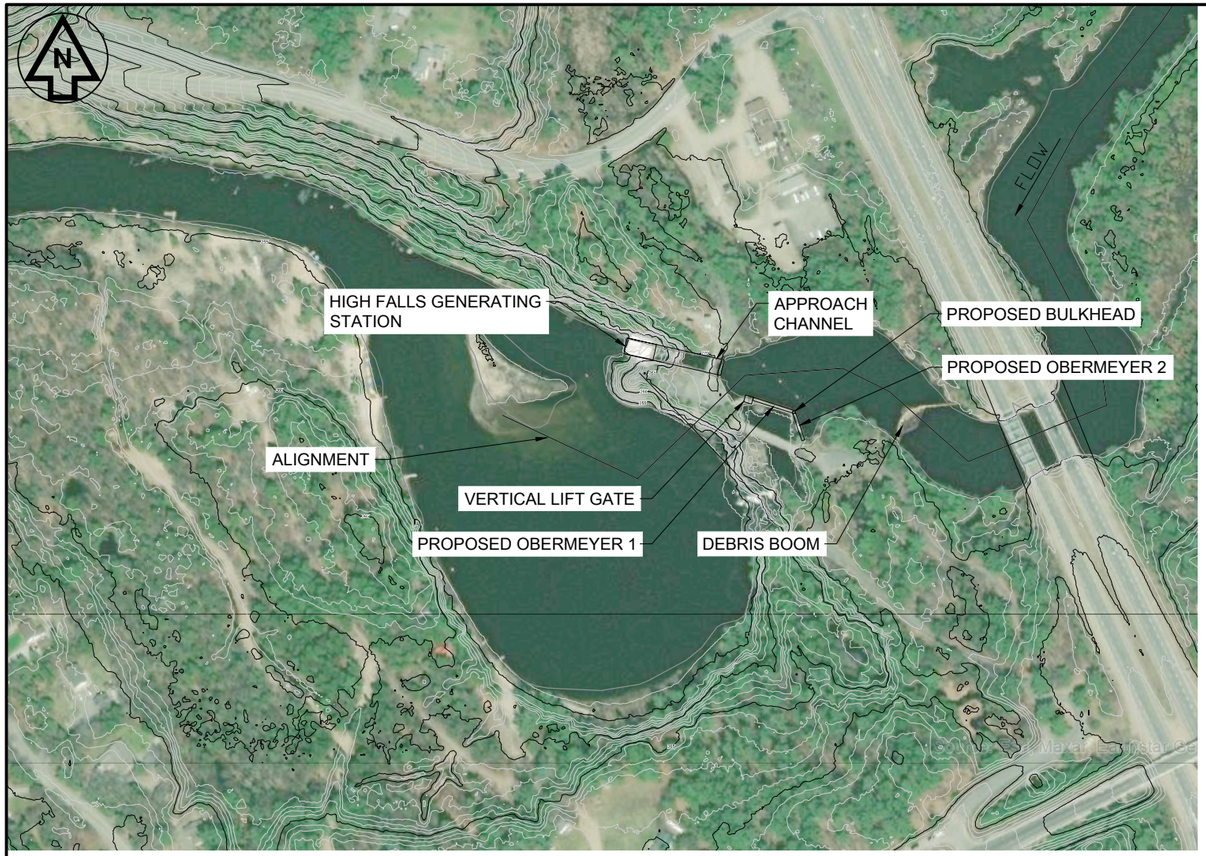
Figure No. H367619-0000-220-271-0020

THE DISTRICT MUNICIPALITY OF MUSKOKA
FLOOD MODIFICATIONS REVIEW

OPTION 2 - HUNTSVILLE BERM PROTECTION

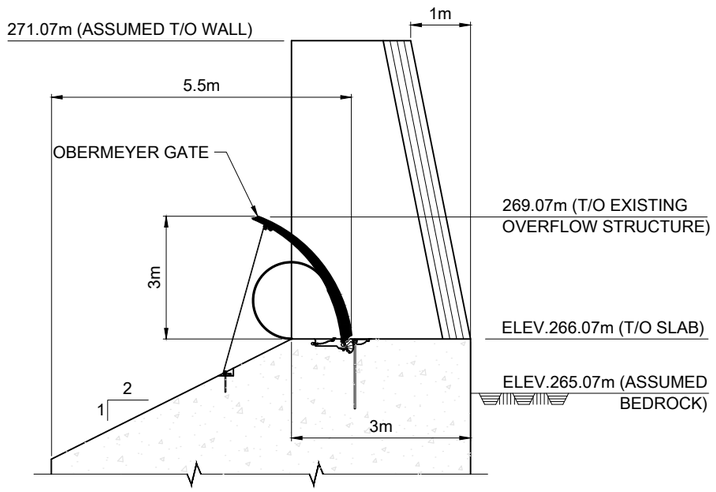
HATCH

Nov 30 , 2022 , 7:07pm Login name: MAQA71078
Drawing Name: C:\pwworking\hatch-dpd-canada_central\d0124555\H367619-0000-220-271-0020.dwg



PLAN OF SPILLWAY, GENERATING STATION AND SURROUNDING AREA

SCALE 1:4000

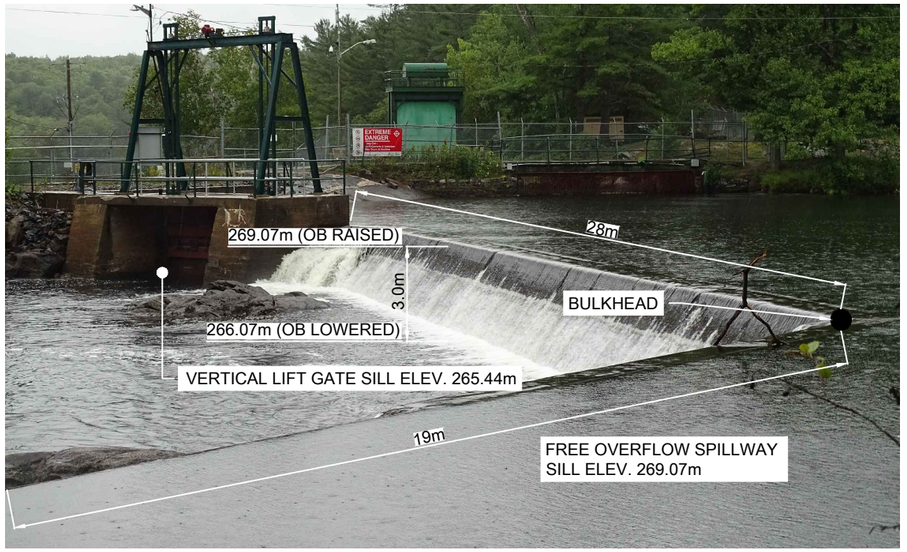


SECTION - PROPOSED OBERMEYER GATE

SCALE: 1:100

NOTES:

1. ALL DIMENSIONS ARE IN METERS.
2. COORDINATES ARE IN UTM NAD 83 ZONE 17.
3. SPECIFIC DESIGN FEATURES OF GATE WILL BE DETERMINED IN A FUTURE DESIGN PHASE.



OVERLAY OF GATE DIMENSIONS ON EXISTING STRUCTURE

SCALE: N.T.S.



TYPICAL OBERMEYER GATE

SCALE: N.T.S.
(SEE NOTE 3)

0 1 2 3 4 5 METRES
SCALE: 1:100

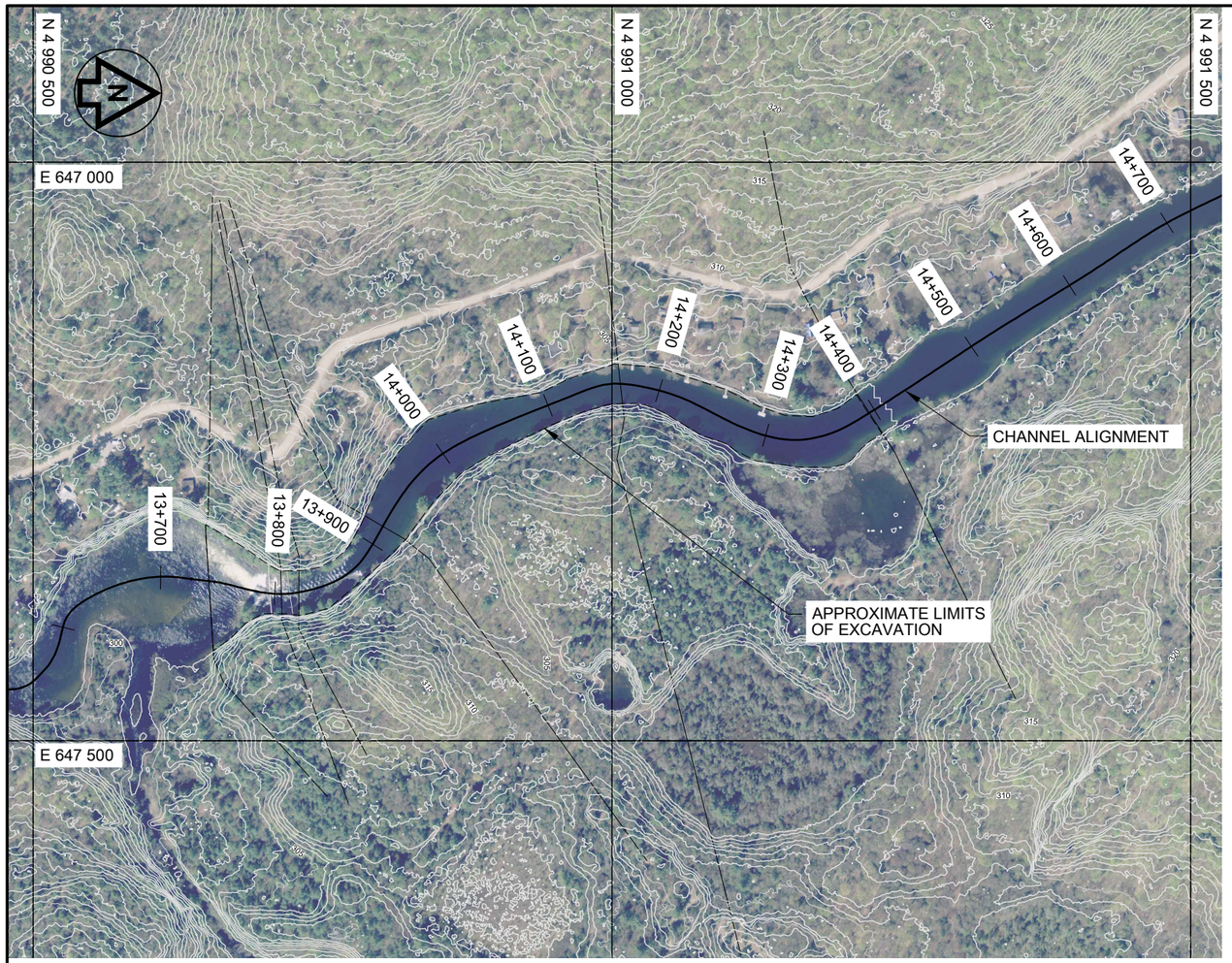
0 40 80 120 160 200 METRES
SCALE: 1:4000

Figure No. H367619-0000-220-271-0040

THE DISTRICT MUNICIPALITY OF MUSKOKA
FLOOD MITIGATIONS REVIEW
OPTION 4 - HIGH FALLS

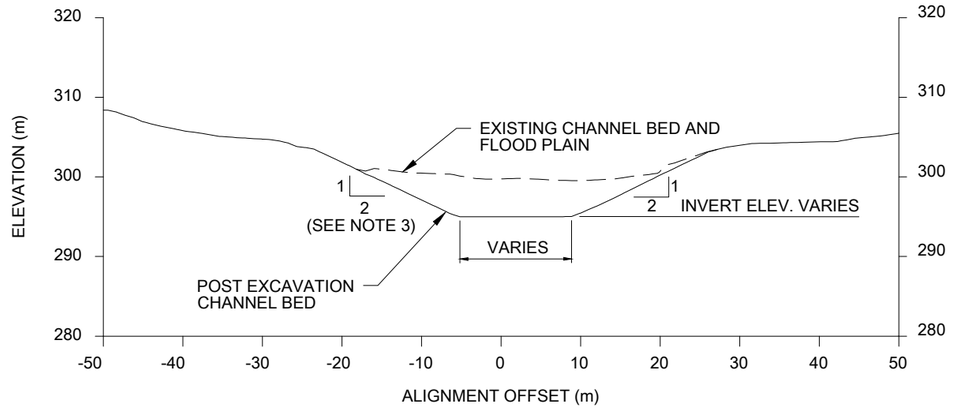
HATCH

Nov 30, 2022 - 7:09pm Login name: MKA71078
Drawing Name: C:\powerdrive\hatch-dept-canada_central\h\d312455\h367619-0000-220-271-0040.dwg



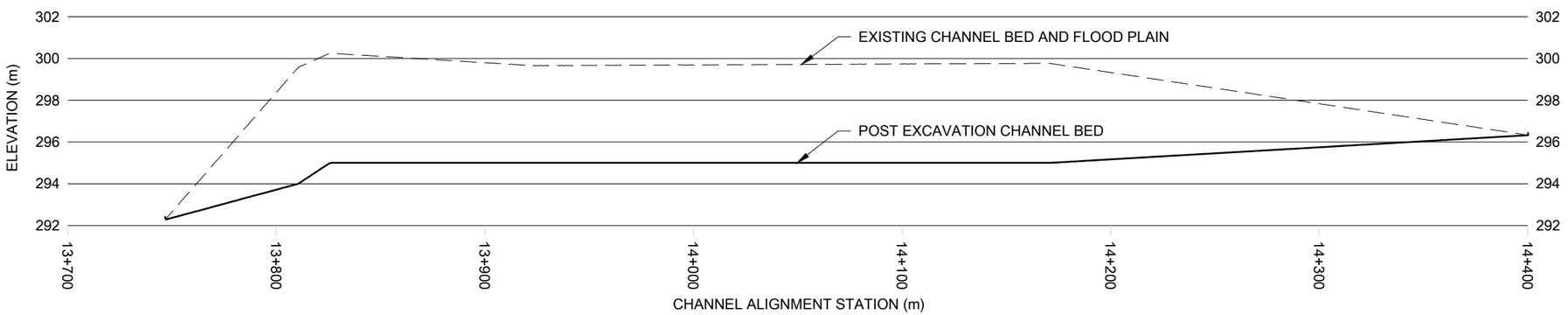
PLAN OF MAY CHUTES

SCALE 1:5000



TYPICAL EXCAVATION SECTION

SCALE 1:750



PROFILE OF MAY CHUTES

SCALE HOR.1:2500
SCALE VER.1:250

NOTES:

1. ALL DIMENSIONS ARE IN METERS.
2. COORDINATES ARE IN UTM NAD 83 ZONE 17.
3. SIDE SLOPES MAY VARY BETWEEN SECTIONS

SCALE: 1:5000
SCALE: 1:2500
SCALE: 1:750
SCALE: 1:250

PRELIMINARY
NOT FOR CONSTRUCTION

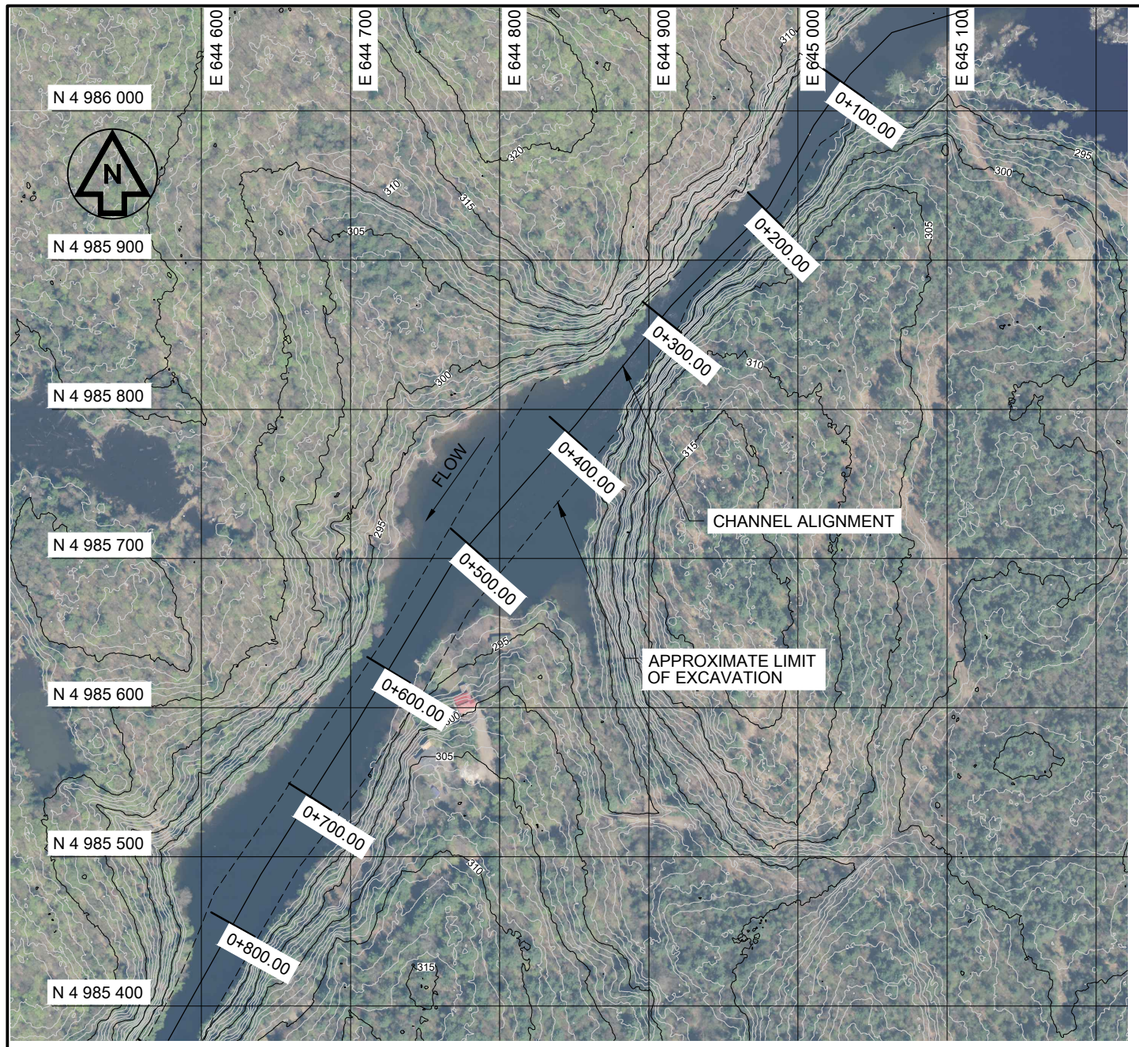
Figure No. H367619-0000-220-271-0050

THE DISTRICT MUNICIPALITY OF MUSKOKA
FLOOD MODIFICATIONS REVIEW

OPTION 5 - MAY CHUTES EXCAVATION

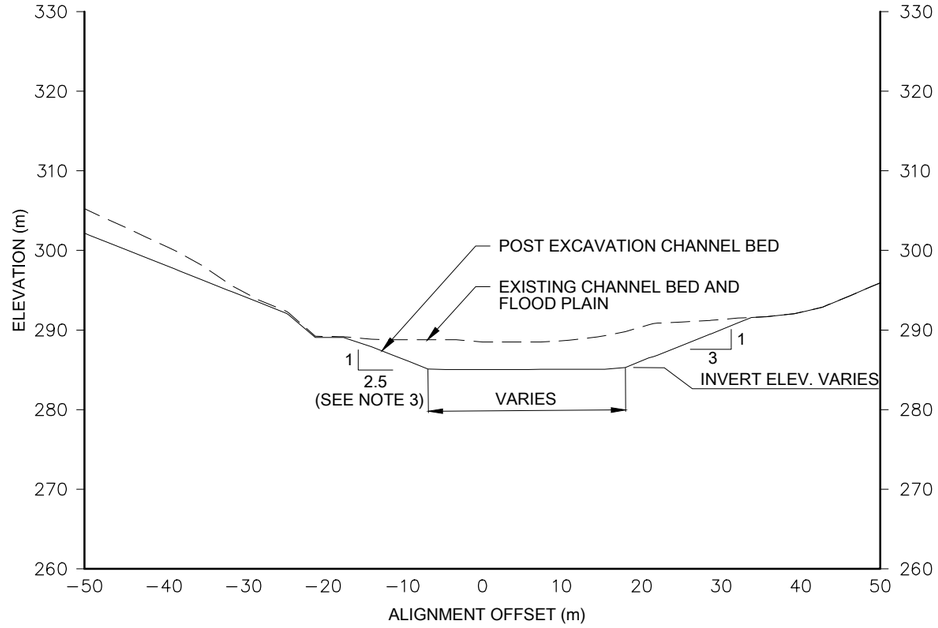
HATCH

Nov 30, 2022 - 4:29pm Login name: MAZ471078
Drawing Name: C:\jawsnking\hatch-dpot-canada_central\d\124555\h367619-0000-220-271-0050.dwg



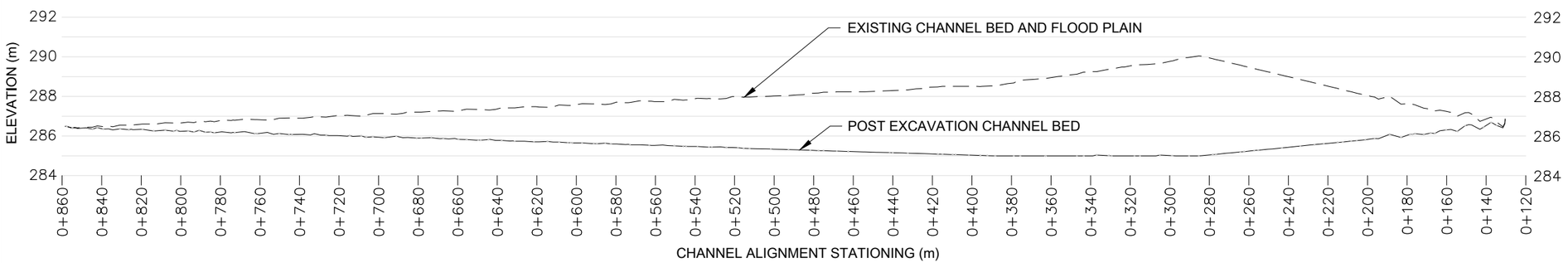
PLAN OF ROCKY RAPIDS EXCAVATION

SCALE 1:4000



TYPICAL SECTION OF EXCAVATION

SCALE 1:750



NOTES:

1. ALL DIMENSIONS ARE IN METERS.
2. COORDINATES ARE IN UTM NAD 83 ZONE 17.
3. SIDE SLOPES MAY VARY BETWEEN SECTIONS

LONGITUDINAL PROFILE OF ROCKY RAPIDS EXCAVATION

SCALE HOR.1:2500
SCALE VER.1:250

0 40 80 120 160 200 METRES
SCALE: 1:4000

0 25 50 75 100 125 METRES
SCALE: 1:2500

0 7.5 15 22.5 30 37.5 METRES
SCALE: 1:750

0 2.5 5 7.5 10 12.5 METRES
SCALE: 1:250

0 2 4 6 8 10 METRES
SCALE: 1:200

PRELIMINARY
NOT FOR CONSTRUCTION

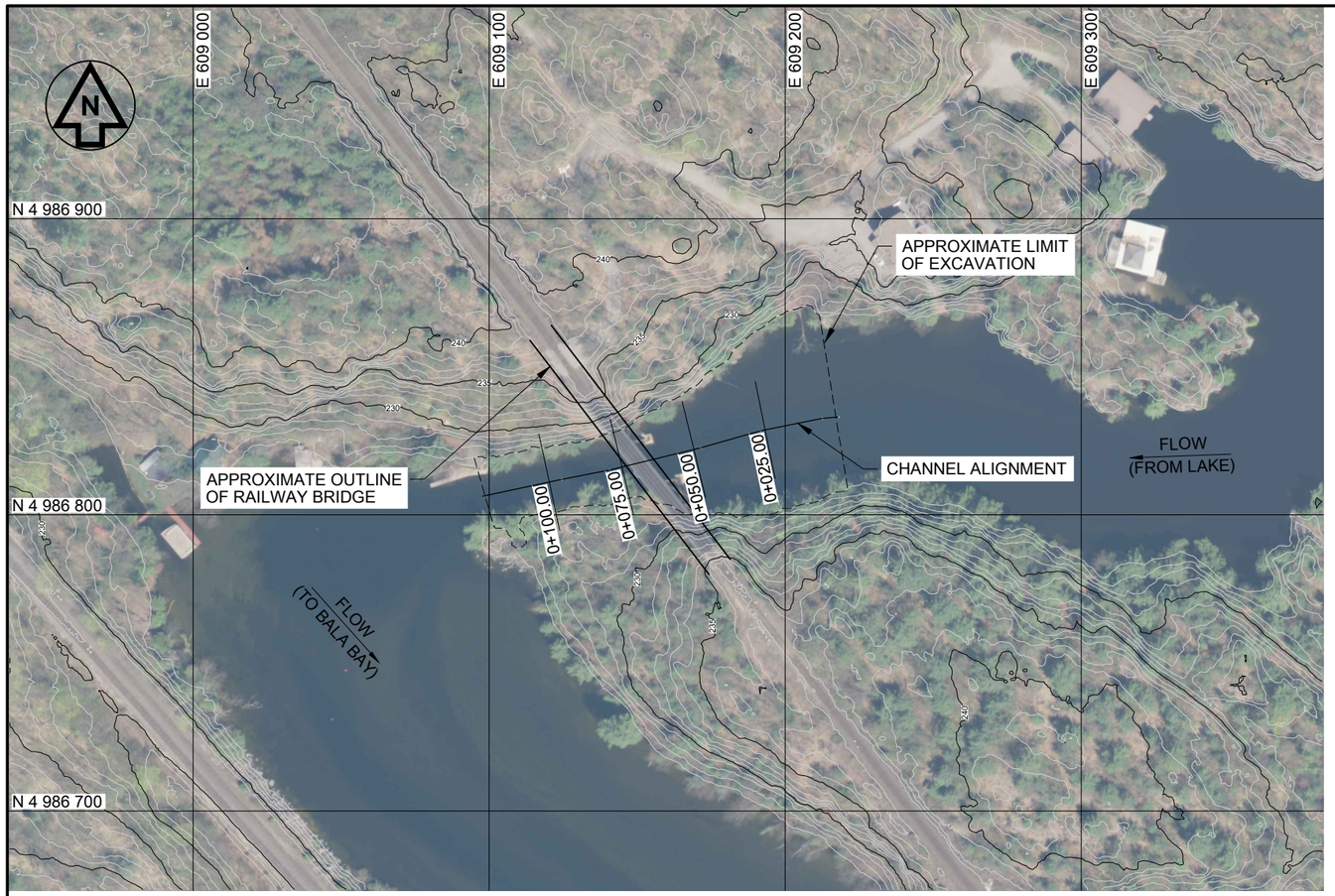
Figure No.H367619-0000-220-271-060

THE DISTRICT MUNICIPALITY OF MUSKOKA
FLOOD MODIFICATIONS REVIEW

OPTION 6 - ROCKY RAPIDS EXCAVATION

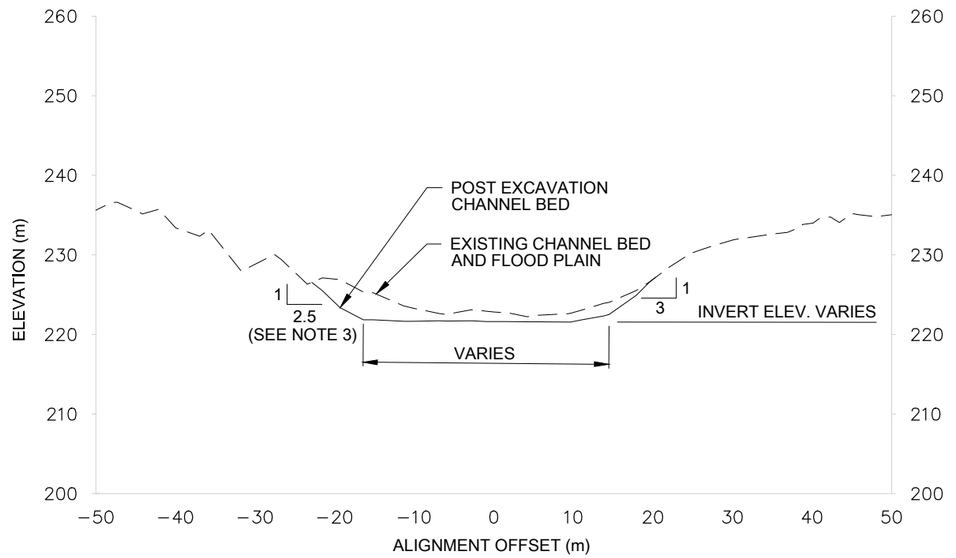
HATCH

Nov. 30, 2022 - 7:12pm Login name: MACA71078
Drawing Name: C:\jaworking\hatch-dgd-canada\...central\a012455\h367619-0000-220-271-0060.dwg



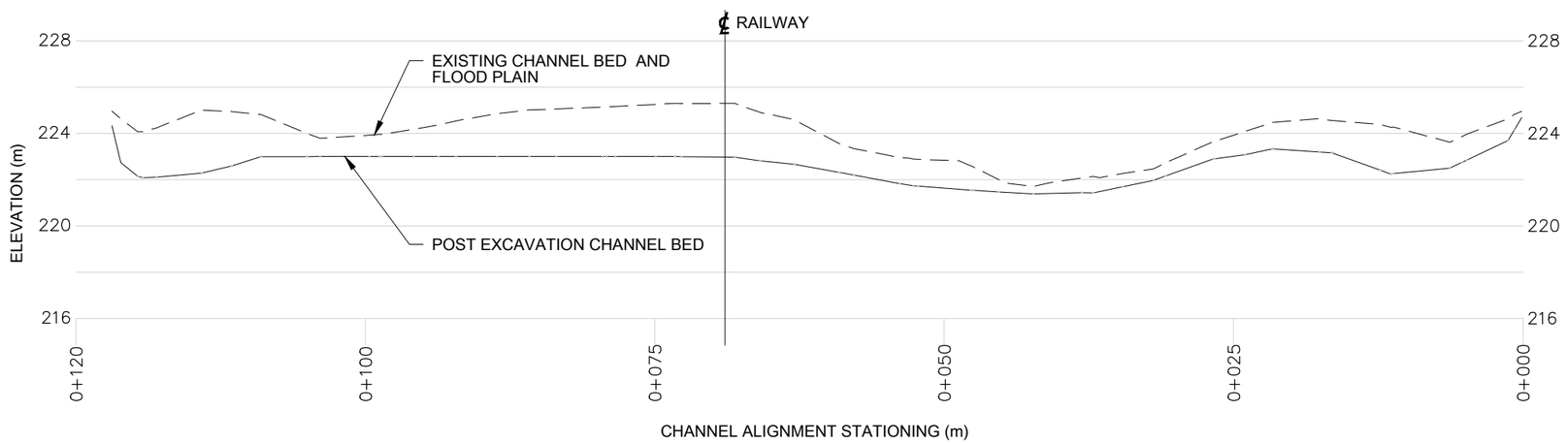
PLAN OF WALLIS CUT EXCAVATION

SCALE 1:2000



TYPICAL SECTION OF EXCAVATION

SCALE 1:750



LONGITUDINAL PROFILE OF EXCAVATION

SCALE HOR. 1:2000
SCALE VER. 1:500

0 20 40 60 80 100 METRES
SCALE: 1:2000

0 7.5 15 22.5 30 37.5 METRES
SCALE: 1:750

0 5 10 15 20 METRES
SCALE: 1:500

PRELIMINARY
NOT FOR CONSTRUCTION

Figure No. H367619-0000-220-271-0080

NOTES:

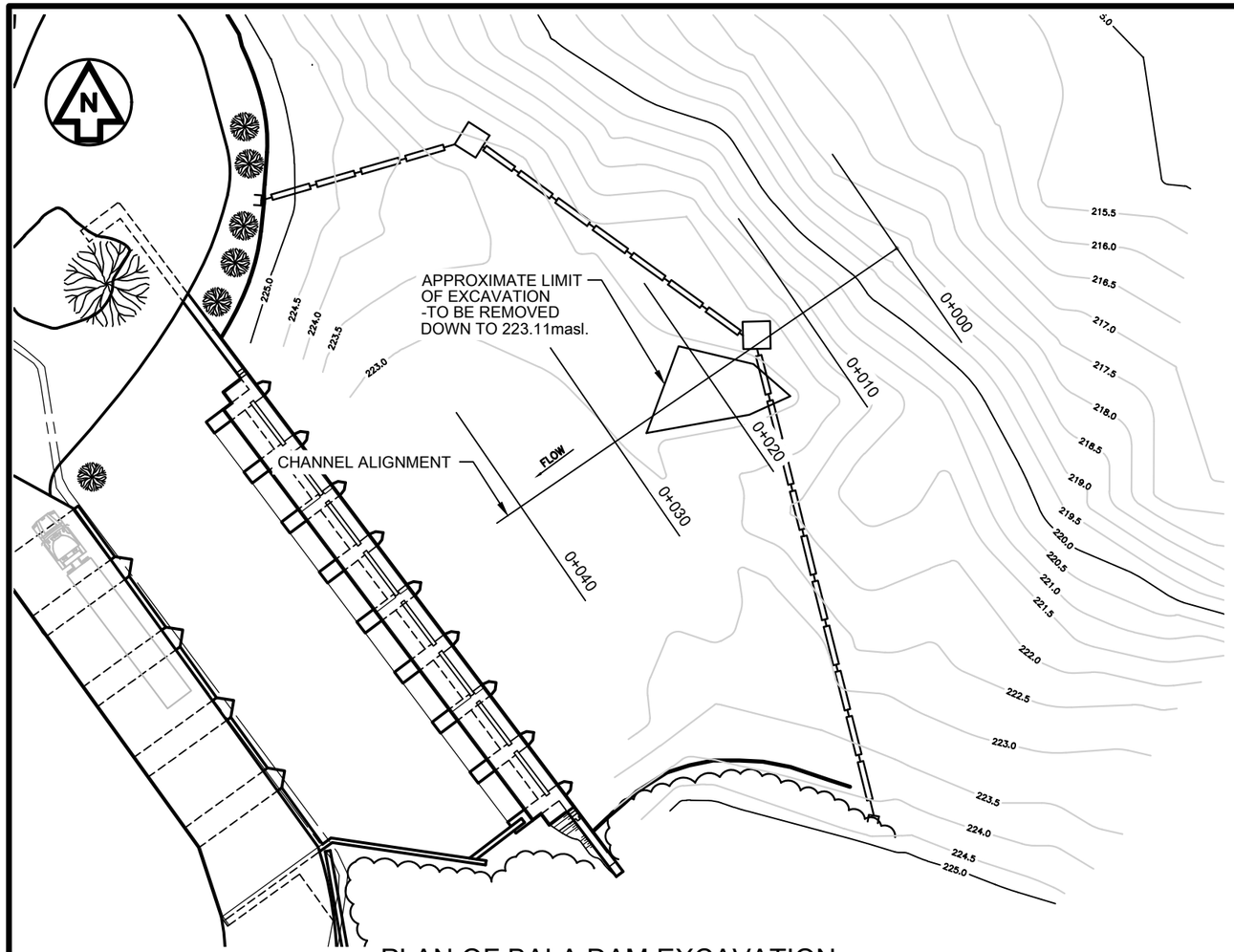
1. ALL DIMENSIONS ARE IN METERS.
2. COORDINATES ARE IN UTM NAD 83 ZONE 17.
3. SIDE SLOPES MAY VARY BETWEEN SECTIONS

THE DISTRICT MUNICIPALITY OF MUSKOKA
FLOOD MODIFICATIONS REVIEW

OPTION 8 - WALLIS CUT EXCAVATION

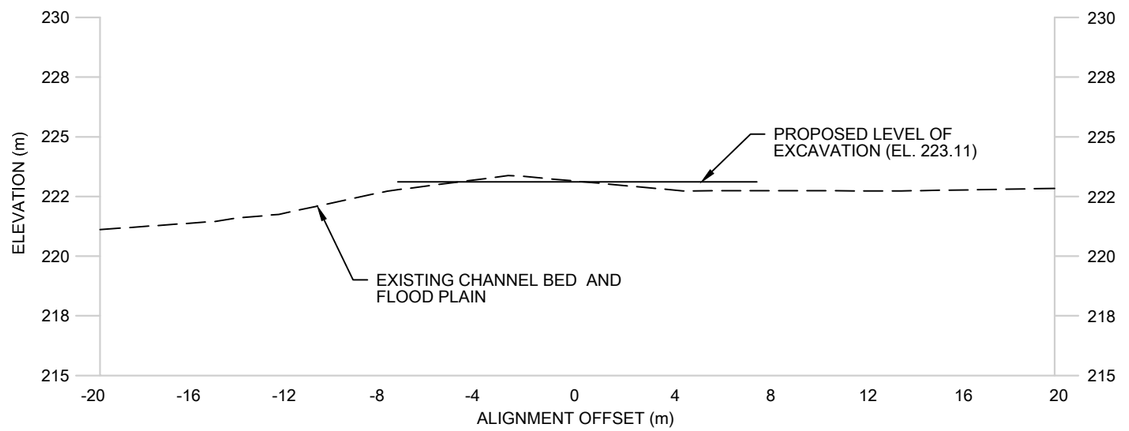
HATCH

Nov. 30, 2022 - 7:14pm Login name: MACA71078
Drawing Name: C:\pwworking\hatch-dpd-canada_central\d0124565\h367619-0000-220-271-0080.dwg



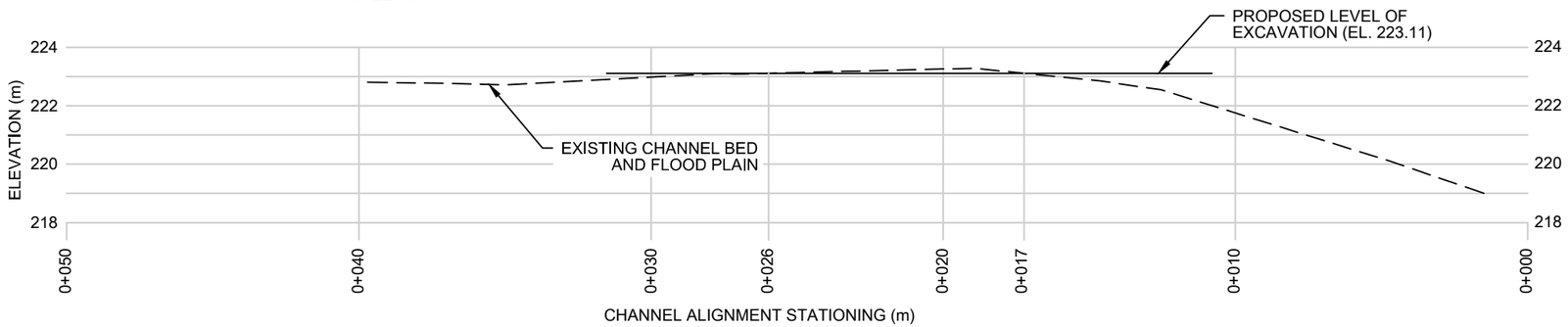
PLAN OF BALA DAM EXCAVATION

SCALE 1:500



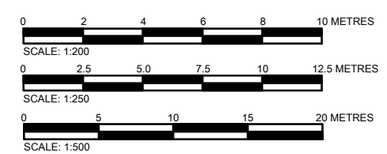
TYPICAL SECTION OF EXCAVATION

SCALE 1:250



LONGITUDINAL PROFILE OF EXCAVATION

SCALE 1:200



PRELIMINARY
NOT FOR CONSTRUCTION

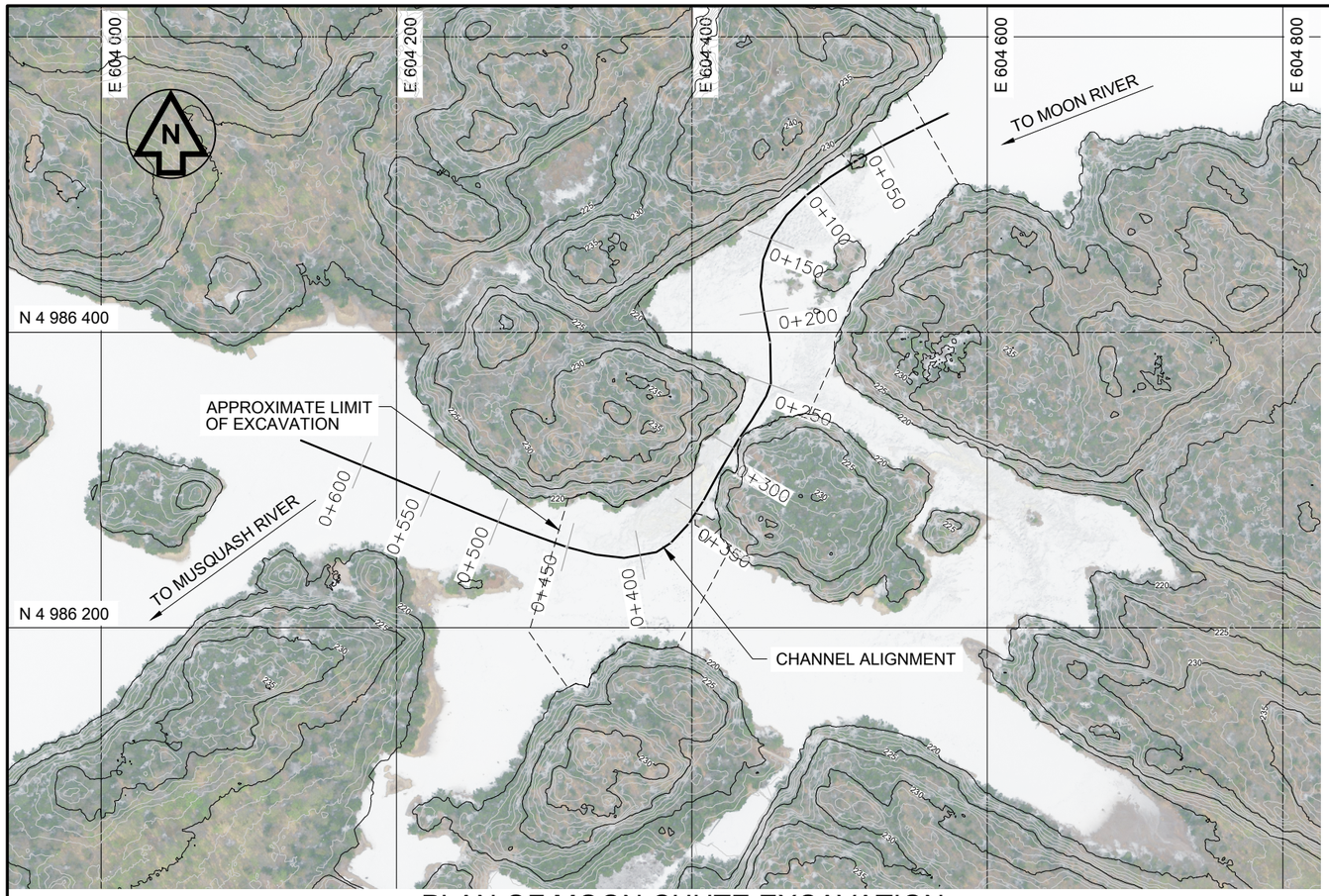
Figure No. H367619-0000-220-271-0090

NOTES:

1. ALL DIMENSIONS ARE IN METERS.
2. COORDINATES ARE IN UTM NAD 83 ZONE 17.

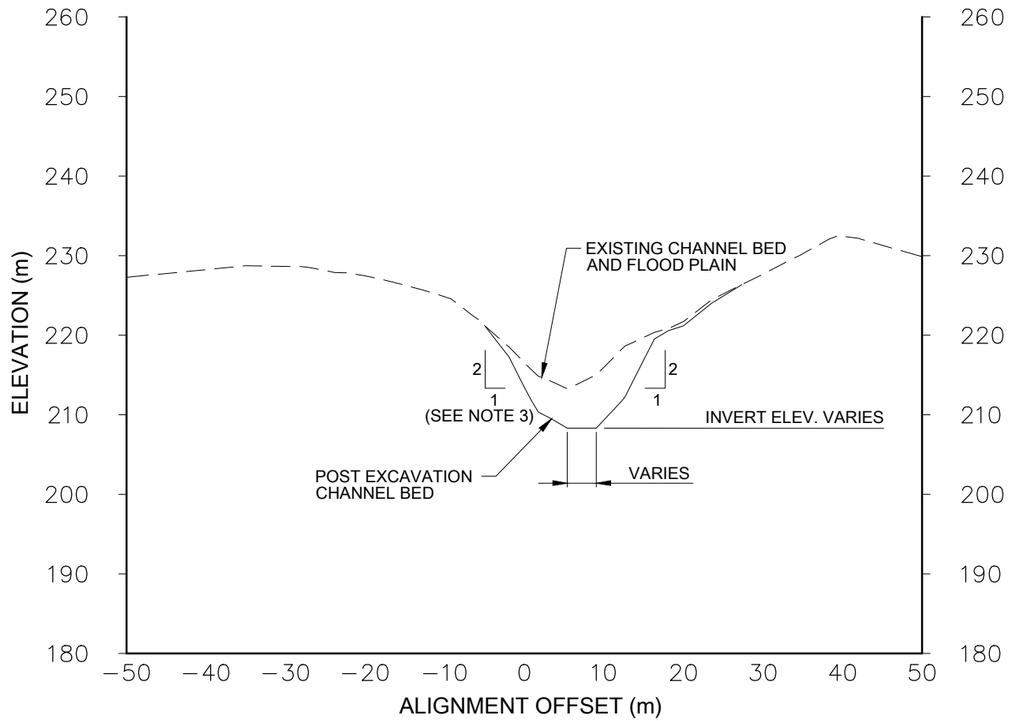
THE DISTRICT MUNICIPALITY OF MUSKOKA
FLOOD MODIFICATIONS REVIEW
OPTION 9 - BALA DAM

HATCH



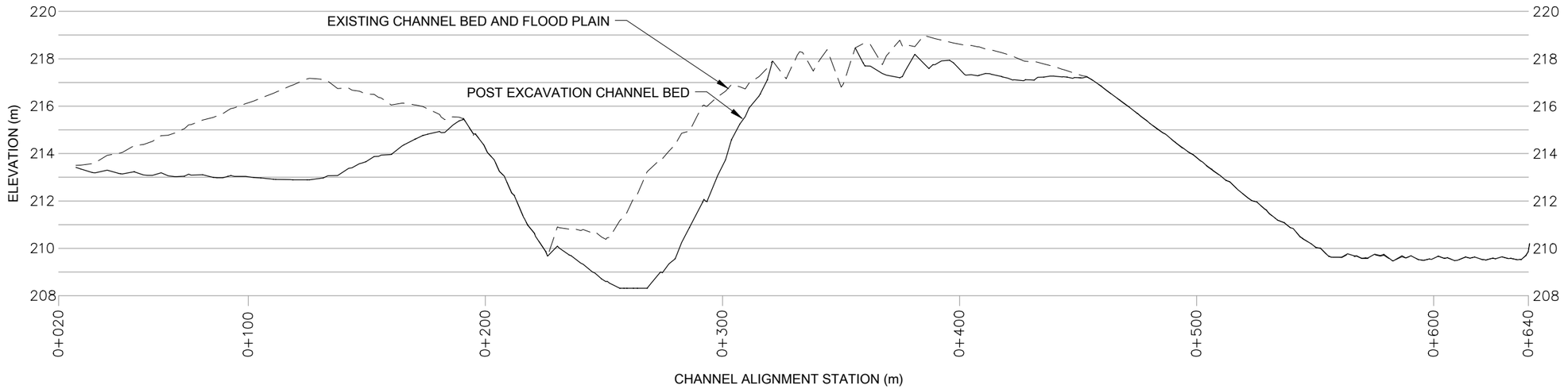
PLAN OF MOON CHUTE EXCAVATION

SCALE 1:4000



TYPICAL SECTION OF EXCAVATION

SCALE 1:750



LONGITUDINAL PROFILE OF EXCAVATION

SCALE: HOR.1:2000
SCALE: VERT.1:200

SCALE: 1:200
SCALE: 1:750
SCALE: 1:2000
SCALE: 1:4000

PRELIMINARY
NOT FOR CONSTRUCTION

Figure No. H367619-0000-220-271-0100

NOTES:

1. ALL DIMENSIONS ARE IN METERS.
2. COORDINATES ARE IN UTM NAD 83 ZONE 17.
3. SIDE SLOPES MAY VARY BETWEEN SECTIONS

THE DISTRICT MUNICIPALITY OF MUSKOKA
FLOOD MODIFICATIONS REVIEW

OPTION 10 - MOON CHUTE EXCAVATION

HATCH

Nov. 30, 2022 - 6:57pm Login name: MACA71078
Drawing Name: C:\jwworking\hotch-dgd-conodb_central\d0124565\l367619-0000-220-271-0100.dwg