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February 7, 2020

VIA ELECTRONIC FILING

Secretary Kimberly D. Bose
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Crescent Hydroelectric Project, FERC Project No. 4678
Vischer Ferry Hydroelectric Project, FERC Project No. 4679
Additional Information for Revised Study Plan and Responses to Comments on PSP

Dear Secretary Bose:

On May 3, 2019, the Power Authority of the State of New York (Power Authority), licensee of the Crescent and Vischer Ferry Hydroelectric Projects (Projects), FERC Nos. 4678 and 4679, respectively, filed a Pre-Application Document (PAD) and Notices of Intent to seek new licenses for the Projects. On June 10, 2019, the Federal Energy Regulatory Commission (FERC, or Commission) issued Scoping Document 1 (SD1) for the Projects' relicensing, and on July 10-11, 2019, FERC held scoping meetings and Project site visits. Agencies, non-governmental organizations, and other stakeholders provided their comments on SD1 and requested certain resource studies. On September 23, 2019 the Power Authority filed a Proposed Study Plan (PSP) with the Commission and held a PSP meeting on October 23, 2019. Comments on the PSP were due to FERC on or before December 22, 2019.

In response to the PSP, several stakeholders commented on the need for additional study of ice-jams and ice-jam flooding in the lower Mohawk River upstream of the Vischer Ferry dam. In its comments on the PSP, FERC staff acknowledged the concerns about ice-jam flooding and requested that the Power Authority conduct a study of ice-jam flooding upstream of Vischer Ferry. Specifically, staff requested a study with the following objectives:

1. *Characterize and understand ice jam processes in the Mohawk River upstream of the project dam, including ice jam formation, location of ice jams, and ice jam induced flooding.*
2. *Develop an ice jam hydraulic model to evaluate the effects, if any of the Vischer Ferry Project and its operation on ice jam formation and flooding.*

3. *Identify structural and nonstructural options for the mitigation of ice jam impacts if the Project is shown to increase flood risk in any part of the study reach.*[1]

In accordance with the Integrated Licensing Process (ILP) schedule included in SD1, on January 21, 2020 the Power Authority filed its Revised Study Plan (RSP), responses to comments on the PSP, and responses to FERC staff's additional information requests. In the RSP filed with FERC, the Power Authority did not propose to conduct the requested ice-jam study because such a study has been and is continuing to be conducted as part of New York Governor Andrew Cuomo's recently unveiled "Reimagine the Canals" initiative.

As discussed in the RSP, Governor Cuomo convened a Reimagine the Canals Task Force (Task Force) in May 2019 to identify ideas/solutions that promote economic development, recreation, and resiliency along the New York State Canal System.

Since the filing of the RSP on January 21, 2020, the Power Authority has further determined the extent to which the Task Force studied ice-jams and ice-jam flooding in the lower Mohawk River in the vicinity of the Projects.

The Task Force convened an Ice Jam Mitigation Panel tasked with evaluating ice-jam flooding, including developing a river ice model with the following objectives:

1. *Assist wintertime operation and management of water resources on the Mohawk.*
2. *Assist formulation and validation of theories on ice jam formation with field and lab data.*
3. *Help identify any additional factors causing ice jam formation and breakup that are currently unknown.*[2]

The Ice Jam Mitigation Panel is comprised of the U.S. Geological Survey, the U.S. Army Corps of Engineers, Dr. John Garver (Union College), the New York State Canal Corporation, the Power Authority, and Dr. Hung Tao Shen and Dr. Fengbin Huang (Clarkson University). The research effort is led by Dr. Shen, a Distinguished Research Professor in Hydraulic Engineering at Clarkson University and a world-renowned expert on river ice processes. Dr. Shen has developed the transport capacity theory for frazil ice jams and the theory on ice jam dynamics. His research group has developed comprehensive computer models for river ice processes. These models have been applied to rivers worldwide.

In their proposal to study ice jams along the Mohawk River (attached), Dr. Shen and his team recognized that in January 2018, an ice jam of historic proportions formed on the lower Mohawk River, causing severe damage to the Schenectady area.[3] Utilizing satellite imagery, data from USGS real time gauges, comprehensive bathymetry data from a 2019 bathymetry survey[4] and

[1] Staff Comments on the Proposed Study Plan for the Crescent Hydroelectric Project and the Vischer Ferry Hydroelectric Project. December 17, 2019.
[2] BuroHappold. Ice Jams in the Mohawk River Valley. Report to the Reimagine the Canals Task Force. October 8, 2019.
[3] Clarkson University. A Research Proposal Submitted to BuroHappold Engineering. July 2019.
[4] Ice Jams in the Mohawk River Valley, pp.14-18.

real time field observations by local experts, Dr. Shen and his team developed and are continuing to refine a numerical river ice model that produced simulated results that agreed with the typical ice jamming process observed in past studies (Garver 2018[5]).[6] With the successful modeling of the January 2018 ice-jam event, the model will provide a "baseline" that, "[a]fter further calibration, could be used as a potential tool for studying the breakup ice jams in the lower Mohawk River and assist the design of ice jam flood mitigation methods."[7]

Efforts to identify, evaluate and implement solutions to the ice-jam issues will continue as part of the Reimagine the Canals initiative. On January 29, 2020, the Board of Trustees for the Power Authority and Canal Corporation approved $300 million toward the implementation of the Governor's initiative, with $30 million made immediately available for specified work, including the continued study of ice jam mitigation in the vicinity of the Projects. Work on the ice-jam study will continue through 2020 and will include further analysis of ice-jam flooding and potential mitigation, including:

- Currently assessing structural and non-structural options to determine if additional mitigation can be achieved by physical modifications at the Vischer Ferry project.
- Currently assessing a variety of interventions to identify if they would provide appropriate mitigation in the vicinity of the Projects, including the use of an ice breaker, channel modifications, and an early warning system.

Further information on the Task Force efforts, including the technical analyses, was included with the RSP that the Power Authority filed on January 21, 2020.

Based on the work completed by the Ice Jam Mitigation Panel with respect to modeling and evaluating ice-jam flooding in the Lower Mohawk, and the continuing efforts to evaluate potential interventions to alleviate ice-jams and related flooding, it is clear that the objectives outlined by FERC in their study request are being addressed through the Reimagine the Canals initiative. The Clarkson modelling team has developed and is refining a numerical ice jam model to evaluate the effects, if any, of the Vischer Ferry Project on ice jam formation and related flooding. The modeling work has and will continue to facilitate the characterization and understanding of ice jam processes in the Mohawk River upstream of the Vischer Ferry dam. Finally, structural and non-structural options at Vischer Ferry dam for the mitigation of ice-jam impacts continue to be assessed. Given all the above, and with further information forthcoming, it is clear that no additional study of ice-jams in the vicinity of the Projects is needed in this relicensing effort.

The Power Authority looks forward to continuing to work with the Commission, resource agencies, Native American nations, local governments, and members of the public on the relicensing of the Crescent and Vischer Ferry Projects. If you have any questions regarding the additional information, please do not hesitate to contact me. Information regarding the

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[5] Garver, J.I. Ice Jam flooding on the lower Mohawk River and the 2018 mid-winter ice jam event, Proceedings of the 2014 Mohawk Watershed Symposium, Union College. 2018.
[6] Huang, Shen. Numerical Modeling of Breakup Ice Dynamics in the Lower Mohawk River. 2020.
[7] *Id.*

relicensing of the Crescent and Vischer Ferry Projects can be found at the Power Authority's relicensing website at http://www.nypa.gov/cvf.

Sincerely,

Robert Daly
Licensing Manager

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Attachments:
Research Proposal for a Numerical Model Study on Breakup Ice Jams on the Mohawk River
Numerical Modeling of Breakup Ice Dynamics in the Lower Mohawk River
Ice Jams in the Mohawk River Valley

Research Proposal for a Numerical Model Study
on Breakup Ice Jam on the Mohawk River
Privilege Information - Non-Public

Numerical Modeling of Breakup Ice Dynamics
in the Lower Mohawk River
Privilege Information - Non-Public

Report to the
Reimagine the Canals Task Force

Ice Jams in the Mohawk River Valley

Date of Issue: October 8, 2019

Ice Jam Mitigation Panel Report
Prepared by: BuroHappold, on behalf of NYPA

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1. Executive Summary

In the summer of 2019, the New York Power Authority (NYPA) convened an Ice Jam Mitigation Panel to review the historical ice-jam-related flood events in the Mohawk River, identify changes in climate and river conditions driving future ice jam formation, and determine ways to reduce or eliminate this threat. The Panel was comprised of representatives from the Canal Corporation, NYPA, US Geological Service, US Army Corps of Engineers, academic experts, and consultants to NYPA. This report summarizes the Panel's findings and recommendations to the Task Force.

Ice jams occur on rivers when ice accumulates at a natural or man-made feature, blocking the ice formation's movement downstream and impeding the river's flow. Ice jams have local, upstream, and downstream impacts and consist of two main processes: formation and breakup. Formation is caused by slow-moving waters, and narrow, deep channels. Breakup can by caused by melting (thermal) or because water pressure/water levels in the river get too high (mechanical). Both formation and breakup can cause damages upstream, downstream, and at the location of the ice jam.

Largely due to the configuration of the river channel, ice jams are a chronic problem on the Mohawk River. Ice jam events are recorded as causing damages along the Mohawk as far back as 1914, but significant flooding has occurred in 1996, 2007, 2009, 2018, and as recently as 2019 – particularly in Schenectady's historic Stockade District. Ice jams along the Mohawk can cause flooding, scouring, injuries and significant structural and environmental damage. Every effort to reduce the frequency of these occurrences should be undertaken.

While the factors contributing to ice jams in the Mohawk have long been anecdotally understood, prior to this study the Canal Corporation/NYPA has not had a model that could be used to understand exactly how, where, and why Mohawk ice jams are forming, breaking up, and causing flooding. As part of this study, NYPA commissioned the development of an ice jam model, equipped with new bathymetric survey data (procured in August, 2019).

This model has been developed by Dr. Hung Tao Shen of Clarkson University, a global expert on ice jam hydraulic modeling, and reviewed by Dr. John Garver of Union College, an expert on Mohawk River ice jams (both served on the Ice Jam Mitigation Panel convened by NYPA). The new ice jam model has been used to establish a baseline for analysis, recreating the conditions resulting in the January 2018 ice jam and subsequent flooding.

On the basis of this model, the Ice Jam Mitigation Panel recommends further study of four potential physical interventions:

1. **Ice breakers / cutters:** Using specialized boats/machinery to physically break up ice jams in hotspot areas.
2. **Obermeyer Spillway Gates:** Modifying the Vischer Ferry Dam (at Lock E-7) to better manage water flows, and potentially "flush out" ice jams.
3. **River channel re-profiling (dredging):** Modifying the Mohawk River to alleviate choke points to water flow which result in ice jam formation.
4. **Removal or modification of bridge abutments:** Removing abandoned bridge abutments, and potentially retrofitting existing bridges to help break up ice jams.

Further work involves developing the recommended interventions and inputting them into the model to test their effectiveness in mitigating ice jams.

In addition, the panel assessed the performance of the ice jam/flood warning system that was developed via a multi-agency effort in 2012 and expanded in 2019. The system uses a variety of sensors and web cameras, as well as a great number of human spotters along the riverbanks. While this ice jam monitoring system is useful as a monitoring tool for emergency managers and the public, the system is limited to monitoring and does not have forecasting capabilities.

An ice jam forecasting system would serve to help understand ice jam evolution and potentially mitigate the impacts associated with ice jam flooding. As a result, the Ice Jam Mitigation Panel recommends **a greatly expanded and more sophisticated ice jam forecasting / flood warning system** providing communities and emergency managers far more lead time to prepare for a flood event. The recommended system would comprise new sensors for real-time monitoring, to be monitored by the New York State Division of Homeland Security and Emergency Services (DHSES) 24-hour Watch Center.

2. Context

The purpose of this report is to present the results of a modeling and research exercise on the problem of ice jams in the Mohawk River Valley. The report consists of four main parts:

1. **Context**: an overview of the different types and impacts of ice jams, and historical examples in the Mohawk region
2. **Study Mandate**: a description of the consultant team's study mandate and its outputs
3. **Ice Jam Model**: an explanation of the hydraulic model of ice jam formation in the Mohawk River that has been developed to establish a baseline and test potential interventions
4. **Interventions:** an evaluation of potential interventions considered by the Ice Jam Mitigation Panel

A set of consolidated recommendations for the Task Force are presented at the conclusion of the report, ranging from infrastructure retrofits to operational changes.

2.1. Background

Ice jams occur on rivers when ice accumulates at a natural or man-made feature, blocking the ice formation's movement downstream and impeding the river's flow. Ice jams have local, upstream, and downstream impacts.

- **Around the ice jam:** localized and regional flooding can occur during storm events, as the blockage precludes the ability of stormwater runoff to drain into the river
- **Upstream of the ice jam:** the blockage and significantly reduced water flow rates in the river can cause flooding
- **Downstream of the ice jam:** a sudden failure of the ice jam can release large volumes of water and ice, damaging structures, croplands, and wildlife habitats

Ice jams are unique flooding phenomena. Whereas most flooding typically happens during springtime melts of snowpack or during storm events, ice jams generate flood risk during the winter. They typically occur when warming temperatures and heavy rains cause snow and ice to melt rapidly. As river waters rise and discharges increase, the surface layer of ice breaks into chunks that are carried downstream by the rushing waters, forcing the chunks to lodge against one another. The chunks of ice can accumulate near bridge piers or other abutments, areas of elevation change (potentially due to sedimentation or deposition of debris), stream confluences, between narrow passages, and around bends in the river. Ice chunk accumulations are most pronounced at locations where the slope of a river changes from steeper to milder or where moving ice meets an existing ice cover that is intact.

There are two main types of ice jams:

1) River ice **formation**, known as 'freeze-up jam' or 'anchor ice jam',
2) River ice **breakup**, known as 'break-up jam' or 'mid-winter jam'.

Ice thaws and ice jams always occur on the "rising limb of the hydrograph" – in other words, when the floodwaters are building. When flow starts to rise, it is common for unimpeded ice runs[1] to develop, but invariably the ice's movement gets blocked or impeded by constrictions in the river, particularly where the river's floodplain is reduced in size.

The timing and magnitude of river ice jams are determined by channel morphology (the dimensions of the channel itself), weather conditions, ice cover thickness and strength, and river flow. As such, the ice jamming

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[1] Ice runs are a continuous length of moving ice that may be up to tens of miles in length and typically grades from large ice pieces at downstream end to small ice pieces at upstream end

process is very sensitive to changes in climatic conditions. A wide-ranging change that is already anticipated is the increased incidence of mid-winter breakups and ice jams in parts of Northeastern U.S. and eastern Canada due to changing freeze-thaw cycles.[2]

Spring breakup of ice jams on a river can be either **thermal or mechanical**:

> A **thermal breakup** is essentially a melt-out process where the ice cover deteriorates and melts in place without significant movement. During a thermal breakup, the river discharge remains relatively steady during the spring breakup period without an ice jam.
>
> During a **mechanical breakup**, a relatively stable ice surface fragments under hydraulic forces, associated with a significant rise in river stage (water level). The stage rise typically results from the rapid increase in river discharge due to spring snowmelt runoff, often accompanied by rainfall. Ice runs produced by a mechanical breakup lead to ice jams when the ice discharge exceeds the ice conveyance capacity of the river channel, or when a breakup ice run meets an intact ice cover downstream. Mid-winter breakups are typically mechanical breakups.

Severe damage can occur from both the build-up of water and incident flooding caused by ice jams, as well as the release of large quantities of blocky ice once the ice jams break down. Moreover, warm periods in winter are becoming increasingly more frequent in temperate regions such as New York.[3] During these periods, increased meltwater contributes to the saturation of the floodplain, further exacerbating the risk of flooding during storm events.

Ice jams along rivers cause flooding, scouring, injuries and loss of life, and structural and environmental damage. Communities adjacent to rivers can be extremely vulnerable to flooding from ice jams, and are currently in need of better warning systems, as well as data about ice jam locations, frequencies, and potential threats to lives, property, and other assets.

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[2] Prowse et al. *River-ice break up/freeze-up: a review of climatic drivers, historical trends and future predictions*. 2007

[3] NYSDEC. *Impacts of Climate Change in New York*. Retrieved from https://www.dec.ny.gov/energy/94702.html

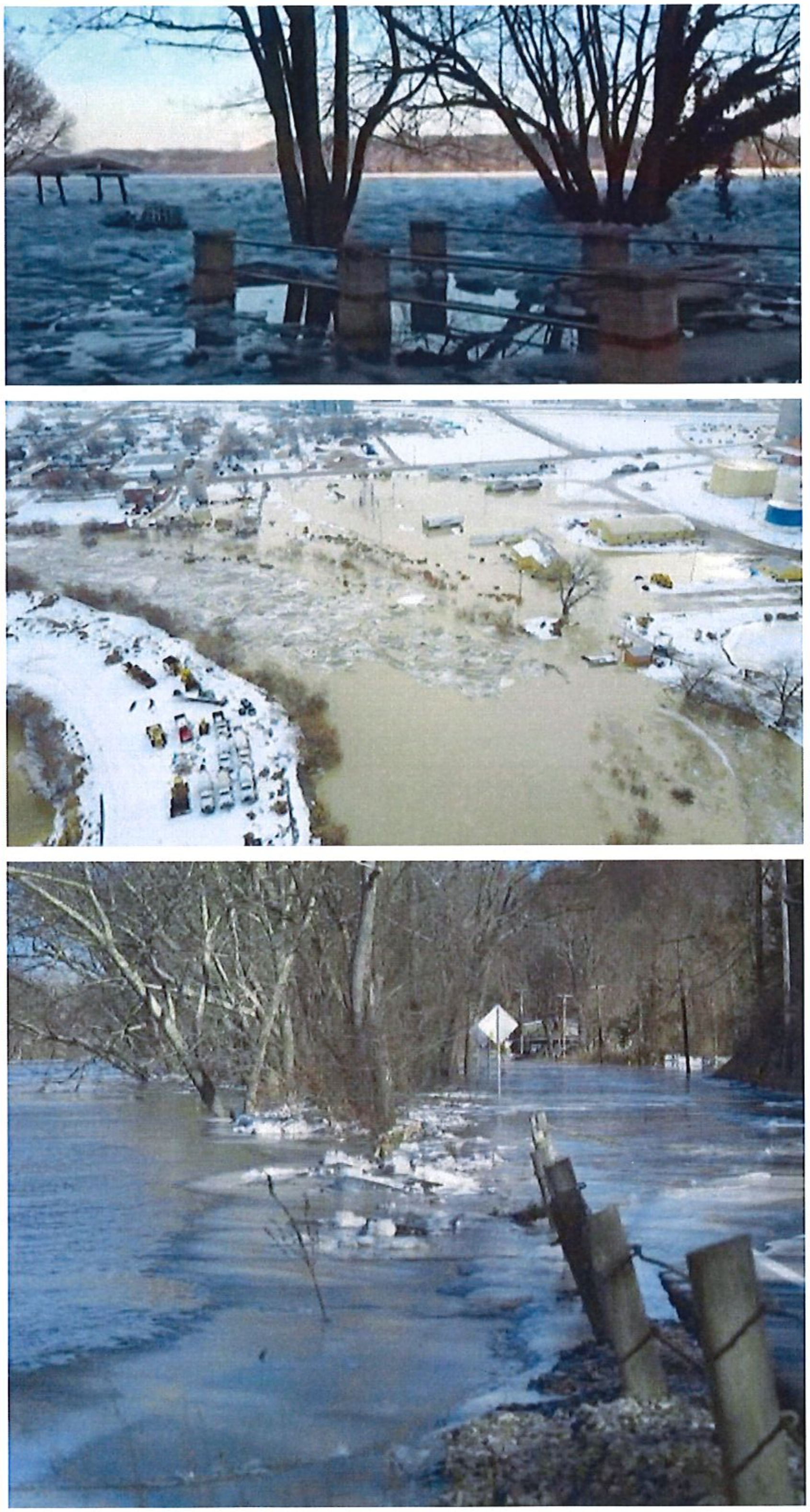

Figure 1: Examples of Damages from Ice Jams

2.2. Historic ice jam occurrences

The lower part of the Mohawk River has chronic ice jam problems due to the natural and man-made structures that obstruct flow. Ice jams in this reach typically form at channel constrictions, bridge piers, lock and dam structures, and sections with a reduced floodplain. The historical record indicates that the section of the river between the Stockade area of Schenectady and the Rexford Knolls, downstream of Schenectady, is the most jam-prone in the entire watershed. Some empirical evidence of ice jam locations is relatively well known to local emergency management authorities. However, there is a general lack of information as to the significance of individual jam points, and how often jams occur in different areas. In addition, many jam sites are inferred based on little or no data.

January 1996

In the figure below (Figure 2), ice jam abrasion elevations are shown on a map of the Schenectady/Locks 7 and 8 area. Scars on trees indicate the elevation of a slow-moving jam that caused damage along the riverbanks. The highest levels of tree scarring occur upstream from the Rexford Bridge and upstream of the Burr Bridge abutments. This area chronically experiences ice jams (from Lederer and Garver, 2000).[4]

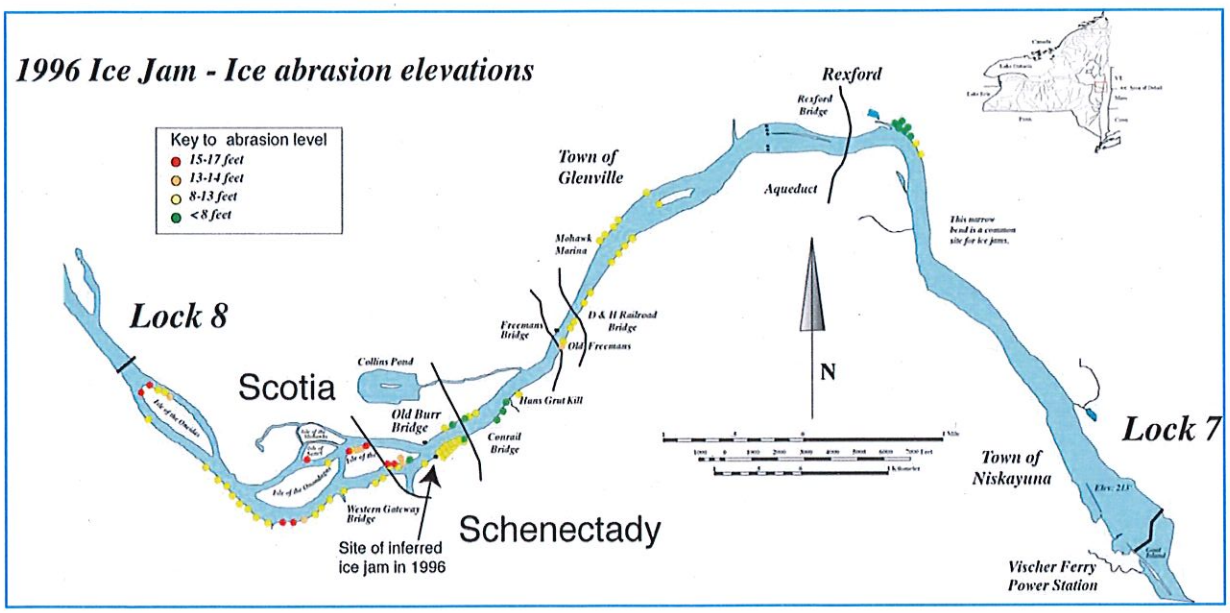

Figure 2: 1996 Ice Jam – Ice Abrasion Elevations

[4] Lederer and Garver. *Ice jams on the lower Mohawk River.* 2001

During this event, ice jammed at the Scotia Bridge, which connects downtown Schenectady with the Village of Scotia. Analysis of the historical records indicates that this is a chronic jam location (same as the Burr Bridge abutments at the end of Washington St.).

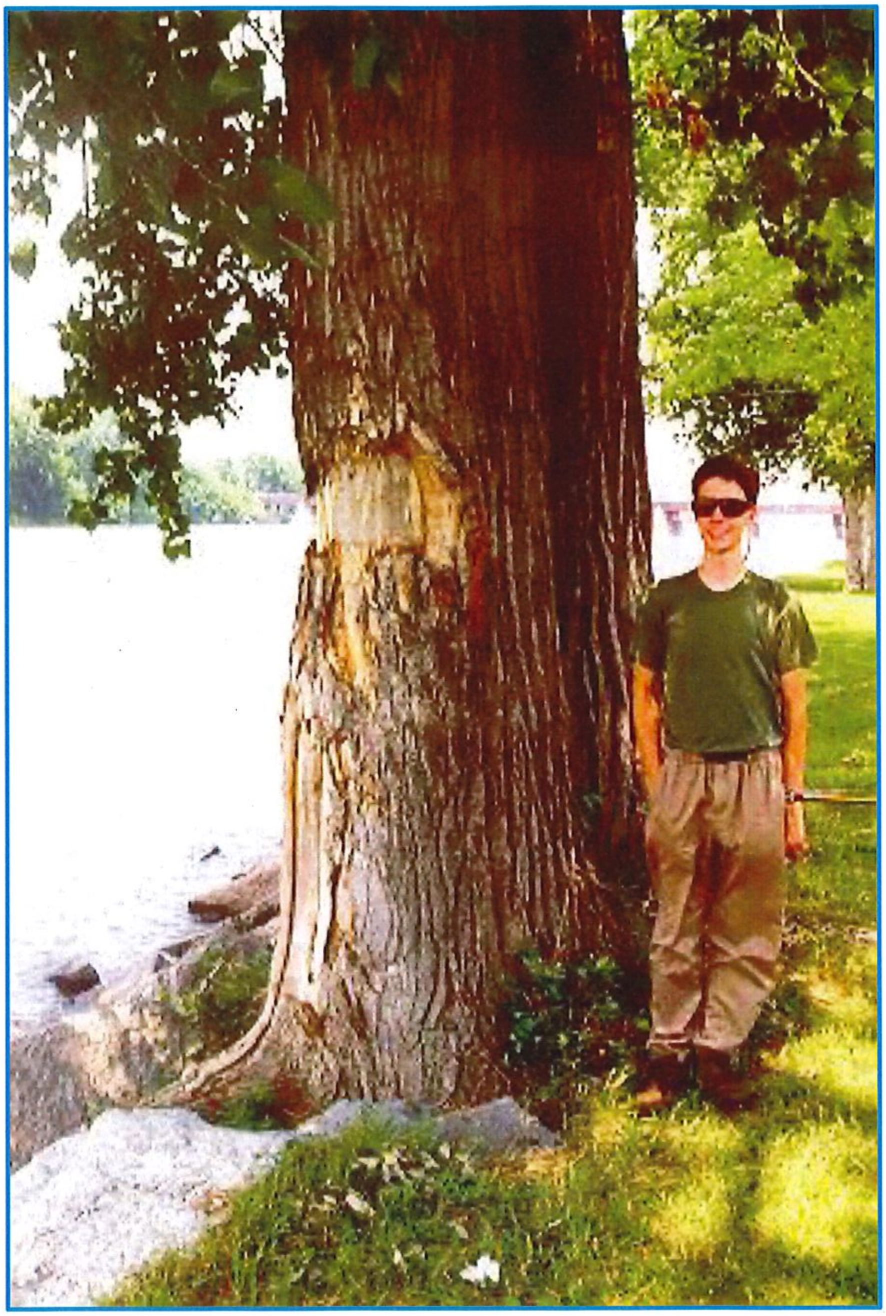

Figure 3: Tree in Schenectady showing damage from the 1996 Ice Jam (apx. 14-15 ft above river level) (Photo: J.R. Lederer)

March 2007

The March 15, 2007 flooding in the Stockade was fully attributable to ice jamming downstream from Schenectady. During this event, river water flows in the Schenectady area of the Mohawk River never surpassed 45,000-50,000 cubic feet per second (cfs) of water – an insignificant sum with respect to expected high water. However, the formation of the ice jam resulted in a backup of this slow-flowing water, leading to the inundation in the Stockade.[5]

Figure 4: Flooding in the Stockade from the 2007 Ice Jam on the Lower Mohawk (Photo: J.I. Garver)

March 2009

The 2009 ice jam was, by historical standards, an insignificant event. The ice thaw out event that occurred between March 8-10, 2009 resulted in bankfull conditions (the water level at which the river is at the top of its banks, and any additional rise would result in water moving into the floodplain), and an ice jam occurred, but it did not cause any significant flooding.

January 2018

The reach of the Mohawk River at the downstream end of the NYS Canal System is prone to the threat of ice jam flooding. Ice jams form in this reach almost every year (Garver and Cockburn, 2009, Garver 2014) and one of

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[5] This reinforces earlier findings that the key component in ice jam events is the evolution of stage elevation (water levels), which is not directly related to discharge (flow rates).

historic proportions formed in January, 2018 on the lower Mohawk River due to that year's mid-winter thaw (Garver 2018).

The January thaw started on the 12th day of the month, with rapid warming accompanied by precipitation and snowmelt. The river discharge increased substantially due to the additional surface runoff and, more importantly, the release of channel storage due to ice cover breakup upstream.

The ice jam was 17 miles long, and the "toe" of the jam was lodged in the Rexford Knolls, a chronic jam point. The very deep channel in the Knolls and several constrictions in this section of the river enhanced the magnitude of the jam formation.

This ice jam caused severe flooding damage in the Schenectady area. The blockage remained in the Rexford Knolls until February 20th, when warm temperatures and precipitation remobilized the jam with breakup upstream and flooded the Stockade.[6]

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[6] With more frequent extreme weather events due to climate change, there is an increasing potential for the occurrence of similar events in the future.

3. Study Mandate

Past natural disasters have had a major impact on the Mohawk River. In the summer of 2011, Hurricane Irene significantly increased the river's water flow, resulting in a canal lock breach. The water levels increased and created a pathway around the lock, rendering it unusable. That same year, Tropical Storm Lee made landfall and caused the Mohawk River to flood. Both events resulted in storm-induced channel modifications, which are difficult to reverse, requiring the construction of new landmasses and river flow control. In addition to modifying the channel's morphology, the storms significantly altered the river's water quality, by increasing the number of suspended solids and reducing water clarity.

Studies conducted by Garver (2019) hypothesize that, within the Mohawk, the two most significant jam points are caused by sediment infill affecting the effective channel width. Below Lock E8 outside of Schenectady, only the south channel is active around the Isle of the Oneidas. This is likely due to sediment infilling in the north channel, which received a tremendous load of sediment during Hurricane Irene (2011) due to the failure and breach around Lock E8 (the north side breach).

Figure 5: Lock E8 Breach after Irene and Lee

Figure 6: Lock E9 Damage after Tropical Storm Lee

The objectives of developing a river ice model are threefold:

1) To assist wintertime operation and management of water resource projects in the Mohawk
2) To assist formulation and validation of theories on ice jam formation with field and lab data
3) To help identify any additional factors causing ice jam formation and breakup that are currently unknown or understudied

The model was developed to include recently procured (August 2019) river bathymetry survey data. Previously, only very limited areas of the Mohawk have had their bathymetry/cross-sections known. The model includes various components, as seen in the diagram below:

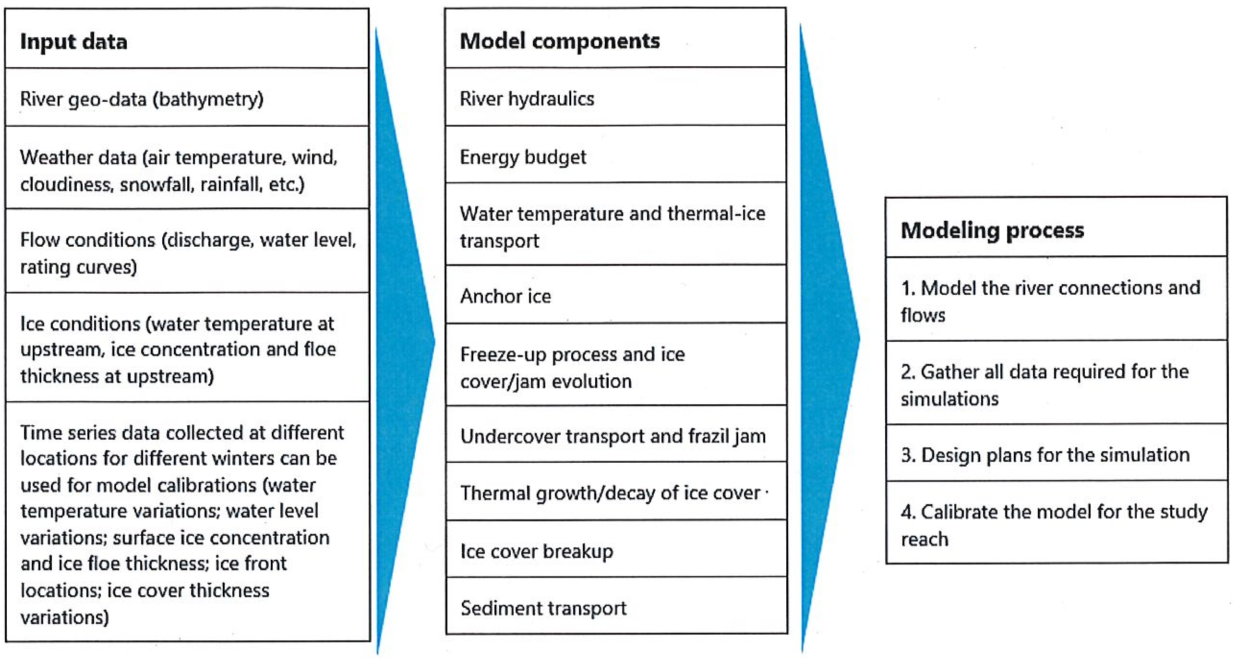

Figure 7: Model Components and Methodology

The completion of the ice jam model generates a much clearer understanding of ice jam formation and associated flooding. This improved understanding of ice jams in the Mohawk allows for the consideration of specific potential interventions, spanning both infrastructure retrofits and operational changes.

The nine interventions to be evaluated in this report are as follows:

1. Ice booms
2. Dynamite
3. Ice retention
4. Ice breaker / cutter
5. Remove Vischer Ferry Dam at Lock E-7
6. Obermeyer Spillway Gates
7. Remove abutments
8. Effluent from wastewater treatment plant
9. Re-profiling

For each of the interventions, high-level costs as well as technical and political feasibility have been evaluated. These considerations have guided the recommendations for future study and implementation.

4. Ice Jam model

4.1. New bathymetry survey (August 2019)

In August 2019, NYPA commissioned H2H Associates to conduct a bathymetric survey of the Mohawk, its backwaters, and its near-shore (land/riverbanks) between Lock E-7 (Vischer Ferry) and Lock E-8 (Scotia) using high-precision LiDAR sensors.

Delivered to the modeling team in mid-September and immediately shared with the Mitigation Panel, the bathymetry results revealed insights into the Mohawk's form, some of which were previously unknown (in the past, data was limited to a cross-section every 1000 feet – anything in between would not be picked up). Some preliminary observations include:

1. As hypothesized by Dr. Garver, there is extreme sedimentation at **Isle of the Oneidas** (outside of Schenectady. This is a key ice jam formation location (Figure 8).
2. At **Freeman's Bridge**, another ice jam location, there is apparent scouring in the center of the river channel from past ice jams. Where this scouring occurs, water velocities slow down, leading to future ice jams (Figure 9).
3. At **Rexford / Knolls**, there is both a narrowing of the river channel in part of the river and extreme drops in riverbed depth (~30ft deep) in others. Both of these factors result in ice jam formation (Figure 10).
4. In the **Vischer Ferry Dam pool**, there is extreme sedimentation, effectively "berming up" to the dam, especially on the northern side of the river channel (Figure 11).

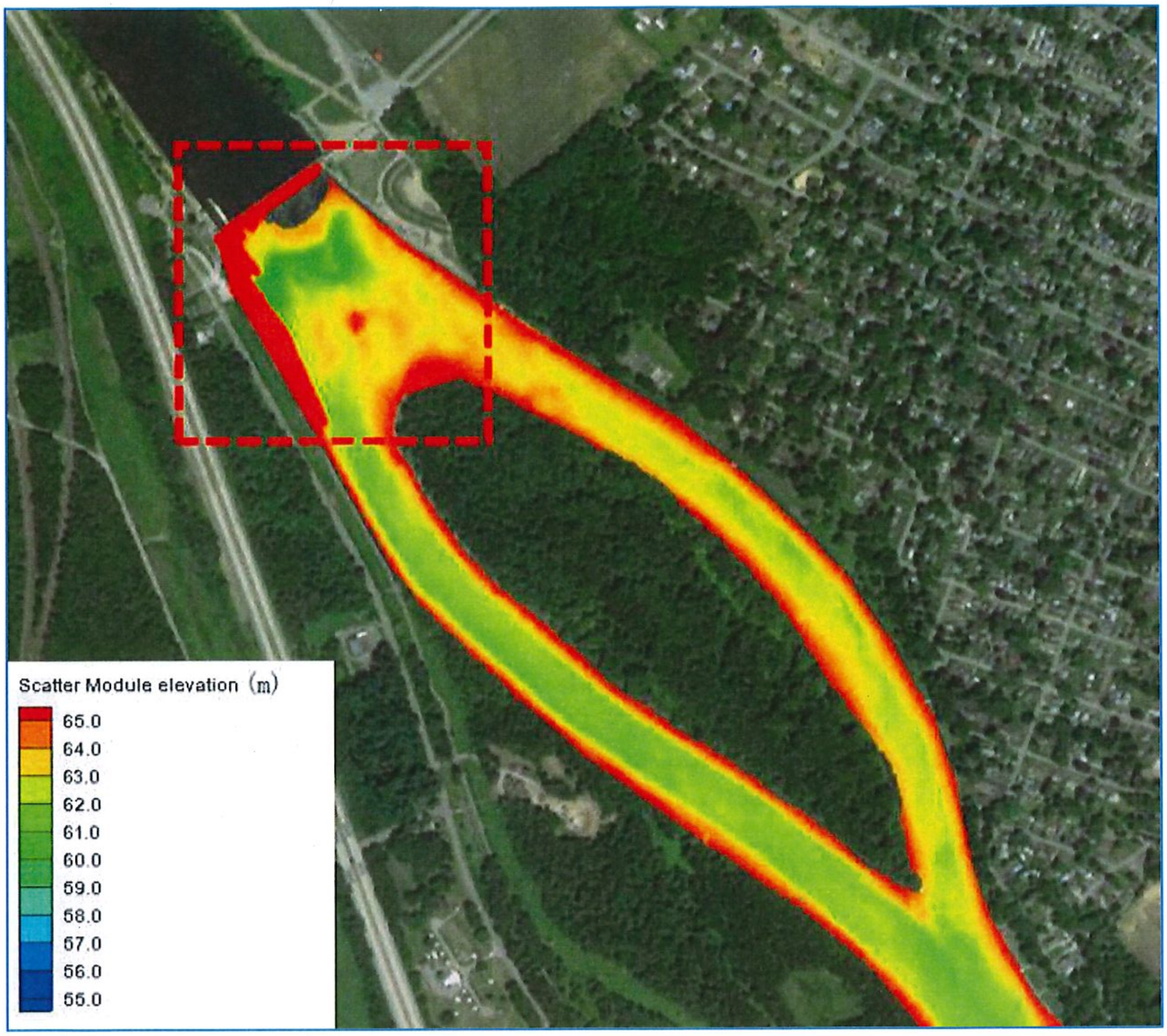

Figure 8: August 2019 Bathymetric Survey of Isle of the Oneidas (outside Schenectady), showing sedimentation and a narrowed river channel

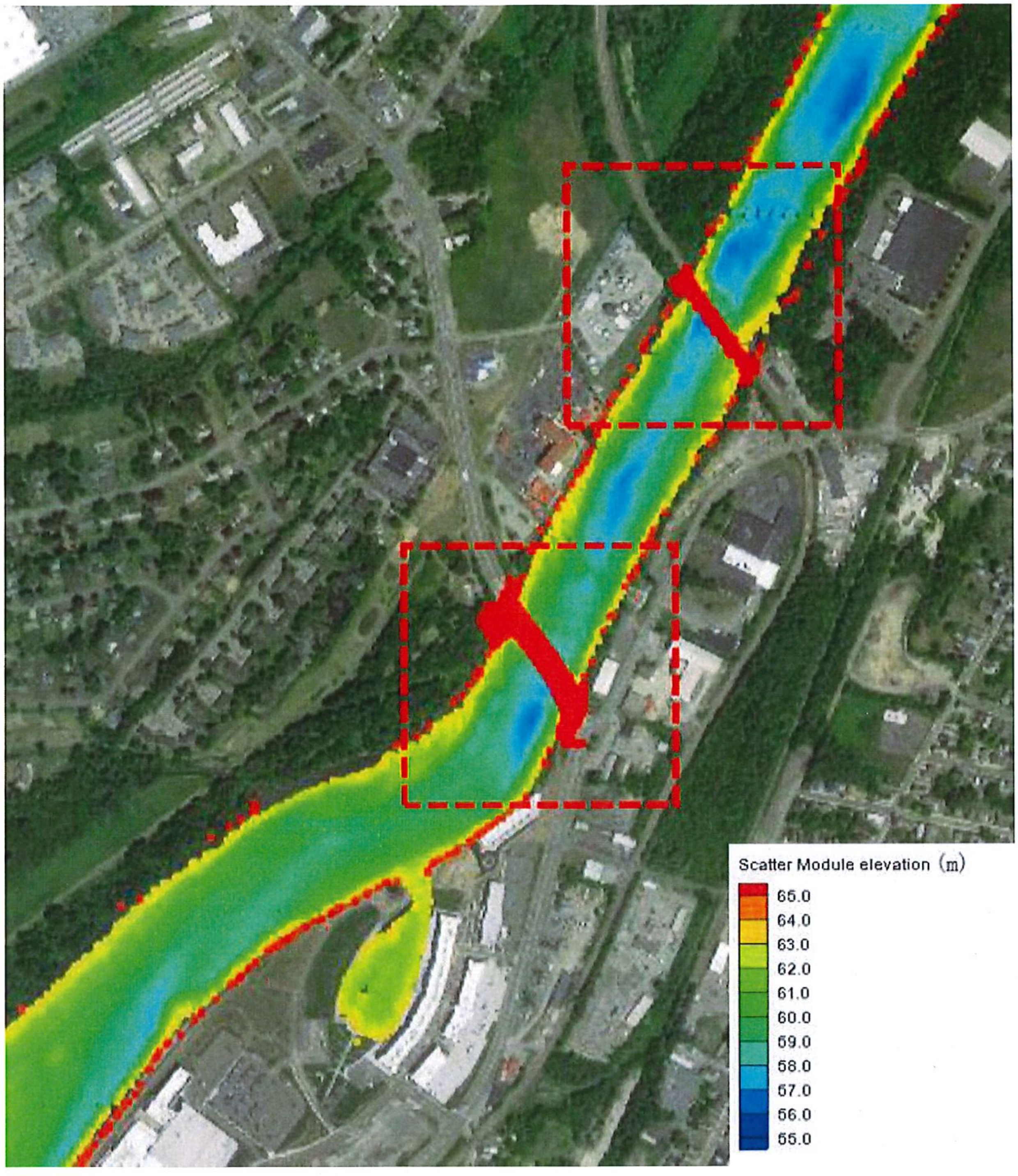

Figure 9: August 2019 Bathymetric Survey at Freeman's Bridge (Schenectady), showing what is likely scouring from past ice jams (center of channel)

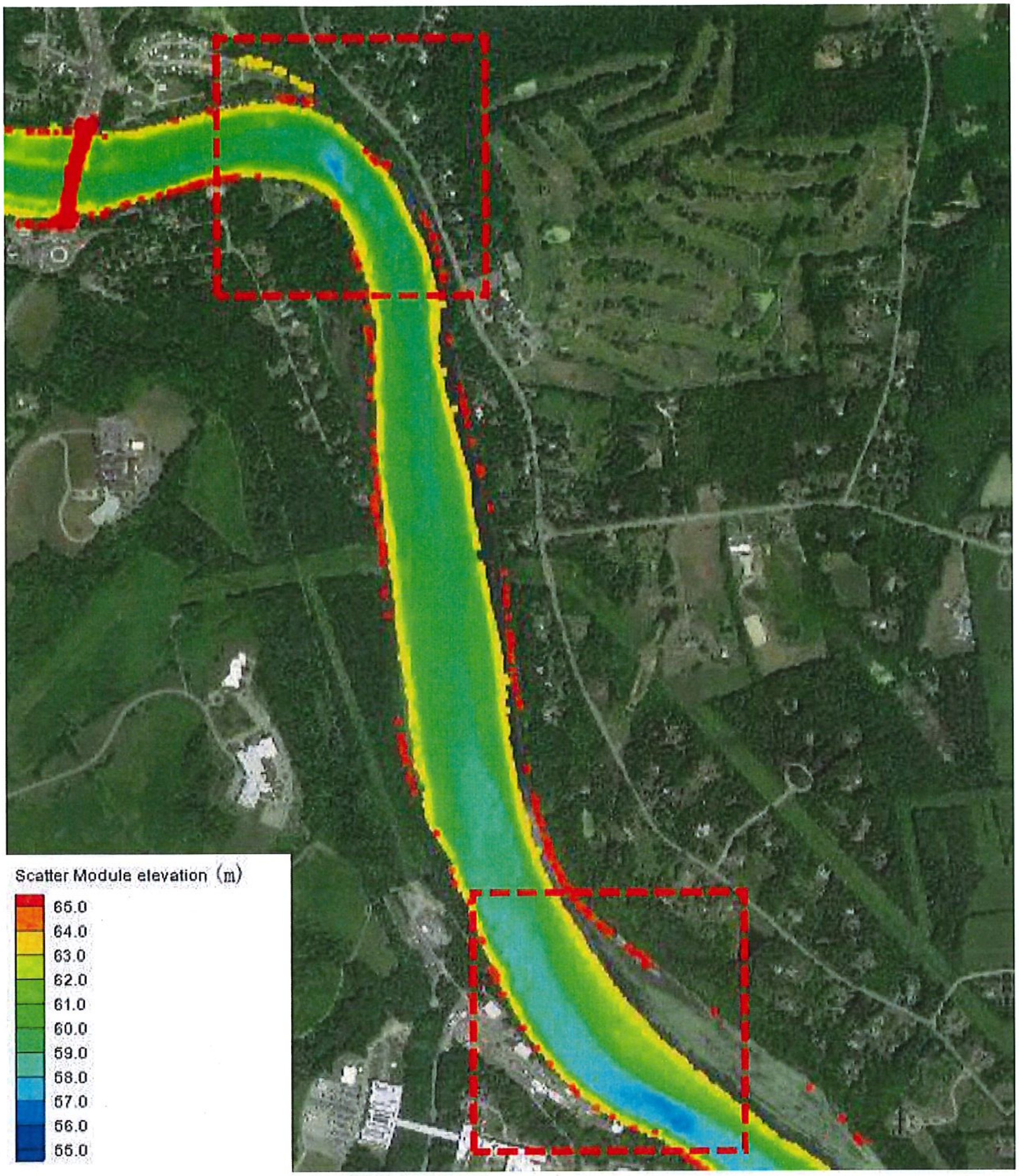

Figure 10: August 2019 Bathymetric Survey at Rexford / Knolls, showing both a narrowed river channel and extreme drops in riverbed depth

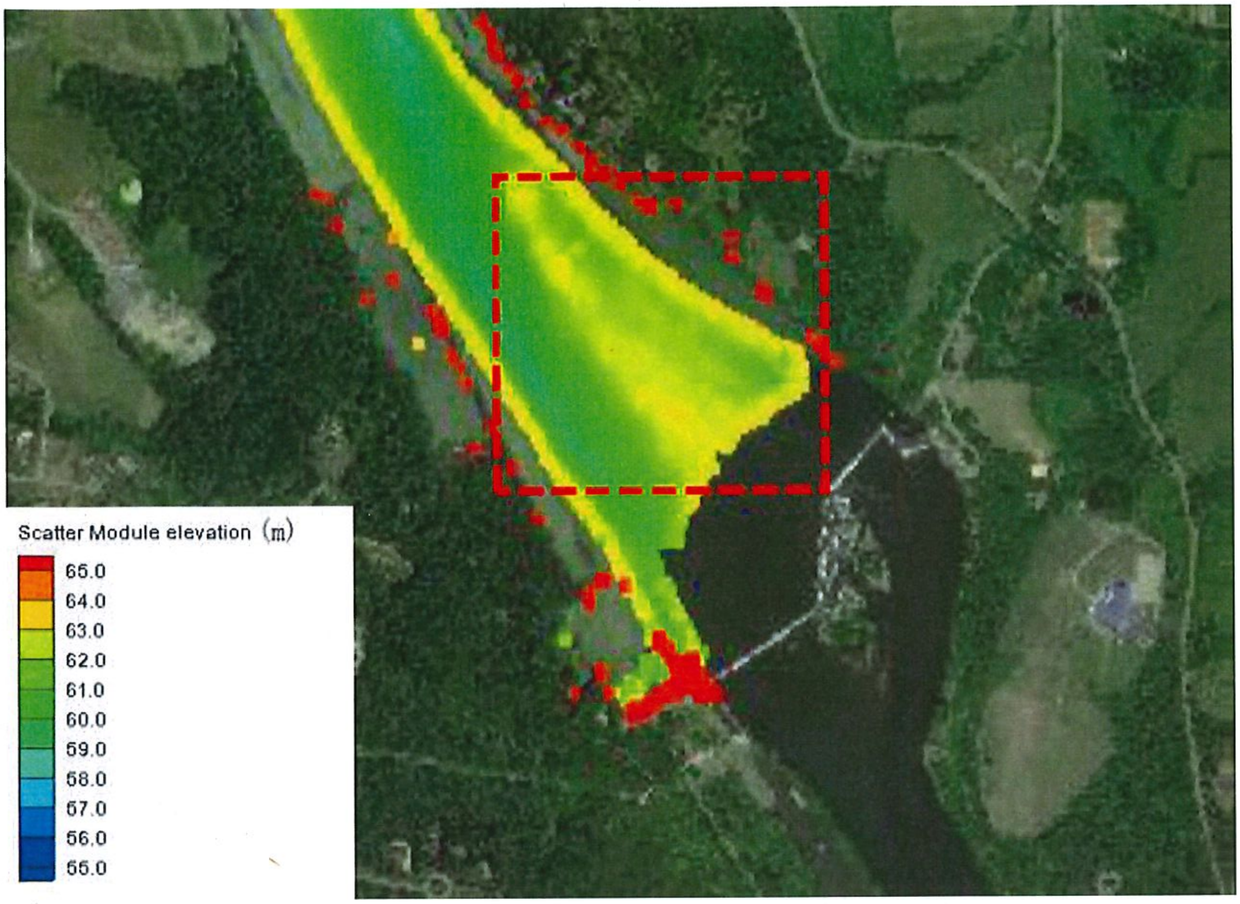

Figure 11: August 2019 Bathymetric Survey of the Vischer Ferry Dam pool, showing sedimentation (specially on the northern side of the channel)

4.2. Ice jam model outputs

The goal of the model, at this stage, was to best replicate the 2018 ice jam formation and breakup events in order to establish a baseline. The ice jam model was run with a set of parameters discussed and agreed upon by the Mitigation Panel (to be further refined in later iterations.[7])

After the baseline was established, it was used to test one of the nine interventions described in the following sections: **the deployment of ice breakers/cutters for sheet ice.** With this intervention developed into the model, some preliminary observations can be made:

1. The use of ice breakers/cutters **does not help mitigate ice jam formation at Isle of the Oneidas.** As discussed above and shown in Figure 8, this is a function of the severe sedimentation and river channel narrowing at this location.
2. There are minor **improvements at Freeman's Bridge**, although at this location the riverbed depth/channel geometry also presents continuing challenges.
3. There are **significant improvements at Rexford / Knolls**, as major segments of the ice jam break up earlier, allowing the Mohawk to flow past the bend in the river.
4. There are **improvements at the Vischer Ferry Dam pool**, which sees its sheet ice flushed out of the pool and over the dam crest.

[7] Key parameters are:

- Upstream boundary at Fonda; Schoharie Creek discharge data from USGS gage
- Downstream boundary at Vischer Ferry Dam; water level data from USGS gage
- Hydrodynamics simulation for ice-covered period between January 1 and January 12
- Bed roughness coefficients: n_{main}= 0.025, n_{fp} = 0.07
- Ice breakup simulation starts at hour 288 (12:00 a.m. on January 13)
- Cover strength was related to the plough by ice at the cover front
- Cover thickness coefficient: $t_{i,0}$ = 0.3m
- Ice cover roughness coefficient: $n_{i,0}$ = 0.02 – 0.06
- No thermal effect or wind data incorporated into simulation at this time

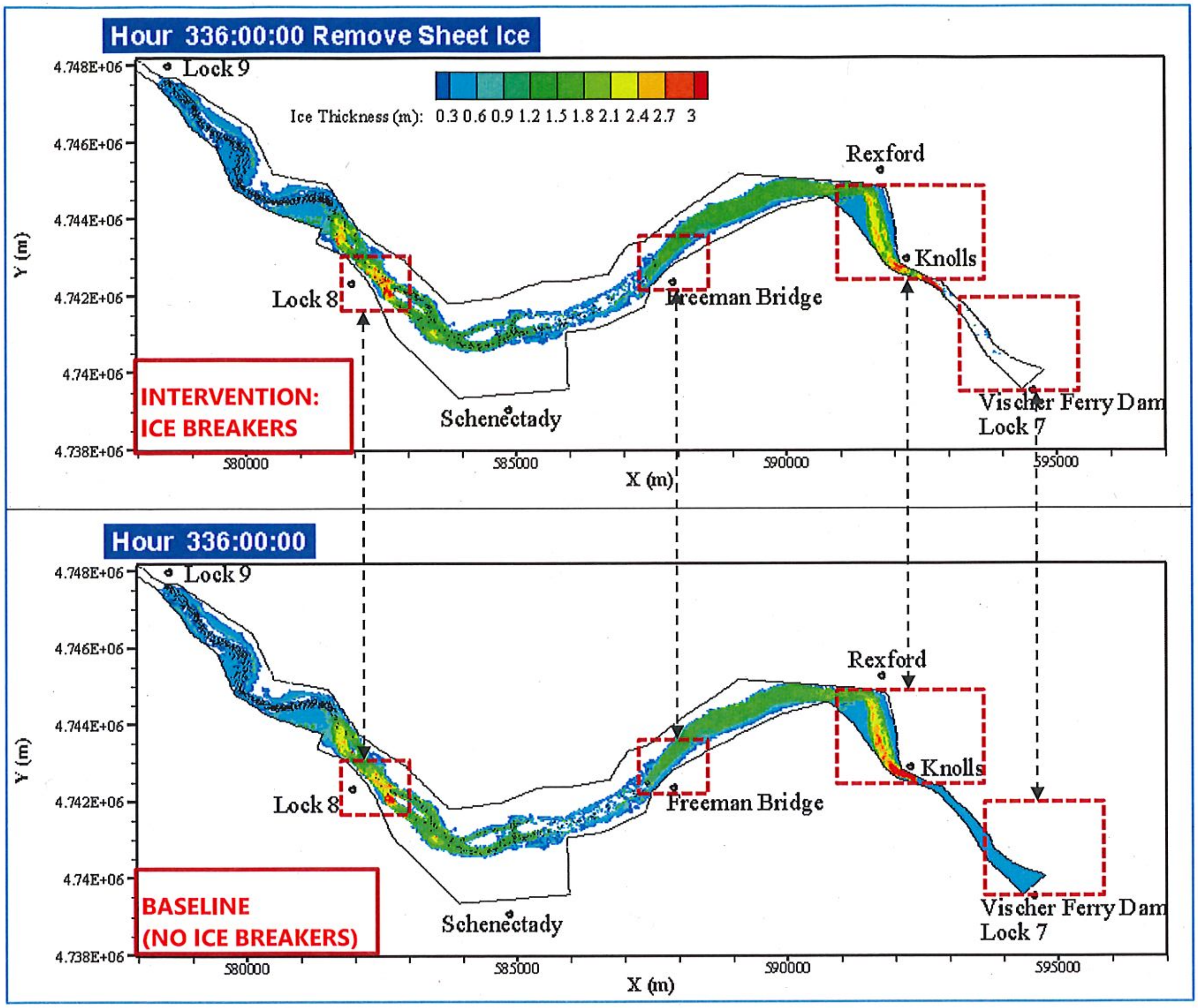

Figure 12: Ice Jam Model output: snapshot taken 8 hours after deployment of ice breakers/cutters

4.3. Next steps

In the coming months, the Clarkson modelling team will continue to refine the model to better calibrate it to the 2018 ice jam. Following this, the modelling team will test the potential interventions recommended by the Mitigation Panel, prioritizing those recommended by the Task Force. The potential interventions are outlined in greater detail in the following section.

5. Potential Interventions

5.1. Ice booms

Ice booms are the most widely used intervention to control ice movement and minimize new ice growth. They can be both a structural/permanent mitigation intervention or be deployed as an emergency measure in high-risk situations. They mainly consist of a series of timber beams or pontoons connected and strung across a river. In North America, ice booms are typically deployed for around five months during the winter season. Once the ice disappears, the booms are moved and transported elsewhere for storage during the summer months.

Figure 13: Ice Booms in Nelson River, Canada (left) and Oil City, US (right)

Ice booms are flexible and can be designed to release ice gradually when overloaded. They can be a relatively cost-effective intervention and can be placed seasonally to reduce potential negative environmental impacts. Ice booms can also be deployed relatively rapidly, rendering them effective as an emergency response measure.

However, the removal of ice booms can be costly since the components of each boom must be disconnected, cleaned, transported and stored until their next deployment. Ice booms can also be ineffective given that ice jams have the potential to circumvent the booms by moving underneath them. Ice booms do not suit all river environments and require low river flow velocity and adequate upstream ice storage capacity.

Recommendation

The intervention is not suitable for the Mohawk River due to the very high flow rate of the river and the relatively limited ice storage areas. Ice booms are more commonly used in Niagara for frazil ice (soft/loosely connected ice). Frazil ice is less common in the Mohawk, however, and the ice jams would likely flow under the booms.

5.2. Dynamite

Dynamite has been used in ice engineering practice for decades, and is particularly effective in addressing thick ice jams. Holes are drilled in the ice and dynamite is inserted to blow the ice apart. The most effective results can be achieved by placing the charges underneath the ice surface. Pieces can safely float down the river when additional support is provided to avoid the creation of bottlenecks.

Figure 14: Ice Mitigation with Dynamite in Ottawa, Canada (left) and Heilongjiang River, China (right)

Ice blasting is a very efficient intervention that can be performed within minutes. It is easily transported to remote locations and does not require any maintenance. The intervention does not require preparations such as clearing the area from snow and other debris.

Using dynamite to clear ice can, however, be harmful to the environment. It is also a dangerous method to employ with potentially fatal consequences. As such, dynamite use is highly-regulated and is prohibited within urban areas. Dynamite is not a sustainable solution and can require multiple treatments during extreme cold. It also requires the containment of large areas, which might have to be repeated several times. Dynamite handling also requires medium-skilled workers for safety reasons and in order to determine the correct application. The effectiveness of the blast can also vary with the type of ice. Thermally-grown ice is relatively easy to break up by blasting, while frazil ice is more difficult because it absorbs much of the blast energy.

Recommendation

The U.S. Army Corps of Engineers does not recommend the use of dynamite. Its inherent danger adds risk to addressing ice jams. It is also a hyper-local intervention that would have to be repeated at many locations along the Mohawk in order to have the desired effect.

5.3. Ice retention

Ice retention structures are used to control ice jams by actively initiating jams in more suitable locations where they are less damaging. Ice is captured and retained upstream of populated and otherwise sensitive areas. Ice retention structures can range from suspended structures to submarine nets and vertically oriented booms. Successful retention interventions consider both ice break-up and ice development areas.

Figure 15: Ice Retention Structures, Cazenovia Creek, West Seneca, NY

Figure 16: Ice Retention Structure in Salmon River, CT

Ice retention is cost-effective and its implementation does not require a skilled labor force. The structures can be highly customized and adapted to local needs, including the use of different materials. The retention structures also only partially block the river, allowing for recreational navigation and fish passage, and can thus be installed permanently.

However, ice retention is likely to be an ineffective tool for the Mohawk. This is primarily due to the spatial requirements that allow for the ice to collect and spread out, which most reaches of the Mohawk River lack. The intervention is generally more suitable for small rivers and streams. Additionally, the structures require maintenance and protection against scour.

__Recommendation__

Ice retention is not a suitable intervention due to its spatial requirements. There is currently no suitable area for ice storage between Lock E-6 and Lock E-9.

5.4. Ice breaker and cutter

Ice breakers or cutters are specialized vessels designed to break ice jams. They represent a non-structural ice jam mitigation method that is used globally in lakes, wide rivers, and oceans. Ice breakers are generally operated when temperatures start to rise, instead of at peak freeze. They are most suitable for ice sheet breaking, as there are limitations for the ice thickness that they are capable of breaking. Ice cutting can also mechanically weaken the ice, for example, by using strong vibrations or an amphibex floating backhoe. Ice breaking close to the coast or embankment can also be achieved using a land-based vessel, such as vehicle with a wrecking ball.

Figure 17: Amphibex Floating Backhoe (left) and Coast Guard Ice Breaker (right)

Ice breakers can typically break thick ice of up to three to 10 feet. Ice breakers have proven to be effective tools for breaking up ice cover on rivers. There are multiple types of ice breakers and, being a mobile solution, they can be flexibly targeted at areas with the most need.

Operating ice breakers requires a highly-skilled command and crew and are not suitable in all environments. For example, they struggle to operate effectively in narrow and shallow waters. Transporting ice breakers is also relatively difficult, making it a time-consuming and potentially cost-intensive solution. Moreover, there is the added risk that new ice jams are created as a result of the broken-up pieces of ice moving downstream.

Recommendation

Ice breaking can be considered as a potential intervention for use between Lock E-7 and Lock E-8. The risk of broken-up ice accumulating downstream could potentially be mitigated by dam modifications to NYPA's Vischer Ferry Dam at Lock E-7 (discussed later in this report).

5.5. Removal of the Vischer Ferry Dam at Lock E-7

Most of the dams at the Erie Canal locks are movable and swing upwards in the winter. Vischer Ferry is a critical exception, as it is a fixed, earthen dam. Under ice jam conditions, this dam can block the flow of water, elevating water levels, and ice jams easily accumulate at locks and related facilities. Ice can interfere with the movement of the locks and place additional load on their structural and mechanical components by, for example, preventing full gate opening. Changing water levels also present threats, given uncertainty regarding how rapidly the water rises and potential dam failure. Removing Vischer Ferry Dam would reduce the risk of ice jam creation by removing the existing obstructions to water flow.

Figure 18: Vischer Ferry Dam at Lock E-7

The intervention is cost-effective in the sense that it requires only a one-time investment and implementation. However, removing the dam could potentially lead to the river over-flooding during the summer months and to other issues downstream. Removal of Vischer Ferry Dam would preclude through-navigation except for shallow-draft boats (approximately 3-4 ft draft). Furthermore, the 11.8 MW power generation facility would be shut down.

Recommendation

Removing Vischer Ferry Dam is not recommended as it may yield increased flooding in the summer months and would shut down the power generation facility.

5.6. Obermeyer Spillway Gates (at Vischer Ferry Dam)

The Obermeyer Spillway Gates consist of a row of steel gate panels installed either at the top of dams or as free-standing structures. The system utilizes a combination of metal flap-gate panels supported by multiple small inflatable "bladders" that adjust the panels' angle and elevation. By controlling the pressure in the bladders, the water flow can be infinitely adjusted within the system control range. Panels can also be designed to include heated abutment plates to prevent ice formation.

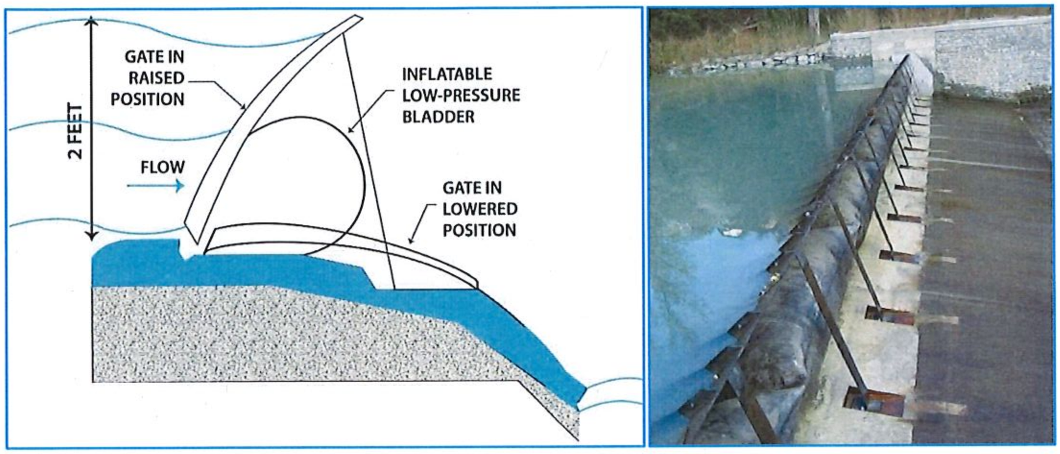

Figure 19: Obermeyer Spillway Gates diagram (left) and Installation in Uganda (right)

Obermeyer Spillway Gates are custom designed to conform to an existing or desired spillway cross-section. They are highly flexible and can be altered in accordance with seasonal needs. They can also be placed in narrow locations. The gates do not require an external power supply, which increases their reliability. The inflatable bladders which operate the gates are highly resilient (designed to withstand a shotgun blast), but large debris may damage them.

When upstream ice jams or sheet ice enter the Vischer Ferry pool, the Oberymeyer Gates would be lowered to allow the ice to spill over the crest. (During past ice jam events when the water level exceeded the existing dam elevation, this "wash-over" effect allowed for ice chunks to break up into smaller pieces that did not re-jam downstream past the dam.) Depending on the outputs of the ice jam modeling, it may be recommended that the Obermeyer Gates be "oscillated" between the up and down positions to best flush out and break up any ice in the Vischer Ferry pool.

Recommendation

The Obermeyer Spillway Gates can be considered as a potential solution at the Vischer Ferry Dam. The gates would replace the existing dam flash boards (Figure 20) if implemented. The gates could also help NYPA with regulating hydropower output.

Figure 20: Flash Boards at Vischer Ferry Dam

5.7. Removal of bridge abutments

The main purpose of abutments in waterways is to support bridges or other structures. Abutment bottoms can either be submerged in the water or situated on the riverbanks; when they are submerged in the water, they can obstruct ice passage and therefore increase the frequency and severity of ice jams. Removing abutments would likely result in smoother ice passage and ecosystem restoration.

Removing abutments is a cost-effective solution and would not require any ongoing maintenance. Ice-related flood events have the ability to destroy bridges; removing abutments would decrease the risk of bridge accidents.

However, removing abutments can make bridge structures weaker, limiting possible use and loading. To maximize benefits while minimizing the potential risks, the removal locations must be carefully considered. Furthermore, abutment removal is only an effective solution when ice jams have not already formed upstream of the bridge.

Recommendation

More detailed engineering and cost-benefit analyses will be required. One potential location is proposed for further evaluation immediately: the old **Burr Bridge in Scotia** (Figure 21).

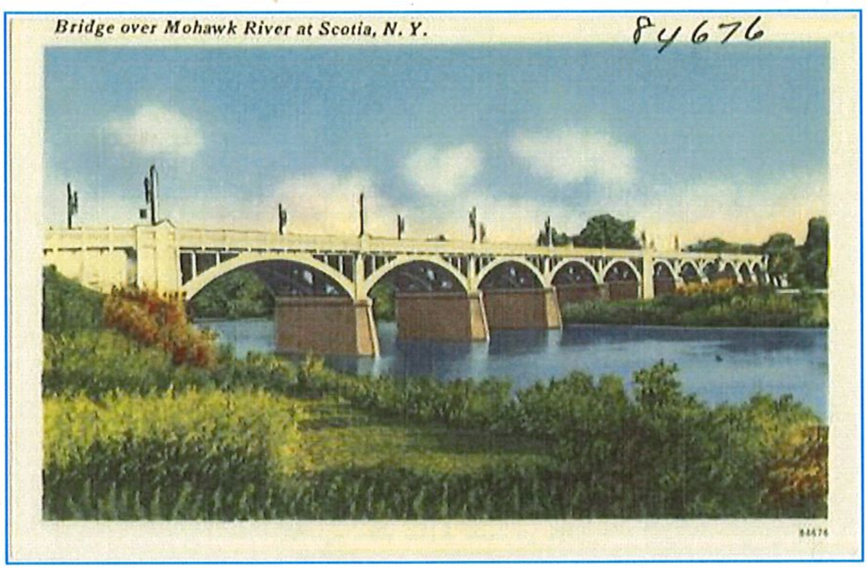

Figure 21: Postcard of the Old Burr Bridge in Scotia, NY

Other potential locations to be studied going forward include:

- **Pan Am Railway Bridge in Rotterdam:** this bridge is an ice jam hotspot, but the bridge is still frequently used.
- **Washington Avenue Bridge in Schenectady**: has small abutments on the Mohawk River's edges.
- **Freeman's Bridge in Schenectady**
- **Old trolley track in Glenville**: the bridge's tracks/bed was removed during World War II, but the piers remain and may be contributing to ice jam formation.
- **Amtrak Bridge in Schenectady**: not likely to be causing ice jams, as it appears to have been constructed with ice breakers on its piers.

5.8. Effluent from wastewater treatment plant

The release of warm water waves into a river from a nearby wastewater treatment plant (WWTP) can help mitigate ice jam formation. Provided that the effluent is added to the river prior to ice jam formation, the additional water volume can increase the river flow velocities and prevent ice jam creation in the first place. The wastewater can also be used for the thermal control of ice, as the released warm water can melt or thin ice jams.

WWTP water can effectively melt ice over a period of days or weeks. To maximize the impacts, the warm input water can be brought to the surface using air bubblers, pumps, or flow enhancers.

However, in the case of the Erie Canal there is a risk of contamination to the river as the water quality is not controlled by NYPA/Canals, but rather by the WWTP operator. The usefulness of this intervention is limited, given that the WWTP effluent outflow needs to be aligned with the ice jam problem areas. As previously noted, it is also crucial that the effluent be added before the ice jams have formed: once they have formed, it only serves to exacerbate the flood risk.

Recommendation

This intervention is not recommended for the Mohawk, as the warm water effluent from the WWTPs along the Mohawk is too small in volume and has inconsistent flows.

5.9. River channel reprofiling

Channel morphology (e.g. width and depth) is a key factor affecting ice jam formation. Changes in river channel width, such as from debris or sedimentation processes, for example, can cause bottlenecking and ice jam formation. Channel depth is also important given that deeper water moves more slowly and thus promotes ice jamming. Implementing such modifications to river channel morphology requires detailed planning and should be done in stages.

Figure 22: River Channel Modifications to both depth (left) and width (right)

The recently-procured bathymetric data can be used to compare the difference between the as-designed 14-foot draft for the Erie Canal and its actual condition (for example, differences between the two would indicate areas that might be suitable for dredging). Once identified, dredging or excavation can be performed in these areas to widen, deepen or straighten the natural channel in order to improve water flow. Accumulated sediments can also be removed and diversions can be built to bypass ice jamming sites. These diversion channels can improve the performance of ice control structures. Channel modifications are generally easy and low-cost solutions.

Some complexity in environmental permitting is associated with channel reprofiling: the Canal Corporation is permitted to dredge in its primary navigation channel, but it would require additional permission from NYS DEC to perform additional dredging to aid navigability. Beyond permitting, the primary disadvantage of river channel re-profiling is that it may require continuous monitoring, study, and re-dredging. Dredging could be required indefinitely given that sedimentation and debris can accumulate year after year.

Recommendation

River channel modifications should be considered as a potential intervention, but more detailed study is required to confirm its feasibility and value in specific locations. The bathymetry survey should be compared to the as-designed channel drawings to identify potential areas of channel modification. The impacts of these modifications should then be inputted into the ice jam model to determine the potential impacts of dredging or reprofiling on ice jam formation.

6. Ice Jam Forecasting

Ice jam floods are a threat to lives and properties in the low-lying areas along the Mohawk River, particularly in Schenectady's historic Stockade District. Backwater from an ice jam can cause flooding upstream of the jam, and the abrupt release of backwater from a jam breakup remains a threat to lives and property downstream of the jam. Historically, emergency managers have monitored ice jams and the corresponding water levels through on-site observations, which is inefficient and not always accurate and does not adequately describe the extent of the ice jam conditions, which can spread over many river miles.

During the winter of 2012, the New York Science Center of the U.S. Geological Survey (USGS), in cooperation with New York State Department of Environmental Conservation's (DEC) Mohawk River Basin Program, the New York State Power Authority, Brookfield Renewable Power and Union College, launched an initial monitoring tool to help emergency managers assess river conditions and the potential for ice jam flooding in the vicinity of the Stockade District in Schenectady. Initially, two web cameras located at Lock E-8 and Freeman's Bridge combined with four USGS stream gages along the Mohawk River between Lock E-8 and the Vischer Ferry Dam, 11 miles downstream from Lock E-8, were used to provide an alternative to the previous on-site observations made by local emergency managers.

Data from these stream gages are used as input to simple models that estimate the amount of ice-related backwater between each stream gage. Graphs depicting the changing backwater conditions are updated every five minutes on the project webpage. Additionally, the web camera located in the Stockade District provides real-time images of the river during the winter months. The initial system was expanded in 2019 with the installation of web cameras at the Vischer Ferry Dam (Lock E-7) and at the movable dam in Rotterdam Junction (Lock E-9) and USGS stream gages were installed at the Vischer Ferry Dam and at the Rexford Bridge. This monitoring tool is available to the public as a web-based product.[8]

However, the ice cover observation system currently in place to track the potential development of ice jams requires extensive field observation and may have considerable uncertainty due to time lags between observations and reporting. While this ice jam monitoring system is useful as a monitoring tool for emergency managers and the public, the system is limited to monitoring and does not have forecasting capabilities.

Forecasting the occurrence of ice jams is challenging for several reasons. The processes of ice cover breakup and ice jamming are complex and nonlinear, and numerous morphological, meteorological, thermodynamic, and hydrological factors interact during ice jam formation. Yet flood forecasting and risk mapping are urgently needed by state and local emergency managers. An ice jam forecasting system would serve to help understand ice jam evolution and potentially mitigate the impacts associated with ice jam flooding.

Recommendation

A Mohawk River Ice Jam Flood Forecasting System is proposed to be developed for the portion of the Mohawk River between Lock E-7, Vischer Ferry and Lock E-9, Rotterdam Junction. The system should include increased near real-time monitoring to improve the situational awareness of the ever-changing ice jam conditions throughout this reach.

Data collected from an improved monitoring system can serve as input to a hydrodynamic ice jam modeling system which will serve to forecast ice jam formation location and the magnitude of ice-related backwater. When ice jam formations occur, the system will provide forecasts associated with ice jam releases including the expected

[8] See for more detail: http://ny.water.usgs.gov/flood/MohawkIce/

timing of ice jam release, associated magnitude of the flow release, and corresponding forecasted inundation mapping.

This system will provide actionable information to state and local emergency managers, to allow them to prepare for potential ice jam flooding by identifying the consequences and risks to communities along the river as ice conditions evolve throughout each winter. This system will also provide emergency managers information to properly evacuate flood-prone areas when conditions are conducive to flooding, rather than wait until the flooding begins to occur.

It is proposed to have the Mohawk River Ice Jam Forecasting System implemented as soon as possible, and be operated by the New York State Division of Homeland Security and Emergency Services (DHSES) 24-hour Watch Center, to ensure robust situational awareness of ice jam monitoring data and forecasts as ice jams develop. DHSES is best suited for this role given its continual monitoring of emergency threats throughout New York State. The system will be developed to provide warnings of potential ice jam conditions using the National Weather Service emergency alert warnings (television/radio broadcasts, NOAA weather radio, wireless emergency alerts, and web-based products) and reverse 911 to warn residents of potentially developing conditions.

7. Recommended Interventions

Five initiatives are recommended for further study and potentially subsequent implementation:

1. **Ice breakers / cutters:** Using specialized boats/machinery to physically break up ice jams in hotspot areas.
2. **Obermeyer Spillway Gates:** Modifying the Vischer Ferry Dam (at Lock E-7) to better manage water flows, and potentially "flush out" ice jams.
3. **River channel reprofiling (dredging):** Modifying the Mohawk River to alleviate choke points to water flow which result in ice jam formation.
4. **Removal or modification of bridge abutments:** Removing abandoned bridge abutments, and potentially retrofitting existing bridges to help break up ice jams.
5. **Ice Jam Flood Forecasting System:** Expanding on the ice jam model produced for this study to better predict ice jam flooding, providing communities and emergency managers far more lead time to prepare for a flood event.

Of these, only the Ice Jam Flood Forecasting System is recommended for immediate implementation. For the other interventions, the scope of further study should include additional hydraulic modeling (i.e. recreating the ice jam model with select interventions included), more detailed cost estimation, environmental permitting feasibility analysis, and implementation feasibility/implementation planning.