# Great Lakes - St. Lawrence River Adaptive Management (GLAM) Committee

## Annex 1:

## Supplementary impact assessment information for Lake Ontario and the St. Lawrence River

November 26, 2018

# Contents

*Cover photo: High water conditions near Fair Haven, New York Photo credit: US Army Corps of Engineers, June 2017.*

# 1.0 Introduction

This Annex (**Annex 1**) provides further information on the impacts of 2017 water level and flow conditions within the Lake Ontario-St. Lawrence River system on various interest categories and is intended as a supplemental reference to the main report.

The year 2017 provided a unique opportunity to gather data under extreme conditions and the GLAM Committee endeavored to collect or gain access to as much data and information as possible about the impacts that occurred in 2017 across many different areas of interest. While it was well beyond the GLAM Committee's current resources to pursue this information whole-scale, the GLAM Committee concentrated on the most efficient data collection efforts by focusing on information that could contribute in the short term to the evaluation of the existing agreed-upon performance metrics. Having said that, much of the quantitative economic data on impacts from high water levels in 2017 needed to support the validation of models used to evaluate the performance of the regulation plans is not yet available and, in some cases, may never be available. It should also be noted that effects of the 2017 event on some performance indicators are not observed within a year of the extreme conditions. For example, it may be several years before the 2017 impacts to the ecosystem are realized in full. The GLAM Committee is acutely aware of the dangers of making premature conclusions based on what has been observed and reported since the spring of 2017. Aside from the efforts reported on here, it is critical to pursue the development of a long-term monitoring strategy to ensure that the GLAM Committee continues to collect the information necessary to contextualize the 2017 data in terms of the long-term effects. The information reported on here is merely a stepping stone to understanding the effects of 2017 conditions on the entire system over time and the GLAM Committee is continuing to pursue efforts to document impacts throughout the system.

# 2.0 Impact Assessment Background

This report provides a general overview of impacts, both positive and negative, experienced across a range of sectors in 2017 throughout the Lake Ontario-St. Lawrence River system based on observed water levels and conditions. **It is important to clarify that this Annex is not intended to represent a full economic or environmental analysis of high water impacts in 2017. Instead, the intent is to capture the critical types of impacts and, where possible, get a sense of the geographic distribution to support long-term efforts to validate and improve existing models linking water level changes to positive and negative impacts and ultimately, evaluate the performance of the outflow regulation strategies that are currently in place.**

Water level impacts from the 2017 high water event were gathered through:

- efforts the GLAM Committee directly manages; and
- efforts undertaken by outside groups and agencies independent of the GLAM Committee.

**Performance Indicators (PI):**

Six key interest categories are covered in this review including municipal and industrial water use, commercial navigation, hydropower, shoreline property interests, environmental interests and recreational boating and tourism. All of these sectors are affected by changes in Great Lakes water levels or flows and all were impacted to varying degrees by the high water levels in 2017. In documenting impacts, both positive and negative, the GLAM Committee paid particular attention to the existing PIs that had been established by the previous IJC studies including the Lake Ontario-St. Lawrence River Study (LOSLRS) and the International Upper Great Lakes Study (IUGLS) and had been part of the models used in the evaluation and ultimate selection of the existing regulation plans.

PIs represent a quantifiable measure of the relationship between an economic, social or environmental impact and different water levels and flows in the Great Lakes-St. Lawrence River. These relationships must:

- represent something of **significance** to the interest;
- demonstrate a measurable **sensitivity** to water level changes; and
- have confidence/**certainty** in the data and science that support it.

PIs developed during the LOSLRS and IUGLS were not meant to be used in isolation or to reflect absolute impacts, rather they were designed to be used in a relative comparison of regulation plan alternatives and were supposed to represent broader societal impacts, both positive and negative, and capture outcomes and tradeoffs between interests and over broad geographic scales and be representative of broad objectives established by the IJC and governments, such as overall net benefits.

The record conditions of 2017 on Lake Ontario and the St. Lawrence River were outside the range of conditions for which data were available to develop the existing PIs. Therefore, information from 2017 is critical to support the validation and improvement of a number of the LOSLRS PIs and to add new information and give new insights into what is likely to occur under conditions that had previously only been simulated.

A full list of the existing PIs used for the Lake Ontario-St. Lawrence River system during the past IJC studies can be found in Appendix 1 of the main report.

This Annex describes each interest category and their general sensitivity to water level fluctuations and summarizes specific positive and negative impacts from the high water levels in 2017 based on information that is currently available to the GLAM Committee. In many cases, the available information is from secondary and anecdotal sources and the GLAM Committee is not able to independently verify the impacts. However, the information is included as a reflection of the types of issues that were reported. The GLAM Committee continues to pursue efforts to identify potential data sources in support of long-term adaptive management efforts. For example, data may eventually become available through formal agency reporting and the GLAM Committee has also initiated efforts (or intends to) to directly acquire further information where particular gaps have been identified.

# 3.0 Municipal and Industrial

## 3.1 Summary of GLAM work and other agency activities to assess impacts

Based on extreme 2017 water levels in the Lake Ontario-St. Lawrence River basin, the GLAM Committee initiated a group of complimentary efforts to track impacts associated with 2017 water levels (Table 3-1). Impact information related to municipal and industrial water use must primarily be obtained from the system operators. As such, GLAM Committee associates from the Buffalo District of the US Army Corps of Engineers (USACE) on the US side were in direct contact with a number of US operators. A total of 16 water treatment plants (WTP) and 24 waste water treatment plants (WWTP) were contacted in the counties bordering Lake Ontario based on New York Department of Environmental Conservation (NYDEC) inventories. A series of questions were asked to plant operators, waste water treatment plant employees and village representatives. The questions were used to gauge which plants were impacted by the flooding on Lake Ontario in 2017. As well, GLAM Committee associates reviewed oblique photography and site visit photographs taken along the Lake Ontario shoreline as well as on the St. Lawrence River from Montreal downstream during high water conditions to identify evidence of drainage problems. Media reports from 2017 were also reviewed. An online questionnaire was developed for shoreline property owners to report problems associated with 2017 high water conditions and some information is available regarding shore wells and septic systems for self-supply residential users. Going forward, the GLAM Committee has initiated a contract for further follow-up with water supply and wastewater operators to fill gaps and that work is expected to be completed in 2019.

Table 3-1: Activities managed by the GLAM Committee that provide information on municipal and industrial water use impacts from 2017.

| Activity | Lake Ontario | | Upper St. Lawrence | | Lower St. Lawrence | Relation to Municipal and Industrial Water Use PIs |
|---|---|---|---|---|---|---|
| | **US** | **CAN** | **US** | **CAN** | **CAN** | |
| Direct contact with water and wastewater system operators | Yes | No | Yes | No | No | Provides information on the two key PIs, 1) municipal and industrial intakes, and 2) wastewater treatment plants and outflows |
| Oblique Imagery Acquisition and Assessment | Yes | Yes | No | No | Yes | Evidence of poor municipal drainage capacity in low-lying shoreline areas |
| Database of Site Visit Photographs | No | Yes | No | Yes | Partial | Evidence of poor municipal drainage capacity in low-lying shoreline areas |
| Development and Implementation of online, self-reporting questionnaire for coastal property owners | Yes | Yes | Yes | Yes | Yes | Allows self-reporting from property owners on impacts to self-supply water or wastewater (septic) service. ***NOTE: The questionnaire was intended to allow direct input from property owners on their perspective regarding impacts but is not considered a statistically robust methodology for extrapolation purposes.*** |
| Tracking of media report | Yes | Yes | Yes | Yes | Partial | Examples of impacts to municipal water and wastewater services that may not be otherwise reported |

Other agencies and groups are also looking at impacts associated with 2017 high water conditions for various emergency response, recovery and operational purposes (Table 3-2). Much of this information is not directly accessible to the GLAM Committee at this time as these agencies and groups have not yet released the information publicly. Efforts will continue to gain access to this impact information in support of long-term GLAM Committee activities.

Table 3-2: Activities that are undertaken by outside groups and agencies independently from the GLAM Committee related to municipal and industrial water uses but where the results and information, if available, directly relate to GLAM Committee objectives of understanding impacts due to changing water levels.

| **Activity** | **Lake Ontario** | | **Upper St. Lawrence** | | **Lower St. Lawrence** | **Relation to Municipal and Industrial Water Use PIs** |
|---|---|---|---|---|---|---|
| | **US** | **CAN** | **US** | **CAN** | **CAN** | |
| New York State Flood Relief/Recovery Program | Yes | NA | Yes | NA | NA | Information on the types and extent of damages to water and wastewater services observed by shoreline municipalities |
| FEMA Disaster Declaration Process | Yes | NA | Yes | NA | NA | Information on the types and extent of damages to water and wastewater services observed by shoreline municipalities in New York |
| Province of Quebec "Special financial assistance program for the flooding that occurred between April 5 and May 16, 2017" | NA | NA | NA | NA | Yes | Information on the types and extent of damages to water and wastewater services observed by shoreline property owners in Quebec |
| Province of Ontario Disaster Recovery Assistance Program | NA | Yes | NA | Yes | NA | Information on the types and extent of damages to water and wastewater services observed by shoreline municipalities in Ontario |
| New York State Emergency Response | Yes | NA | Yes | NA | NA | Summary of emergency response efforts, by county (e.g. deployment of sandbagging and associated equipment) |
| Review of municipal and other agency documentation on impacts and costs | No | Yes | No | Yes | No | Water and wastewater treatment impacts reported by Canadian shoreline municipalities through standard public reporting purposes (e.g. council meeting minutes) |

## 3.2 Media coverage

The GLAM Committee has been tracking media reports since mid-April 2017, with particular focus on English media covering the Lake Ontario and the upper St. Lawrence River and a lesser focus for French media due to search criteria used. While much of the coverage on municipalities related to general costs to the individual cities, the reports were reviewed for discussion of direct impacts to related stakeholders with regards to water and wastewater treatment. There was news coverage of several wastewater treatment facilities experiencing inflow surcharges as a result of storm water infiltration of the collection system, as well as a few accounts of releasing untreated sewage into the Niagara River and Lake Ontario. There has also been news coverage of inundated self-supplied and municipally serviced residential systems located in low-lying areas from high-water levels in Lake Ontario. For example, on May 2, 2017, the Hamilton Spectator quoted Hamilton City Councilor Chad Collins stating that "Although the City has installed new pumping stations and changed building rules to ban full basements in new beach strip housing, even in a "normal" year he still receives regular calls about spring flooding." (http://www.thespec.com/news-story/7271902-heavy-rains-batter-hamilton-s-waterfront-flood-basements/). On May 17, 2017, CBC News reported that with the water much higher than usual, the City of Toronto was finding that a small number of the City's catch basins were now below the lake's surface level, forcing the water upwards in some cases (Figure 3-1) (http://www.cbc.ca/news/canada/toronto/lake-water-is-spilling-out-of-sewers-and-onto-eastern-avenue-1.4120024). On June 13, 2017 WHEC reported that the Town of Greece, NY suffered $500,000 in infrastructure costs and that the Village of Sodus Point would receive $500,000 from the State of New York to "repair the flood-damaged waste water system" (http://www.whec.com/news/governor-cuomo-visits-flooded-areas-along-lake-ontario-tuesday-/4511959/).


CBCnews | Toronto

Lake water is spilling out of sewers and onto Eastern Avenue

City says low-lying sewers can discharge lake water on wavy days

By Nick Boisvert, CBC News Posted: May 17, 2017 3:10 PM ET | Last Updated: May 17, 2017 5:07 PM ET

Figure 3-1: News story from CBC News Toronto on May 17, 2017 (http://www.cbc.ca/news/canada/toronto/lake-water-is-spilling-out-of-sewers-and-onto-eastern-avenue-1.4120024)

# 3.3 Impacts of 2017 water level conditions

## 3.3.1 Lake Ontario and the upper St. Lawrence River – State of New York

### *3.3.1.1 Municipal Water Treatment*

Information was collected from an inventory of 16 WTPs in New York villages, towns and cities having a large variation in the size of the treatment facilities by GLAM Committee associates at the USACE Buffalo District. Each of these facilities operate intakes that withdraw water from Lake Ontario or the St. Lawrence River. These facilities have reported intake depths that range from 12 to 60 ft. (4 to 18 m) and intake lengths extending out into the lake from 50 to 6,600 ft. (15 to 2,012 m).

In general, water treatment facilities benefit more when lake water levels are high (i.e. the source from which the water is extracted) when compared to when water levels are low due to changes in water levels above the intake. A consensus of information collected from operational personnel at the treatment facilities by USACE staff indicated the high water level conditions in 2017 did not have significant impacts on treatment operations. In fact, the majority of the operators indicated operations were improved as a result of the high water levels.

Two of the larger water treatment facilities, Monroe County Water Authority (Rochester, NY) and Metropolitan Water Board (Oswego, NY), which account for approximately 90 percent of water production and population served along the south shore of Lake Ontario, did not report any significant impacts to operations, but the operators did note water levels rose to within approximately 1 to 2 ft (0.3 to 0.6 m) of the critical elevation of the lift station with the potential of causing equipment damage. During the LOSLRS, it was noted that the Monroe County Water Authority drinking water plant did have some high water concerns about possible pumping station flooding (CDM, 2005; International Lake Ontario-St. Lawrence River Study Board, 2006).

### *3.3.1.2 Municipal Wastewater Treatment*

Information was collected from 13 of 24 WWTPs in New York villages, towns and cities by staff at USACE Buffalo District. Each of these facilities discharge treated wastewater to Lake Ontario, the St. Lawrence River or a near-shore tributary. Information was evaluated and it was determined that WWTPs were more vulnerable to impacts when compared to WTPs during 2017 high-water level conditions. Of the 13 responses, 6 reported experiencing some degree of impact based on 2017 water levels.

The singular most common impact reported was storm water infiltration into the system causing combined sewer or sanitary sewer overflows at the plant during periods of wet weather flow. Inflow & infiltration is a common problem in wastewater treatment. During rain events, there is typically more inflow to the system through combined storm- and sanitary- sewers, as well as grandfathered or illegal downspout and sump pump connections to the sanitary sewer. When rainfall percolates through the soil, or runoff causes the water table to rise, ground water infiltrates the collection system through cracks in the piping. These all contribute to higher WWTP inflows during precipitation events. More facilities reported impacts from high precipitation than from high lake levels, which is to be expected as inflow and infiltration is a regular concern of wastewater treatment facilities under normal conditions. According to city officials that responded, many of the systems do not have the capacity to accommodate the volume from the influx of wet weather flows. In some cases, WWTPs are left to discharge untreated wastewater to the outfall source to protect against overflows. This can be partly related to high Lake Ontario water levels, but is predominantly driven by the amount of water coming into the system with significant rain events in the watershed being a primary driver.

Additional impacts noted by the Buffalo office of USACE during site visits in May of 2017 include septic leach field inundation in Kendall, NY. The Ogdensburg Combined Sewer Outfall pumps were inoperable for a period in May due to the volume of water exceeding pump capacity, leading to high water above Combined Sewer Outfall outlets. In Oswego, NY, the sanitary sewer lift station at the end of West Shore Road becomes inundated as backwater from Wine Creek floods the nearby marsh and activates the pump alarm. Primarily driven by wind events and not static water levels, there was no observed inundation of the lift station during the site visit, however high water levels observed in the marsh are only approximately 12 in (0.3 m) from inundating the pump station. Local authorities had taken the preventative measure to stock sandbags next to the lift station. In Sandy Creek, NY all of these residences' septic systems were flooded at the Sandy Pond Beach Campground rendering all sanitary facilities inoperable at that site. In Wilson, NY, the town storm sewer outfall was truncated due to wave action, approximately 20 feet of the 30-inch diameter HDPE pipe was lost along with the protective stone bedding. Braley Road was closed due to erosion pockets and sink holes caused by a seepage path forming along the existing twin-arched corrugated metal pipe culverts. Wilson authorities were consulting with an Architecture and Engineering Firm at the time of the site visit to repair the culverts. Shoreline erosion along Lakestone Drive was observed to be threatening a sanitary sewer line and protective riprap had been lost due to wave action (Figure 3-2). The WWTP outflow at Featherly Drive was threatened with erosion (Figure 3-3). A follow-up site visit to Sodus Point on 26 May showed additional riprap protection was placed to protect the sanitary sewer line on Lakestone Drive (Figure 3-4).

Figure 3-2: Shoreline erosion observed adjacent to sanitary sewer line in Sodus Point, NY, 19 May, 2017. Photo credit: USACE Buffalo, 2017.

Figure 3-3: Bluff erosion approximately 10 ft. from WWTP outfall, in Sodus Point, NY, 19 May, 2017. Photo credit: USACE Buffalo, 2017.

Figure 3-4: Additional rip rap placed to protect sanitary sewer line in Sodus Point observed on 26 May 2018 Photo credit: USACE Buffalo, 2017.

The following WWTPs reported impacts due to being inundated with large volumes that resulted in the release of untreated wastewater. Also noted is the number of instances each of the plants released untreated wastewater:

- Village of Waddington (2 to 3 times)
- Village of Sodus Point (2 times)
- Village of Clayton (8 times)

In a few cases, such as the Village of Sodus Point, the Village of Clayton and the Town of Ontario, there were reports of a few specific lift stations that had infiltration from high water levels that contributed to water quality impacts, excessive pump operations and even pump damage in one situation. In the case of the Village of Sodus Point, sandbags were installed to protect some lift stations. The problems in the Village of Sodus Point are consistent with some of the concerns raised during the IJC Hearings regarding Plan 2014. For example, it was noted in the hearings that five of fourteen lift stations in the Sodus Point sewer system have elevation below 250 ft (76.2 m) and one of the lift stations at 248 ft (75.6 m) pumps about 40% of the sewage in the village. The GLAM Committee does not currently have information to understand how the 2017 water level impacts to lift stations directly contributed to loss of service within the Village of Sodus Point and that will require further investigation, but it has been reported that the State of New York will be providing $500,000 to support infrastructure repairs (NYS

Department of Financial Services, 2017). Monroe County received $1.5 million for repairs and resiliency improvements to prevent future damage (McDermott, 2018). Although Monroe County Water Authority had not been reached at the time of this report and is not included in the responses, based on media reports (impacts not directly verified by the GLAM Committee), their system suffered from erosion and manhole flooding along Edgemere Drive in Greece, NY. Monroe County and Newfane were affected by erosion, whereas Sodus Bay was affected by flooding due to wave action, as opposed to erosion. Impacted municipalities had to enlist the assistance of contractors or other municipal departments when protective measures were taken.

This information is consistent with preliminary results from the responses to the Conservation Ontario shoreline questionnaire regarding self-supply residential water and wastewater functions. From November, 2017 through January, 2018, Conservation Ontario collected responses to an on-line survey. Respondents answered questions regarding the observed impacts on their properties throughout 2017. This was a self-reporting survey and the GLAM Committee has not independently verified questionnaire responses, nor are the responses intended to be a statistically representative sample. Nevertheless, the responses provide information on the types of impacts that were identified by shoreline property owners. Impacts reported for the self-supply residential category included flooding of property features including wastewater treatment and potable water supply systems. On the US shoreline of Lake Ontario and the Upper St. Lawrence River, there were 1024 usable responses to the Conservation Ontario survey. Of those responses, 155 reported flooding or inundation or septic beds primarily in Oswego, Jefferson and Monroe counties, and the municipalities of Hilton, Hamlin, Sandy Creek and Mexico, each having greater than 10 responses. In terms of self-supply water, there were 100 respondents that indicated their shore wells flooded (Figure 3-5). The majority were in Jefferson and Monroe counties, with greater than 20 responses (Figure 3-6). Because this is not a statistically representative sample of shoreline impacts, the findings cannot be extrapolated to estimate full lake damages and further assessment is required to determine the full extent of septic and shore well impacts along the Lake Ontario and southern St. Lawrence River shoreline.

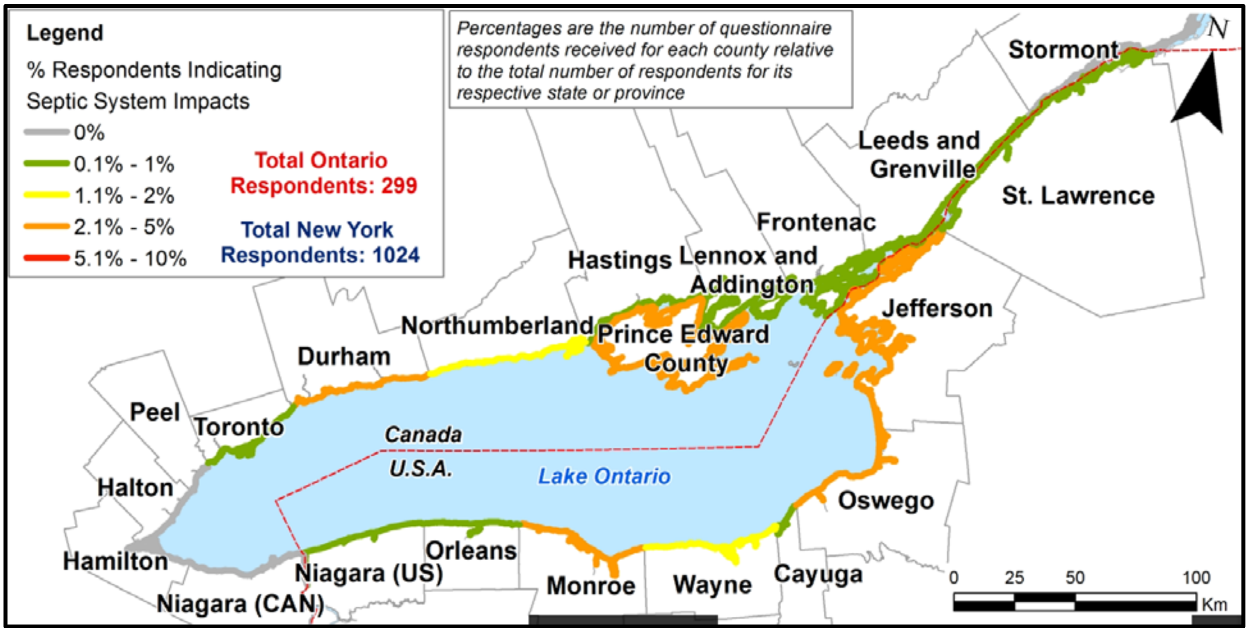

Figure 1-5: Percent of survey responses indicating septic flooding (shown as a %, by County, relative to total number of survey responses in that Country) (Source: Environment and Climate Change Canada (ECCC), based on data acquired through Conservation Ontario survey for IJC)

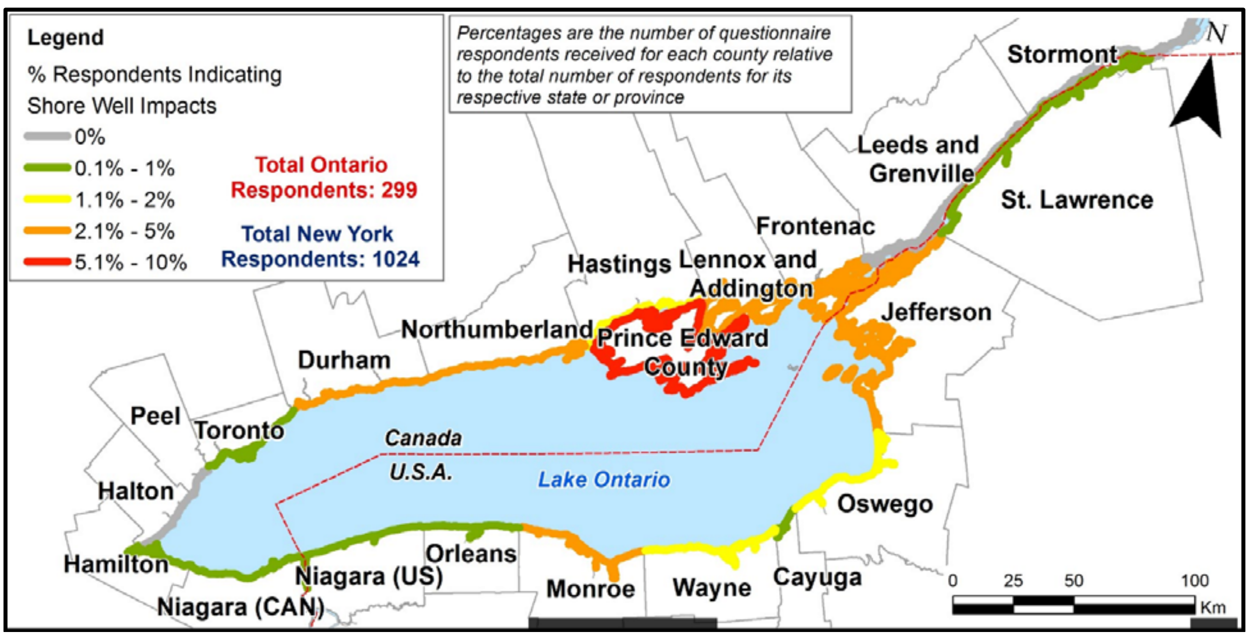

Figure 3-6: Percent of survey responses indicating shore well flooding (shown as a % by County relative to total number of that reported impact for Country) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

#### *3.3.1.3 Industrial Water Intake/Discharge (Nuclear Power)*

The GLAM Committee has not acquired direct information on nuclear power impacts from the 2017 high water levels. A media report by WVRO public media from July 14th, 2017 (*http://wrvo.org/post/high-lake-ontario-levels-nearly-pushed-nine-mile-nuclear-plant-emergency-action*) noted that "according to the Nuclear Regulatory Commission (NRC), Lake

Ontario was only a foot short of placing Nine Mile [Point Nuclear Facility] in the lowest-level emergency action plan." However, the article follows up to say that "Despite the close call, the plant's owner Exelon did not feel the situation warranted the unusual event status because the high water levels were not threatening operations."

### 3.3.2 Lake Ontario and the upper St. Lawrence River – Province of Ontario

GLAM Committee members and associates have been reviewing municipal reports (e.g. staff reports to town councils, etc.), looking for information on high water impacts in 2017. This effort focused on municipalities within the Province of Ontario. Based on initial information, there is very little documentation of high water impacts limiting WTP operations. The GLAM Committee intends to acquire further information in this area through a follow-up survey conducted in the fall of 2018 and early 2019.

The combination of high water levels and excessive precipitation in April and May did lead to some problems for WWTP facilities along the Canadian Lake Ontario shoreline. The City of Hamilton relies, in part, on combined sewer overflow tanks during significant rain events and a staff report to Council noted that the storage capacity of some of those facilities (specifically the Strachan and Eastwood facilities) were partially compromised by the high lake level conditions (City of Hamilton, 2017). The implications are that during significant precipitation events, some untreated wastewater must be discharged without full treatment because the amount of wastewater exceeds the combined capacity of the WWTP and the combined sewer overflow tanks. Page 2 of the City of Hamilton (2017) report also notes "as a result of the combined sewer overflow tanks and associated infrastructure being submerged, staff are seeing evidence of fish entering the sewer system. They are being removed at the wastewater treatment facility. This situation is quite unusual and staff do not have any previous records of fish appearing in the sewer system in this manner".

Similar to the US review, there were also identified issues in some shoreline areas related to drainage of water. This was particularly the case for low lying areas such as the "dock area" of Niagara-on-the-Lake and portions of the shoreline in the City of Toronto. In Niagara-on-the-Lake, the town plugged manhole outlets in that area and used pumps to remove water (https://notl.civicweb.net/document/7696/Media%20Release%20-%20Town%20Executes%20a%20De-watering%20Progra.pdf?handle=97EC5196311E4AAC80019A579C3B255E). In Toronto, media reports (e.g. http://www.cbc.ca/news/canada/toronto/lake-water-is-spilling-out-of-sewers-and-onto-eastern-avenue-1.4120024) indicated some low-lying sewers were struggling to contain Lake Ontario's record high water levels and lake water was coming out of the sewers and flooding streets. However, issues regarding inundation of low lying sewers was not captured in the summary report to the city's Executive Committee (City of Toronto, 2018) and further information is required to determine how significant an issue this was for the city. In the City of Hamilton, the Hamilton Beach strip was particularly impacted and the city had to implement additional pumping of catch basins to reduce standing water. High lake levels reduce the drainage capacity contributing to the inability to remove runoff from the neighborhood. A report from the City of Hamilton's Public Works Department estimates the additional pumping and remedial grading work by city staff and contractors in 2017 cost approximately $130,000 and a study to look at longer-term management options another $75,000 (City of Hamilton, 2017). The City of Oakville also reported some problems with sewer outflows to the lake that experienced impacts due to the high lake levels (City of Oakville, 2018). Specifically, a lake outfall that was considered in acceptable condition during inspections prior to 2017 was identified to be in need of repair following the high water conditions. There were other outflows that required further maintenance (e.g. removal of debris). As well, there was road damage to a portion of Water Street due to flooding caused by water backing up in the catch basin system near the mouth of Sixteen Mile Creek (see Figure 3-7) (City of Oakville, 2018).

A review of shoreline oblique imagery identified a few examples where poor drainage was evident in the Brighton, ON area as well as the Belleville, ON area leading to water backing up onto roads, parking lots, and vegetation. This was not a common occurrence (fewer than 10 examples were spotted in the Brighton area from the oblique imagery) and it is not clear whether there were other contributing factors beyond high lake levels.

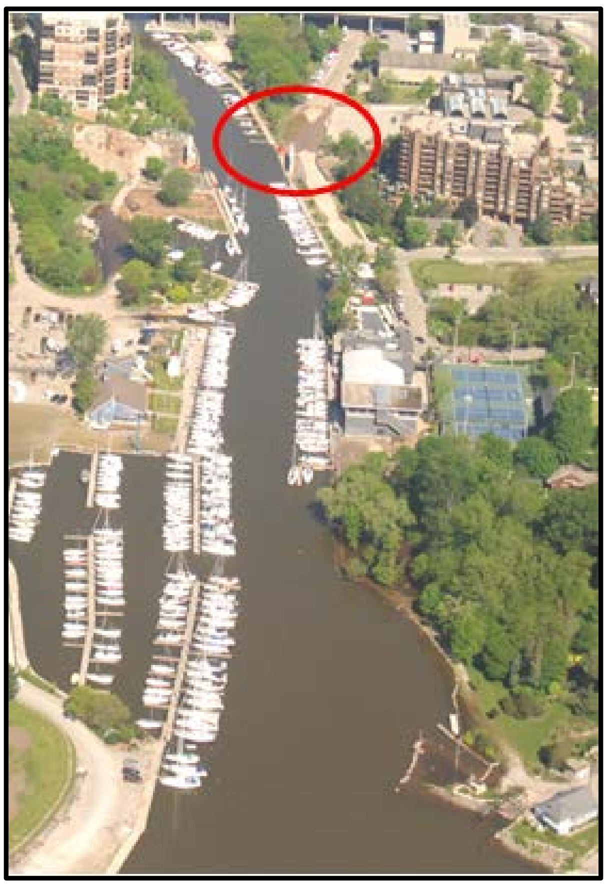

Figure 3-7: Inundation along Water Street in Oakville associated with high Lake Ontario levels (Source: Transport Canada National Aerial Surveillance Program, 2017)

The flooding of septic beds was identified as an issue in some low lying areas along the lakeshore (Municipality of Clarington, 2017). In Port Darlington, ON, residential flooding in the Cedar Crest Beach area compromised the function of septic systems and posed a risk to contamination of shallow wells. The municipality supplied potable water, portable toilets, and portable shower facilities for a portion of the high water period (Municipality of Clarington, 2017) (for context, the GLAM Committee estimates around 80 homes directly along the shoreline in that area but that number needs to be refined).

In Prince Edward County and within the jurisdiction of Quinte Conservation, submerged storm sewer outlets and wastewater effluent pipes were experienced during the high water period along with some sewer bypasses (presentation to fall 2017 Ontario Provincial Flood Forecasting and Warning Committee (PFFWC) workshop). There were also examples of erosion around shore wells as well as flooding of roads indicating drainage problems (see Figure 3-8 with an example from

Belleville – May 14th). Similar issues were identified by the Chief of the Mohawks of the Bay of Quinte First Nation at the fall 2017 PFFWC workshop. They include shoreline wells and septic systems being compromised, capacity issues at the Desoronto Sewage Plant during extreme rainfall events, and the requirement to distribute bottled water in some cases due to well issues. At this point, the GLAM Committee does not have an assessment of the full extent of these types of impacts.

The anecdotal information is consistent with results from the responses to the shoreline questionnaire implemented by Conservation Ontario on behalf of the IJC and the GLAM Committee regarding self-supply residential water and wastewater functions. Of the 299 fully or partially completed questionnaires for the Lake Ontario and upper St. Lawrence River shoreline within the Province of Ontario, there were 29 respondents that indicated they had flooding of their septic systems with 20 of those responses being in Durham Region (includes the Municipality of Clarington) and Prince Edward County (Figure 3-5). In terms of self-supply water, there were 63 respondents (of 299) indicating they had flooding of their shore wells. The majority of those responses were in the central and eastern portion of the Lake Ontario shoreline (18 such responses in Prince Edward County, 14 in Leeds and Grenville, and nine in Frontenac). There were also seven such reports in both Durham Region and Northumberland County (Figure 3-6). Impacts to both septic systems and shore wells were investigated during the LOSLRS but not enough data were available to support the development of an economic PI at the time, although water level metrics were used (LOSLRS, 2006). Again, the Conservation Ontario survey was a self-reporting approach and is not considered a statistically representative sample of shoreline impacts and therefore, the findings cannot be extrapolated to estimate full lake damages and further assessment is required to determine the full extent of septic and shore well impacts along the Lake Ontario and upper St. Lawrence River shoreline.


Figure 3-8: Oblique imagery of street flooding in Belleville, ON, May 14th, 2017. Photo credit: Transport Canada National Aerial Surveillance Program, 2017.

### 3.2.3 St. Lawrence River – Province of Quebec

The GLAM Committee currently has a data gap for the lower river regarding Municipal and Industrial impacts from high water levels in 2017. A survey of Municipal and Industrial facilities was initiated in the fall of 2018 to gather further information in support of longer-term GLAM Committee activities.

## 3.3 Model/PI validation

The descriptive information developed during the LOSLRS suggested that the vast majority of municipal water supply and wastewater services would remain operational during high water levels within the historical range with only three examples in the sample for Lake Ontario indicating vulnerabilities below the 2017 levels (see Table 3-3 as taken from Carriere et al, 2004). Water levels exceeded historic maximums in 2017 but based on the limited preliminary information available (mainly for the US shoreline), it appears that the vast majority of service was able to be supplied in 2017, which is a consistent finding. Of the three vulnerable Lake Ontario locations identified in the table, the power plant's (Russell Nuclear Power Plant) reported critical high levels are below the lake's record high that was observed in 2017 (75.88 m; 248.95 ft). The nuclear plant has been shut down since the LOSLRS was completed and Rochester Gas & Electric will close and fill the portion of the cooling water intake tunnel that runs from the Lake Ontario shore to the station's outer wall. The GLAM Committee is not aware of any public reporting on problems at either the Dupont or Clarkson WWTP which were the other two facilities identified with high water thresholds below the peak 2017 level (see Table 3-3 as taken from Carriere et al, 2004). The GLAM Committee will follow up with more detailed information through the upcoming survey discussed previously. The GLAM Committee does not currently have enough information to determine how well the lower St. Lawrence River impact models capture what took place in 2017 in terms of municipal water supply or wastewater treatment and again, this will be conducted as a follow-up effort.

There were reports of specific operational challenges and adaptive responses in some locations as well as more general challenges with drainage in low lying areas serviced by municipal sewer networks that are not captured in the current PIs and require further assessment. Further investigation of the contributions of high lake levels to sewer backup and street flooding is likely required in some locations. During the LOSLRS, a study team investigated and could not find convincing evidence that lake levels were causing previously identified sewer flooding in the Town of Greece (Monroe County). The Municipal and Industrial report developed by CDM included a table showing the dates and locations of street flooding (Table F-1 from CDM, 2005). The analysis from the LOSLRS found the street flooding events were all associated with heavy rain (at least 1.7 inches, up to 6 inches). As well, 70% of the events occurred when lake levels were 246 ft. 3 inches or less (75.06 m), which is well below 2017 peak levels suggesting lake levels are not the only driver of such conditions.

In addition to drainage issues, 2017 conditions may shed light on potential high water impacts to self-supply domestic water users that were not captured during the LOSLRS.  Further processing and review of the impact information is needed before a full comparison can be completed between results from the existing models and observed conditions.

The GLAM Committee has little validation information available regarding industrial water users and it is not yet clear how that gap will be filled.

Table 3-3: Summary of reported high critical water elevations for wastewater infrastructure reported by facilities that discharge into Lake Ontario and the Upper St. Lawrence River (From Carriere et al, 2004)

| Facility | Receiving Waters | Type of facility | Avg. Daily Discharge (mgd) | Avg. Daily Discharges (mld) | Critical Elevation (feet) | Critical Elevation (meters) | Chart Datum (feet) | Chart Datum (meters) | Deviation from Chart Datum (feet) | Deviation from Chart Data (meters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Village of Lydonville | LO | M | 0.18 | 0.68 | 263.00 | 80.16 | 243.43 | 74.20 | 19.57 | 5.96 |
| Village of Sodus Point WWTP | LO | M | 0.12 | 0.45 | 260.00 | 79.25 | 243.43 | 74.20 | 16.57 | 5.05 |
| Lakeview WWTP (OCWA) | LO | M | 93.46 | 354.00 | 254.46 | 77.56 | 243.43 | 74.20 | 11.03 | 3.36 |
| Essroc Canada Inc., Picton | LO | I | 1.32 | 5.00 | 254.46 | 76.15 | 243.43 | 74.20 | 11.03 | 3.36 |
| Oswego Harbor Power LLC | LO | P | 50.00 | 189.39 | 254.00 | 77.42 | 243.43 | 74.20 | 10.57 | 3.22 |
| Wilson WWTP | LO | M | 0.20 | 0.76 | 253.22 | 77.18 | 243.43 | 74.20 | 9.79 | 2.98 |
| ALCAN (Oswego) | LO | I | 0.25 | 0.95 | 253.22 | 77.18 | 243.43 | 74.20 | 9.79 | 2.98 |
| Ginna Nuclear Power Plant | LO | P | 436.50 | 1653.41 | 253.00 | 77.11 | 243.43 | 74.20 | 9.57 | 2.92 |
| Skyway WPCP | LO | M | 23.76 | 90.00 | 252.72 | 77.03 | 243.43 | 74.20 | 9.29 | 2.83 |
| Town of Williamson WWTP | LO | M | 0.58 | 2.20 | 252.00 | 76.81 | 243.43 | 74.20 | 8.57 | 2.61 |
| Metropolitan Water Board | LO | M | 26.20 | 99.24 | 252.00 | 76.81 | 243.43 | 74.20 | 8.57 | 2.61 |
| City of Oswego (Eastside STP) | LO | M | 1.98 | 7.50 | 251.25 | 76.58 | 243.43 | 74.20 | 7.82 | 2.38 |
| City of Oswego (Westside STP) | LO | M | 3.20 | 12.12 | 250.50 | 76.35 | 243.43 | 74.20 | 7.07 | 2.15 |
| Frank E Van Lare STP | LO | M | 92.19 | 349.20 | 252.22 | 76.27 | 243.43 | 74.20 | 6.79 | 2.07 |
| Port Weller WPCP | LO | M | - | - | 250.00 | 76.20 | 243.43 | 74.20 | 6.57 | 2.00 |
| Cameco Corp. (Port Hope) | LO | I | 3.96 | 15.00 | 250.00 | 76.20 | 243.43 | 74.20 | 6.57 | 2.00 |
| Nine Mile Point Nuclear Station | LO | P | 432.60 | 1638.64 | 250.00 | 76.20 | 243.43 | 74.20 | 6.57 | 2.00 |
| Village of Chaumont | LO | M | 0.03 | 0.11 | 250.00 | 76.20 | 243.43 | 74.20 | 6.57 | 2.00 |
| Somerset-Barker WWTP | LO | M | 0.03 | 0.13 | 249.22 | 75.96 | 243.43 | 74.20 | 5.79 | 1.76 |
| Clarkson WWTP (OCWA) | LO | M | - | - | 248.20 | 75.65 | 243.43 | 74.20 | 4.77 | 1.45 |
| Dupont (Kingston) | LO | I | - | - | 248.00 | 75.59 | 243.43 | 74.20 | 4.57 | 1.39 |
| Russell Nuclear Power Plant | LO | P | 148.40 | 562.12 | 248.00 | 75.59 | 243.43 | 74.20 | 4.57 | 1.39 |
| ALCOA, Inc. | SLR | I | - | - | 160.00 | 48.77 | 152.23 | 46.40 | 7.77 | 2.37 |
| Glen Walter WPCP | SLR | M | 0.137 | 0.52 | 243.73 | 74.29 | 240.29 | 73.24 | 3.44 | 1.05 |
| Lancaster Sewage Lagoon | SLR | M | 0.165 | 0.62 | 155.77 | 47.48 | 152.23 | 46.40 | 3.54 | 1.08 |
| Dupont (Maitland) | SLR | I | - | - | 247.38 | 75.40 | 242.45 | 73.90 | 4.93 | 1.50 |
| Domtar Cornwall Mill | SLR | I | 31.86 | 120.70 | 165.81 | 50.54 | 152.23 | 46.40 | 13.58 | 4.14 |
| R.H. Saunders Hydrodam | SLR | P | 85536 | 324000 | 244.36 | 74.48 | 237.86 | 72.50 | 6.50 | 1.98 |

* "LO" = Lake Ontario, "SLR" = St. Lawrence River, M = municipal wastewater treatment plant, I = industrial discharge, P = power generation facility (nuclear and fossil fuel) "-" indicates that data were unknown or not reported. All elevations are referenced to IGLD 85.

# 3.4 Adaptive responses

Pumping of storm water runoff was one of the primary adaptive responses to improve drainage from low lying areas close to Lake Ontario and the St. Lawrence River with examples on both the US and Canadian shoreline of these water bodies. For example, both the City of Hamilton (City of Hamilton, 2017) and the Town of Niagara-on-the-Lake (https://notl.civicweb.net/document/7696/Media%20Release%20-%20Town%20Executes%20a%20De-watering%20Progra.pdf?handle=97EC5196311E4AAC80019A579C3B255E) incurred extra operating expenses to pump excess water from low lying areas directly adjacent to the lakeshore. The Town of Greece, NY installed new shut-off valves, pipes and a berm structure to help minimize flood damage in the future, according to a February 5th, 2018 news report from WHAM Rochester (http://13wham.com/news/local/greece-adds-new-pipes-valves-in-high-risk-flood-locations) (Figure 3-9).

Figure 3-9: Installation of pipes and shut-off valve in Greece, NY as a flood response (Source: WHAM, Rochester, February 5, 2018 - http://13wham.com/news/local/greece-adds-new-pipes-valves-in-high-risk-flood-locations)

In some cases, sandbagging was required to protect water or wastewater distribution facilities. For example, low lying infrastructure in the Sodus Point area of New York had to be protected to ensure continued operation. As well, the Monroe County Water Authority and the Metropolitan Water Board indicated that sandbagging was required in a few locations to protect some infrastructure where high water levels were putting some pumping stations at risk. In a number of cases, these are similar to known vulnerabilities highlighted during past IJC study efforts (e.g. CDM, 2005). Other adaptive responses identified through the USACE follow up with operators noted that manhole covers were sealed in some areas of Cape Vincent and Sodus Bay; additional pumping water was required in Newfane and Sodus Bay; and, a berm was raised on the east side of Oswego to prevent water backups.

# 4.0 Commercial Navigation

## 4.1 Summary of GLAM work and other agency activities to assess impacts

The GLAM Committee sought information from a range of stakeholder representatives and data sources including:

- Both the St. Lawrence Seaway Management Corporation (SLSMC, Canada) and the St. Lawrence Seaway Development Corporation (United States) analysis and collaboration with the trade to develop mitigation measures as well as the SLSMC report, "Navigating at High Flows – 2017" which was published on 20 April 2018.
- Seaway summary statistics from the Great Lakes-St. Lawrence Seaway System website http://www.greatlakes-seaway.com/en/seaway/facts/traffic/index.html
- ECCC interviews with Jean-Francois Belzile (Port of Montreal), Jean Aubry-Morin (St. Lawrence Seaway Management Corporation) and Tom Lavigne (St. Lawrence Seaway Development Corporation) before or during week of 11 December 2017 and followed up with all three experts over the next several months.

## 4.2 Media coverage

There was considerable media coverage in anticipation of the high flows and focused on the possibility of a shutdown. Once the high flows started, media attention was more focused on the maintenance of transits. An article in the Seaway News on June 14, 2017 said the following: "Wallace James, a ship captain with Algoma Central, said the higher water and stronger currents have made it a challenge to navigate the St. Lawrence Seaway. Mr. James, a captain for 16 years, called conditions 'terrible'. He said strong currents around locks near Montreal made it difficult to steer his 225 m (738.19 ft) vessel into a channel on his way upriver to Lake Ontario this week. 'It almost turned us around' Mr. James said aboard the Algoma Strongfield in Hamilton, ON."

Above-average profits for the Seaway and Port of Montreal were reported on The Duluth News Tribune reported on Jan 17, 2018 "The final tally recorded 38.1 million tons of goods moved through the St. Lawrence Seaway in 2017. The tonnage reflected solid increases over the previous year, including a nine percent overall jump in total cargo traffic." The American Journal of Transportation reported on the Port of Montreal on Jan 4, 2018 stating "Canada's second-biggest port after Vancouver handled close to 38 million metric tons in total 2017 traffic, representing an increase of nearly 7% from 2016 while container volume rose by 5.7% to 13.8 million tons. This translated into 1.46 million TEUs".

## 4.3 Impacts of 2017 water level conditions

### 4.3.1 Lake Ontario (Welland Canal to St. Lawrence River – Cape Vincent)

A total of 3,248 vessels transited the Welland Canal in 2017, a 6.6 percent increase over 2016. Tonnage through the canal was up 15.2 percent over 2016. Figure 4.1 and 4.2 illustrate portions of the Welland Canal and Montreal stretches of the system.

Figure 4-1: Welland Canal. Photo credit: https://en.wikipedia.org/wiki/Welland_Canal.

Figure 4-2: South shore canal near Montreal, Quebec along the St. Lawrence Seaway. Photo credit:

Martin Beaulieu, Canadian Geographic, July 2, 2009, https://www.canadiangeographic.ca/article/st-lawrence-seaway-inland-superhighway.

Beginning at the start of May 2017, the Seaway Corporations issued a number of notices to shipping in relation to the high water levels of Lake Ontario, including:

- speed restrictions between Iroquois Lock and Tibbets Point (2 May);
- caution that fenders on approach wall at Iroquois Lock may not be visible (3 May); and
- additional speed restrictions for the upper St. Lawrence River (8 May and 15 May).

As the Ottawa River flow into the lower St. Lawrence River declined from its record peak on 8 May, outflow from Lake Ontario was gradually increased while maintaining Lake Saint Louis levels according to Plan 2014's F-limit. The ILOSLRB discussed still higher flows that would be achieved through deviations under Criterion H14 starting in mid-May. The Seaway Corporations requested the ILOSLRB grant two weeks' notice before higher flows up to 10,200 $m^3/s$ (360,000 $ft^3/s$) began, and this was provided by the ILOSLRB on 16 May.

On 16 May, the Seaway Corporations advised mariners of the higher outflows expected and that the Seaway Corporations planned to continue operations at these outflows, but warned that the higher flows "will create velocities higher than normal in the navigation channels and variations in the normal current patterns may occur" and advised mariners to exercise caution and "take these conditions into account when transiting the Montreal-Lake Ontario [MLO] Section." The Seaway Corporations also implemented the following measures at this time:

- no ship meeting or passing would be permitted in critical areas (American Narrows, between Sunken Rock Shoal, US LT 189 and Rock Island Light, US LT 213; Brockville Narrows, between buoys 138 and 147; Wiley Dondero Canal, between Eisenhower Lock and buoy 56, revised 19 May to Wiley Dondero Canal, between CIP 9 (buoy 56) to mooring cells below Copeland Cut);
- request to exercise caution when navigating in areas of high cross currents such as Galop Island, Toussaint Island, Ogden Island, Copeland Cut and South Cornwall Channel (Polly's Gut); and
- request for mariners to operate at the lowest safe speed to minimize wake, particularly near shoreline areas.

Beginning 24 May, as conditions permitted downstream, the ILOSLRB began major deviations from Plan 2014, releasing a constant flow of 10,200 $m^3/s$ (360,000 $ft^3/s$) from Lake Ontario, which exceeded the Plan 2014 flow of 9,900 $m^3/s$ (350,000 $ft^3/s$) (Rule Curve) at the time and corresponded to Plan 2014's maximum L-limit flow at the Lake Ontario level of 75.88 m (248.95 ft) at the time. This flow also matched the record-high average weekly flow and was the highest flow ever released on a sustained basis.

To provide further relief to shoreline riparians, the ILOSLRB discussed further increases in outflows that could be possible provided the Seaway Corporations implemented mitigation measures to ensure safe navigation could continue.

The flow of 10,200 $m^3/s$ (360,000 $ft^3/s$) was equivalent to the maximum quarter-monthly average flow that had ever been recorded since 1900. Still higher outflows would increase velocities and cross currents further, presenting additional challenges in the MLO Section and threatening a possible shutdown. However, the Seaway Corporations decided to implement mitigation measures to keep the vessels transiting safely and to mitigate impacts to the trade. These measures included:

- zero tolerance for ship's draft in excess of the maximum permissible draft and reminder to operate at the lowest safe speeds to minimize ship wake, particularly when navigating close to shore (13 June);
- a number of transit requirements (13 June), including;
  - requirements that all ships equipped with a bow thruster shall have the bow thruster operational when transiting the MLO section of the Seaway;
  - all Tall Ships and Tows (Tug/Barge) transiting the MLO section of the Seaway shall be capable of making a minimum of 8 knots through the water;
  - no transits of Dead Ship tows permitted; and
  - ships unable to transit safely at these flows may be subject to transit restriction
- assignment of ship inspectors to mission-critical navigation monitoring (13 June), cancelled (23 June);
- modifications to critical areas identified as no meeting or passing zones (13 June);
- tug assisted ships at Iroquois lock as and when requested (14 June); and
- no ship meets below Beauharnois Lock 3 (14 June) due to high outflows from Pointe des Cascades control dam and the increased cross-currents.

Following implementation of these mitigation measures, beginning 15 June, the ILOSLRB further increased the flow above Plan 2014 and the maximum L-limit, to a value of 10,400 $m^3/s$ (367,000 $ft^3/s$), which was also a new record-high flow and was sustained through 7 August. On 20 June, the Seaway Corporations added a request to exercise caution when navigating in additional identified critical areas in the vicinity of Cardinal and Canada Island due to strong currents. From 27 June through 10 August, the Seaway Corporations restricted the draft for upbound vessels to 8.0 m (26.25 ft) in the MLO section.

These mitigation measures resulted in the maintenance of safe navigation in more challenging conditions. Decreased maneuverability, ship speed management and increases in ship rental costs were the main impacts to the trade. Fuel costs also went up as a result of the delays. In their report on "Navigation at High Flows – 2017", SLSMC (2018) reported that transit times increased by two or more hours from the typical 24-hour upbound transit or 22-hour downbound transit times through the MLO Section, as ships took the necessary precautions to safely navigate the system (especially during the period when flows were 10,200 $m^3/s$ (360,000 $ft^3/s$) or higher).

Iroquois Lock proved to be the most impacted by the high flows as vessel approaches to the lock both downbound and upbound were considerably more difficult. The tug that was made available for assistance was used on a regular basis, either assisting with the use of lines or simply being on stand-by in the event it was needed. Sixty-one percent of vessels requested tug assistance, with more requests by downbound vessels. Another impact, albeit a lesser one, was the reduced number of "walk-throughs" performed at Iroquois Lock (i.e., lockage without the use of mooring lines). Typically, there are approximately 1500 walk-throughs per year at Iroquois, but in 2017 there were only 72 recorded walk-throughs (all in March and April, prior to the higher flows). This translated to slower lockage time as lock personnel had to secure mooring lines. There was also reduced availability of ship inspectors for ship inspections due to their reassignment to the critical command centre in the SLSMC Operations Centre from 13 to 23 June so that a marine officer would be on duty at all times.

As the level of Lake Ontario declined throughout the summer months, velocities and water level gradients in the upper St. Lawrence River gradually increased. This can be illustrated through hydrodynamic modeling and confirmed from observations. On 27 June, as a precautionary response to the declining water levels, the Seaway Corporations issued a draft reduction to 80.0 dm (26 ft 3in) for upbound vessels (which squat more than downbound vessels), effective 14 July. The Seaway Corporations also issued a notice of stronger currents near Cardinal and Canada Island, and reported that cross-currents downstream of Lock 3 at Beauharnois proved particularly challenging and that requests for tug assistance at Iroquois continued. Of the 44 upbound ocean vessel transits during the draft restriction period from July 14 to August 11, 23 of these vessels were at a draft greater than 78 dm (25.5 ft). Of these, 13 were possibly limited by the draft restriction. It is also possible that a few more ocean vessels were impacted than those listed above as vessels loaded for overseas may have loaded when the restriction was in place, but arrived at St. Lambert lock by the time the restriction was lifted. These were not taken into consideration. In addition, it was reported by SLSMC that at least two dead-ship tows were delayed and at least four vessels used a tug escort for transit.

With the higher river currents at lower Lake Ontario levels (for a given outflow), navigation safety dictated that the ILOSLRB revert back to maximum L-limit rules which they did on August 8, 2017. As outflows were reduced and conditions gradually improved, some of the mitigation measures that had been employed by the Seaway Corporations to allow for safe navigation during the record-high flows were progressively withdrawn based on ongoing mitigation-risk review, including the removal of the tug at Iroquois (11 Aug); maximum permissible draft was restored to 80.8 dm (26 ft 6 in) for all vessels (11 Aug); meets and passing at critical areas were left to mariners' discretion until the end of the navigation season (23 Aug) and some specific vessel speed restrictions were lifted (12 Sep). Nonetheless, the release of maximum L-limit flows continued and was a deviation from the Plan-prescribed flow until the end of August.

Starting in September, the ILOSLRB ended deviations and returned to Plan 2014. However, Plan 2014 itself began to prescribe maximum L-limit flows as levels of Lake Ontario remained high.

L-limit flows were prescribed by Plan 2014 from September through the first week of December. As conditions continued to improve, the Seaway Corporations cancelled the final mitigation measures previously employed, including the transit requirements (15 Sep) and finally the no-meet zone downstream of Beauharnois Lock 3 (2 Oct). At this point, it was safe to remove this measure as the cross-currents had subsided and feedback from the mariners was favourable.

Following a minor under-discharge deviation to temporarily raise water levels and assist recreational boat haul-out on Lake St. Lawrence in October, the water temporarily stored on Lake Ontario during this event was released over the course of several days at flows 30 to 150 $m^3/s$ (1,060 to 5,300 $ft^3/s$) higher than the L-limit values.

Note, too, that since the beginning-of-week lake level is used in setting the flow for the entire week, when Lake Ontario's levels are falling and the plan's L-limit release is prescribed, the actual flow is often slightly higher than the continuous L-limit rule curve would prescribe at that moment (using, say, daily mean lake levels instead). Therefore, there was a considerable period of time in 2017 when flows exceeded those defined by the L-limit rule curve (see Figure 4.3). But it is important to note that some of the mitigation measures implemented (with prior concurrence of the mariners) remained in place.

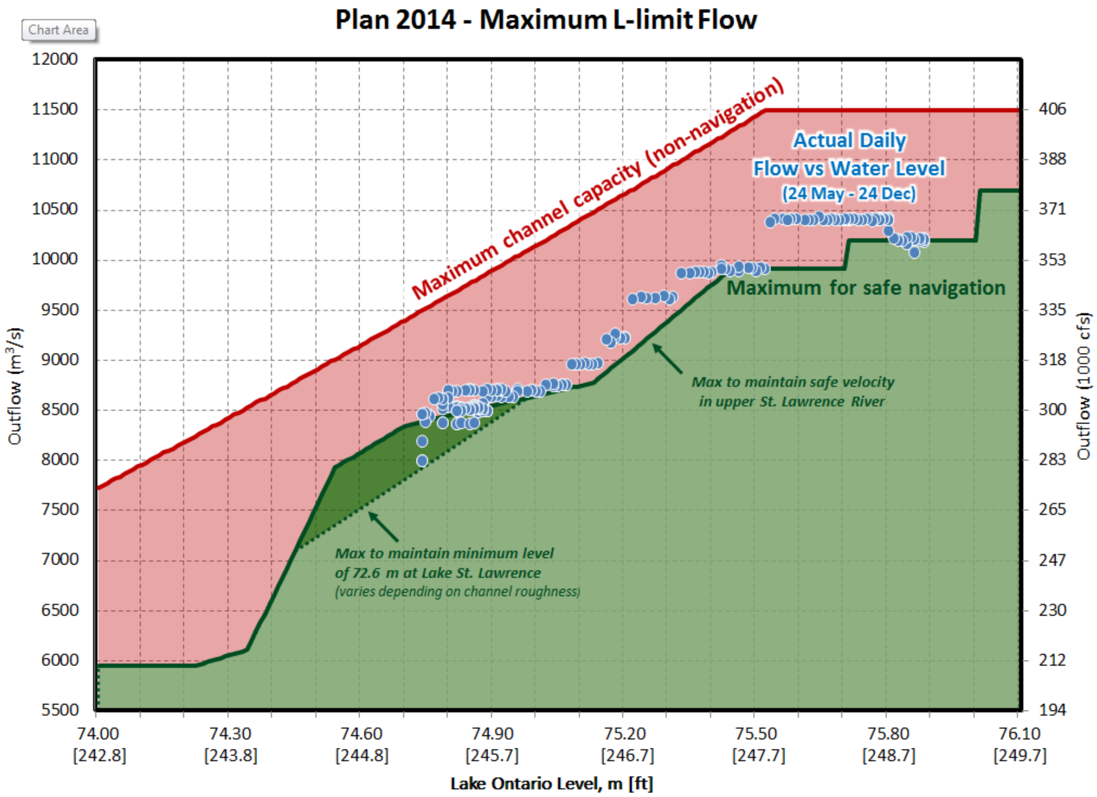


Figure 4-3: Actual daily outflows were generally consistent with the Plan 2014 maximum L-limit as it relates to Lake Ontario levels, but at times were somewhat higher, most notably from June 14 to Aug 8 when the flow of 10,400 $m^3/s$ (367,000 $ft^3/s$) was released and mitigation measures were imposed to ensure safe navigation could continue.

Following the record high flows, many mitigation measures were progressively withdrawn by Seaway officials. Nonetheless, Seaway officials stressed that navigation conditions remained challenging, while at the discretion of mariners. Preliminary analyses by the ILOSLRB's Regulation Representatives suggests conditions improved somewhat from September through about November (i.e., despite following the maximum L-limit during this time, currents and gradients were slightly lower than they had been at times in July and August when outflows were higher and water levels of Lake Ontario were declining more rapidly in between flow changes). Furthermore, in December, through the closing of the Seaway on 11 January, conditions again seemed more critical, particularly as water levels on Lake St. Lawrence had dropped substantially and approached alert levels during periods of east winds. Together, these findings might suggest that (with improvements in ship technology and perhaps with mitigation measures in place) it may, in fact be preferable to the trade to release flows slightly higher than the middle range of the existing L-limit values in order to reduce the risk of prolonged L-limit releases later in the season.

Hydrodynamic modelling may be used to assess conditions under these scenarios and potentially identify more precisely when mitigation measures are warranted.

In late November, the Seaway Corporations agreed to pass flows marginally higher than provided for under the L-limit rules in order to assist in accelerating and increasing the likelihood of Lake Ontario reaching 74.8 m (245.4 ft) by 1 January. The increase was contingent on the maintaining of safe navigation conditions (and those related to petroleum tankers/barges were given much higher priority than for grain or iron ore ships, etc., to prevent catastrophic spillage during the risk assessments for implementation of mitigation measures). As of 5 December, the ILOSLRB passed flows that were marginally higher than provided for under the L-limit rules. This was done in accordance with Condition J of the Order, which permits the ILOSLRB to seek IJC approval to make temporary, minor modifications to the flow in order to test potential changes to the regulation plan. However, one week later, the Seaway Corporations requested a temporary return to the L-limit as high winds had caused a significant reduction in water levels at critical points on Lake St. Lawrence. Observations regarding the impact of higher flows during this period of time provided insights over a limited range of operating conditions (and were only observed over specific reaches of the river, given one distinct Lake Ontario water level at the time). Therefore, this initial set of observations does not provide any substantive findings that would warrant an increase to the L-limit to be prescribed. But the GLAM Committee will look at all available data relating to the periods when flows exceeded the L-limit values (in 2017 as well as in previous years).

Ice formation began in late December 2017 along the river, creating major challenges for the Seaway Corporations, who originally set the closing date at 31 December for the MLO Section. A large ship became stuck in an icy Snell lock for several days into January, which resulted in a significant delay in closing until 11 January. A total of five ships were involved in this delay. Two of four tugs were pulled away from the Port of Montreal for a total of ten days to assist the efforts upstream, resulting in some delays at the port. This incident precipitated a delay in the full closure of the two main ice booms between Prescott and Cardinal, ON ("A" and "G" booms) until 10 January (i.e., the stuck ship delayed the upbound passage of a tug until the morning of 8 January). As the power entity, Ontario Power Generation (OPG), is charged with the safe operation of the booms, they have indicated their desire to prevent such occurrences from happening in the future. They plan to work with the Seaway Corporations to develop and impose a water-temperature threshold at which a certain number of days' warning will be provided to the trade before the main booms will be closed. Seaway officials reiterate the need for OPG to contract a boom tug suitable for the possible ice and weather conditions.

The Seaway Corporations' initial choice of 31 December for a closing date could have impacted flows given the early ice formation that season (starting 24 December 2017 in the Beauharnois Canal). Fortunately, that was not the case and ice and navigation limits within Plan 2014 were followed.

### 4.3.2 St. Lawrence Ship Channel (Below the Port of Montreal)

Despite some relatively minor negative impacts, the Port of Montreal generally benefitted from the high water levels. While numbers have not been finalized, preliminary estimates suggest record loads of 37.8 Mt in 2017, breaking the previous record, set in 2016, of approximately 35.4 Mt. One way to help quantify this number for laypersons is that throughput at the Port equates to roughly one tonne per Canadian citizen each year. Approximately six ships per day enter and exit the Port. An increase between 2016 and 2017 of 4 percent had been forecasted (based primarily on organic growth and establishment of new markets), but the actual increase was 7 percent. The majority of the 3 percent difference was due to the opportunity created by the increase in water depths.

Levels at the Port remained about one meter or more above chart datum until the end of the year, and vessels continued to take advantage of it. The port did suffer several minor impacts too. The most significant is Transport Canada's speed restriction downstream on Lake Saint-Pierre when levels exceed +2 m (6.56 ft) (relative to chart datum). Minimum increases in transit times are about one hour, but if the tide effect is missed, it can result in a 12-hour delay. Some pavement and concrete were damaged at the Port due to inundation and erosive action during the spring (e.g. Figure 4-4). Damages around the Port of Montreal were minimal in 2017, but had the waters risen 60 cm (1.97 ft) or so higher, it might have been catastrophic. As it was, some ships needed to be moved around the Port to avoid their hulls riding up onto the docks. Power to many docks had to be cut as a safety measure from 7 to 17 May 2017, when water levels reached +3 m (+9.8 ft) above chart datum at Pier 1.

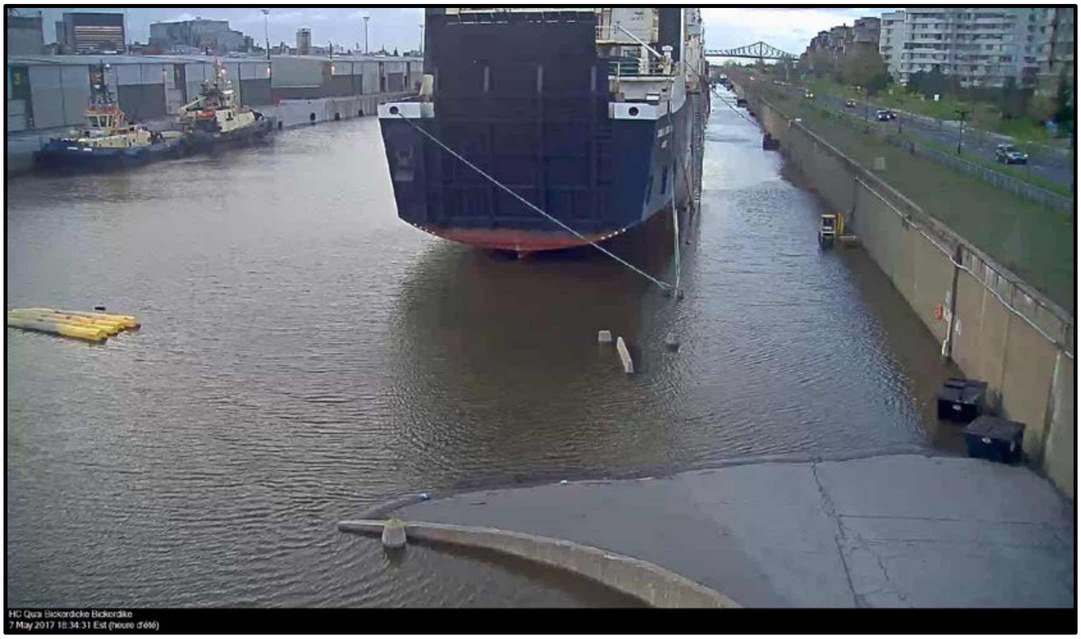

Figure 4-4: Flooded docks in the Port of Montreal. Photo credit: Montreal Port Authority, May 7, 2017.

Some cruise passengers using the Port of Montreal were shuttled by bus while cruise ships were unable to pass under the Jacques Cartier bridge during the extreme high levels. That said, passenger/crew throughput was up 37 percent since 2016 (when refurbishment of the passenger terminal reduced usage considerably), with a total of 117,000 people in 2017. It is estimated that cruise activity at the port equates to an additional \$200 to \$400 of economic activity per passenger. The port itself only receives a \$26 tariff from each passenger, with the remainder of the money going to regional restaurants, hotels, taxis, airports, etc.

## 4.4 Model Assessment/PI validation

### 4.4.1 Commercial Navigation PIs

During the LOSLRS, there were three commercial navigation PIs developed, including:

- Transportation costs on Lake Ontario – based on ton-km travel time;
- Transportation costs on the Seaway – based on ton-km travel time; and
- Transportation costs on downstream of the Port of Montreal – based on ton-km travel time.

Data collection during the LOSLRS focused on four main types of data: data on commercial vessels, data on vessel trips, data on cargo carried and data on the ports. These data were used to model economic impacts of various water levels on commercial navigation. The navigation PIs developed during the LOSLRS were based on 1995-1999 shipping data (e.g., oil tanker transits) and may not accurately represent current or future conditions. Containership traffic at the Port of Montreal has increased since the LOSLRS was conducted, and this has yet to be fully assessed. Vessel transits information and tons of cargo are readily available for each section of the Seaway over the past decade. However, the navigation models used in LOSLRS were different and were disconnected from the upper Great Lakes models used during the IUGLS. A full system model recognizing the importance of lake-to-lake navigation could be pursued in the future. The upper Great Lakes model similarly used ship transits and detailed cost information to produce depth-cost curves. Additional costs of gradient delays due to high velocities would need to be incorporated. The information gathered in 2017, especially due to high velocities and cost of mitigation measures, could help in the development of a new system-wide commercial navigation model. The USACE-developed model used in IUGLS contained confidential information that was aggregated to mask any sensitive information employed.

Impacts to individual shipping companies and cargo owners are not readily available in a form that can be shared, as these results concern highly proprietary details on business contracts and commercial trade patterns. Relative comparisons using the Shared Vision Model (SVM) with respect to hydrologic condition perturbations might be possible and appropriate as most absolute impacts/benefits cannot be released due to confidentiality, as noted above. The Seaway Corporations expect to be able to eventually provide aggregated direct dollar-amount impacts to operations in 2017, but not until 2019.

There were many challenges made to the ILOSLRB by the media, politicians and other stakeholders as to why they did not increase flows further and close the Seaway to provide additional benefits to Lake Ontario riparians. The ILOSLRB weighed the additional relief possible to coastal interests against the potential impacts owing to a shutdown. In a 30 May CTV Ottawa news report, Chamber of Marine Commerce president, Bruce Burrows, said suspending shipping traffic would have been an expensive proposition with far-reaching economic fallout. "Those affected in Canada and the US could potentially lose over $50 million in sales per day." SLSMC spokesperson, Andrew Bogora "pegs the 'total impact' of the Seaway system at about $35 billion per year." These values stem from the original Martin Associates Economic Impact Study released in 2011 (and verified later in 2018). These studies provide aggregate information and evidence that any interruption in trade flows over the waterway would have an immediate and pronounced impact upon a wide range of business interests. There is also considerable potential for unintended consequences, such as shortages of certain inputs leading to the shutdown of manufacturing activity and the disruption of employment. The GLAM Committee may consider further assessing the implications of a Seaway shut down and the related benefits and costs of such an action both upstream and downstream.

The GLAM Committee is charged with evaluating regulation plans and recommending potential improvements. The GLAM Committee will undertake a comprehensive review of Plan 2014, including its maximum and minimum limits. Initial evidence and hydraulic analyses using data from 2017 and previous years suggests that the L-limit is generally an accurate representation of the maximum flow that will still permit safe navigation, but that some small revisions to the L-limit rules may be warranted. However, it must be noted that any changes proposed would be done in cooperation with the commercial navigation interests and only after a careful, comprehensive review and while ensuring the safety of commercial navigation remains the paramount consideration. In that light, it should also be noted that, particularly during periods of extreme conditions as seen in 2017, potential changes to plan rules such as to the L-limit, need to be considered collectively and, in fact, might prove beneficial to all interests, including commercial navigation.

A review of observed water levels and gradients during the high flows of 2017, as well as the results of hydraulic modelling analyses and of the very limited Condition J testing and other periods of flows in excess of L-limit values has been completed, but to date does not support changes in Plan 2014 L-limit rules (refer to Annex 2 – Plan Review). However, these results do suggest that there were times in 2017 that slightly higher flows than the maximum L-limit were possible, which raises the question of how accurately the current L-limit values depict the "maximum safe flows for commercial navigation" (as they pertain to the entire MLO section). Before any changes would be made, however, an exhaustive risk analysis will be performed encompassing all critical locations, over a full range of operating conditions and for the types of products transported under such conditions. Moreover, additional mitigation measures may need to be considered to allow the Seaway Corporations to sustain navigation under revised (higher) L-limit values, given the potential for adverse conditions to manifest themselves faster as a result of increased sensitivity to environmental factors (such as high winds). Furthermore, any changes would be subject to extensive consultations, including direct input from federal government and their respective experts. Conditions H and J of the Order require that proposed changes respect the Boundary Water Treaty's Article VIII orders of precedence. The concurrence of both the US and Canadian Governments would be necessary.

## 4.5 Adaptive responses

Unprecedented mitigation measures were imposed by the Seaway Corporations during a period of record-high flows: speed restrictions, passing limitations, tug placements (at Iroquois Lock, Beauharnois, Cote-Ste.Catherine, and Ports in Quebec), change in lockage procedures, etc. In so doing, the Seaway Corporations ensured vessel safety was maintained, while ensuring it would not be necessary to shut down vessel traffic.

The Seaway Corporations imposed mitigation measures when the ILOSLRB raised flows above the plan's L-limit releases. Nowadays, some ships have bow thrusters, improved power-to-length ratios, automatic information systems (AIS), etc., permitting operation under more extreme conditions than previously (i.e., when the Seaway initially opened and the L-limit rules were initially developed). Furthermore, squat studies, speed monitoring, hydrodynamic modelling, and weir construction have also improved hydraulic considerations and knowledge.

Port of Montreal cruise ship clients were shuttled in from a downstream berth when cruise ships were unable to pass under the Jacques Cartier bridge at the height of the flooding. Several ships were moved around at the Port of Montreal to prevent their hulls from riding up over submerged docks.

The Port of Montreal also deferred construction of their new fendering system, since high water resulted in many of the docks being inaccessible or unsafe for this major refurbishment project. Several tug boats were moved to an alternate location from 2 to 31 May when dock fenders became ineffective and water levels reached 2.5 m (8.2 ft) above chart datum at Pier 1.

All of these adaptive responses affect how resilient the commercial navigation sector is to high water conditions. These adaptive responses experienced this year will help us assess further transportation costs under these extremes and the sensitivity and resiliency of commercial navigation to high water conditions in the future.

## 4.6 General surveillance

The lack of economic information from the commercial navigation sector due to proprietary restrictions was noted as an issue by some ILOSLRB members (as well as staff) in making operational decisions during the extreme conditions of 2017. The GLAM Committee also recognizes the issue of proprietary information for use in validating and updating existing models and will continue to work with the commercial navigation sector to determine an appropriate path forward for assessing economic impacts under a range of conditions.

Given the high velocities experienced in 2017 and recognizing that pleasure craft users often refer to them for information, the SLSMC warned the general public of the conditions, issuing three pleasure craft bulletins regarding this event. In addition, two requests were made to the ILOSLRB's regulation representatives to use their communications channels to send advisories of the high flows to the public.

Hydrodynamic analyses and assessment of water level data to date suggest river currents may not be overly sensitive to relatively small flow variations when outflows are high, and ship transits were often able to continue in 2017 - even though velocities, river gradients and water levels were sometimes beyond previously established thresholds. The GLAM Committee will continue to expand on this analysis as opportunities warrant and will explore the availability of ship-based velocity information and will consider any flow and current measurements taken during such periods.

The Port of Montreal is undertaking a major capital dredging project to ensure that vessels can take full advantage of the available water depths at all times. The volume of dredged sediment is expected to be sufficient to fill Montreal's Olympic Stadium three times.

Canadian Coast Guard officials will undertake a refurbishment of the weirs in and around Lake Saint-Pierre in 2018. This will ultimately raise water levels locally by between 17 and 40 cm (0.56 and 1.31 ft). The impact will be greater as flows and water levels decline.

Laval University will be creating a database on erosion vulnerability on the St. Lawrence River between Cornwall and Quebec City. Ship wake-related erosion processes will be a primary focus. The project is scheduled to end in 2020. The Quebec Ministère du Développement durable, Environnement et Lutte contre les changements climatiques, is following progress on this project and is also leading a project on floodplains determination on the river following the 2017 freshet. The Canadian Space Agency also monitors shoreline erosion. Images produced with data from Earth Observation satellites permit assessment of changes in a given area. With the RADARSAT Constellation Mission's new capabilities, it will be possible to obtain data on erosion faster (including wake-induced erosion), allowing for quick responses to problems.

The value of the marine logistics chain is well detailed in Martin Associates' 2018 update report, "The Economic Impacts of Maritime Shipping in the Great Lakes-St. Lawrence Region". The details underlying the conclusions that 237,868 jobs and $35.0 billion (USD) in economic activity are supported by cargo moving over the combined Great Lakes-St. Lawrence Seaway System are available at marinedelivers.com. Note that this study provides details such as what the direct impact from a potential Seaway closure might be on, say, New York State socio-economically. The ILOSLRB needs better, more accurate information about the actual costs of a Seaway shutdown to know the ramifications of this should they ever be faced with it again. The 2018 update of this study shed more light on this, but was beyond the direct scope of their economic impact analysis.

One potential, specific impact with respect to a potential shutdown was raised several times – the inability for fuel ships to access inland port cities such as Toronto, which might have resulted in regional gasoline crises and price jumps (e.g., a 7 June Imperial Oil letter to the ILOSLRB). The GLAM Committee wishes to stress that a shutdown was unnecessary, but this example of surveillance received from one particular stakeholder demonstrates the magnitude of concerns among the trade regarding the potential for such a shutdown.

The extraordinary conditions of 2017 may need to also be assessed in terms of human and ecological safety. Oil tankers and chemical ships pose particular risks under extreme velocities related to human error, or equipment failure even with the most modern technology in place. Are the safety studies done previously for the transit of such volumes (light and heavy hydrocarbons) considering such velocities and currents for these sensitive populated areas along the Seaway? Any other cargo doesn't pose a great ecologic or economic threat, but oil and chemicals tankers, during periods of high currents and outflows (~10,400 $m^3/s$ or 367,000 $ft^3/s$) may pose high risks and the consequences of power failure, accident and potential spill. Rail transit could be a safer alternative during these conditions. The idea would be to look at the logistics of adapting the shipment or transfer of these goods in similar critical circumstances as those of 2017 to other modes if parking them would be an issue until lesser outflows and velocities are possible.

# 5.0 Hydropower

## 5.1 Summary of GLAM work and other agency activities to assess impacts

The USACE, Buffalo District collected and evaluated information regarding operational issues related to 2017 high water levels through interviews with sector experts (Richard Fremming, Robert Moses Niagara, and Tim Ahlfeld, St. Lawrence-FDR Power Project). USACE's intent was to collect information with regard to the following topics:

- Hydroelectric generation output
- Damages to production facilities
- Profits earned/lost
- Bypass flow releases
- Regulated outflows

Other agencies collecting information include:

- The Federal Energy Regulatory Commission (FERC) regarding safety inspections, environment, industry activities.

ECCC Cornwall collected and evaluated information regarding operational issues related to 2017 high water levels through interviews with sector experts (Mike McNiven and Don Ferko (OPG), Pierre-Marc Rondeau and Marie Beaumont (H-Q) and Pat Davis (NYPA)).

## 5.2 Media coverage

Very high lake levels and corresponding outflows can result in "excess" water diverted through the spillway and thus a missed opportunity to generate additional power due to lack of available hydropower capacity. Several area news outlets reported on the use of the spillway at Long Sault Dam. Several indicated that Moses-Saunders had been run at capacity for weeks. The press noted that this was stressing the equipment and damage could ensue (though follow up by the GLAM Committee with the various hydropower entities suggests this would be impossible to quantify). An assumed increase in profits due to the higher outflows was also broadly covered, though the basis for this assertion has been questioned (e.g., NYPA's revenue in 2017 was less than in 2016).

## 5.3 Impacts of 2017 water level conditions

The Moses-Saunders facility (Figure 5-1) was run at capacity for much of 2017, and the Long Sault Dam spillway (Figure 5-2) was employed from 17 May to 1 September, 7 September, 19 to

22 September, 27 September to 6 October, and 8 to 31 October, with daily mean spillage rates as high as almost 2,600 $m^3/s$ (91,800 $ft^3/s$) (on 15 October; this spill equated to approximately 520 MW of potential lost production, or just over ¼ of the rated capacity of Moses-Saunders generating station).

Figure 5-1: Moses-Saunders Dam. Photo Credit: ILOSLRB.

Figure 5-2: Long Sault Dam, May 21, 2017. Photo credit: NYPA.

The increased flows during much of 2017 resulted in increased generation. A gross estimate of up to about a 25 percent increase in flow over average was observed. However, a decrease in operating head (the elevation difference between the water in the forebay upstream of the dam and that in the tailrace downstream) also affected generation slightly. A gross estimate of up to about a two percent decrease from normal head was observed. Also, the plants were run out of efficiency at full available capacity for months, requiring some important maintenance activities to be deferred to later dates. It is not possible to include additional maintenance as a "cost" (as running units more equates to additional compensation from increased power generation), but it must be noted that there can be considerable cost overruns when plants are run for extended periods and generating units suffer breakdowns. Additionally, operation and maintenance costs for some activities were higher than initially forecasted due to the higher flow. For example, mobilizing crews to perform extra dam or spillway operations and increased debris clearing resulted in higher operating costs in 2017.

It is important to note that it is hard to distinguish (and impossible to quantify) the incremental maintenance costs due to additional gate operations, spill structure usage, etc. Long Sault Dam gate operations are not considered in NYPA's normal operating budget, and many such operations are managed by bringing in additional staff on premium time. Also, many gate movements at Iroquois Dam (Figure 5-3) were necessary to maintain water levels on Lake St. Lawrence downstream below established high water thresholds (gates are lowered to suppress water levels downstream of the structure). The gates at Iroquois Dam were partially closed from 6 April to 23 May to suppress high water levels on Lake St. Lawrence. Many gate operations (over and above the normal number of movements) were necessary during this period (as well as during final raising of the gates and debris removal operations lasting until 30 May) to adjust the gate settings and prevent flooding on Lake St. Lawrence. Two to ten gates at Long Sault Dam were partially opened from 17 May to 31 August to spill the amounts of the total Lake Ontario outflows that exceeded the capacity of the Moses-Saunders Dam. The total amount of water spilled during this period and lost to electrical power generation reached a maximum weekly average of 1,270 $m^3$/s (44,800 cfs) during the week ending 24 May and equated to nearly 166 billion cubic meters (almost 6 trillion cubic feet) of water. The power entities also spilled various amounts of water at Long Sault Dam occasionally during September through December according to their ongoing maintenance requirements.


Figure 5-3: Iroquois Dam in winter. Photo credit: St. Lawrence Seaway Management Corporation.

Additional costs were incurred due to impacted project and maintenance work including: the OPG water level gauge upgrade project, several scheduled bank outages, unit outages and other various maintenance activities. Some of these works were deferred and rescheduled, while others required additional spill in order to be completed (transfer of water from unit generation to spillage). The full cost of deferred outages has not yet been fully realized, as not all deferred work has been completed.

The Robert Moses Niagara and St. Lawrence-FDR Power Project hydroelectric plants both benefited in 2017 from high water levels and increased flows by generating more hydroelectricity depending on the demand. However, NYPA did not realize an economic benefit from the increased generation due to depressed market prices for energy. Neither of the US plants' power generating equipment were damaged due to the high water levels.

OPG and NYPA do not have the authority to store water on Lake Erie or Lake Ontario. On Lake Erie, the ability to store water does not exist owing to the lack of regulatory structures. On Lake Ontario and the St. Lawrence River, during times that the available flow exceeds the capacity of the hydropower plant, spill will be required at Long Sault Dam unless the power entities request and receive approval from the ILOSLRB to temporarily reduce flows below the plan-prescribed value (this would be considered a deviation from Plan 2014 and would also require a subsequent increase in flows to offset the effects on water levels of Lake Ontario). During the high water event of 2017, with outflows maximized in an attempt to lower the high level of Lake Ontario, such a request was neither requested nor granted. Consequently, the power entities were required to release excess water over Niagara Falls and through the Long Sault Dam on the St. Lawrence River. The power entities were able to maintain water levels below critical levels; however, they were unable to store water for future hydroelectric generation.

Hydro-Quebec (H-Q) reported having a challenging year, especially during ice management periods at the beginning and end of 2017 as well as during the Ottawa River flood period. Ice management challenges in 2017 included broken booms (at Autoroute 30 bridge and at km 10), anchor ice buildup, frozen control gates, as well as active formation occurring while the Seaway remained operational. The main booms ("A" and "G") in the International Rapids Section remained open until 10 January 2018 following an 11-day delay in the Seaway season closing at the end of the year, and an extremely frigid period in December. H-Q finds that Plan 2014 brings improvements in terms of flexibility with regards to setting flows during the ice season. H-Q also appreciates the excellent collaboration with the Canadian Regulation Representative team during the Ottawa River spring peak outflow period. Collaboration between the ILOSLRB and the Ottawa River Regulation and Planning Board was also appreciated. H-Q appreciated the choice of a constant (10,400 $m^3/s$) (367,000 $ft^3/s$) flowrate from Lake Ontario during the height of the flood, as it limited the number of operational maneuvers required at various control structures operated by the entity such as the Beauharnois/Les Cèdres complex (Figure 5-4).

Figure 5-4: Beauharnois/Les Cèdres Complex of Hydro-Quebec. Photo credit: Hydro-Quebec

Flowrates were maintained below the overall capacity of H-Q's complex, but still resulted in significant local impacts, including significant spill and the impact of high velocities on the natural bed of the river to the north of the Beauharnois Canal. Valleyfield Beach, in the St. Timothy Basin, was closed for the entire season. H-Q's booms were damaged at Ile-Juillet dam, requiring enhanced communications with the public regarding safe use of nearby waterbodies. Work at Ile-Juillet dam was deferred for two months (to ensure adequate operational capacity given the potential for even higher flows). That said, there were no reports of major impacts on residents as a result of H-Q operations in the area between Lake St. Francis and Lake Saint Louis.

## 5.4 Model Assessment/PI validation

### 5.4.1 Hydropower PIs

During the LOSLRS, there was one primary hydropower PI and several secondary ones developed including:

- Value to society of energy produced – based on megawatt hours by quarter month (QM), valued using estimated market values for each QM of the year. Estimates are totaled for OPG and NYPA, and H-Q estimates are given separately.
- Several secondary PIs are calculated as well:

- The net value of peaking power (OPG/NYPA totals, H-Q totals)
- Economic penalty of unstable flows (OPG/NYPA totals, H-Q totals)
- Predictability (correlation factor between lake level and flow)
- The likelihood of spill at Long Sault Dam during spawning season (in terms of frequency and severity of spill)

The calculation of energy produced at the Moses-Saunders dam was based on an Excel spreadsheet model developed by a former OPG engineer. The calculation of energy produced by H-Q was based on a model by a former H-Q engineer. Economic advisors during the LOSLRS agreed to use estimated market prices to measure the value of energy to society. Energy prices used came from a study by Synapse Energy Economics, Inc. of Cambridge, Massachusetts in 2005. All elements of the model were thoroughly debated and agreed to by the LOSLRS Plan Formulation and Evaluation Group, economic experts, Study Board and hydropower technical working group although even at the time, the energy prices in the Synapse Energy Economics report were considered highly uncertain and remain an area requiring further investigation and updating to better reflect current market conditions. The algorithm used to calculate energy produced each QM for NYPA and OPG was quite different from the algorithm used for H-Q, owing to the very different nature of those facilities.

NYPA and OPG share the same dam and each has an equal number of turbines. A NYPA expert approved adopting the OPG model for energy production. The tailwater elevations at the Niagara River power plants are related to the levels of Lake Ontario, so a regulation plan that increases Lake Ontario levels may increase energy production at Moses-Saunders, but reduce power production at Niagara Falls. So, for the purposes of Lake Ontario-St. Lawrence River plan evaluations, model estimates of energy produced at Niagara Falls are included. Higher Lake Ontario levels may increase the water levels above Moses-Saunders, but that elevation is also strongly influenced by the flow through the dam.

Figure 5-5: OPG and NYPA generating stations on the Niagara River. Sir Adam Beck Dam is on the left and Robert Moses Dam is on the right. Photo credit: Google Photos.

The basic equations for energy used in the H-Q model are similar to those in the OPG model, but most of the H-Q model is devoted to splitting flows between Beauharnois Canal and Les Cedres based on the elevation of water that is allowed in the Beauharnois Canal and minimum and maximum amounts that can pass through Les Cedres. The model also calculates how much flow is spilled (without producing power) at Les Cedres.

The net value of peaking power is the change in the energy benefit because a regulation plan produces more or fewer releases within the range of releases for which peaking is allowed (full peaking is allowed for flows ≤ 7,080 $m^3/s$ (250,000 $ft^3/s$) [100% of potential peaking value]; no peaking is allowed for flows ≥ 7,930 $m^3/s$ (280,000 $ft^3/s$) [0%]; partial peaking is allowed between these thresholds [linear interpolation]). A $50,000 daily peaking value was estimated based on an analysis of historical data.

Predictability and stability are complimentary indicators of the chance of losing potential energy creation because flows unexpectedly increase when some of the turbines are taken off line for maintenance. The power companies try to schedule turbine maintenance for periods when the flows are small enough to be passed through the remaining turbines. If flows increase substantially when one or more turbines are off line, some of the release may have to bypass the turbines without generating energy. Stability is defined as the absolute difference between releases from one QM to the next. Predictability is the similarity of flows to Lake Ontario levels.

The similarity is the correlation between a given number of quarter-monthly Lake Ontario levels and corresponding releases.

Net penalty for flow instability was an attempt to capture the dollar impact of energy not produced because of unexpected changes in releases. It is calculated by multiplying the average marginal price of power for NYPA and OPG times the lost power because of instability. The impact on H-Q is assumed to be double that of NYPA and OPG (given the same difference between the quarter-monthly release and the five QM average release).

NYPA is required under the terms of its Federal Energy Regulatory Commission license to report all spills at Long Sault Dam. Spills occur when the release exceeds the capacity of the Moses-Saunders dam and some of the water is passed through Long Sault Dam. Spills from April to mid-June can negatively impact fish spawning. This PI is measured by tracking the frequency at which spills occur during the spawning season, and, when they occur, the magnitude of those spills. Water temperatures are also monitored during this critical spawning period to ensure adverse temperature decreases do not impact warm-water species such as sturgeon.

Power entities' compensation rates and mechanisms are confidential, so it will not be possible to report absolute socio-economic benefits/impacts in dollars for 2017. All generating stations on the Niagara and St. Lawrence Rivers had an increased potential for generation due to high flows; however, in some instances, the greater-than-expected generation could not be fully used due to an excess of generation in the electrical system. That is, spillage of water is required at such times to avoid negative financial impacts.

The database will be updated with 2017 water levels and outflows when final values are made available. SVM simulations will be made to assess hydropower benefits/impacts.

## 5.5 Adaptive responses

The method that H-Q employed in the drawdown of the pool at Coteau compensation works prior to the ice formation period in late 2017 precluded the need for flow decreases. Each November, H-Q must draw down the Coteau compensation works prior to winter. A maximum flow of 900 $m^3/s$ (31,800 $ft^3/s$) through these works must not be exceeded thereafter for safety reasons (i.e., to prevent undue water velocities). To prevent the need for a Lake Ontario outflow reduction, H-Q decided to pass water through the Beauharnois spillway. Generally, H-Q keeps this spillway closed except during emergencies, but in 2017, they maintained an outflow of over 600 $m^3/s$ (21,200 $ft^3/s$) at this structure for one week.

## 5.6 General surveillance

NYPA noted that any loss of revenue due to spill at Long Sault Dam was partly offset by postponing a major four-unit maintenance outage scheduled for a June start until later in the year.

This action prevented some spillage, permitting the power entity to take advantage of the higher flows and generation potential.

Flow verification measurements performed by Water Survey of Canada experts on 14 and 29 June and 17 October demonstrated an apparent over-reporting of spill rates at Long Sault Dam. It's important to note that this was a very limited set of flow measurements. Further investigations will be required to confirm whether or not the apparent over-reporting is, indeed, an issue, and whether or not the flow computation process (involving the gate settings used, the rating table implemented, and the data in the rating table itself) warrants changes. Additional flow measurements in 2018 are planned. A full report is expected thereafter that will outline any further ramifications and establish a path forward, if necessary.

It's worth noting that a small (8-mm or .03 in) revision was made to the entire Long Sault Dam rating table due to an error adjusting from the previous IGLD of 1955 to IGLD 1985. Note that this is an extremely minor impact relative to the potential impact of the above issue currently being investigated.

The gates at Iroquois Dam were closed from 6 April to 23 May to suppress high water levels on Lake St. Lawrence. Removal of gates from the water began on 24 May and was completed on 30 May. The two gates that are normally raised to a higher position above the water line to allow recreational boat passage were left lower than normal by OPG since high currents caused by the unprecedented outflows were deemed unsafe. Boaters instead were required to use the Iroquois Lock for passage. Two fishing derbies (the Huk Bassmaster Elite on 20 to 23 July in Waddington, NY and the Renegade Bass Tour on 19 August in Morrisburg, ON) were impacted. Several boats still chose to slip under the still-open gates, but this was very dangerous and should be avoided in the future.

It is important to note that there was some considerable erosion impacts to some of the infrastructure owned and maintained by the power entities and other related agencies. For example, the City of Ogdensburg cordoned off a large part of the riverfront park where the local water level gauging station is located. This station is owned and maintained by the National Oceanic and Atmospheric Association but NYPA operates equipment there too. It is currently unknown whether the structure suffered any damage and estimates are not available for the damages incurred at the park as a whole.

As one power entity official put it, 2017 was the kind of year "one does not need to speak much about optimization". In other words, stakeholders, including the power entities, struggled with many aspects of their operations and use of the water as hydrological, hydraulic and weather conditions all proved extremely challenging for everyone involved.

# 6.0 Coastal Impacts

## 6.1 Summary of GLAM work and other agency activities to assess impacts

Water level impacts from the 2017 high water were gathered in:

- efforts the GLAM Committee directly manages, and
- efforts undertaken by outside groups and agencies independently from the GLAM Committee.

Based on extreme 2017 water levels in the Lake Ontario and St. Lawrence River basin, the GLAM Committee initiated a group of complimentary efforts to track impacts associated with 2017 water levels. These activities included:

- a review of oblique photography taken along the Lake Ontario shoreline as well as on the St. Lawrence River from Montreal downstream during high water conditions;
- the development of a database of site visit photographs;
- a review of shore protection permit applications along the US shoreline of Lake Ontario;
- a review of various municipal summaries;
- development and implementation of an online, self-reporting survey for shoreline property owners; and
- Compilation of media reports throughout 2017.

Table 6-1 identifies which current GLAM activities provide information to the existing flooding, erosion, and shore protection PIs and Figure 6-1 shows the distribution of survey responses for the Canadian and US shoreline of Lake Ontario (shown as the percent of responses, by county or municipality, relative to the total number of responses in that country). Further details on methods and approaches for the imagery review, survey and site visits are provided in the following subsections.

Table 6-1: Activities managed by the GLAM Committee that provide information on coastal impacts from 2017.

| **Activity** | **Lake Ontario** | | **Upper St. Lawrence** | | **Lower St. Lawrence** | **Relation to Coastal PIs** |
|---|---|---|---|---|---|---|
| | **US** | **CAN** | **US** | **CAN** | **CAN** | |
| Oblique Imagery Acquisition and Assessment | Yes | Yes | No | No | Yes | Flooding (**inundation under static water level conditions**), significant shoreline changes due to erosion, failed shoreline protection |

| Activity | Lake Ontario | | Upper St. Lawrence | | Lower St. Lawrence | Relation to Coastal PIs |
|---|---|---|---|---|---|---|
| | US | CAN | US | CAN | CAN | |
| Database of Site Visit Photographs | Partial | Yes | No | Yes | Partial | Site specific examples of flooding (inundation), significant changes due to erosion, failed shore protection, adaptive responses |
| Review of shore protection permit applications | Yes | No | No | Yes | No | Shore protection maintenance, new shore protection |
| Development and Implementation of online, self-reporting questionnaire for coastal property owners | Yes | Yes | Yes | Yes | Yes | Allows self-reporting from property owners on flooding, erosion, failed shoreline protection, other observed impacts and adaptive responses. ***NOTE: The questionnaire was intended to allow direct input from property owners on their perspective regarding impacts, but is not considered a statistically robust methodology for extrapolation purposes.*** |
| Tracking of media report | Yes | Yes | Yes | Yes | Yes | General consideration of the types, location, and general magnitude of shoreline impacts commonly reported in media outlets |

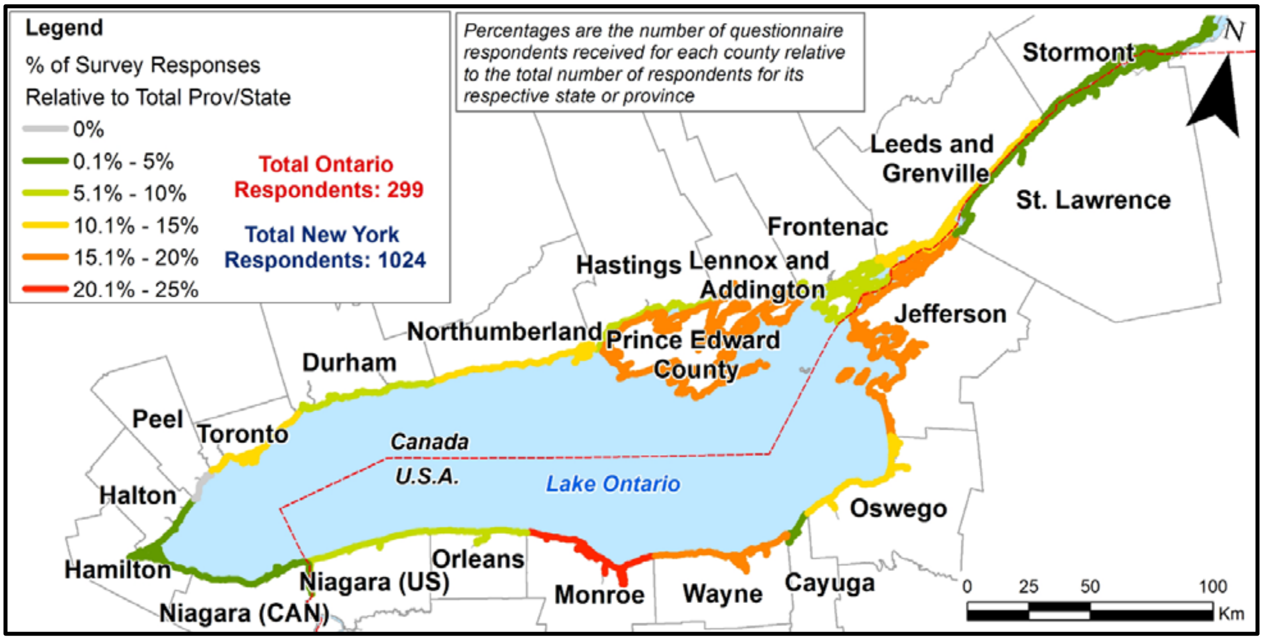

Figure 6-1: Percent of survey responses indicating flooding impacts (shown as a % by County relative to the total number for each Country)

**Review of aerial imagery:**

The USACE contracted with Fugro to collect oblique and ortho imagery of the entire US shoreline to support the assessment of shoreline impacts during the high water period of 2017. Imagery was collected between June 2, 2017 and July 19, 2017. Red-Green-Blue-Near Infrared (RGBN) nadir images and Red-Green-Blue (RGB) Oblique images were collected with a resolution of 6 in Ground Sample Distance (GSD) or less. During the collection, the minimum solar elevation was 30° and the imagery contains no more than 5% cloud cover for the entire image and 0% cloud cover for the shoreline areas. The USACE team then compared these data to the 2016 NOAA imagery to assess the impacts associated with the high water levels of 2017. For the Canadian shoreline of Lake Ontario, Transport Canada's National Aerial Surveillance Program collected true-colour RBG oblique images on May 14, 2017 and June 8, 2017 and for various locations on the St. Lawrence River from Montreal downstream. Coverage areas are illustrated in Figure 6-2, highlighting areas that have been reviewed for the current assessment.

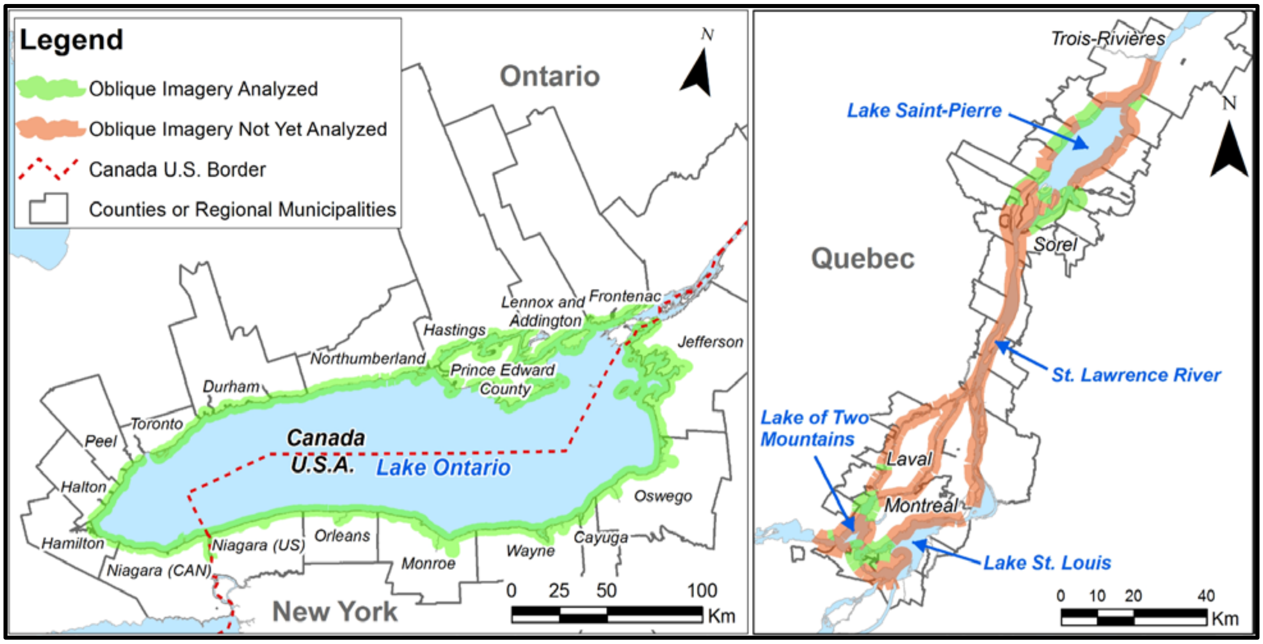

Figure 6-2: Coverage of aerial imagery collected by the USACE (US) and NASP (Canada) based on high water conditions in 2017 for Lake Ontario and the St. Lawrence River and portions reviewed for report

Assessment of shoreline impacts was undertaken by GLAM Committee associates within the USACE Buffalo District, ECCC and the IJC. From the imagery, it is possible to identify a range of impacts on a fairly consistent basis across a large stretch of shoreline. However, it should be pointed out that not all impacts can be identified through the imagery and there is considerable judgement required by the individuals assessing the images that can impact the results. While both countries were responsible for their own shoreline assessment, they collaborated to ensure that the data were consistent. This was done through several email, phone call, WebEx conversations and workshops held amongst the team members to cross-check portions of the interpretation. The visual inspections were performed on a county by county basis. Impacts to the coastal, commercial shipping, municipal and industrial, environment and wetlands, and recreational boating and tourism stakeholder groups were flagged and noted within a geospatial database. These flagged points included erosion, flooding of features on an individual property and adaptive actions taken to alleviate these impacts. Erosion was noted through close examination of shoreline imagery differences between 2017 and previous years. Areas were noted as eroded due to indicators such as removed vegetation, fallen trees, and property landscaping or lawn missing. Areas of flooding were identified with similar methods, but different indicators. Standing water and debris or mud left behind by water, were both main indications of flooding. Adaptation was used as a term to describe a property where an individual took the time to set up impact prevention measures, but no impacts were observed on the date of the image. These protective actions included sandbagging, excavation, temporary shore wall barriers and pumping. Often impacts existed even when protective actions were taken. Commonly impacted features included building foundations, shore protection, landscaping or lawns, trees, boat launches, docks, boat houses, decks, walkways, roads, parking lots, piers and beaches. Note that impacts for individual feature types were only captured once for each parcel (e.g. dock inundation was counted once, even if there were multiple docks inundated on the property) but that impacts to different features were captured for the same property (e.g. docks, roads, buildings). Quality control checks were done by a separate analyst for a few locations to compare interpretation after all the property impacts were noted. The data was then exported and sorted in Microsoft Excel. The fields included impact type, feature(s), stakeholder, possible protective actions, property type, comments, source and location. Finally, the statistical results were tabulated.

On the lower St. Lawrence River, the oblique imagery was reviewed for clusters of buildings where the water appeared to be near the side of the building. As opposed to the Lake Ontario shoreline review, the lower St. Lawrence River review did not include a parcel level assessment of other types of impacts. The clusters of impacted buildings were then mapped.

**Conservation Ontario/GLAM survey summary results:**

Conservation Ontario conducted a questionnaire of shoreline residents and business owners on behalf of the IJC and the GLAM Committee. The questionnaire was developed using a previous questionnaire from the New York Sea Grant and Cornell University used along the US shoreline of Lake Ontario earlier in 2018. Further information regarding the New York Sea Grant and Cornell University survey is provided on the New York Sea Grant website. The Conservation Ontario/GLAM survey was conducted between November, 2017 and January, 2018 and covered a series of questions pertaining to impacts of flooding and erosion and subsequent severity of the damages and was promoted through media, Conservation Authorities and local contacts inviting Ontario, New York and Quebec residents to respond. Review of the survey results that pertain to GLAM Committee performance indicators is summarized in the main report for the entire region and for select sub-regions in the sections below.

**Official agency site visits:**

The USACE Buffalo Office of Emergency Management conducted site visits to several municipalities within Niagara and Orleans counties during the high water event of 2017. These site visits were done in partnership with local and state emergency management coordinators. During these site visits, the impacts of the high water were observed and recorded. Summaries of these impacts are provided below.

In addition to the USACE site visits, informal site visits were carried out by ECCC and IJC staff at various Canadian locations from Niagara through to Montreal. The primary purpose was to observe site conditions and to take photographs of impacted features for documentation.

**Efforts by outside agencies independent of the GLAM Committee:**

Other agencies and groups are also looking at impacts associated with 2017 high water conditions for various emergency response and recovery purposes. Much of this information is not directly accessible to the GLAM Committee at this time as these agencies and groups have not yet released the information publicly. Efforts are underway to gain access to this impact information in support of long-term GLAM Committee activities. Table 6-2 identifies which non-GLAM activities relate to the existing flooding, erosion and shore protection PIs.

Table 6-2: Activities that are undertaken by outside groups and agencies independently from the GLAM but where the results and information directly relates to long-term GLAM Committee objectives of understanding impacts due to changing water levels.

| **Activity** | **Lake Ontario** | | **Upper St. Lawrence** | | **Lower St. Lawrence** | **Relation to Coastal PIs** |
|---|---|---|---|---|---|---|
| | **US** | **CAN** | **US** | **CAN** | **CAN** | |
| Cornell University/ NY Sea Grant online, self-reporting questionnaire for coastal property owners | Yes | NA | Yes | NA | NA | Flooding, erosion, failed shoreline protection, other observed impacts, adaptive responses |
| New York State Flood Relief/Recovery Program | Yes | NA | Yes | NA | NA | Information on the types and extent of damages observed by shoreline property owners |
| FEMA Disaster Declaration Process | Yes | NA | Yes | NA | NA | Information on the types and extent of flooding damages observed by shoreline counties in New York |
| Province of Quebec "Special financial assistance program for the flooding that occurred between April 5 and May 16, 2017" | NA | NA | NA | NA | Yes | Information on the types and extent of flooding damages experienced by shoreline property owners in Quebec |
| Province of Ontario Disaster Recovery Assistance Program | NA | Yes | NA | Yes | NA | Information on the types and extent of damages observed by shoreline municipalities in Ontario |
| New York State Emergency Response | Yes | NA | Yes | NA | NA | Summary of emergency response efforts, by county (e.g. deployment |

| Activity | Lake Ontario | | Upper St. Lawrence | | Lower St. Lawrence | Relation to Coastal PIs |
|---|---|---|---|---|---|---|
| | US | CAN | US | CAN | CAN | |
| | | | | | | of sandbagging and associated equipment) |
| Review of municipal and other agency documentation on impacts and costs | No | Yes | No | Yes | Yes | Impacts reported by Canadian shoreline municipalities through standard public reporting purposes, primarily damaged shore protection infrastructure, erosion to public lands, flooding of municipal infrastructure |

## 6.2 Media Coverage

There was extensive media coverage of high water impacts throughout the Lake Ontario-St. Lawrence River system in 2017. The GLAM Committee reviewed 1,400 English media articles from throughout 2017. The intent of the review was to get a sense of the types of impacts reported in the media and the relative intensity of that reporting. As part of the review, efforts were made to identify articles that included reports of specific damages or had photographs of high water impacts. Figure 6-3 illustrates the timing of articles, by week, to illustrate the relative intensity of media coverage related to high water level impacts categorized as coastal impacts throughout much of 2017. Through the review, a database was developed with approximately 680 unique impact reports identified from 750 unique articles. All articles with impact reports were categorized based on the nature and extent of the described impact. The majority of those impacts were classified as "coastal" impacts with a fairly even distribution of the percent of overall catalogued impacts between Canada and the US (see Figure 6-4).

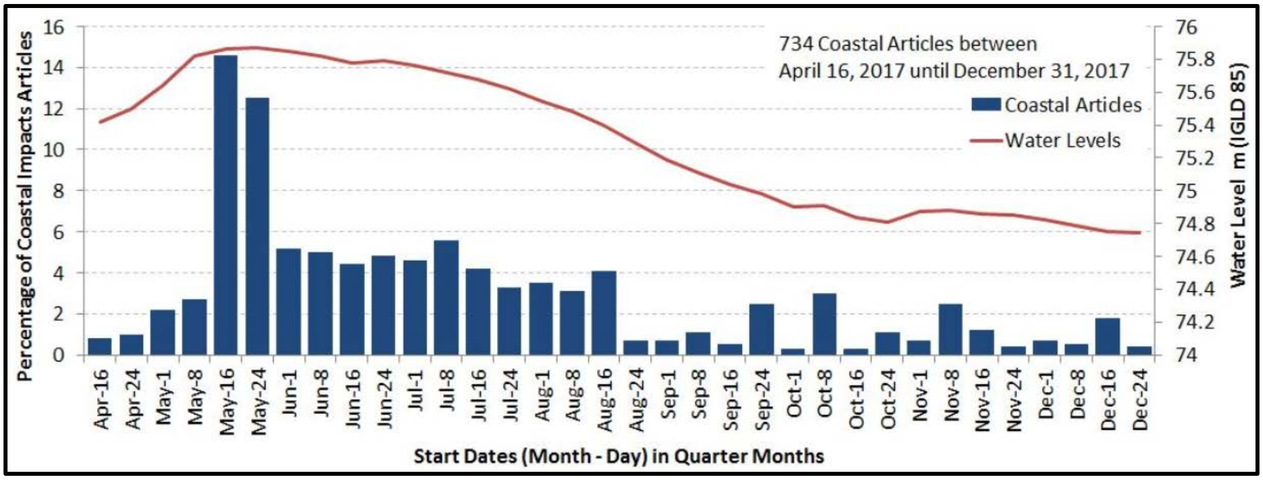

Figure 6-3: Graph of percent of media reports in GLAM database, by week

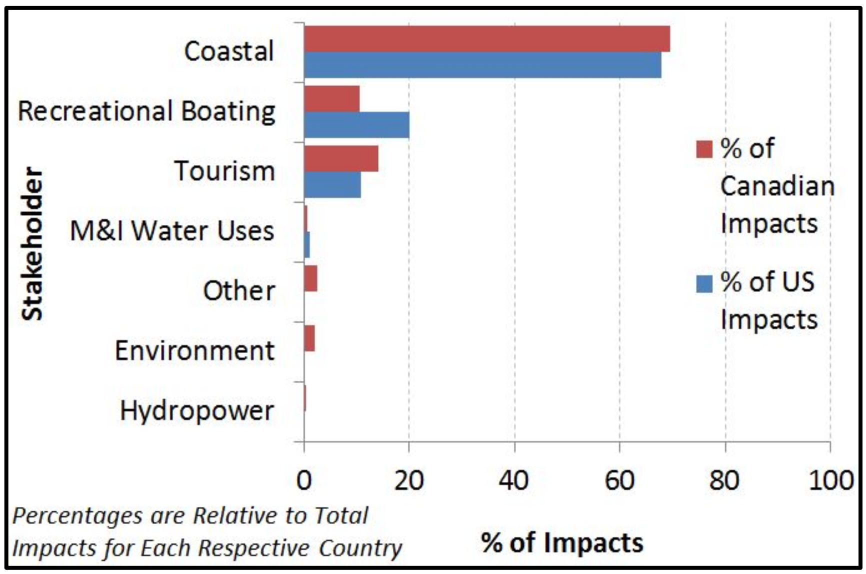

Figure 6-4: Distribution of reported impacts on stakeholders, as identified through media articles, for the LOSLR basin in Canada vs. US

Flooding damages were the primary impact category identified through the media reports, with a smaller percent related to adaptive response, other, and erosion (Figure 6-5). For articles related to Canadian impacts, the majority of the reported impacts were characterized as "public space" impacts with "private property" and "business property" types being the next most reported (Figure 6-6). On the US shoreline, the largest percentage of responses was categorized as "private property" impacts followed by "public space" and "business uses" (Figure 6-6). The media reports used in the categorization were distributed across the Lake Ontario and upper St. Lawrence River shoreline (Figure 6-7).

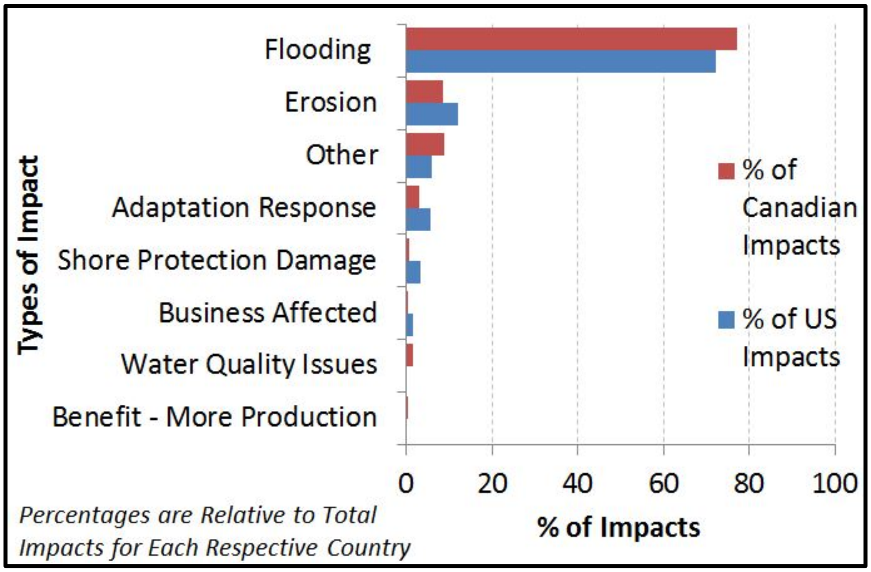


Figure 6-5: Distribution of primary and secondary reported impacts on stakeholders, as identified through media articles, for the LOSLR basin in Canada vs. US.

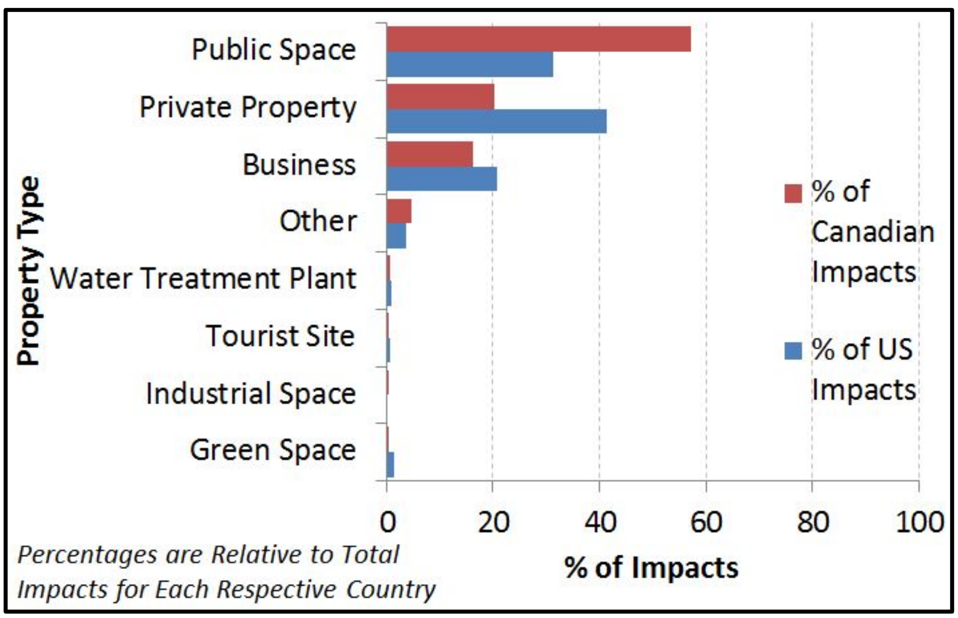


Figure 6-6: Distribution of reported impacts on stakeholders by property type, as identified through media articles, for the LOSLR basin in Canada vs. US.

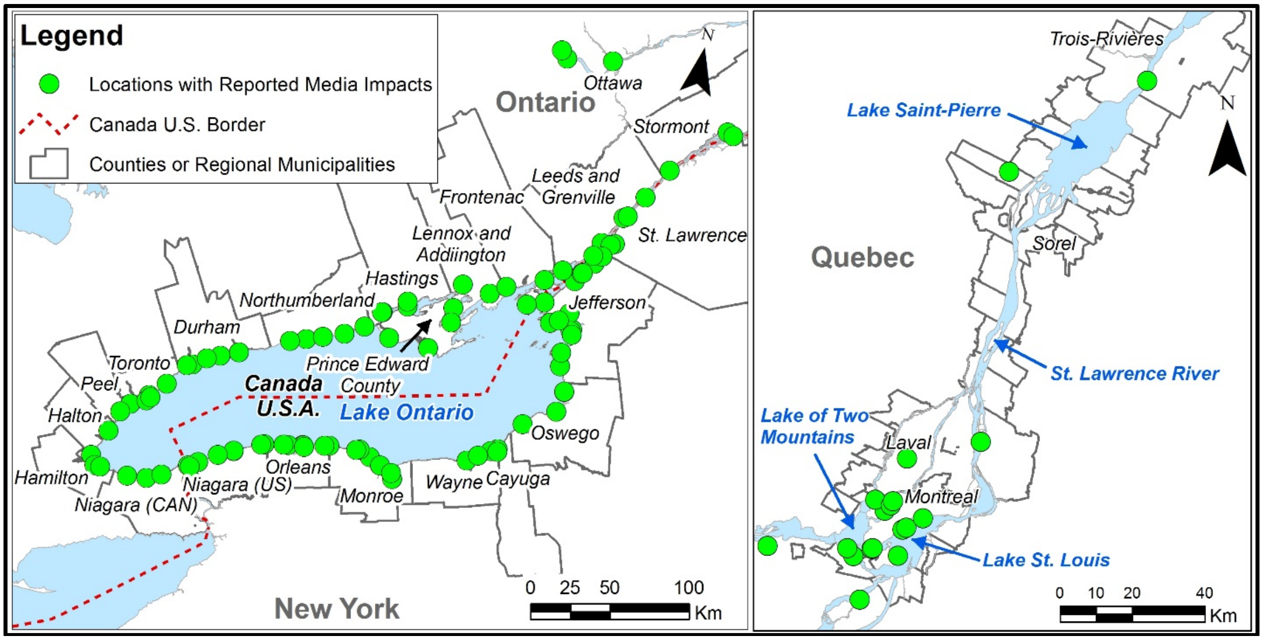


Figure 6-7: Locations of Towns/Cities with English media reports of high water impacts in 2017 (note that Quebec impacts, particularly downstream of Montreal, were not fully captured by the English language media tracking). (Source: GLAM Committee)

# 6.3 Impacts of 2017 water level conditions

Impacts to the Lake Ontario and upper St. Lawrence River coastal interest were captured using a variety of sources as described in Section 6.1 and general results are summarized in the main report. For this Annex, further details are provided based on a regional breakdown of information using the groupings shown in Figure 6-8. For both the US and Canadian section, discussion starts at the Niagara River and moves along the shoreline towards the St. Lawrence River.

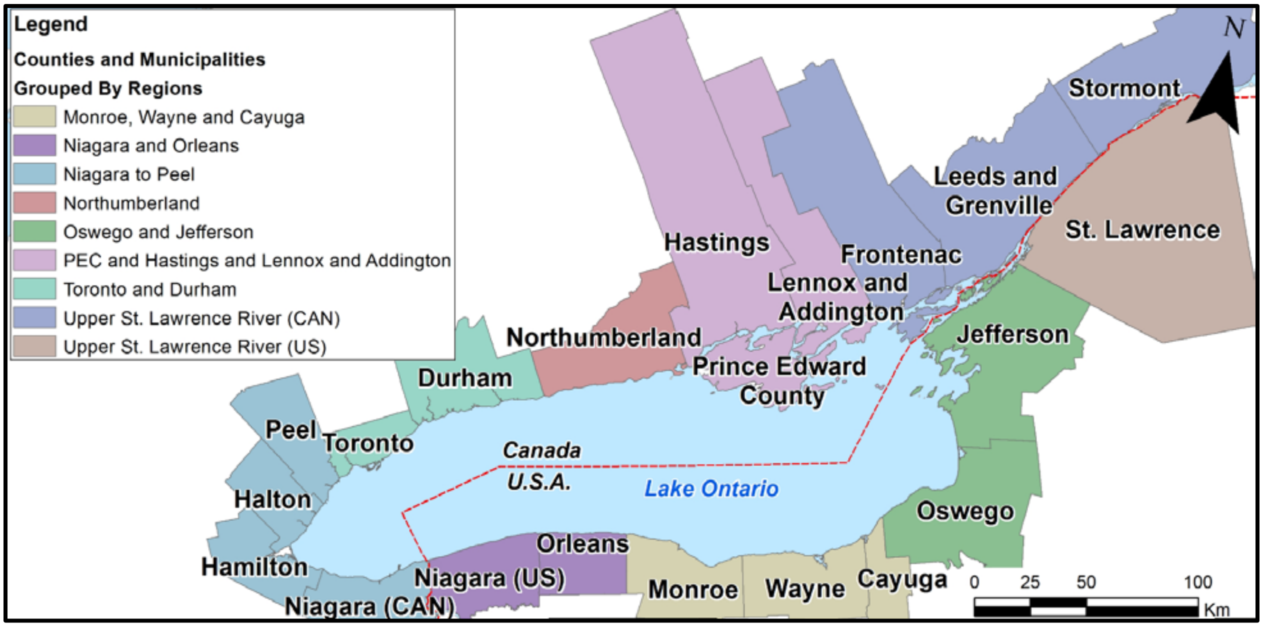

Figure 6-8: Lake Ontario and upper St. Lawrence River regions used for the coastal analysis in the impact assessment annex.

### 6.3.1 Lake Ontario and upper St. Lawrence River – State of New York

#### *6.3.1.1 Niagara and Orleans County:*

**Aerial Imagery Assessment:**

Niagara and Orleans counties contain approximately 4,292 property parcels within 1000 feet of the shoreline and almost all coastal impacts identified through the imagery review are within this zone and 983 properties were identified as being impacted, primarily by either flooding (38%) or erosion (60%) or were cases of adaptation (5%). Twenty-eight of the properties were classified as having impacts from both flooding and erosion. Impacts to properties varied based on whether a property was located on the open lake and thus exposed to wave action or located on a wetland or protected embayment where waves tend to be smaller.

In Niagara County, erosion impacts were the most commonly observed along the open lake shoreline (75% of impacted properties), whereas in the protected embayments, flooding impacts were the most commonly observed (95% of impacted properties). The impacts to properties located in wetlands, rivers and inland were 100% classified as flooding. In Orleans County, 61% of impacted properties located in the open lake experienced erosion, whereas 100% of impacted properties located in bays experienced flooding. The impacted properties located in wetlands and inland were also 100% due to flooding.

This area has fewer protected bays than the other regions of the US Lake Ontario shoreline. In the Niagara and Orleans regions, a greater percentage of properties were affected by erosion than in the other regions. About 60% of the combined region damages identified through the imagery review were due to erosion and mainly located in open lake shoreline areas. Very rarely were signs of major erosion observed in bays or protected bays on the imagery, suggesting wave action could be an important contributor. Due to minimal embayment properties in this region, observed flooding impacts were far fewer than in the other regions.

Figure 6-9 illustrates the type and quantity of property impacts in Niagara and Orleans Counties identified through the imagery assessment and Figure 6-10 shows an example from the imagery. Vegetation and trees are the leading impact feature disrupted by the high water event, followed by landscaping and lawns. Impacts to docks and roads were observed less frequently than in other regions. Orleans County was observed to have the greatest number of impacts to shore protection structures whereas Niagara County had very few observable impacts to shore protection structures.

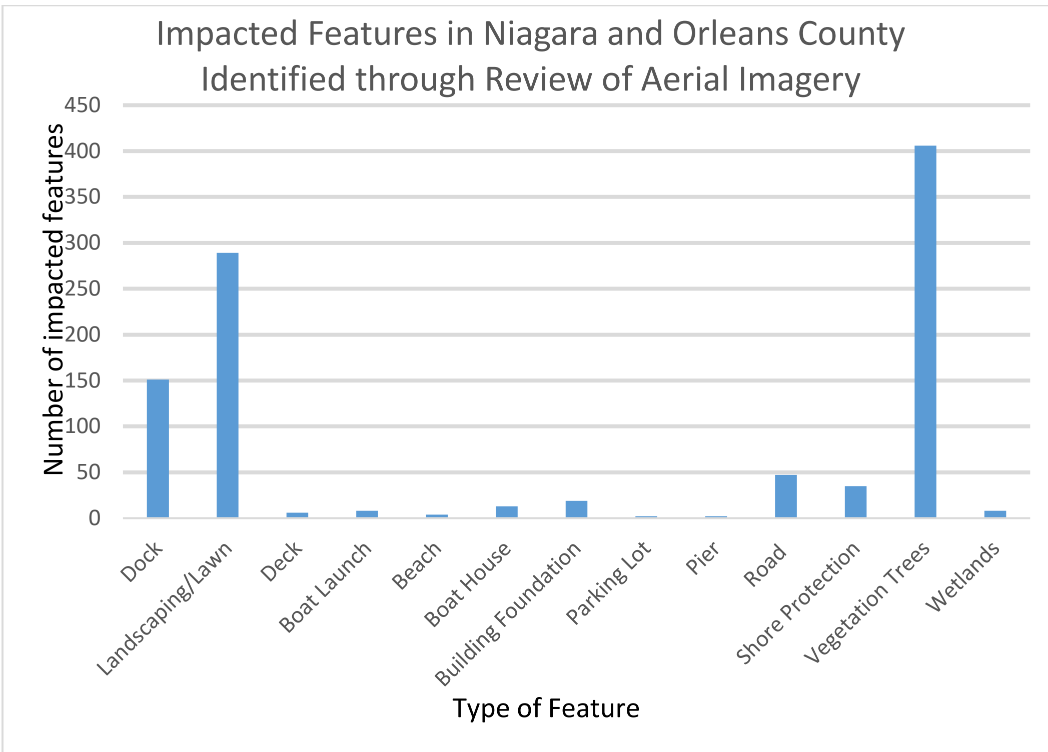


Figure 6-9: Impacted Features in Niagara and Orleans counties as identified through the aerial imagery assessment


Figure 6-10: Example of shoreline erosion observed for a specific property in Niagara County. Note the trees and vegetation in the water. (Source: USACE Aerial Imagery – June 2, 2017).

Of the 983 total property impacts in this region, 101 had taken protective measures at the time the aerial imagery was taken. Table 6-3 below shows that the majority of visible protection took the form of sandbagging. This method uses sandbags as a physical barrier to hold water back and dissipate the force of the waves. Some other more expensive measures were taken, such as excavation, to add stronger shoreline material and the construction of temporary shore wall barriers.

Table 6-3: Protective measures observed from aerial imagery assessment for Niagara and Orleans counties (Source: USACE Aerial Imagery Assessment)

| Protective Measures Observed | Count |
|---|---|
| Sandbagging | 76 |
| Pumping | 0 |
| Excavation | 22 |
| Temporary Shorewall Barrier | 3 |

Impacts identified through the aerial imagery analysis were mapped by 10 km (6.2 miles) coastal reaches across the entire Canadian and US shoreline of Lake Ontario covered by the imagery to allow a relative comparison of the photo interpretation results. The impacts are represented as average per 10 km (6.2 miles) of shoreline within each city/town/township (e.g. total number of city/town/township impacts / (length of shoreline in the city, town, or township/10)). Figure 6-11 represents the number of main building structures that appeared inundated by static water levels in a specific stretch of coast on the date the image was taken. Figure 6-12 represents the number of small structures or undeveloped property inundated by static water levels. Figure 6-13 represents the number of shore protection structures inundated by static water levels.

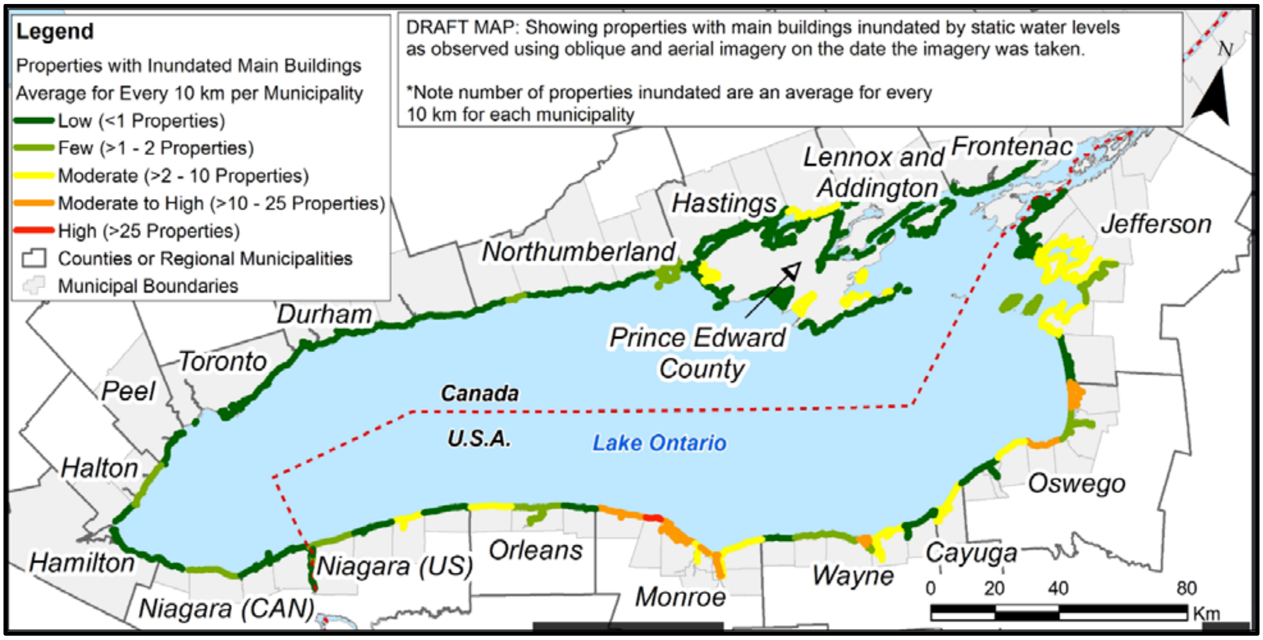


Figure 6-11: Main building inundation under static water levels as identified through review of available oblique and orthoimagery from 2017 (represented by town based on a relative scale of the total number of identified instances/(total county shoreline length/10)) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

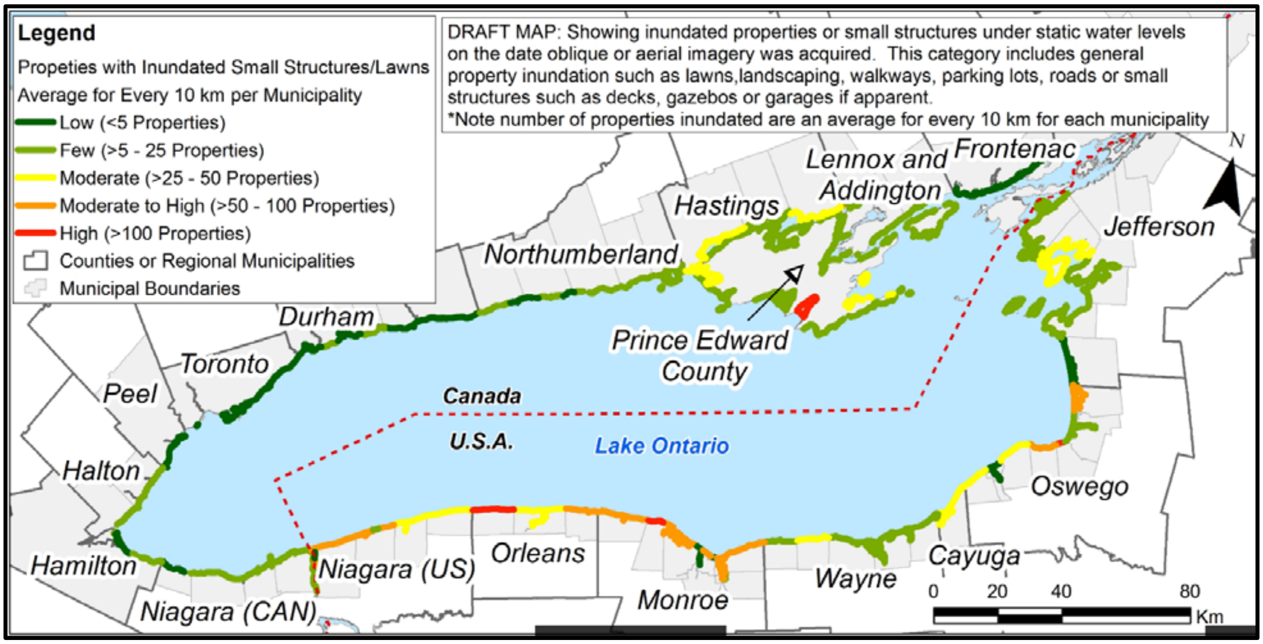


Figure 6-12: Property or small structure inundation under static water levels as identified through review of available oblique and orthoimagery from 2017 (represented by town based on a relative scale of the total number of identified instances/(total county shoreline length/10)) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

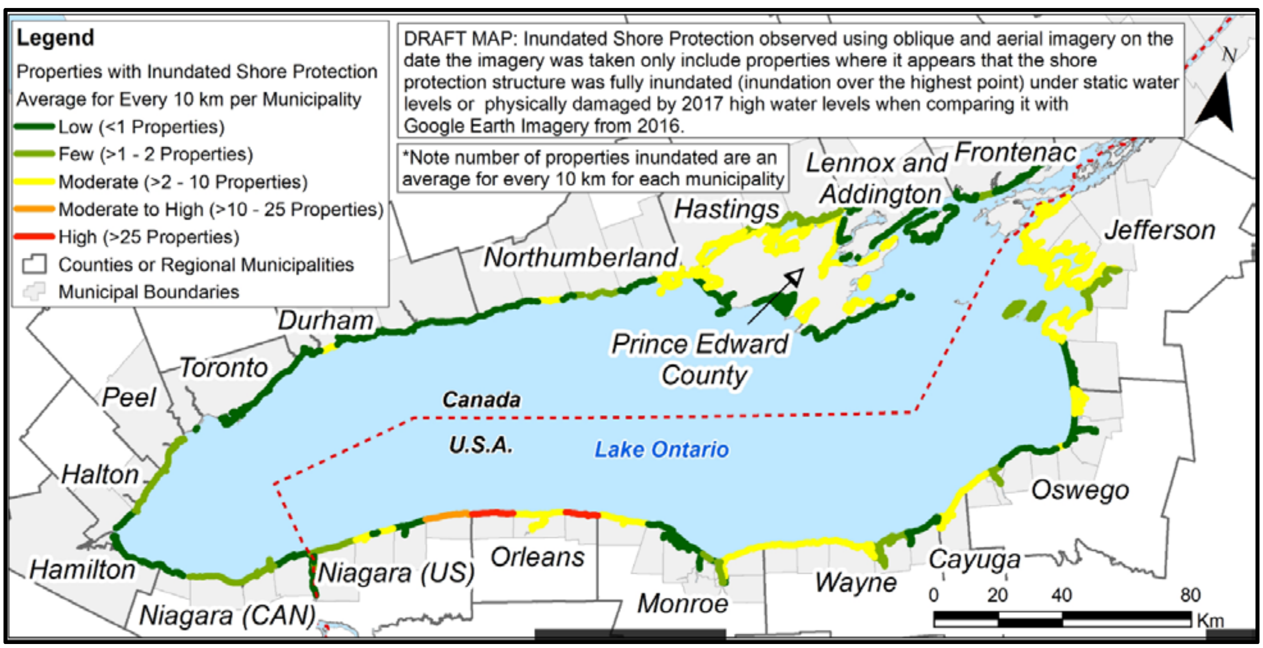


Figure 6-13: Shore protection inundation under static water levels as identified through review of available oblique and orthoimagery from 2017 (represented by town based on a relative scale of the total number of identified instances/(total county shoreline length/10)) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

**Conservation Ontario/GLAM Shoreline Survey:**

There were 202 responses to the Conservation Ontario/GLAM shoreline survey in Niagara and Orleans Counties. Of those responses, 160 reported some degree of flooding impacts. The greatest response was for the dock/pier flooding and lawn flooding categories with a much smaller response for first floor, basement, or crawl space flooding (Figure 6-14). Note that respondents could select multiple types of flooding impacts if they were observed on their property.

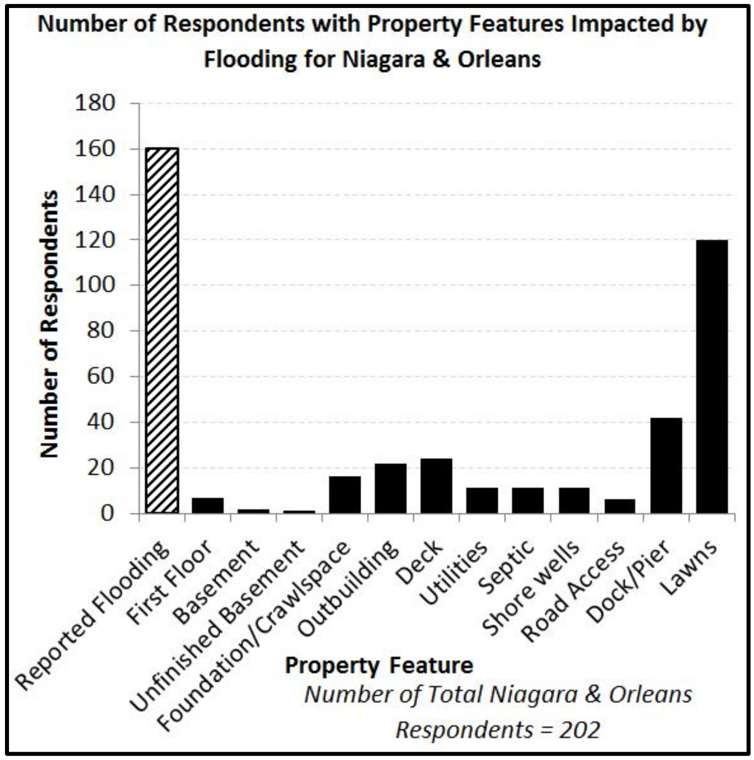


Figure 6-14: Summary of Conservation Ontario questionnaire responses for flooded property within Niagara and Orleans Counties (US). (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Of the 202 respondents, 168 also reported some degree of erosion impacts in Niagara and Orleans Counties. The responses were provided by the impacted feature (e.g. main building, deck, beach, etc.) and respondents were asked to represent the degree of impact (small, moderate, or substantial). Based on the responses, stairs/ramps, vegetation, beaches, and "other" were the most commonly reported categories (Figure 6-15). There were a lot of responses in the "other" category and a review of those responses suggests many were related to impacted shoreline protection structures. As with the flooding responses, respondents could select multiple types of erosion impacts if they were observed on their property.

Survey respondents had the option to submit photos showing examples of the high water impacts they experienced (if they chose to) and a few of those photos from across the Lake Ontario-St. Lawrence River shoreline are included at the end of the coastal section for reference.

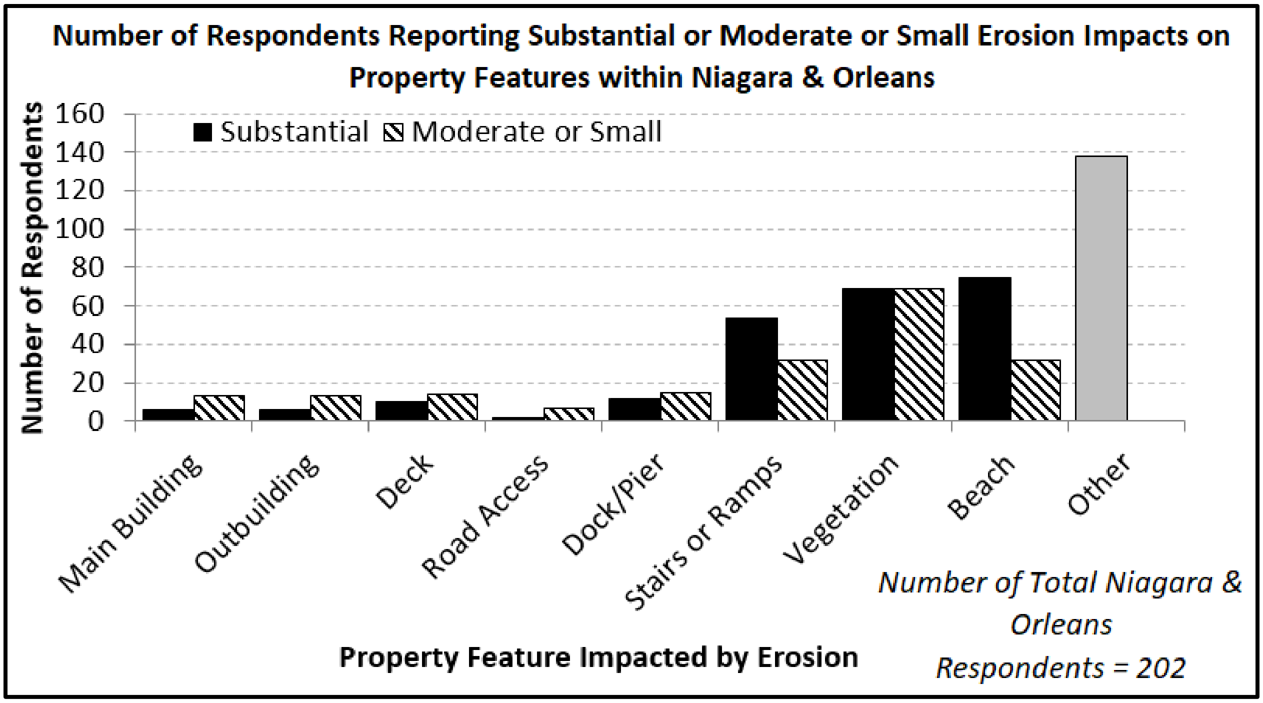


Figure 6-15: Summary of Conservation Ontario questionnaire responses for erosion impacts within Niagara and Orleans Counties (US). (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

**US Army Corps of Engineers Site Visits:**

The USACE Buffalo Office of Emergency Management conducted site visits to several municipalities within Niagara and Orleans counties during the high water event of 2017 (Table 6-4). These site visits were done in partnership with local and state emergency management coordinators and several impacts were observed.

Table 6-4: USACE site visit locations in Niagara and Orleans counties (Source: USACE Buffalo)

| Location | Site Visit Date |
|---|---|
| Kendall, NY | May 12, 2017 |
| Olcott, NY | May 12, 2017 |
| Wilson, NY | May 25, 2017 |

In Kendall, NY, shoreline erosion was observed at residential homes, although it was not imminently threatening any structures at the time of the site visit. Other impacts observed in Kendall were erosion and undermining of dead-end access roads to Lake Ontario. Public infrastructure was only minimally impacted. Adaptive responses observed in Kendall included sandbagging of eroded areas of the shoreline and additional stone replacement at both main jetties as well as the shoreline west of the channel entrance.

In Olcott, NY, flooding was observed to be impacting local roadways, businesses and residences. Adaptive actions employed included sandbagging and low elevation pumping. The static water level resulted in first floor flooding at Hedley Marina, McDonough's Boathouse and several residential homes.

### *6.3.1.2 Monroe, Wayne and Cayuga Counties:*

Monroe, Wayne and Cayuga counties contain approximately 12,140 property parcels within 1000 feet of the shoreline and almost all coastal impacts identified through the aerial imagery were within this zone. In these counties, 2,471 properties were identified as impacted based on the aerial imagery review, primarily due to either flooding (92%) or erosion (9%); 14 of the properties were impacted by both flooding and erosion. Impacts to properties varied based on whether a property was located on the open lake and thus exposed to wave action or located on a wetland or protected embayment.

Figure 6-16 illustrates the type and quantity of property impacts in Monroe, Wayne and Cayuga counties as identified through the imagery and Figure 6-17 and 6-18 are examples from the imagery to illustrate what was observed. In this region, there was a significant amount of landscaping, lawns and docks that were impacted. Property impacts to building foundations and vegetation and trees were also commonly impacted.

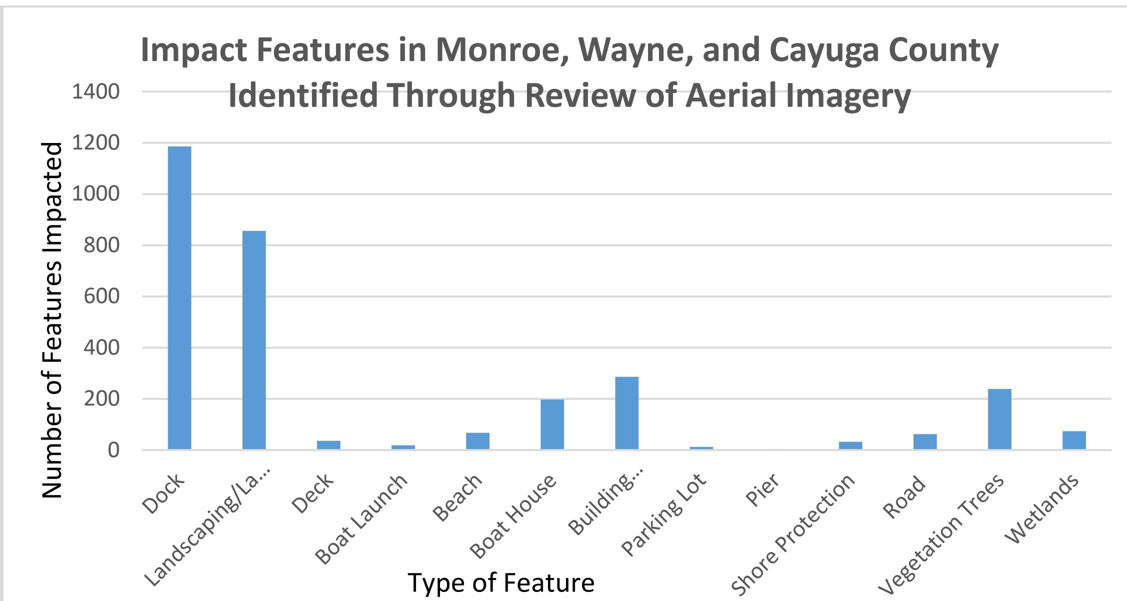


Figure 6-16: Impact features in Monroe, Wayne and Cayuga counties as identified through the aerial imagery assessment.

Figure 6-17: Example of flooding of lawn/landscaping in Irondequit Bay, Monroe County on June 3, 2017 (left) and April 15, 2015 (right). Photo Credit: USACE Aerial Imagery – June 3, 2017, and ESRI – April 15, 2015.

Figure 6-18: Example of flooding of residential building foundation in Monroe County, June 3, 2017 (left) and April 15, 2015 (right). Photo Credit: USACE Aerial Imagery – June 24, 2017, ESRI Imagery – April 15, 2015.

In Wayne County, 38% of impacted properties located in the open lake appeared to experience erosion, whereas 99% of impacted properties located in bays appeared to experience flooding. The impacted properties located in wetlands, protected bays and inland areas were 100% classified as flooding; no erosion impacts were noted in these areas.

In Monroe County, 11% of impacted properties located in the open lake experienced erosion, whereas 98% of impacted properties located in bays experienced flooding. The remaining impacted properties located in wetlands, protected bays and inland were 100% due to flooding, with the exception of one wetland also exhibiting signs of erosion based on review of the aerial imagery.

In Cayuga County, 87% of impacted properties located in the open lake appeared to experience erosion. The remaining impacted properties located in wetlands and protected bays were 100% due to flooding.

Cayuga County shoreline appeared to suffer great amounts of erosion in the open lake area compared to Monroe and Wayne counties. Twenty-two percent of Cayuga County property impacts were due to erosion compared to Monroe and Wayne counties which had 8% and 6%, respectively. This stretch of shoreline is located on the east end of the lake, affected by westerly winds. Significant flooding was mainly located amongst embayment shoreline properties, where the population is much greater. Docks and lawns were the predominant flooded feature in the embayment shorelines. Note that docks are more commonly located in protected waters than on the open lake shoreline.

Of the 2,471 total property impacts identified through the aerial imagery, 342 appeared to take protective measures with the majority of visible protection taking the form of sandbagging (Table 6-5).

Table 6-5: Protective measures observed in Cayuga, Monroe and Wayne counties (Source: USACE Aerial Imagery Analysis)

| Protective Measures Observed | Count |
|---|---|
| Sandbagging | 312 |
| Pumping | 1 |
| Excavation | 12 |
| Temporary Shorewall Barrier | 17 |

**Conservation Ontario/GLAM Shoreline Survey:**

There were 466 responses to the Conservation Ontario/GLAM shoreline survey in Monroe, Wayne and Cayuga Counties. Of those responses, 425 reported some degree of flooding impacts. Like Niagara and Orleans Counties, the greatest response was for the dock/pier flooding or lawn flooding categories. However, there was also a high number of responses for the foundation/crawlspace, outbuilding, deck and road access categories (Figure 6-19). Note that respondents could select multiple types of flooding impacts if they were observed on their property.

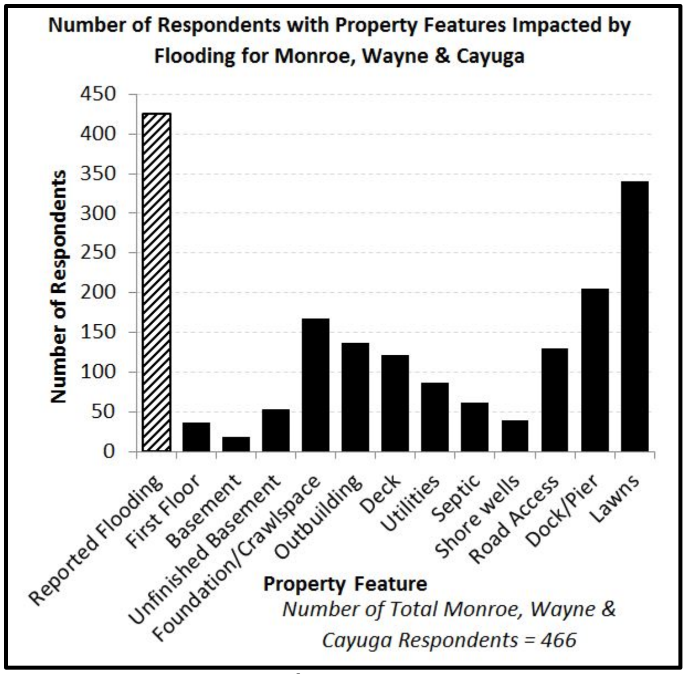


Figure 6-19: Summary of Conservation Ontario questionnaire responses for flooded property within Monroe, Wayne and Cayuga Counties (US). (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Erosion impacts were reported by 298 of the 466 survey responses for Monroe, Wayne and Cayuga Counties. The responses were provided by the impacted feature (e.g. main building, deck, beach, etc.) and respondents were asked to represent the degree of impact (small, moderate, or substantial). Like Niagara and Orleans Counties, the "other" category had a high number of responses and they were primarily related to impacts to shoreline protection impacts. As well, there were impacts to docks/piers, stairs/ramps, vegetation and beaches reported and for the stairs/ramps and beach categories, the substantial degree of impact was reported more frequently than the combined moderate/small degree of impact category (Figure 6-20). Main building and outbuilding impacts were also reported with a higher number being categorized in the moderate/small impact category compared to the substantial category. As with the flooding responses, respondents could select multiple types of erosion impacts if they were observed on their property.

Survey respondents had the option to submit photos showing examples of the high water impacts they experienced (if they chose to) and a few of those photos from across the Lake Ontario – St. Lawrence River shoreline are included at the end of the coastal section for reference.

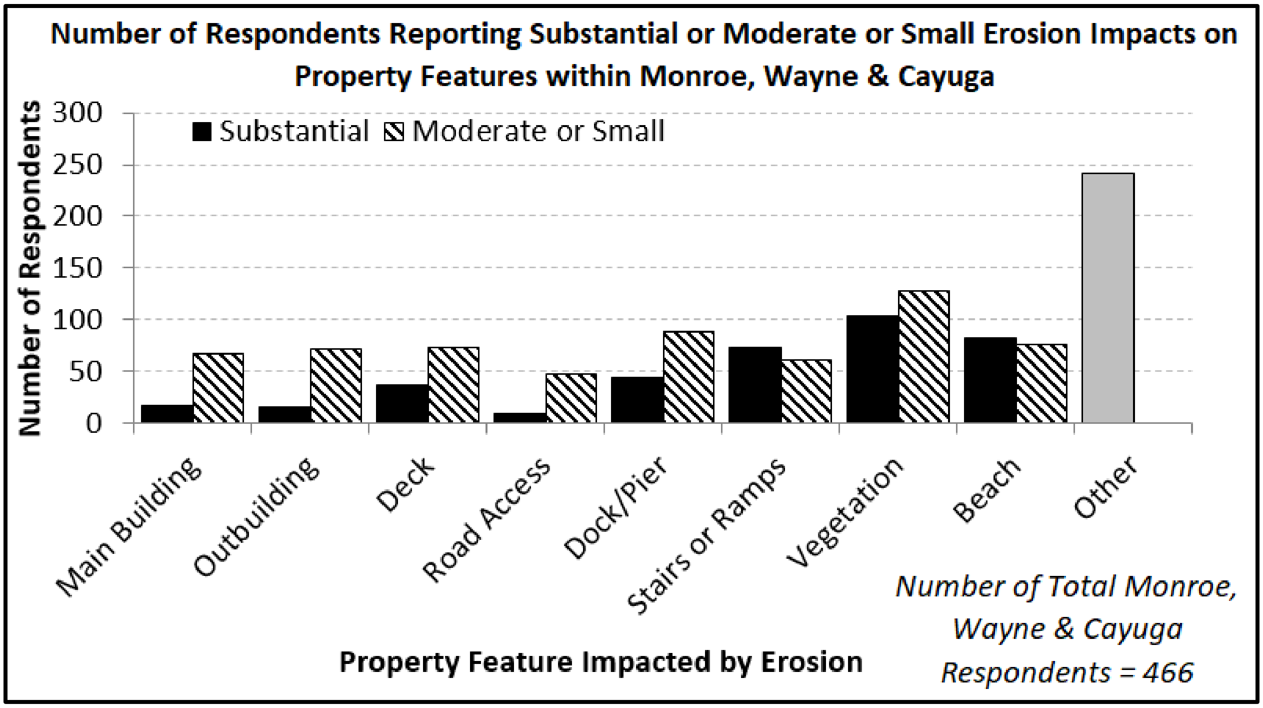


Figure 6-20: Summary of Conservation Ontario questionnaire responses for flooded property within Monroe, Wayne and Cayuga Counties (US). (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

**US Army Corps of Engineers Site Visits:**

The USACE Buffalo Office of Emergency Management conducted site visits to several municipalities within Wayne, Monroe and Cayuga counties during the high water event of 2017 (Table 6-6). These site visits were done in partnership with local and state emergency management coordinators and several impacts were observed.

Table 6-6: List of Site Visits in Wayne, Monroe and Cayuga counties (Source: USACE Buffalo, 2017)

| Location | Site Visit Date |
|---|---|
| Greece, NY | 12 May, 2017 |
| Hamlin, NY | 12 May, 2017 |
| Huron, NY | 12 May, 2017 |
| Irondequoit, NY | 12 May, 2017 |
| Webster, NY | 12 May, 2017 |
| Fair Haven, NY | 16 May, 2017 |
| Sodus Point, NY | 19 May, 2017 |
| Webster, NY | 19 May, 2017 |
| Sodus Point, NY | 26 May, 2017 |

In Greece, NY flooding of four ponds was observed: Round Pond, Bucks Pond, Long Pond and Cranberry Pond. Each of these ponds connect to Lake Ontario under Edgemere Drive and associated residential streets. The flooding impacted these roadways, obstructing access and disrupting residents. Over 90,000 sandbags were distributed to the public and the town engaged in pumping operations in the inundated areas. Impacts observed included flooded roads, compromised sanitary sewers and overwhelmed storm sewers.

In Hamlin, NY two properties on Sandy Harbor Drive were observed to have basement and garage flooding, septic field flooding and local access road flooding. On Sandy Shore Drive, several residences experienced front yard flooding and impacted septic fields impacting the ability of the residents to use their bathrooms and sink drains.

In Huron, NY a breach to a barrier beach at Crescent Beach was observed causing downed power lines. Flooded docks and boathouses were also observed.

In Webster, NY approximately one mile (1.6 km) of shoreline was impacted. Flooding of streets and minor flooding of residential homes sub-structures was observed, but no first-floor flooding was observed on 12 May, 2017. Approximately 30 homes were impacted by minor flooding. The recreation association was observed to have significant erosion between their dock and the neighboring seawall on 19 May, 2017. Sandbags and sandbags in wire baskets had been placed to protect approximately 50 ft (15.24 m) of shoreline (Figure 6-21).

Figure 6-21: Sandbag protection at Recreation Association in Webster, NY on 19 May, 2017 (Source: USACE Buffalo, 2017)

In Sodus Point, NY on 19 May, Sand Point Peninsula was observed to have flooded with approximately 12” (30.5 cm) of water observed on Greig Street and Gardenier Lane (Figure 6-22 and Figure 6-23). No first-floor flooding was reported due to elevation of homes above street level, but access to homes was cut off and some garages and sheds were flooded.


Figure 6-22: Impacts observed at Sodus Point (Source: USACE Buffalo, 2017)

Figure 6-23: Interior flooding along Gardenier Lane in Sodus Point, NY, 19 May, 2017 (Source: USACE Buffalo, 2017)

### *6.3.1.3 Oswego County and Jefferson County:*

Oswego and Jefferson County contain approximately 18,911 property parcels within 1000 feet of the shoreline and almost all coastal impacts identified from the aerial imagery are within this zone. In these counties, 1,727 properties were identified as impacted through the aerial imagery review, primarily as a result of either flooding (90%) or erosion (9%), with 2% being cases of adaptation. Fourteen of the properties received impacts from both flooding and erosion. Impacts to properties varied based on whether a property was located on the open lake and thus exposed to wave action or located on a wetland or protected embayment.

Figure 6-24 illustrates the number of property parcels that experienced impacts on their respective impact features. In this region, there was a significant amount of landscaping/lawns and docks impacted. Property impacts on building foundations, shore protection and vegetation/trees were observed more infrequently.

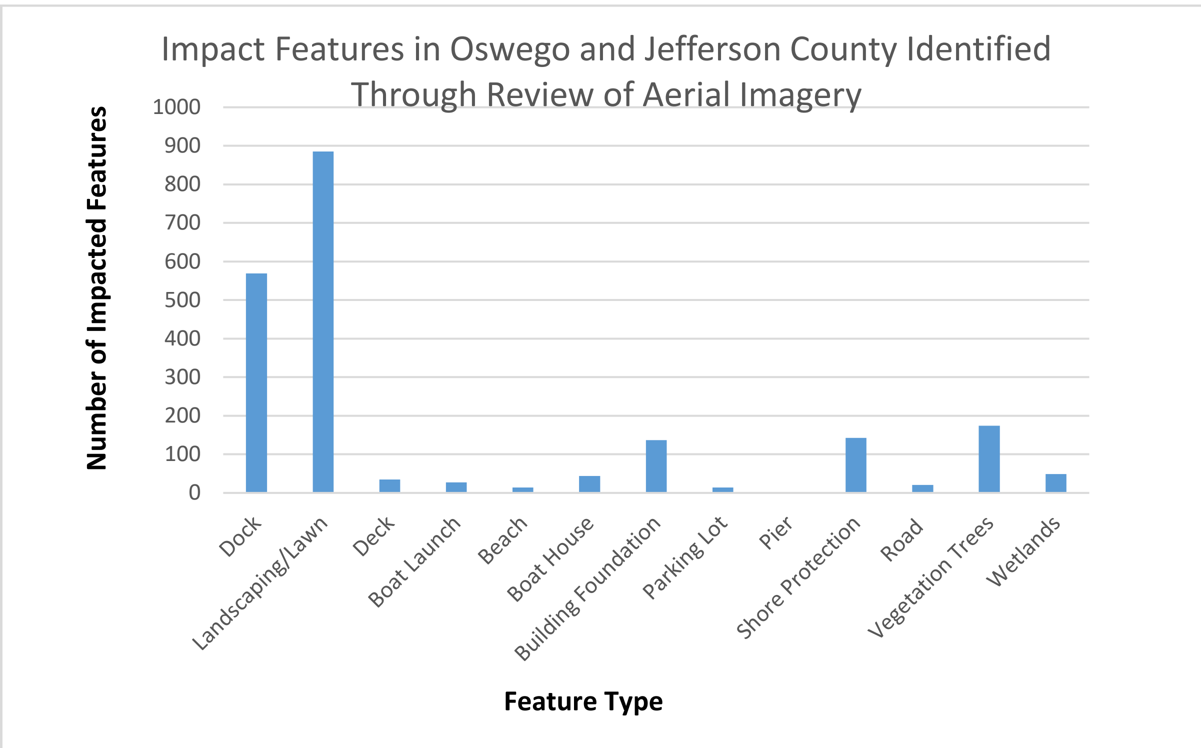


Figure 6-24: Impacted features in Oswego and Jefferson counties as identified through the aerial imagery assessment.

In Oswego County, 26% of impacted properties located in the open lake appeared to experience erosion, whereas 99% of impacted properties located in protected bays appeared to experience flooding (e.g. Figure 6-25). The remaining impacted properties located in wetlands were 100% due to flooding.

In Jefferson County, 14% of impacted properties located in the open lake appeared to experience erosion, whereas 94% of impacted properties located in bays appeared to experience flooding.

The remaining impacted properties located in wetlands and inland were 100% due to flooding, with the exception of one wetland also exhibiting signs of erosion.

Erosion of both vegetation/trees and property landscaping or lawn were mainly located in open lake shoreline areas. Oswego County had a slightly higher proportion of identified impacts classified as erosion in the open lake area compared to Jefferson County, 10% of Oswego property impacts was due to erosion compared to Jefferson which had 9%. Oswego, similar to Cayuga County, has great stretches of shoreline located on the east end of Lake Ontario where westerly winds usually hit. Embayment flooding was commonly observed, given the relatively high density of development in those areas. Docks and lawns were the predominant flooded feature in the embayment shorelines. Note that docks are much more commonly located in protected waters than on open lake shorelines.

Figure 6-25: Example of flooding impacts to a public marina in Oswego County on June 24, 2017 (top left) and April 15, 2015 (top right), and to a private dock in Oswego County on June 24, 2017 (bottom left) and April, 15, 2015 (bottom right). Photo Credit: USACE Aerial Imagery – June 24, 2017, ESRI Imagery – April 15, 2015.

Of the 1,727 total property parcel impacts identified through the aerial imagery, 174 appeared to have taken protective measures with the majority of visible protection taking the form of sandbagging (Table 6-7).

Table 6-7: Protective measures observed in Oswego and Jefferson counties (Source: USACE Imagery Analysis)

| Protective Measures Observed | Count |
|---|---|
| Sandbagging | 160 |
| Pumping | 0 |
| Excavation | 10 |
| Temporary Shorewall Barrier | 4 |

**Conservation Ontario/GLAM Shoreline Survey:**

There were 310 responses to the Conservation Ontario/GLAM shoreline survey in Oswego and Jefferson Counties. Of those responses, 282 reported some degree of flooding impacts. Like the other counties on the US shoreline, the greatest response was for the dock/pier flooding or lawn flooding categories. There was also a high number of responses for the foundation/crawlspace, outbuilding, deck and road access categories (Figure 6-26). There were also a number of responses for the septic category. First floor and basement flooding were the least commonly reported impact categories of the choices available. Note that respondents could select multiple types of flooding impacts if they were observed on their property.

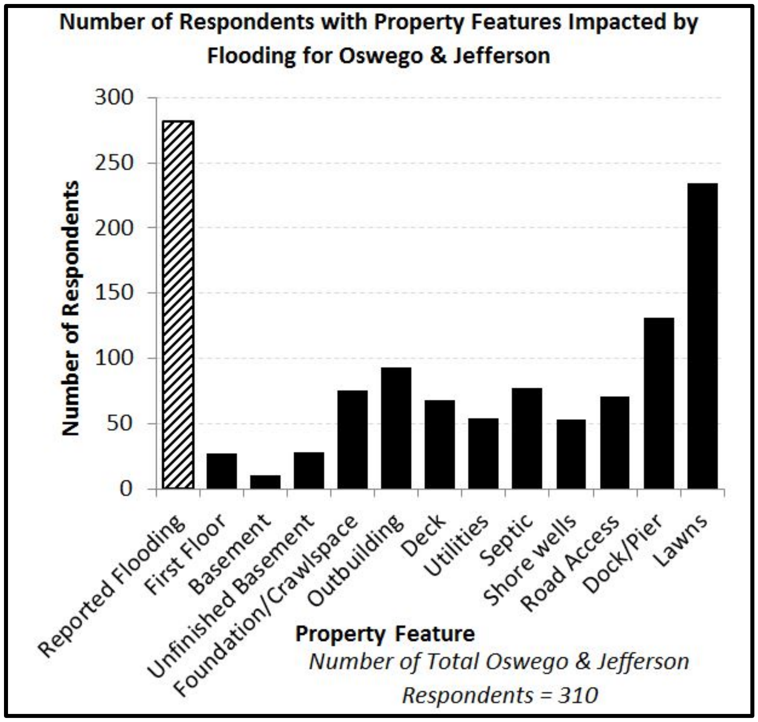


Figure 6-26: Summary of Conservation Ontario questionnaire responses for flooded property within Monroe, Wayne and Cayuga Counties (US). (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Erosion impacts were reported by 239 of the 310 survey responses for Oswego and Jefferson Counties. The responses were provided by the impacted feature (e.g. main building, deck, beach, etc.) and respondents were asked to represent the degree of impact (small, moderate or substantial). Like the other US counties reported previously, the "other" category had a high number of responses and they were primarily related to impacts to shoreline protection. As well, impacts to stairs/ramps, vegetation, and beaches were commonly reported (Figure 6-27). Impacts to various buildings (main and outbuildings) were also reported by a number of respondents. In those categories, respondents more commonly categorized their impacts as moderate/small as opposed to substantial (Figure 6-27). As with the flooding responses, respondents could select multiple types of erosion impacts if they were observed on their property.

Survey respondents had the option to submit photos showing examples of the high water impacts they experienced (if they chose to) and a few of those photos from across the Lake Ontario-St. Lawrence River shoreline are included at the end of the coastal section for reference.

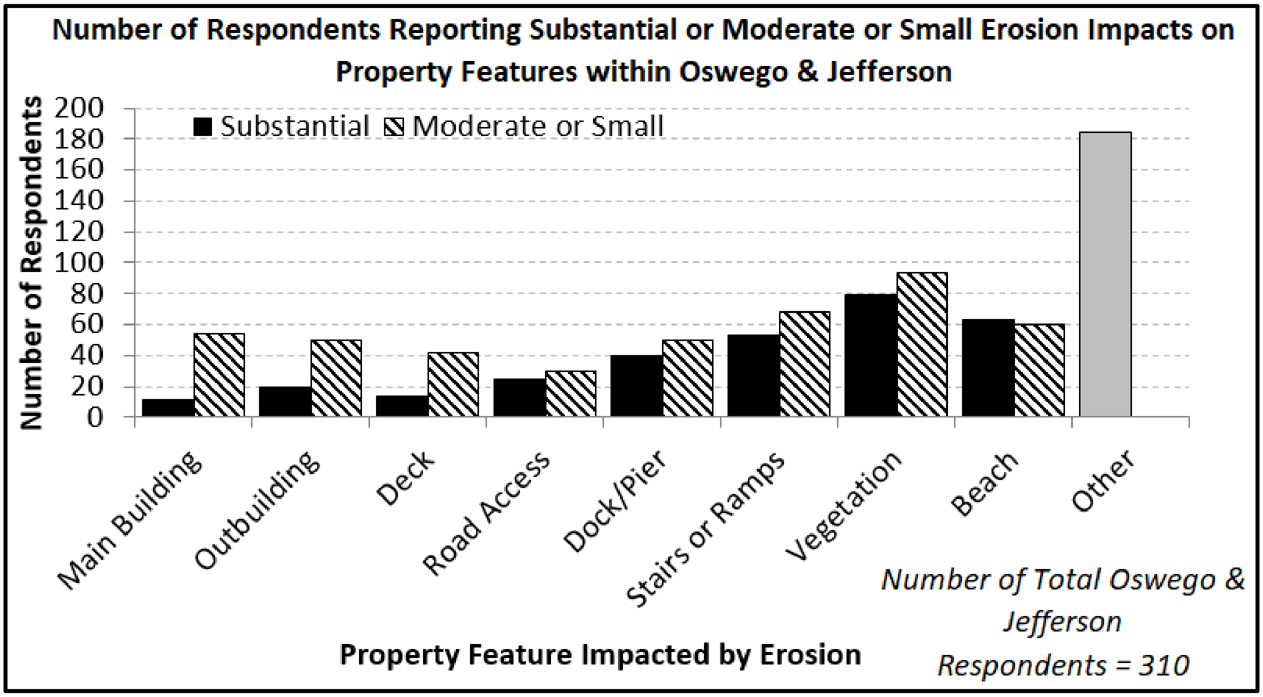


Figure 6-27: Summary of Conservation Ontario questionnaire responses for erosion impacts within Niagara and Orleans Counties (US). (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

**US Army Corps of Engineers Site Visits:**

The USACE Buffalo Office of Emergency Management conducted site visits to several municipalities within Oswego and Jefferson counties during the high water event of 2017 (Table 6-8) in partnership with local and state emergency management coordinators.

Table 6-8: List of official site visits in Jefferson and Oswego counties (Source: USACE Buffalo, 2017)

| Location | Date of Visit |
|---|---|
| Lyme, NY | May 16th, 2017 |
| Mexico Point, NY | May 16th, 2017 |
| Oswego, NY | May 25th, 2017 |
| Sandy Creek, NY | May 26th, 2017 |
| Alexandria Bay, NY | May 26th, 2017 |

In Lyme, NY, impacts to several residential homes were observed on South Shore Road and Water Street (Figure 6-28). Adaptive actions to protect private residences included sandbagging and pumping of low-lying areas. A historic boat house was inundated and sandbags were replaced in an attempt to prevent further damage due to wave action (Figure 6-29). Along County Route 57, wave run-up was inundating the road and eroding the isthmus. Erosion along Beach Road was observed due to wave run-up. At Long Point State Park, the boat launch and dock area were closed due to flooding (Figure 6-30).

Figure 6-28: Residential flooding in Lyme, NY, May 16, 2017 (Source: USACE Buffalo, 2017)

Figure 6-29: Flooding of National Historic Registry Boathouse, Lyme, NY, May 16, 2017 (Source: USACE Buffalo, 2017)


Figure 6-30: Flooding in Long Point State Park, Lyme, NY, May 16, 2017 (Source: USACE Buffalo, 2017)

In Mexico Point, NY, significant erosion was observed at Mexico Point State Park. An estimated 10 to 15 ft (~3-4.5 m) of land was lost along a 300 to 400 ft (~91-122 m) section of shoreline. Several private residences adjacent to Mexico Point State Park have been impacted by waves breaching the existing shoreline protection structures and causing erosion behind the breakwall. Adaptive actions taken included the placement of sandbags at the private residences and the placement of additional angular rock on the lake side of one structure to reduce wave energy.

In Oswego, NY approximately 12 to 18 homes were observed to be experiencing shoreline erosion due to wave action along East and West Shore Roads. Sandbags had been placed to prevent erosion but due to a sporadic line of protection and inadequate placement techniques many of the sandbags had been destroyed by wave action. The northerly concrete bulkhead of the West Pier was observed to have been affected by differential settlement causing a sink hole to form at the pier edge. Adaptive actions include the employment of an Architecture and Engineering firm to develop an engineered solution to the vulnerabilities exhibited at the pier.

In Sandy Creek, NY a large portion of a sand dune and adjacent beach was lost to high static water levels and wave action at Sandy Island Beach State Park (Figure 6-31). It was noted that littoral drift is rare in this area. At Sandy Pond Beach Campground, 12 residences were experiencing several inches of first floor flooding (Figure 6-32). As noted in the municipal and industrial section earlier (Section 3), all of these residences' septic systems were flooded, rendering all sanitary facilities inoperable. Adaptive actions included installing a line of sandbag defense around the perimeter of the campground. The sandbag line of protection lacked proper construction techniques and therefore proved inadequate in providing the expected protection.

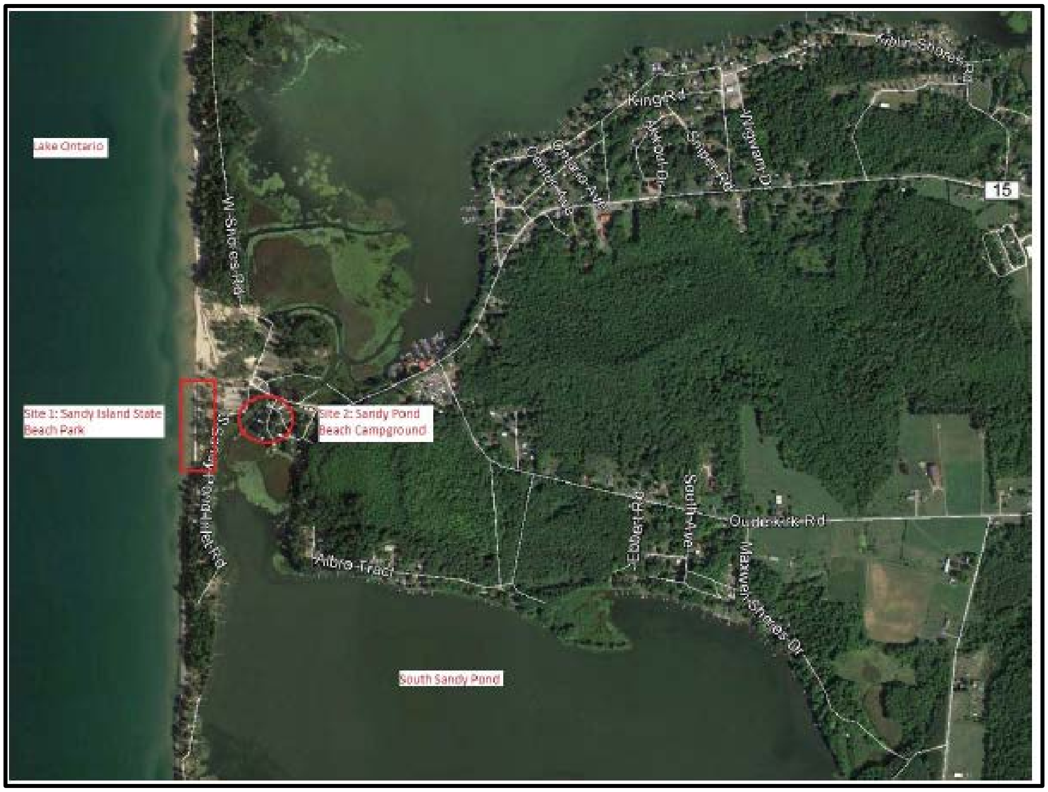


Figure 6-31: Sandy Creek overview of impacted areas (Source: USACE Buffalo, 2017)

Figure 6-32: Sandbag line of protection at Sandy Pond Campground on May 26, 2017 (Source: USACE Buffalo, 2017)

### *6.3.1.4 St. Lawrence River:*

There was no aerial imagery available for analysis on the US shore of the St. Lawrence River and only site visit data from Alexandria Bay on the St. Lawrence River was available. The regional impact assessment for the US side of the St. Lawrence River is limited to the impacts reported during the Alexandria Bay site visit and the Ogdensburg site visit.

In Ogdensburg, NY, erosion was observed at the Patterson street boat launch (Figure 6-33). Impacts at Morisette Park included erosion to parts of marina infrastructure and flooding of access paths for shoreline features. The US Customs and Border Protection facility helicopter pad and parking lot was inundated (Figure 6-34).

Figure 6-33: Shoreline erosion by boat launch in Ogdensburg, NY on May 15, 2017 (Source: USACE Buffalo, 2017)

Figure 6-34: Inundation of US Border Protection Helipad, Ogdensburg, NY on May 15, 2017 (Source: USACE Buffalo, 2017)

**Conservation Ontario/GLAM Shoreline Survey:**

There were 116 responses to the Conservation Ontario/GLAM shoreline survey in St. Lawrence County. Of those responses, 42 reported some degree of flooding impacts. The greatest response was for the dock/pier flooding or lawn flooding categories and was the only US region with more dock flooding than lawn flooding reported. However, there was also a high number of responses for the outbuilding and utilities categories (Figure 6-35). There were also 8 reports of first floor flooding. Note that respondents could select multiple types of flooding impacts if they were observed on their property.

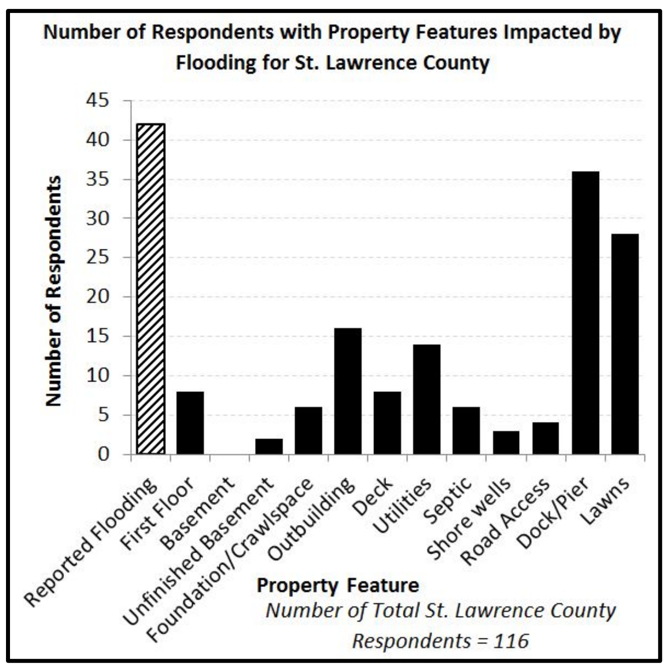


Figure 6-35: Summary of Conservation Ontario questionnaire responses for flooded property within Monroe, Wayne and Cayuga Counties (US). (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Erosion impacts were reported by 81 of the 116 survey responses for Monroe, Wayne and Cayuga Counties. The responses were provided by the impacted feature (e.g. main building, deck, beach, etc.) and respondents were asked to represent the degree of impact (small, moderate, or substantial). Like other US counties, the "other" category had a high number of responses and they were primarily related to impacts to shoreline protection (Figure 6-36). As well, there were impacts to docks/piers, stairs/ramps, vegetation, and beaches reported and for the stairs/ramps and beach categories, the substantial degree of impact was reported more frequently than the combined moderate/small degree of impact category. Main building and outbuilding impacts were also reported with a higher number being categorized in the moderate/small impact category compared to the substantial category. As with the flooding responses, respondents could select multiple types of erosion impacts if they were observed on their property.

Survey respondents had the option to submit photos showing examples of the high water impacts they experienced (if they chose to) and a few of those photos from across the Lake Ontario – St. Lawrence River shoreline are included at the end of the coastal section for reference.

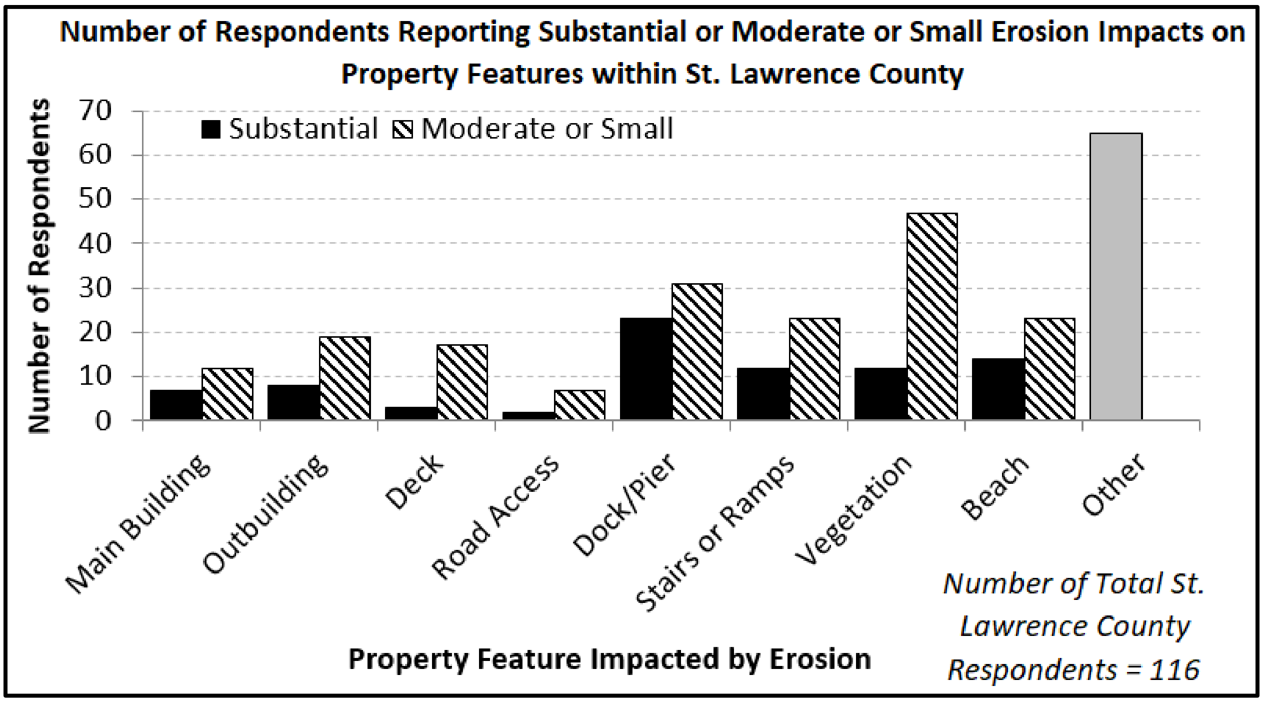


Figure 6-36: Summary of Conservation Ontario questionnaire responses for flooded property within Monroe, Wayne and Cayuga Counties (US). (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

**Review of Protection Permit Information:**

Many riparian and business property owners along the south shore of Lake Ontario and St. Lawrence River in the State of New York received a significant amount of damage from flooding, erosion and failing shoreline protection structures. Property owners filed a number of permits to repair or replace shore protection structures. Construction permits have been collected through NYDEC for counties along the south shore of Lake Ontario in New York through the month of October, 2017. A total of 594 permits had been requested for repair of shoreline damage and the greatest number of permits were concentrated in the counties of Oswego, Orleans and Wayne with Monroe ranking a close fourth in the number of permits that were issued. The counties of Jefferson and St. Lawrence did not issue any permits. Table 6-9 presents the results from evaluating the permit data ranked from highest to lowest in terms of the number of permits issued within each county, type of restoration and the month of the year when restoration occurred.

Table 6-9: Permits in shore protection database for New York shoreline and distribution by County. (Source: New York Department of Environmental Conservation, October 2017)

| New York County | Count | Percent |
|---|---|---|
| Cayuga | 24 | 4 |
| Monroe | 62 | 10 |
| Niagara | 37 | 6 |
| Orleans | 128 | 22 |
| Oswego | 264 | 44 |
| Wayne | 79 | 13 |
| **Total** | **594** | **100** |

The analysis of the data shows the counties with the higher concentration of permits are fairly consistent with shore protection expectations developed through the LOSLRS effort. It should be noted that this analysis is based on the partial number of permits for the year within a time frame when Lake Ontario continued to experience higher than normal water levels. As the water levels recede and as riparian owners are able to assess their damage more thoroughly, it is believed that permit applications will continue well into 2018. Approximately 63 percent of the permit requests were for shoreline stabilization which is the prevailing type of restoration (Table 6-10). It is believed this term used in the approval process is a generic description that could apply to multiple types of restoration. Shoreline stabilization is interpreted in this analysis as restoring embankment in context with other types of restoration. Other common types of restoration that were reported include rip-rap revetment repair (18%), seawall repair (9%) and breakwall repair (7%). The majority of permits were issued between May and September of 2017 (Figure 6-37). This time frame appears to be consistent with the beginning of rising water levels on Lake Ontario.

Table 6-10: Permits in shore protection database for New York shoreline based on restoration description (Source: New York Department of Environmental Conservation, October 2017)

| Restoration Description | Count | Percent |
|---|---|---|
| Boat Ramp Repair | 2 | 0 |
| Breakwall Repair | 40 | 7 |
| Building Repair | 2 | 0 |
| Deck Repair | 4 | 1 |
| Dock Repair | 7 | 1 |
| Erosion Protection Structure | 8 | 1 |
| Rip-Rap Revetment Repair | 107 | 18 |
| Seawall Repair | 51 | 9 |
| Shoreline Stabilization | 373 | 63 |
| **Total** | **594** | **100** |

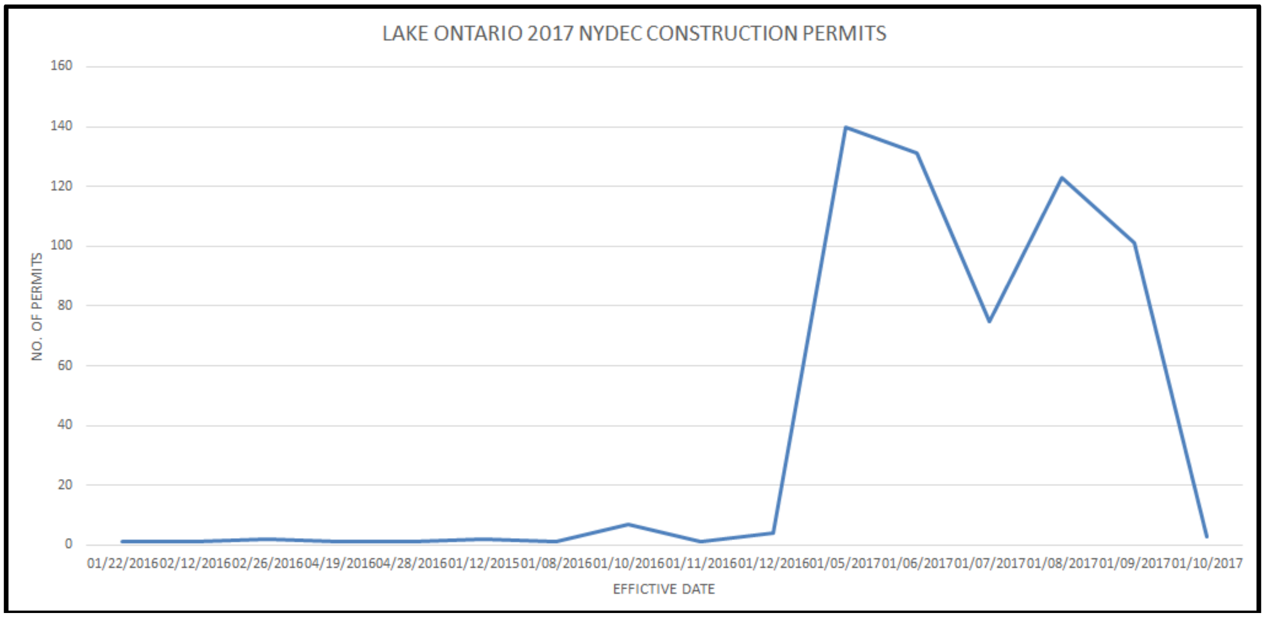


Figure 6-37: Timeline of NYDEC construction permit requests received. (Source: NYDEC, October 2017)

### 6.3.2 Lake Ontario and upper St. Lawrence River – Province of Ontario

#### *6.3.2.1 Regional Municipality of Niagara to Region of Peel*

For the Lake Ontario shoreline in the Province of Ontario, a review of available data suggests impacts varied depending on location. In the western end of Lake Ontario from the Regional Municipality of Niagara through to the City of Mississauga in the Region of Peel (Figure 6-8), there are currently few examples of first floor flooding to residential buildings which was the primary flooding PI during the LOSLRS. For example, an initial assessment of oblique photographs from June 8, 2017 for the Niagara shoreline identified three examples of suspected building flooding due to direct inundation under static water levels on the day the aerial photos were taken (i.e. without storm surge, which was limited on that day, or significant wave effects). First floor inundation flooding was isolated and appeared to be related to non-residential buildings that were located close to the shoreline (e.g. marina buildings) (Figure 6-38). For example, flooding adjacent to buildings at the Dalhousie Yacht Club in Port Dalhousie is visible on the June 8 imagery (Figure 6-38) as well as the inset photograph taken April 30, 2018 during a storm event when hourly water levels at the nearby Port Weller gauge peaked at 75.68 m (248.29 ft) IGLD85.

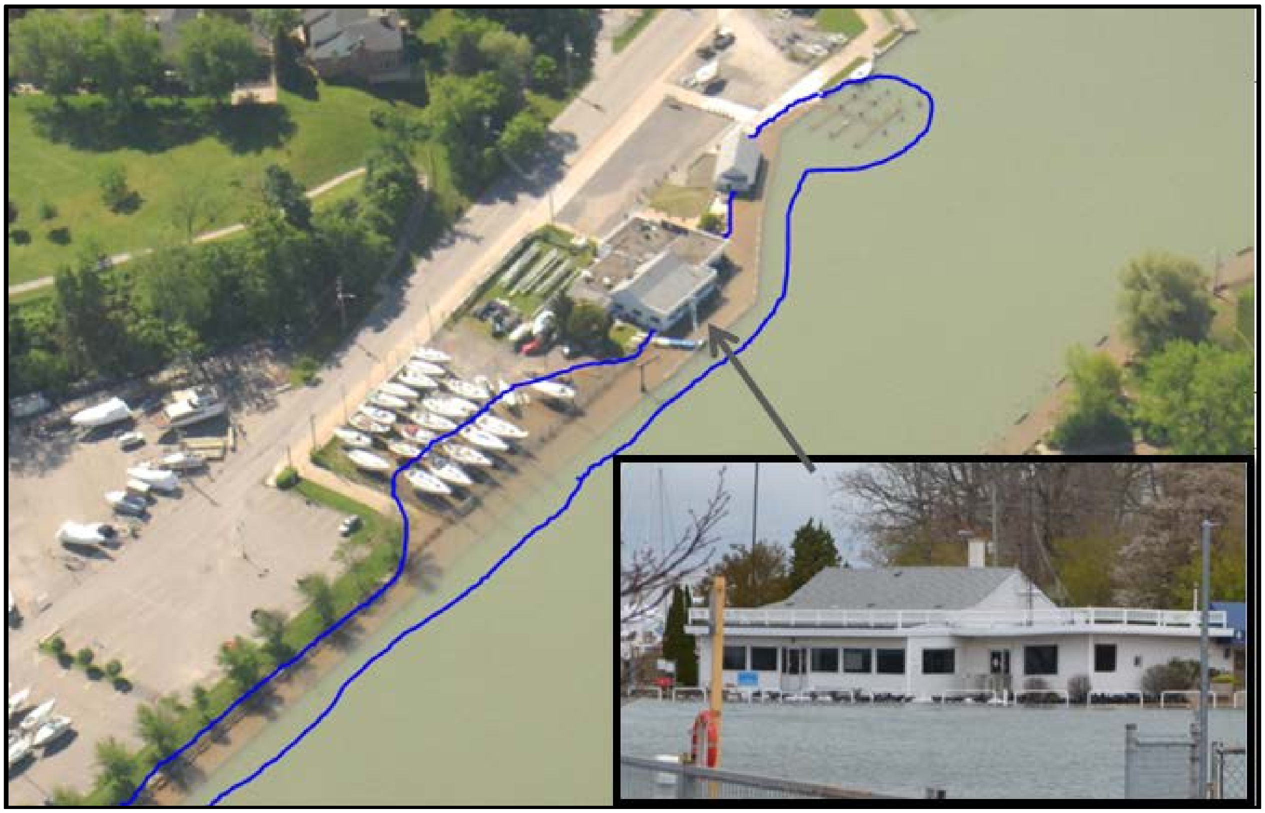

Figure 6-38: Illustration of the flooding/inundation of a building at the Dalhousie Yacht Club on June 8, 2017. The blue line roughly outlines the extent of inundation. Oblique Imagery Credit: Transport Canada National Aerial Surveillance Program, June 8, 2017. The inset photograph was taken April 30, 2018 during a storm event when hourly water levels at the nearby Port Weller gauge peaked at 75.68 m (248.29 ft) IGLD85. Inset photo credit: ECCC.

Of the 16 responses to the online self-reporting questionnaire in this area, none reported direct first-floor flooding, although there was one report of flooding of a foundation or crawl space. The oblique imagery review identified few locations with obvious first-floor flooding in the Hamilton to Mississauga area, which is consistent with informal discussions with staff from local municipalities and Conservation Authorities. However, a number of non-residential marina buildings required sandbagging in the Hamilton Harbour area and both the City of Oakville and the City of Mississauga have identified flooding of marina buildings and other harbour related buildings (e.g. Snug Harbour Restaurant in the City of Mississauga) as an observed impact (City of Mississauga, 2017). For context, the LOSLRS database included 3,023 shoreline properties in this same geographic region with as many as 395 with an estimated elevation below 76.20 m (250.00 ft) IGLD85, and therefore more susceptible to high water levels and wind setup.

Based on reports to city and regional councils, and other site visit information, various flooding problems beyond first-floor residential flooding were observed from Niagara through to the Region of Peel. However, exact estimates of the number of impacted properties is not currently available. For example, on May 18, a press release by the Town of Niagara-on-the-Lake noted a low lying area experienced sewer backups and drainage problems that required town staff to block off certain sections of the drain system and pump excess water (https://notl.civicweb.net/document/7696/Media%20Release%20-%20Town%20Executes%20a%20De-watering%20Progra.pdf?handle=97EC5196311E4AAC80019A579C3B255E). Similar problems were observed in the Hamilton Beach strip area where a combination of high lake levels, high groundwater levels and significant precipitation events led to considerable crawlspace and basement flooding. The City had to spend an estimated $130,000 to pump streets and catch basins (City of Hamilton, 2017). The Town of Lincoln noted "localized basement flooding in Jordan Station and Campden" (Town of Lincoln, 2017). However, further verification is needed as to whether that was due to high lake levels or significant precipitation events. Review of the oblique imagery indicated a number of examples where property or secondary building inundation was evident, although the Niagara to Peel shoreline appeared to have fewer examples when compared to other Canadian and US sections of the Lake Ontario shoreline (Figure 6-8).

Wind and storm events also caused problems from Niagara through to the Region of Peel due to wave action. Wave spray and wave uprush drove water up and onto shoreline properties leading to significant ponding of water around buildings. This occurred in portions of the Stoney Creek shoreline in the City of Hamilton (Figure 6-39). Storm events also caused other challenges. For example, a June 19, 2017 article in NiagaraThisWeek.com noted that voluntary evacuation notices were periodically required for some locations in the Town of Lincoln where wave action was contributing to short term access issues along shoreline roads (https://www.niagarathisweek.com/news-story/7379312-lincoln-still-recovering-from-spring-storms/). Flooding of public park lands and other public infrastructure was observed in many locations along the shoreline. Access to Lakeside Park in Port Dalhousie was restricted for much of the summer and there were flooding problems along portions of Confederation Park in the City of Hamilton. In Oakville, particular problems were reported at Coronation Park causing damages and restricting access as well as Carrington Promenade, Gairlock Gardens, Dingle Park, and Shoreline Park (City of Oakville, 2017) while in Mississauga, St. Lawrence Park, Marina Park, J.J. Plaus Park, and J.C. Saddington Park were among the most heavily impacted (City of Mississauga, 2017). In Burlington, the shoreline section of Burlington Beachway Park was closed from May 17, 2017 due to a combination of high water levels submerging the beach and erosion concerns.

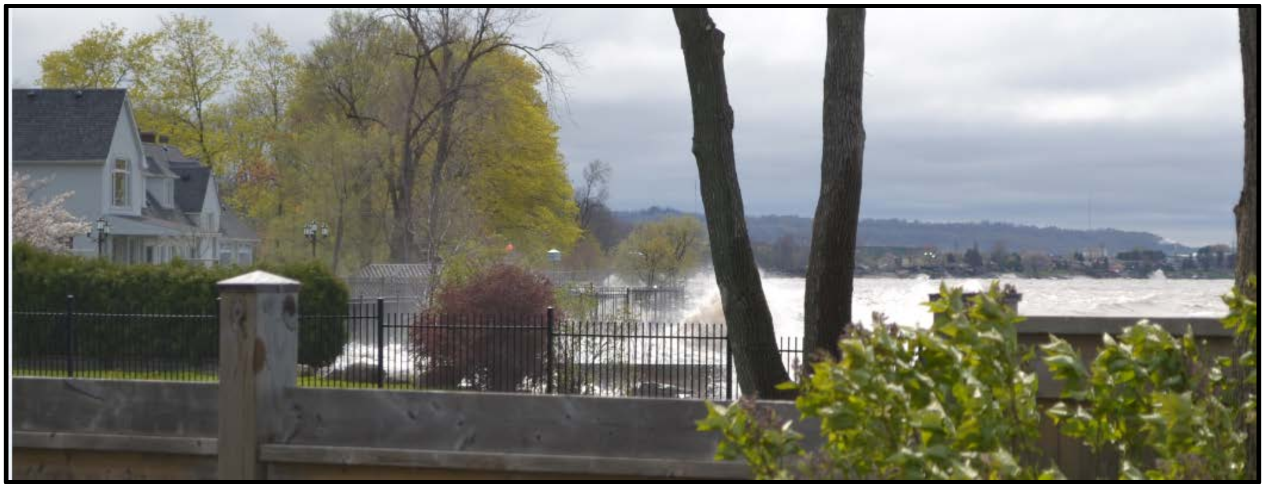
Figure 6-39: Wave action along the City of Hamilton shoreline, April 30, 2017. Photo credit: ECCC.

Erosion issues and associated shore protection maintenance costs were a more common problem along the Regional Municipality of Niagara to Region of Peel shoreline. A number of distinct erosion sites were identified from the oblique imagery review. Both the City of St. Catharines and Town of Lincoln identified erosion issues at select parks (e.g. Lakeside Park, Charles Daley Park) and public spaces, and it is unknown at this time the costs to provide long term protection (Figure 6-40). The Town of Grimsby noted that while erosion is an ongoing issue at both Nelles Lake Park and Lakeside Park, conditions were much worse in 2017 due to high water levels and the Town is awaiting a consultant report on long term efforts to protect the parks (Town of Grimsby, 2017). In the City of Hamilton, erosion and damage to existing shoreline protection was a concern along a number of shoreline parks (Figure 6-41). Current estimates of repairs to various park infrastructure (trails, lookouts, etc.) are in the $1,000,000 to $1,600,000 range and that does not include erosion mitigation efforts for Confederation Beach Park which is the longest stretch of shoreline (City of Hamilton, 2017). Cost estimates for the City of Oakville are not yet available for municipal expenses and potential repair costs and in Mississauga, it is estimated that $2,300,000 in funding "is required to commence procurement, damage repair, detailed design and restoration of damaged waterfront parks to reopen park areas and mitigate future shoreline damage" (City of Mississauga, 2017). Based on the 16 responses to the online self-reporting shoreline property owner questionnaire for the area, there were seven reports of erosion problems in the Niagara to Mississauga shoreline area and eight reports of shore protection problems.

Figure 6-40: Example of shoreline erosion at Charles Daley Park within the Region of Niagara (photo taken May 24th, 2017). Photo credit: ECCC.

Figure 6-41: Example of shoreline erosion at Confederation Beach Park, City of Hamilton, May 17, 2017. Photo credit: City of Hamilton.

### *6.3.2.2 City of Toronto and Durham Region*

Significant high water impacts were observed within the City of Toronto. The City has thoroughly documented the various municipal impacts in a recent staff report to Council and some of the highlights that relate to the coastal impact sector are described in this section while others that relate to tourism impacts are included in the recreational boating and tourism section. Of particular note was the significant flooding impacts observed on Toronto Island. The City of Toronto report notes that almost 800 island residents were impacted along with two schools although the exact nature of those impacts are not described in the report so further investigation is needed to determine how the description related to the metric of first floor residential flooding was used during the LOSLRS. A total of 39 responses to the online shoreline property owner questionnaire were completed within the City of Toronto and from those responses, 35 indicated some form of flooding impact. Respondents could report multiple types of flooding. There was one report of first floor residential flooding, five responses with basement flooding (finished and unfinished), and 22 reports of floodwaters reaching the foundation or crawl space. Figure 6-42 illustrates how many responses were identified in each category for the City of Toronto based on the questionnaire responses.

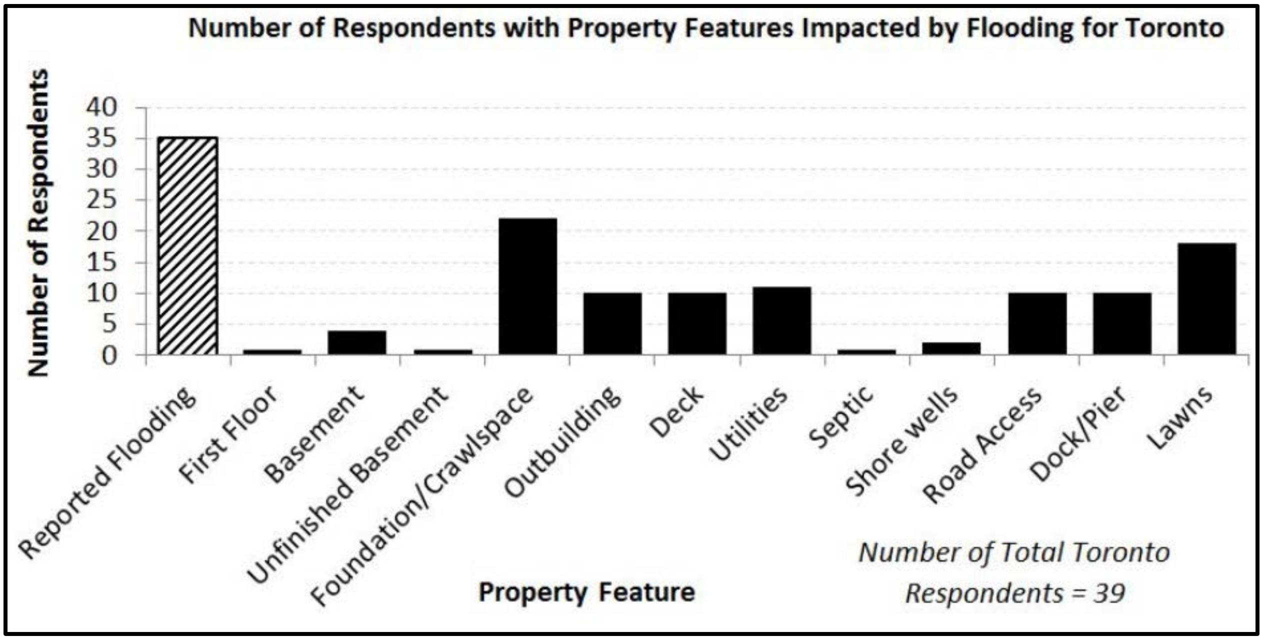


Figure 6-42: Summary of Conservation Ontario questionnaire responses for flooded property within the City of Toronto. (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Emergency response efforts related to high water levels were particularly significant with the City estimating $2.45 million in emergency response expenditures for 2017 (City of Toronto, 2018). This included sandbagging and pumping efforts that may have offset some potential impacts to residential buildings and other infrastructure and further investigation is likely required in that area as it relates to the existing PIs (Figure 6-43 and Figure 6-44). Outside of Toronto Island, direct inundation flooding of residential buildings from high water levels and wave uprush did not appear to be a significant problem for other stretches of the Lake Ontario shoreline within the City of Toronto, although other shoreline park facilities were impacted including Bluffer's Park and Port Union Waterfront Park (City of Toronto, 2018). Flooding of non-residential buildings was observed on Toronto Island and there were also reports of underground parking lot flooding in specific condominium buildings along the Toronto Harbour shoreline (https://www.theglobeandmail.com/news/toronto/lake-ontario-flooding-seeps-into-downtown-toronto-condo-buildings/article35270018/).


Figure 6-43: Sandbagging on Toronto Island, May 26, 2017. Photo credit: ©Toronto and Region Conservation (TRCA).

Figure 6-44: Sandbagging and pumping on Toronto Island, May 26, 2017. Photo credit: ©Toronto and Region Conservation (TRCA).

Erosion and shoreline protection damages were observed across the City of Toronto. Current estimates suggest shoreline remediation work due to the 2017 conditions may cost as much as $7.38 million (City of Toronto, 2018). Specific problems listed in the City of Toronto report include disintegrating seawalls, damaged trails, collapse of building foundations, reconstruction of several sections of boardwalk and trails damaged by flood waters (cause a slide risk), grading of the shoreline and restoration of several sections of waterfront.

Further east in Durham Region, the primary focus of residential flooding was the dynamic barrier beach area of Cedar Crest Beach Road and West Beach Road. Staff reports from the Central Lake Ontario Conservation Authority (CLOCA) on September 25, 2017 indicated that a number of residential buildings in the Municipality of Clarington experienced flooding problems due to a combination of high lake levels, storm events and significant precipitation which caused the rapid rise in water levels on the wetland side of the barrier beach (Municipality of Clarington, 2017). The CLOCA report noted that initial storm events in late April and early May occurred when Lake Ontario water levels were close to 75.5 m (247.7 ft) and led to water flowing over lots and flooding crawl spaces. Access and egress were a problem in the area due to inundation of parts of Cedar Crest Beach and West Beach roads on a number of occasions. As with the Toronto Island example, sandbagging efforts did appear to provide protection in some cases following the initial storm events in late April and early May. Figure 6-45 illustrates the difference in conditions at the site between a stormy day with onshore winds in late May (lakewide water level of 75.88 m (248.95 ft)) and a calmer day in early June with a higher lakewide water level of 75.81 m (248.72 ft) but little wind setup or wave action.

Figure 6-45: Cedar Crest Beach Road. The photo on the left was taken May 25, 2017. Photo credit: Clarington Fire and Emergency Services. The photo on the right was taken June 14, 2017. Photo credit: ECCC.

With regard to impacts to private property owners in Durham Region, approximately 24 responses to the online self-reporting questionnaire were received from residents in the region and based on those responses, 21 indicated some type of flooding problem. Figure 6-46 illustrates the number of impacts reported in each category (note that respondents could select multiple flooding impact categories). Of the 21 respondents, there were three reports of first floor flooding, six of basement flooding, and 13 where water reached the foundation or crawl space. Erosion and shore protection impacts were reported in a number of responses as well with 17 respondents indicating some form of erosion damage and 18 respondents indicating some form of damage to shoreline protection.

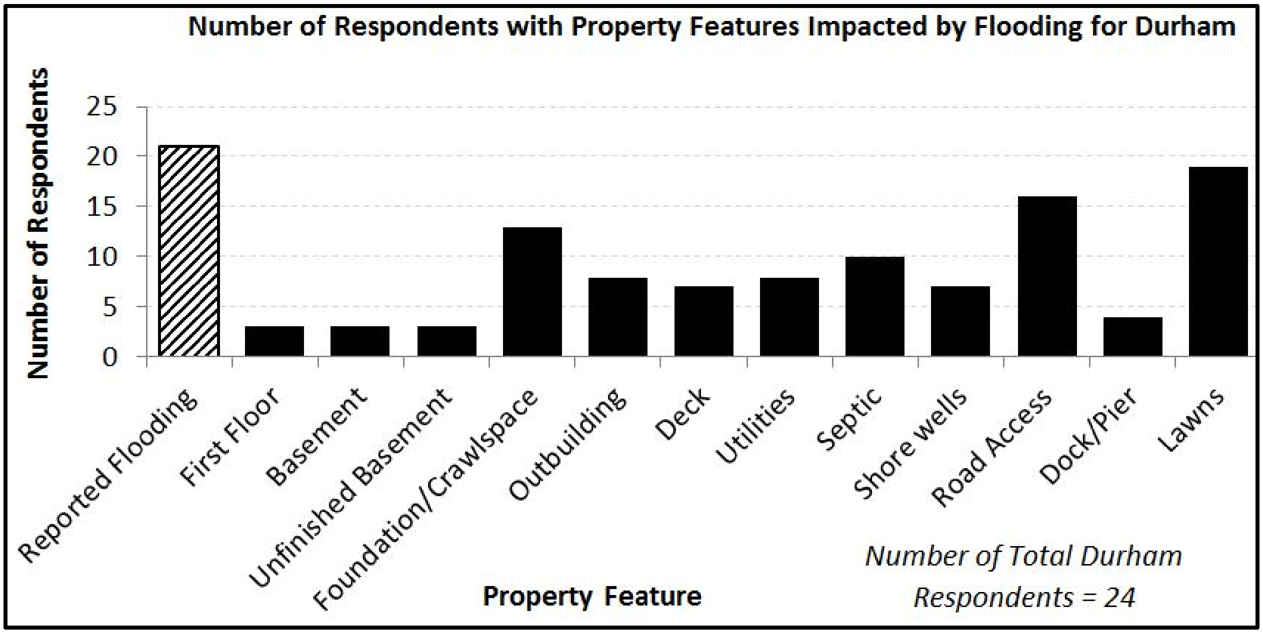

Figure 6-46: Summary of Conservation Ontario questionnaire responses for flooded property within the Durham Region. (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Residential flooding due to high water levels was not commonly reported in other portions of Durham Region but other impacts were observed, particularly due to erosion. For example, the City of Oshawa has estimated $320,000 (as of June 16, 2017 staff report) for repairs to damaged municipal shoreline infrastructure including shoreline breakwall repairs and re-armouring, replacing fencing within Lakeview Park and beach material replacement and re-grading. Expenditures related to repair and restoration of the pier are not currently available (City of Oshawa, 2017). Flooding and erosion issues along waterfront parks and trails were also reported in Whitby, Ajax and Pickering although specifics and cost estimates are not currently available. A review of the oblique imagery and other imagery indicated a variety of impacts for Durham Region, such as examples where shoreline erosion and changes occurred during 2017 (Figure 6-47 through Figure 6-50). Most of the erosion impacts reported in the shoreline questionnaire were related to vegetation loss and beach impacts (Figure 6-51).

Figure 6-47: Example of shoreline erosion and impacts to trail in Ajax Ontario, June 8, 2017. Photo credit: Transport Canada National Aerial Surveillance Program.

Figure 6-48: Example of collapsed shoreline protection in Ajax Ontario, June 8, 2017. Photo credit: Transport Canada National Aerial Surveillance Program.

Figure 6-49: Example of shoreline erosion in Oshawa, Ontario, June 8, 2017. Photo credit: Transport Canada National Aerial Surveillance Program.

Figure 6-50: Shoreline erosion behind failed shoreline protection in Municipality of Clarington, May 26, 2017. Photo credit: Municipality of Clarington Fire and Emergency Services.

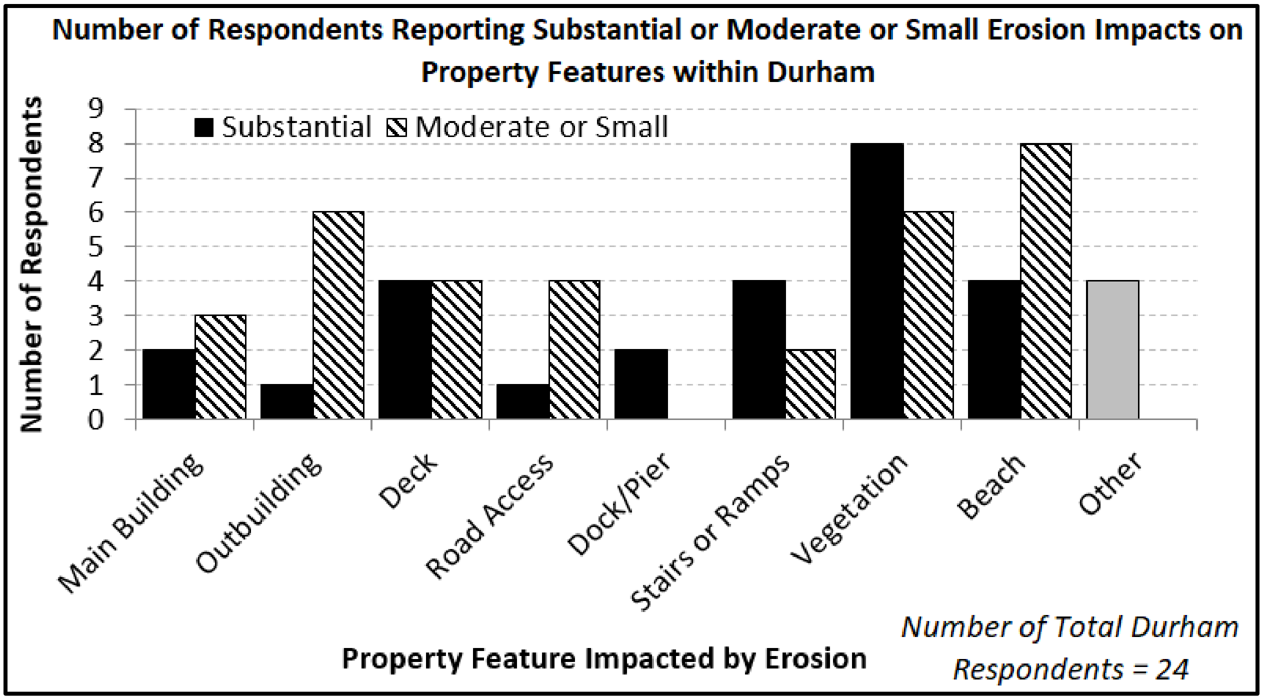

Figure 6-51: Summary of Conservation Ontario questionnaire responses for erosion impacts within the Durham Region. (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

#### *6.3.2.3 Northumberland County*

Further east in Northumberland County, which includes the communities of Port Hope, Cobourg, and Brighton, residential flooding was most commonly reported at the eastern end of the county including in the Brighton area (see map in Figure 6-8). Site visits by support staff for the GLAM Committee in early June illustrated examples of imminent and direct impacts to residences in the Brighton area (Figure 6-52). A review of available oblique imagery for much of the Northumberland shoreline identified 11 examples of flooding under static water level conditions. However, the imagery did not have good quality or coverage in the most highly impacted areas of Brighton and Presqu'ile Bay, and Google Earth images were used to supplement in that area as updated images are available for the time period of interest. There were 37 responses (33 residential, four business) for the online self-reporting shoreline property owner questionnaire for Northumberland County. Of those responses, 30 identified some sort of flooding impact with the most commonly reported impact being to lawn/landscaping. Figure 6-53 shows the number of responses for the various categories identified in the online questionnaire. Outside of residential flooding, the town of Cobourg noted that high water levels caused problems and closures at various local beaches and the cancellation of some events (e.g. beach volleyball). Sandbagging was required to limit road flooding in a number of areas of Brighton, particularly the Gossport neighbourhood.

Figure 6-52: Photographs of flooding impacts in the Brighton area, June 14, 2017. Photo credit: ECCC.

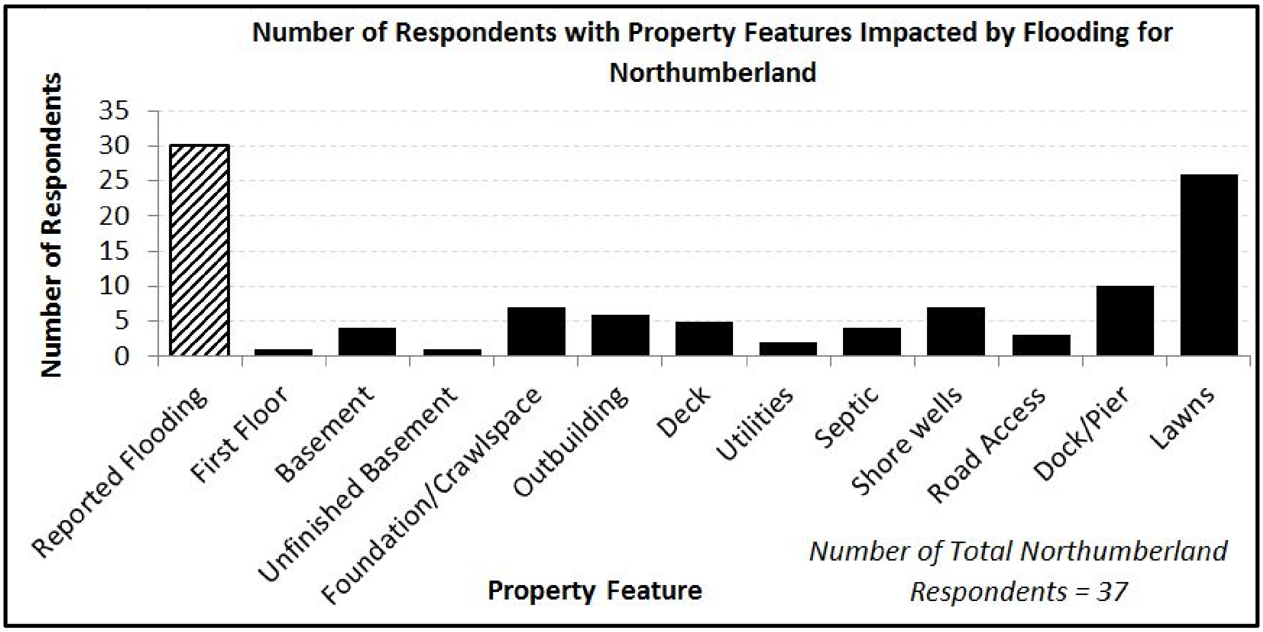


Figure 6-53: Summary of Conservation Ontario questionnaire responses for flooded property within the Northumberland County. (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Based on the oblique photographs, there were a number of areas that appeared to have enhanced erosion in Northumberland County. Figure 6-54 illustrates an example from the oblique imagery. Of the 37 responses for the online self-reporting shoreline property owner questionnaire, there were 23 that identified erosion issues along their shoreline. Figure 6-55 shows the types of impacts reported and the relative level of impact described. As in other areas, vegetation loss and damage to beaches was the most commonly reported erosion impact in the survey responses. There were also 29 reports of damage to shoreline protection and those damages were primarily related to gradual failures throughout the high water period (16) as opposed to a specific event (two).

Figure 6-54: Example of shoreline erosion in Northumberland County, Ontario, June 8, 2017. Photo credit: Transport Canada National Aerial Surveillance Program.

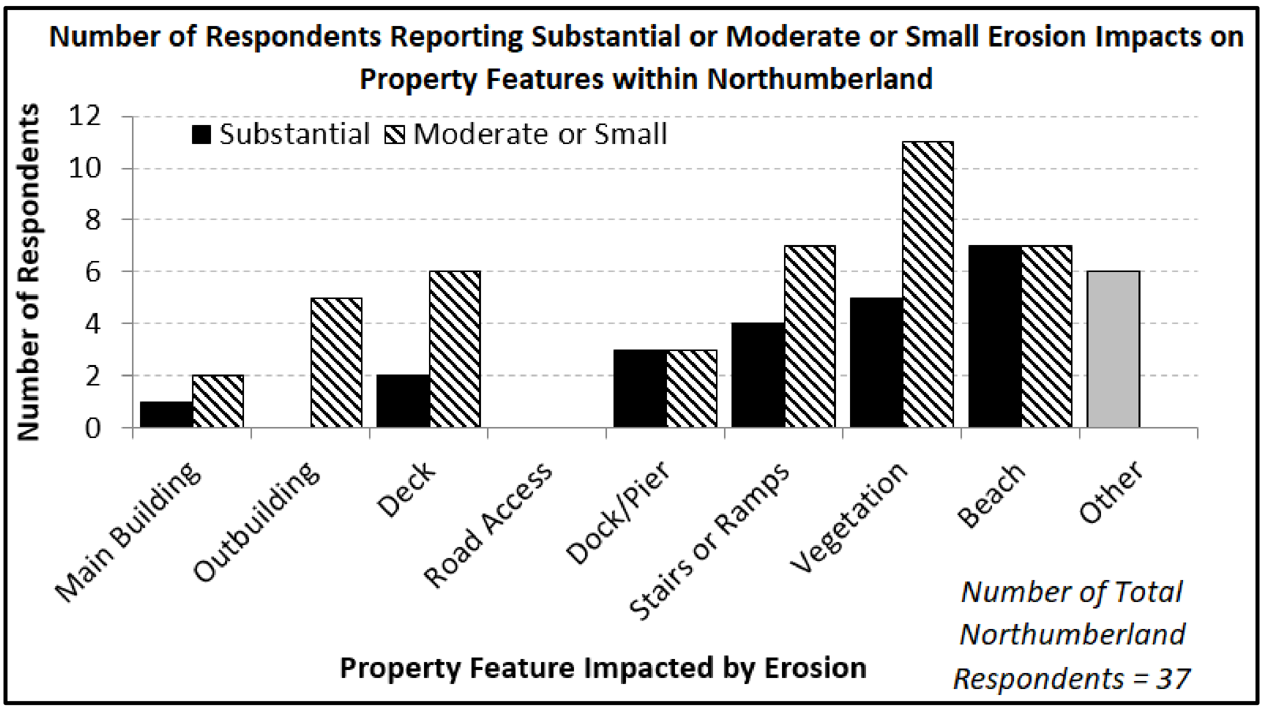


Figure 6-55: Summary of Conservation Ontario questionnaire responses for erosion impacts within the Northumberland County. (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

### *6.3.2.4 Prince Edward, Hastings, Lennox and Addington Counties, and Tyendinaga*

Prince Edward County and neighbouring Hastings, Lennox and Addington Counties along with Tyendinaga (Mohawks of the Bay of Quinte) cover a significant amount of shoreline and include both open coast and the Bay of Quinte (see map in Figure 6-8). Shoreline impacts were observed throughout the region. Prince Edward County declared a state of emergency on May 9, 2017 due to "localized flooding and the continued rising water levels of the Bay of Quinte and Lake Ontario" which lasted until June 22, 2017. In a June 7 press release (http://www.thecounty.ca/news--notices/mayor-quaiff-provides-flood-emergency-update.php), it was noted that 81,000 sandbags had been distributed throughout the county. Other press releases noted that a number of municipal roads had been impacted either directly due to inundation or a combination of inundation and wave action. Information on the Prince Edward County website (http://www.thecounty.ca/county-government/emergency-services/flood-watch/) identified particular areas of flood concern within the Bay of Quinte, and in the Consecon, Picton and Wellington areas. Efforts are still underway to determine the extent of first floor flooding in the area. Preliminary information presented at the September 2017 Ontario PFFWC workshop by Quinte Conservation, which is responsible for regulating the flood hazard zone for much of the area, indicated only a handful of residences with first floor flooding although the GLAM Committee does not yet have documentation on specific numbers (September 2017 PFFWC workshop presentation). Despite the few examples of first floor flooding, it is clear that there were many situations where the static water level or the addition of wave action and storm surge put residential buildings at risk. Oblique imagery flown on June 14, 2017 illustrated a number of these situations. For example, Figure 6-56 illustrates a particularly low-lying section of shoreline in the Rossmore area with significant sandbagging and static water levels approaching a number of buildings. Figure 6-57 uses Google Earth imagery to illustrate the difference in shoreline inundation in a protected embayment near the south west end of Hastings County between April 17 and June 2, 2017.

Figure 6-56: Example of shoreline flooding near Rossmore, Ontario. Photo credit: Transport Canada National Aerial Surveillance Program, May 14th, 2017.

Figure 6-57: Comparison of April 17 and June 2 imagery in the Southwest area of Hastings County. Photo credit: Google maps.

Based on an initial review of the oblique imagery within Prince Edward County, there were a number of buildings that appeared to be directly impacted or at imminent risk of impact due to high water on May 14, 2017 at a water level of 75.84 m (248.82 ft) (Figure 6-11 and Figure 6-12). Figure 6-58 illustrates an on-the-ground photo example in the Consecon area based on similar water level conditions (lakewide average of 75.80 m; 248.69 ft) and illustrates how closely the static water levels approached structures in a number of cases.

Figure 6-58: High water in the Consecon area of Prince Edward County, June 15, 2017. Photo credit: ECCC.

In Hastings, the waterfront area of Belleville experienced a number of high water problems. A photo gallery of some of the municipal impacts are available through the City website (http://belleville.ca/gallery/2017-flood). As with many other areas of the Canadian shoreline, direct first floor flooding did not appear to be the primary problem, although there were some examples where businesses along the waterfront were significantly impacted by floodwaters (Figure 6-59). Flooding of roads and parkland was observed in a portion of the waterfront near downtown (see Figure 6-59) and required a response from the City to facilitate access for local residents by elevating some flooded roadways using gravel. Meanwhile, Lennox and Addington County reported various shoreline impacts totalling up to $800,000 and were going to apply under the Municipal Disaster Recovery Assistance Program (Loyalist Township, 2017). Primary municipal impacts included damage to roadways and damage to existing retaining walls protecting the Fairfield water treatment plant. Cataraqui Region Conservation Authority staff noted flooding problems related to homes in both Hay Bay and Bath although a specific number of impacted properties is not currently available. Oblique photographs in those areas indicated at least a few locations that appeared particularly at risk, recognizing that it can be difficult to make a qualitative assessment of flood vulnerability from the images in some areas.

Figure 6-59: High water in the Belleville area of Hastings County, June 15, 2017 (left) and May 14, 2017 (right). Photo credit: ECCC, and Transport Canada National Aerial Surveillance Program, respectively.

There were 119 responses provided for the self-reporting shoreline property owner questionnaire in the combined areas of Prince Edward, Hastings, Lennox and Addington counties and Tyendinaga; the most commonly reported impact was flooding (109). Other reported impacts included erosion (81 responses) and damage to shoreline protection (65 responses). A further review of the results is required to understand the differences in reported erosion and shore protection impacts between areas of shoreline with high wave energy and more protected areas within the Bay of Quinte. The LOSLRS coastal impact evaluation models did not include erosion or shore protection impacts within the Bay of Quinte as the digital parcel data was not available at the time of the study and there was little evidence of significant erosion or shore protection issues in these areas (Baird and Associates, 2013).

Figure 6-60 illustrates the various types of flooding impacts reported by the combined self-reporting questionnaire responses for the area. Of the 109 responses identifying flooding damage, there were three reports of first floor flooding of a home or business, four reports of flooding of a finished basement, and five reports of flooding of an unfinished basement. By far, the largest reported impact category was lawn/landscaping flooding (91).

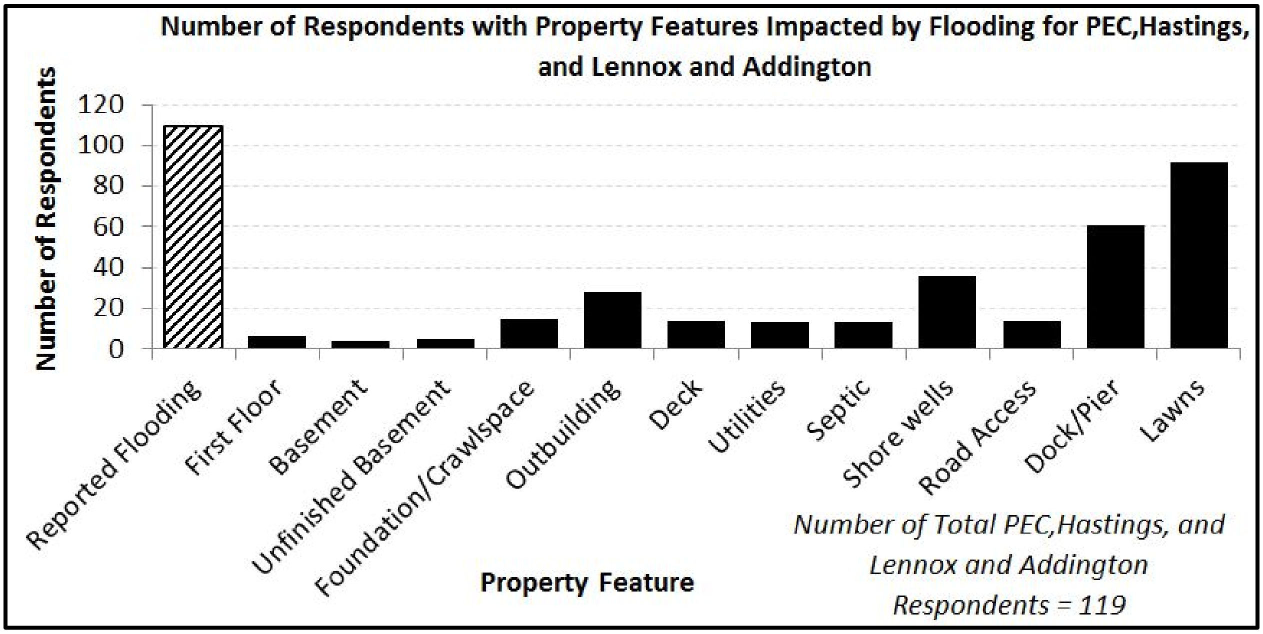

Figure 6-60: Summary of Conservation Ontario questionnaire responses for flooded property within the Hastings, Lennox and Addington, Tyendinaga, and Prince Edward counties. (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Based on the self-reporting questionnaire responses, erosion impacts to shoreline vegetation and beaches were most commonly identified. Figure 6-61 shows the number of reported impacts (respondents could select multiple impacts) as well as the relative degree of damage. There were 57 responses of moderate or substantial impacts to shoreline vegetation, primarily in the responses from Prince Edward County, and Lennox and Addington County and 41 responses for beach impacts. Direct impacts to shoreline buildings were less commonly reported in the self-reporting questionnaire with seven reports of moderate or substantial impacts to the main structure or home, 11 reports of moderate or substantial impacts to an outbuilding (e.g. boat house, shed, garage, etc.) and 11 reports of moderate or substantial impacts to decks.

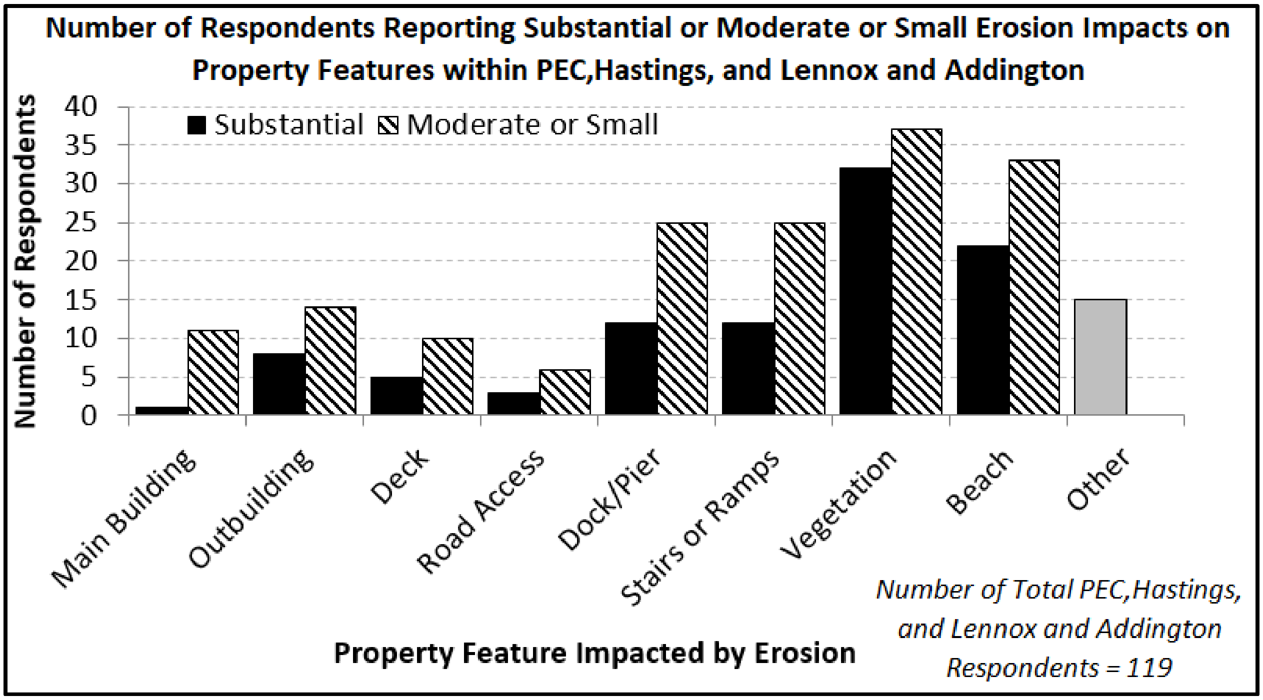


Figure 6-61: Summary of Conservation Ontario questionnaire responses for erosion impacts within the Hastings, Lennox and Addington, Tyendinaga and Prince Edward counties. (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Self-reporting questionnaire results for shore protection impacts were predominantly for Prince Edward County and Lennox and Addington County (30 for each) with only four from Hastings and one from Tyendinaga. Almost all (42) felt the damage to their structures was gradual over the high water period and not particularly associated with a significant storm event.

#### *6.3.2.5 Canadian Shoreline - Upper St. Lawrence River*

Canadian shoreline upper tier municipalities adjacent to the upper St. Lawrence River include Frontenac Islands, Leeds and Grenville, and Stormont, Dundas and Glengarry. The cities of Kingston, Brockville and Cornwall are major urban centres within this broader geographic area (see map in Figure 6-8). High water impacts were observed throughout the shoreline in 2017, primarily in the Thousand Islands area and on low lying shoreline areas upstream of Lake St. Lawrence. Site visits, along with information from the local conservation authorities identified locations where flooding of shoreline buildings was imminent or occurring in the Kingston and Thousand Islands area down to Brockville. A specific number of impacted properties is not available at this time but preliminary information from staff with the Cataraqui Region Conservation Authority suggests flooding damages to buildings and homes within their shoreline management area was concentrated within particular areas while shoreland flooding was more widespread. Sandbagging was observed in a number of locations and a number of areas were considered vulnerable to wave and storm events.

There were also examples of road and other infrastructure flooding throughout the region. The Township of Frontenac Islands applied to the Province of Ontario under the Municipal Disaster Recovery Assistance program and a December 20, 2017 announcement indicated they were eligible for up to $560,593 in provincial funding under the program to go towards infrastructure repairs to bridges, roads and public buildings. Like other Canadian municipalities, flooding and damage to public parks and lands was observed in a number of locations through Kingston, the Thousand Islands Area, Gananoque and downstream through Brockville. Figure 6-62 through Figure 6-63 illustrate a few examples of flooding in those areas based on site visits. Parks Canada also reported significant impacts to park infrastructure within the Thousand Islands National Park. The park superintendent noted that as of late December 2017, direct costs related to park infrastructure were estimated in the $1 to $1.5 million range, primarily for damages to older crib docks, impacts to heritage structures such as the Point Edward Lighthouse and closure or damage to various campsites, shoreline trails, boardwalks, etc.

Figure 6-62: High water in the Thousand Islands area of St. Lawrence River, May 7, 2017. (Source: International Joint Commission)


Figure 6-63: High water in the Brockville area of the St. Lawrence River, May 7, 2017. (Source: International Joint Commission)

The GLAM Committee currently has limited impact information for the area downstream of Brockville within Leeds and Grenville County, and further towards Lake St. Lawrence and Cornwall within Stormont, Dundas and Glengarry United Counties. South Nation Conservation Authority noted that residential flooding did occur during late April and early May in the area but the GLAM Committee does not yet have detailed information on the extent of that flooding and any critical thresholds that may have been identified.

There is a particularly strong linkage between shoreline property owners and recreational boating along the Canadian shoreline between Kingston and Cornwall. In many cases, and particularly in the Thousand Islands, shoreline property owners have docks and boathouses along the shoreline that were impacted by high water through prolonged inundation and wave action. Direct damages to docks or accessory shoreline buildings such as boathouses were not included in either the coastal or recreational boating PIs from the LOSLRS. In addition, many island properties in the area are only accessible by boat access meaning that impacted docking facilities on the mainland or at their islands can significantly impact use of the property. There is anecdotal information to suggest that docks, boathouses and access to property was significantly impacted in the Thousand Island area in 2017. Photos from site visits in May and June 2017 illustrate a few of the more extreme examples (see Figure 6-62 and Figure 6-63). At this point, it is not possible to quantify the full extent of these problems.

There were 64 responses provided for the self-reporting shoreline property owner questionnaire in the combined areas of Frontenac County, Leeds and Grenville United Counties and Stormont, Dundas and Glengarry United Counties and of those, the most commonly reported impact was flooding (56). Erosion was also a reported impact (42 responses) as was damage to shoreline protection (37 responses). A further review of the results is required to understand the impacts of erosion and shore protection impacts on the upper St. Lawrence River shoreline. The

LOSLRS coastal impact evaluation models did not include erosion estimates on the upper St. Lawrence River counties because digital parcel data were not available at the time of the study and differences in regulation plans were expected to be minimal. Shore protection impacts are only estimated for Frontenac County for this stretch of shoreline in the existing models.

Figure 6-64 illustrates the various types of flooding impacts reported by the combined self-reporting questionnaire responses for the area. Of the 56 responses identifying flooding damage, there were two reports of first floor flooding of a home or business, three reports of flooding of a finished basement and six reports of flooding of an unfinished basement. The largest reported impact category was docks (38) followed by lawn/landscaping flooding (35).

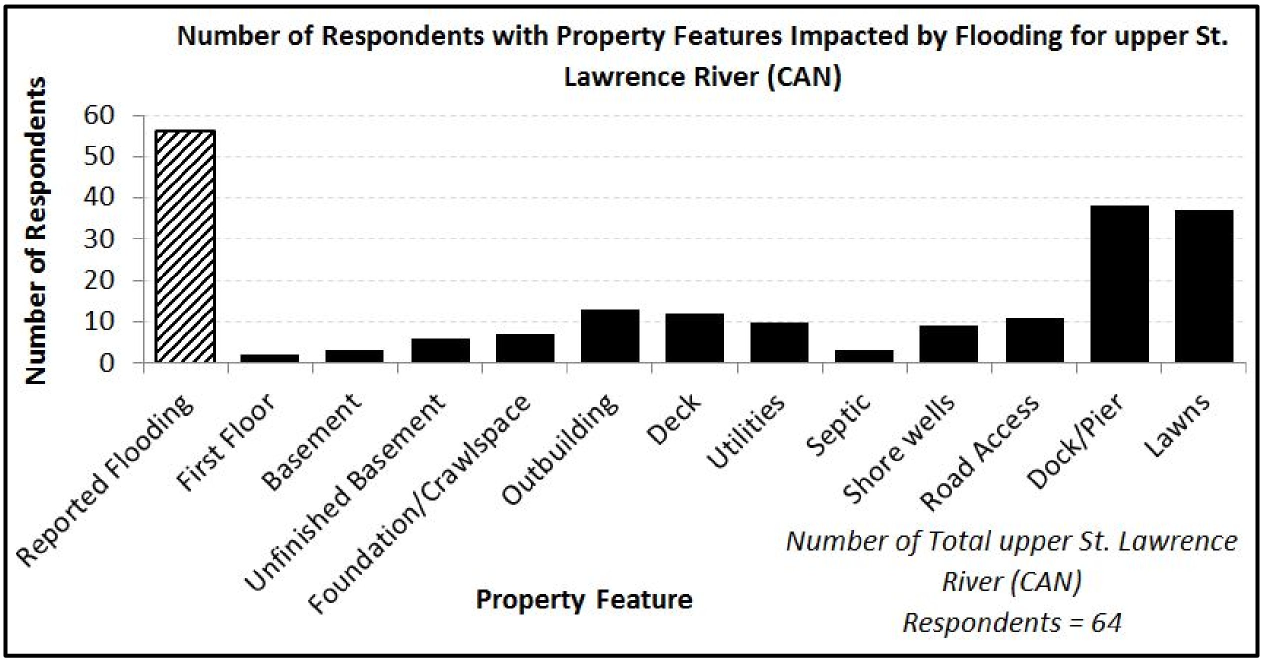


Figure 6-64: Summary of Conservation Ontario questionnaire responses for flooded property within the upper St. Lawrence River Counties (Frontenac County, Leeds and Grenville United Counties and Stormont, Dundas and Glengarry United Counties) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Based on the self-reporting questionnaire responses, erosion impacts to shoreline vegetation, docks/piers, and beaches were most commonly identified. Figure 6-65 shows the number of reported impacts (respondents could select multiple impacts) as well as the relative degree of damage. There were 22 responses of moderate or substantial impacts to shoreline vegetation, 14 to docks/piers, and nine responses for beach impacts. Direct impacts to shoreline buildings were less commonly reported in the self-reporting questionnaire responses with two reports of moderate or substantial impacts to the main structure or home and four reports of moderate or substantial impacts to an outbuilding (e.g. boat house, shed, garage, etc.).

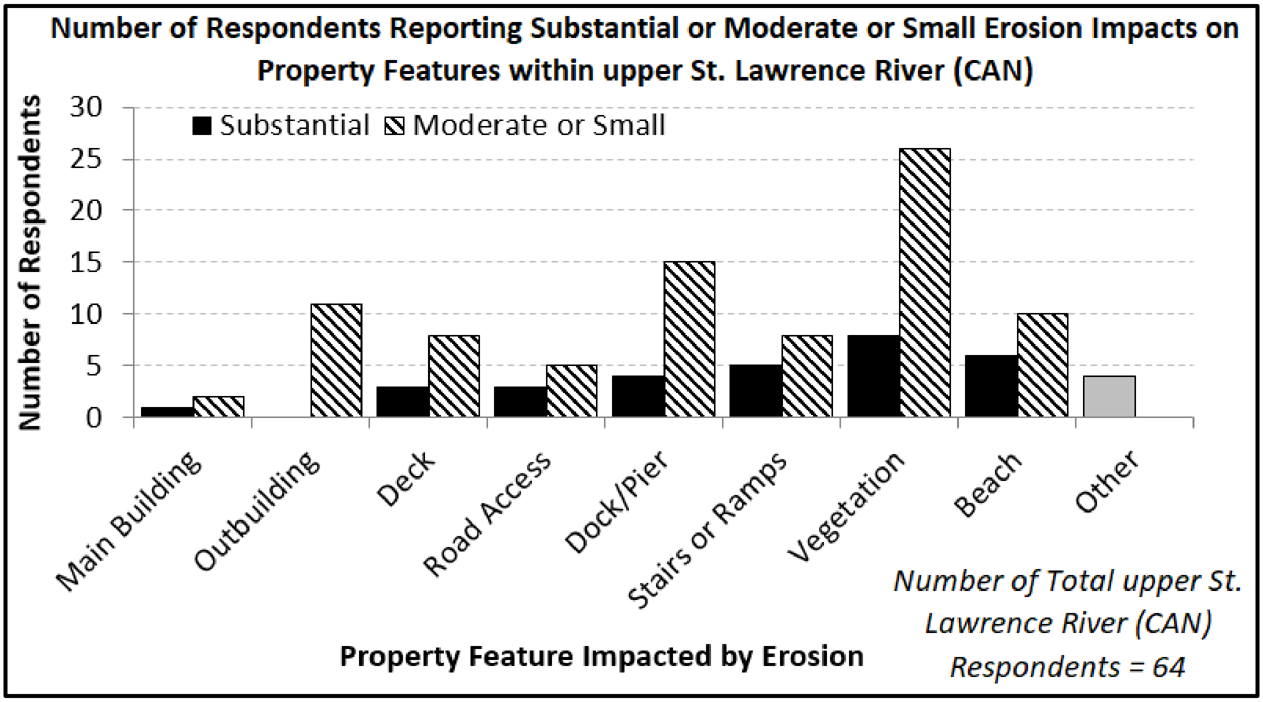


Figure 6-65: Summary of Conservation Ontario questionnaire responses for erosion impacts within the upper St. Lawrence River Counties (Frontenac County, Leeds and Grenville United Counties and Stormont, Dundas and Glengarry United Counties). (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

### 6.3.3 Lower St. Lawrence River

Spring 2017 high water resulted in significant flooding impacts throughout the province of Quebec. A March 2018 article in the Montreal Gazette indicated as many as 5,300 properties across the province were impacted and over $135 million has been paid so far through the disaster reimbursement program (https://montrealgazette.com/news/local-news/quebec-unveils-24-point-plan-to-improve-disaster-relief-preparedness). In the context of St. Lawrence River outflow management and the GLAM Committee 2017 report, the primary areas of consideration for impact assessment are the Lower St. Lawrence River from Cornwall through Trois-Rivières. The GLAM Committee has been looking at available data and trying to separate St. Lawrence River flooding from flooding in other parts of the province.

In order to assess impacts associated with management of St. Lawrence River flows in Cornwall, Ontario and Massena, New York, it is important to understand how outflows impact levels on the lower St. Lawrence River, including around Montreal Island at the outlet of the Ottawa River (Figure 6-66). In general, outflows from the Moses Saunders Dam are released downstream into a widening in the St. Lawrence River known as Lake St. Francis. The outflow of Lake St. Francis is released shortly thereafter through the H-Q facilities at Beauharnois and Les Cedres. There is little storage on the relatively small Lake St. Francis (i.e., the flow of water from Moses-Saunders Dam as well as from local tributaries continues mostly uninterrupted through the H-Q facilities and water is not held back on the lake for any significant duration of time). As long as H-Q outflows match outflows from the Moses-Saunders Dam, which is typically the case, water levels on Lake St. Francis do not typically fluctuate very much, and in 2017, there were no reports of coastal impacts in this location. As noted in Section 4, significant spill and high velocities in the natural bed of the river to the north of the Beauharnois Canal occurred in 2017 owing to the high outflows from Lake Ontario, but there were no reports of major impacts on residents as a result of H-Q operations in this area.

All water released from Lake St. Francis enters into Lake Saint-Louis and continues through the St. Lawrence River south around the Island of Montreal, and down through Lake Saint-Pierre and past Trois-Rivières. The Ottawa River, a major tributary to the St. Lawrence River, partially discharges into Lake Saint-Louis: it first flows into Lake of Two Mountains on the northwest side of Montreal Island, before discharging into the St. Lawrence River through four separate channels: the Vaudreuil and Ste-Anne-de-Bellevue channels enter Lake Saint Louis to the south, while the Des Prairies and Milles-Isles rivers make their way around the Island of Montreal to the north and then join the St. Lawrence River further downstream. During normal flow conditions, about 60% of Ottawa River outflows travel through the two northern channels, with the remainder flowing from Lake of Two Mountains into the St. Lawrence River at Lake Saint-Louis. Depending on the relative flow and water level conditions of the St. Lawrence River at Lake Saint-Louis and the Ottawa River at Lake of Two Mountains, there can be situations where levels of Lake Saint-Louis can have some backwater influence on levels in Lake of Two Mountains. This typically occurs when the Ottawa River is experiencing low to average flow conditions while flows in the St. Lawrence River (and Lake Saint-Louis) are relatively high. Under these circumstances, water levels of the two lakes can become close and even equal on some exceptional occasions. However, this was not experienced during the peak flood conditions in early May of 2017 when Lake of Two Mountains levels were 1 to 2 m (3.28 to 6.56 ft) higher than Lake Saint-Louis, and supercritical flows through the connecting channels was observed. From an impact reporting standpoint, the main branch of the St. Lawrence River (south of Montreal) is the critically important area for the GLAM Committee, as this area is directly influenced by outflows from Lake Ontario as well as the Ottawa River, although impacts on the northern side of Montreal Island, which is primarily influenced by Ottawa River flows alone, are included for context.

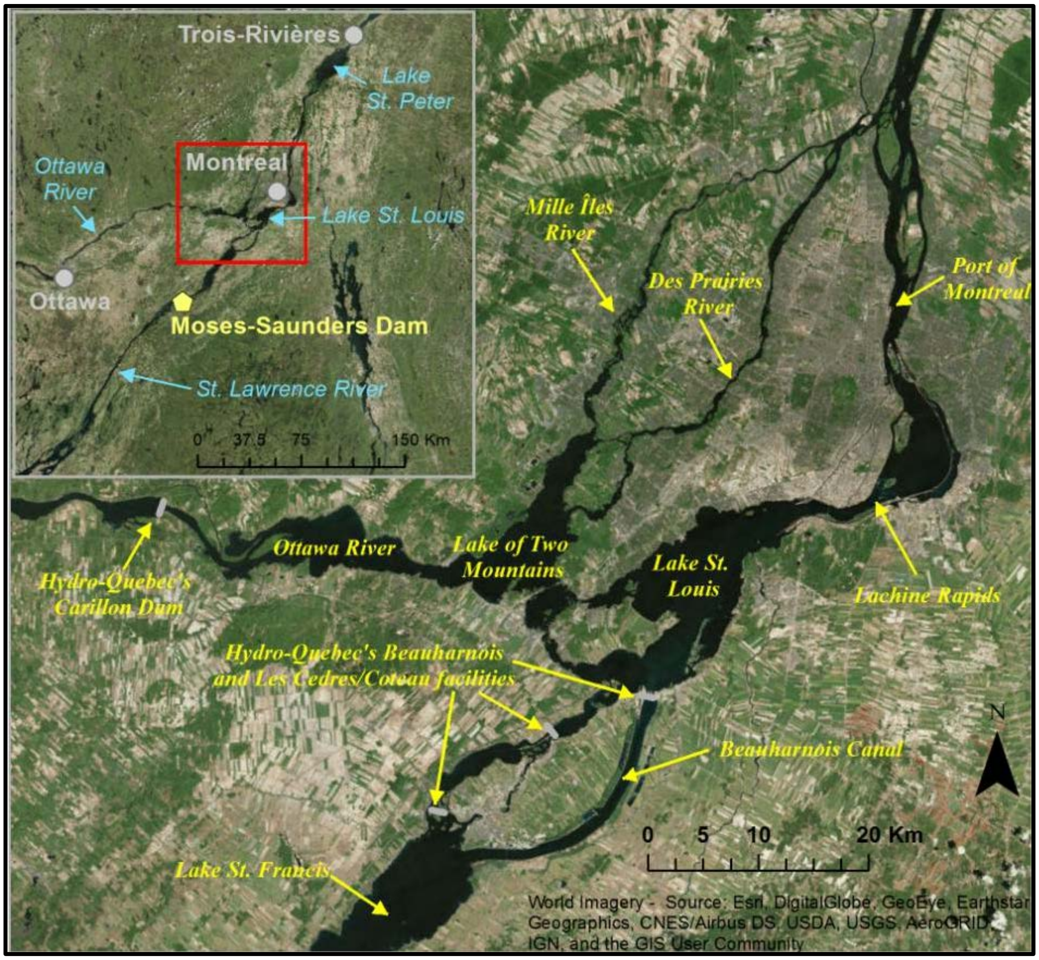


Figure 6-66: Map outlining flow pathways for the St. Lawrence and Ottawa River in the Montreal area.

At the moment, the GLAM Committee is relying on public reporting by the 'Centre des Operations Gouvernementales' from the Provincial Government of Quebec. During the peak flood conditions, daily impact reports were provided for each affected Regional County Municipality (RCM) in Quebec and consolidated in the reporting. The report highlighted the number of:

- Impacted properties each day
- Isolated properties each day
- Threatened residences each day
- Evacuated residences each day
- Impacted roads each day

The daily number of each of these impacts is a cumulative total. Therefore, the day in May with the highest number of impacts is used to determine the maximum number of impacts for each category listed above and for each RCM. **There are limitations to the information provided in the daily reports. For example, there are some municipalities with no reported impacts and it is not clear whether there was simply no reporting or whether there were actually no**

**impacts.** The GLAM Committee has also reviewed oblique photographs in the region to independently identify particularly hard-hit areas.

Two PIs used during the LOSLRS for the lower St. Lawrence River include number of buildings (homes) flooded and km of road impacted for each RCM. Although it is uncertain if the properties impacted or isolated were flooded, those two pieces of information, and the number of roads impacted, will be discussed further.

**Lower St. Lawrence River – Montreal Region:**

The Montreal Region is a series of densely populated islands at the confluence of the Ottawa and St. Lawrence Rivers. High inflows from both the Ottawa and St. Lawrence River in May 2017 caused flooding to many shoreline communities in this region. Figure 6-67 illustrates how the impacts reported through the Centre des Operations Gouvernementales updates are distributed in the area.

It is important to note that beyond the available aerial imagery, the GLAM Committee does not have access to detailed information that would help differentiate municipalities that border both Lake of Two Mountains and Lake Saint-Louis to determine how impacts compared on those two lakes. This is important, because water levels and the factors that influence them differ in these two locations. Specifically, whereas levels in the St. Lawrence River on Lake Saint-Louis and the south side of Montreal are directly influenced by both Lake Ontario outflows and flows out of the Ottawa River, levels in the Lake of Two Mountains area are largely influenced by Ottawa River flows alone, and under most scenarios the influence of Lake Ontario-St. Lawrence River flows and water levels is negligible. As a result, regulation of Lake Ontario outflows is done in consideration of levels on the St. Lawrence River at Lake Saint-Louis (which also provides an indicator of the effects on water levels further downstream on the St. Lawrence River, and indeed throughout the 2017 high water event these conditions were taken into consideration), but it does not consider levels in Lake of Two Mountains, since there is no way to influence them through Lake Ontario regulation.

Because the record outflows from the Ottawa River that occurred in 2017 were the primary cause of high levels and flooding on Lake of Two Mountains and the tributaries on the north part of Montreal Island (Mille Iles and Des Prairies), it is important for the GLAM Committee to differentiate impacts in these areas from impacts that occurred on Lake Saint-Louis and further downstream on the St. Lawrence River, where Lake Ontario outflows have a greater influence. For the current reporting, the GLAM Committee has relied largely on news reports, site visits and anecdotal information to identify impacts and try and make the distinction. However, currently available information is not sufficient to separate out impacts primarily due to Ottawa River outflows compared with those mainly related to Lake Ontario outflows.

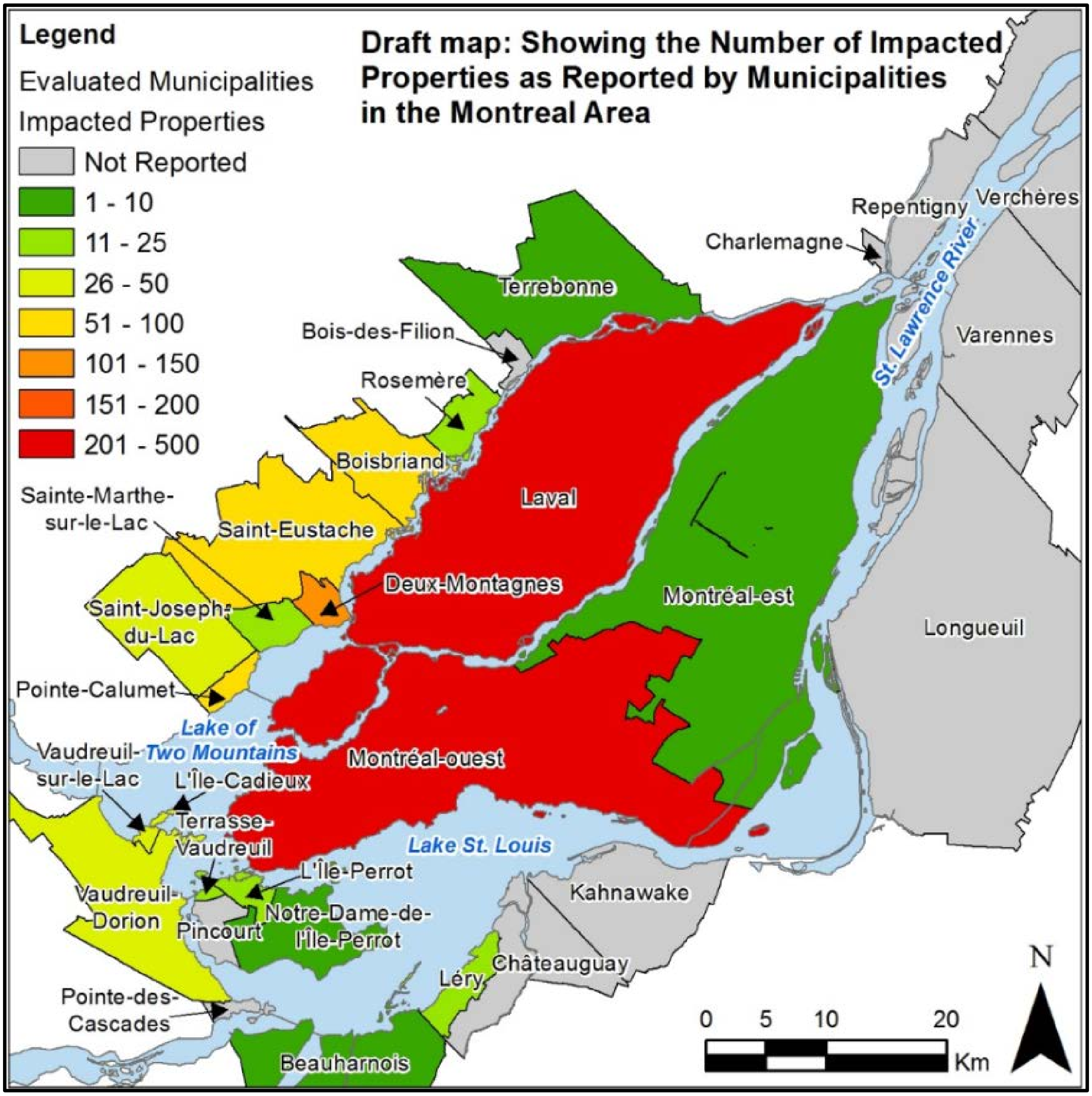


Figure 6-67: Locations of the RCMs with the number of impacted properties in the Montreal area. (Source: Quebec Centre des Operations Gouvernementales)

The RCMs located along Lake of Two Mountains and its outlets, the Des Prairies and Milles-Isles Rivers, had a greater number of impacted properties relative to RCMs along Lake Saint-Louis and the St. Lawrence River East of Montreal. This was due to the record high levels and flows from the Ottawa River (Figure 6-66). The highly populated RCM Laval and Montréal-Ouest had the most impacted properties: 450 to 500. Montréal-Ouest is a large region spanning both Lake of Two Mountains and Lake Saint-Louis. Several media reports such as the Montreal Gazette reported that neighbourhoods in Montréal-Ouest with large impacts include Ile Bizard-Ste-Geneviève, Senneville, and Pierrefonds which are on the north shoreline along Lake of Two Mountains (http://montrealgazette.com/news/local-news/flood-victims-voice-frustration-at-public-consultation-in-pointe-claire) and not influenced by Lake Ontario outflows. In addition to Montréal-Ouest and Laval, Figure 6-67 shows:

- Over 25 impacted properties along Lake of Two Mountains and its two outlets
- Over 100 impacted properties within the municipality of Deux-Montagnes
- Between 51 and 100 impacted properties for Saint-Eustache, Pointe-Calumet, and Boisbriand
- Between 26 and 50 impacted properties for Vaudreuil-Dorion, Saint-Joseph-du-Lac, L'Île-Cadieux, and Vaudreuil-sur-le-Lac
- All other RCMs in the Montreal Region have 25 or fewer impacted properties

Site visits for Lake Saint-Louis area specifically during the flooding event illustrate some of the high water impacts along the shoreline (Figure 6-68). Flooding was observed at several marinas, a small number of businesses in Saint Anne-de-Bellevue, and an apartment parking garage in Dorval (e.g. Figure 6-68). Inundation was observed at a number of parks and green space, though no serious damages were observed. Protective measures (sandbagging) were observed at multiple businesses and homes, but actual inundation appeared minimal. However, damages on Lake Saint-Louis specifically appeared to be reduced relative to the north side of Montreal in large part because outflows from Lake Ontario were regulated to manage impacts. Downstream of Lake Saint-Louis, where combined Ottawa River and Lake Ontario outflows have an influence, saw greater damages (see discussion below).

The event reports do not clearly define what parameters are used for isolated properties. It is also unclear if the isolated properties are also counted as impacted properties if a property is both isolated and flooded. It is assumed that flooding blocked access to properties and isolated the property from the resident. Figure 6-69 displays the number of properties that were isolated. The map shows that the RCMs that had isolated properties were generally around the Lake Saint-Louis and Lake of Two Mountains portion of the Greater Montreal Area.

Figure 6-68: Illustrations of flooding in the Lake Saint-Louis Area on May 6, 2017. Photo credit: ECCC.

The RCMs with the highest number of isolated properties are Saint-Eustache (Figure 6-69) and Terrasse-Vaudreuil with 76 to 100 isolated properties. Vaudreuil-Dorion and Pointe-Calumet had 51-75 isolated properties (Figure 6-69). Deux Montagnes, Pincourt, Montréal-Ouest, Léry and Beauharnois had between 26 and 50 isolated properties while L'Île-Cadieux, Vaudreuil-sur-le-Lac and L'Île-Perrot and Châteauguay had between one and 25 isolated properties. Isolated properties were not reported for the other RCMs in the area.

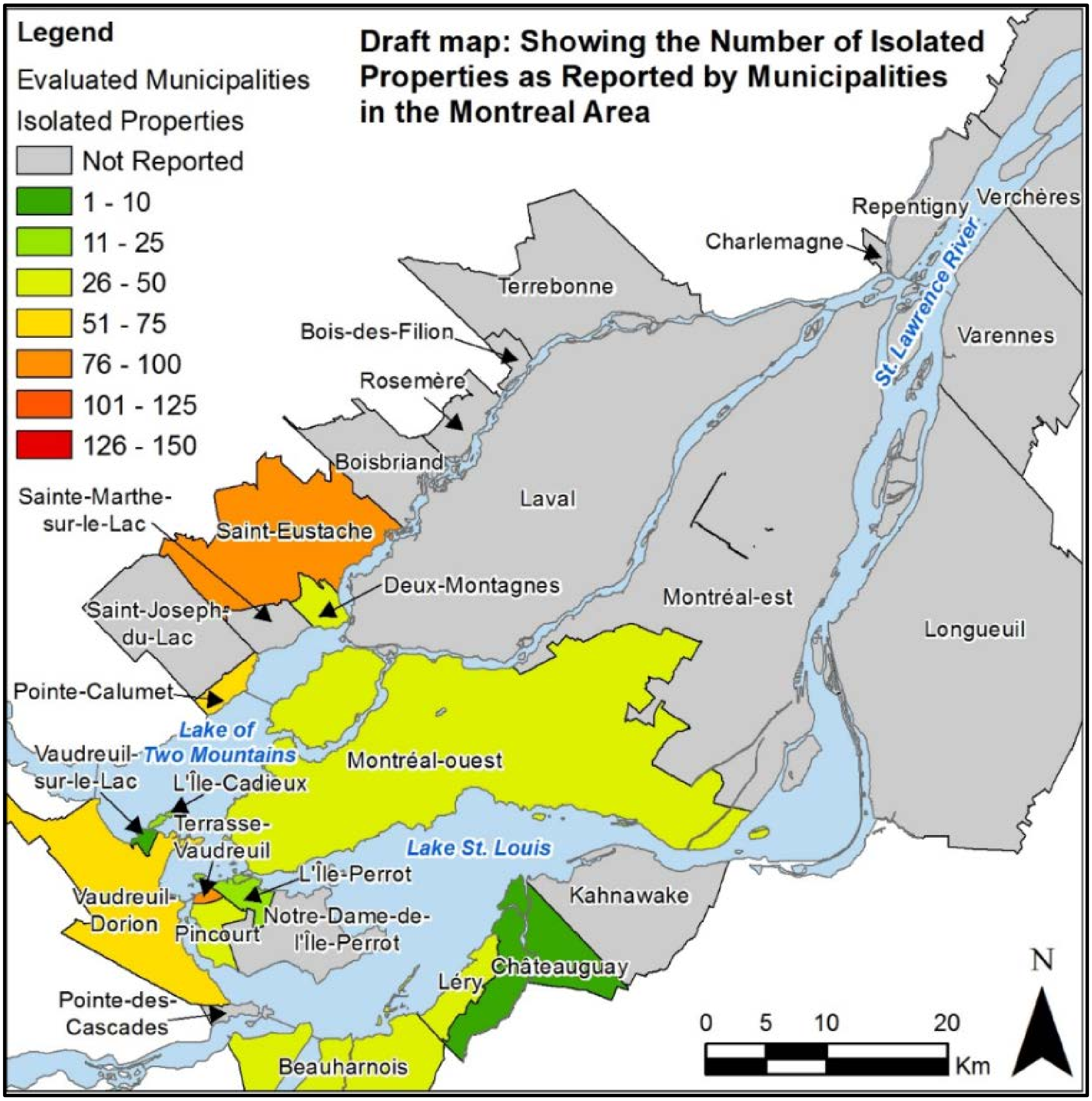


Figure 6-69: Locations of the RCMs with the number of isolated properties in the Montreal area (Source: Quebec Centre des Operations Gouvernementales)

Similar to the discussion of impacted properties, the RCMs around Lake of Two Mountains appear to have more impacted roads due to high water levels than RCMs around Lake Saint-

Louis and along the St. Lawrence River. The RCM most impacted is Laval with over 75 roads impacted (Figure 6-70). Other RCMs with impacted roads include Saint-Eustache with 26 to 50 impacted roads and Montréal-Ouest with 16 to 25 impacted roads. However, it is likely that the impacts were on the areas adjacent to Lake of Two Mountains such as Ile Bizard-Ste-Geneviève, Senneville, and Pierrefonds. All other RCMs in the area had reported 10 or fewer roads impacted by high water levels.

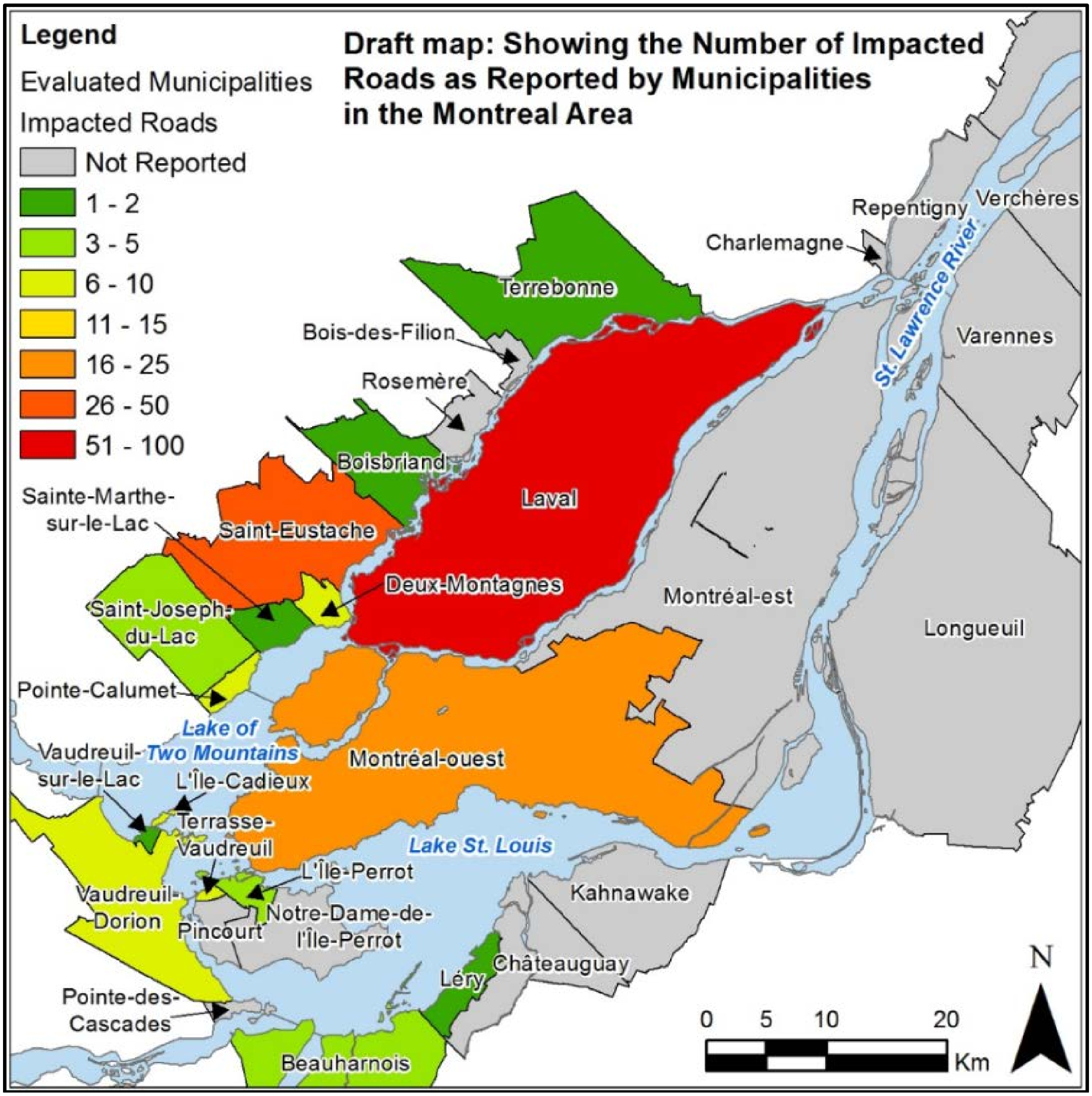


Figure 6-70: Locations of the RCMs with the number of impacted properties within Regions 1 and 2. Source: Quebec Centre des Operations Gouvernementales

Figure 6-71 displays the locations of buildings that appear to be impacted by high water levels based on visual interpretation of reaches along the St. Lawrence River shoreline. Geographic areas are highlighted where there appeared to be clusters of impacted buildings and they are color coded based on a count of the number of buildings that appeared to have water around their foundation. Figure 6-72 shows an example of the oblique imagery for a portion of Lake of Two Mountains that was included in the interpretation to illustrate observed impacts.

In frame 1 of Figure 6-71, impacted buildings were also generally found throughout the analyzed reaches with a greater concentration of impacted roads and buildings on the shoreline of L'Île-Perrot facing the Lake of Two Mountains and the shoreline of Terrasse-Vaudreuil. Neighborhoods that appear visually impacted in the oblique imagery include the peninsula with L'Île-Cadieux, Vaudreuil-sur-le-Lac and Vaudreuil-Dorion. Another shoreline reach on Vaudreuil-Dorion on the southern portion of the Lake of Two Mountains at the river outlet to Lake Saint-Louis is also impacted. Although not in the current area of scope, there is an impacted neighborhood at Oka, Quebec at the northwest corner of Lake of Two Mountains.

In frame 1 of Figure 6-71, impacted buildings were generally found throughout the analyzed reaches with a greater concentration of impacted roads and buildings in the Pierrefonds area of western Montreal. There are several neighborhoods that were not assessed for road and building impacts due to flooding that appear visually affected by water levels. The channel running south of L'Île-Bizard and West Montreal (Montréal-Ouest) have an additional four to five neighborhoods that were impacted in addition to those already assessed. There are several impacted neighborhoods along the channel north of L'Île-Bizard and Laval that were also impacted. Laval has about four neighborhoods impacted and Saint-Joseph-du-Lac, Pointe-Calumet, Sainte-Marthe-sur-le-Lac, Deux-Montagnes and Boisbriand each have at least one neighborhood impacted.

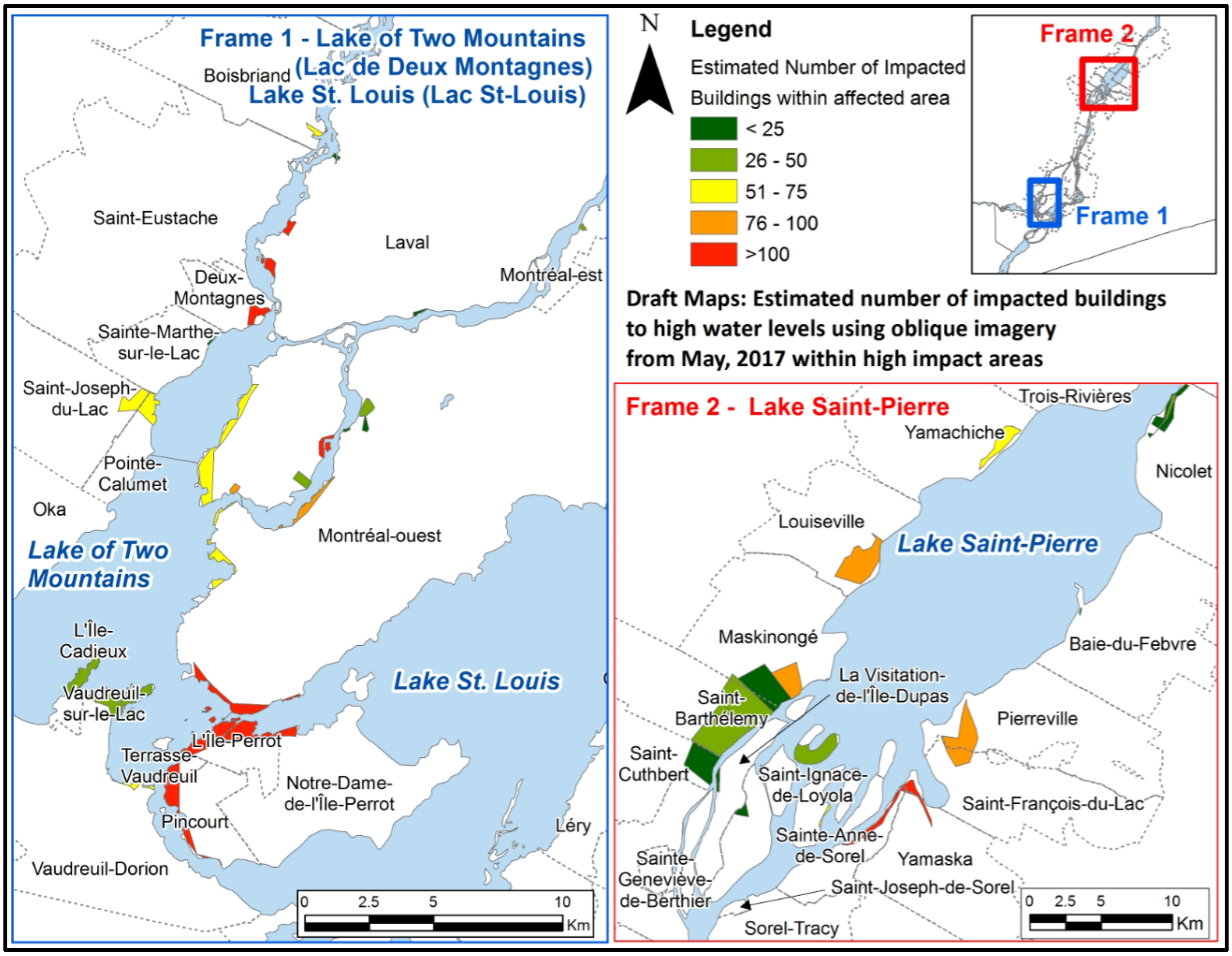


Figure 6-71: High concentration building impacts identified through oblique imagery review.

Figure 6-72: South shore of Lake of Two Mountains on May 8, 2017. Photo credit: Transport Canada National Aerial Surveillance Program.

**Lower St. Lawrence River – St. Lawrence River Region:**

This region is the St. Lawrence River between Montreal to Sorel, Quebec. This region is a mix of towns, villages and agricultural communities. In this area, the St. Lawrence River conveys the full flow of water received from both the Ottawa River and Lake Ontario basins. During the LOSLRS, minimal flooding impacts were expected in this area and the event reports provided by the Quebec Government did not highlight particular issues for this region.

**Lower St. Lawrence River – Lake Saint-Pierre Region:**

The Lake Saint-Pierre Region is located further downstream on the St. Lawrence River between Sorel and Trois-Rivières, Quebec. The St. Lawrence River enters the southwest end of the lake and continues downstream from the northeast end of the lake. Water levels in this area are influenced by outflows from both the Lake Ontario and Ottawa River basins, as well as a number of smaller tributaries in the area. The region is low lying with several islands located at the southwest end of the lake, as well as several wetlands, marshes and flat agricultural lands. The low-lying geography of the region makes it vulnerable to flooding and there were considerable impacts in May 2017 due to the high outflows it received from the Ottawa River and the smaller local tributaries, as well as the outflow that was released from Lake Ontario, all of which contributed to extremely high water levels and associated impacts.

In general, there are more RCMs with impacted properties in the central and eastern portions of Lake Saint-Pierre towards Trois-Rivières but there were a number of municipalities where impacts were not reported, but it is not clear why (Figure 6-73). For example, Figure 6-74 shows an oblique photograph that illustrates impacted buildings from the Chenail-du-Moine area near Sorel on the St. Lawrence River. However, there are no results for that municipality on the impacted properties map based on the information reported in the Centre des Operations Gouvernementales summaries.

In terms of RCMs with reported impacts in the Centre des Operations Gouvernementales summaries, the RCM with the highest impact in the Lake Saint-Pierre area was Saint-Barthélemy, located on the north side of Lake Saint-Pierre, with approximately 160 impacted properties. In addition to Saint-Barthélemy, RCMs located on the central shoreline of Lake Saint-Pierre had larger amounts of impacted properties relative to other areas. On the north side of the lake, Maskinonge and Louiseville had between 101 and 150 impacted properties and Yamachiche had between 26 to 50. On the south side of the lake, Pierreville had between 51-100 impacted properties. On the east end of the lake, Trois-Rivières, Nicolet and Becancour had between one and 25 impacted properties each. On the west end of the lake, Sainte-Geneviève-de-Berthier and La Visitation-de-l'Île-Dupas had between one and 10 impacted properties each.

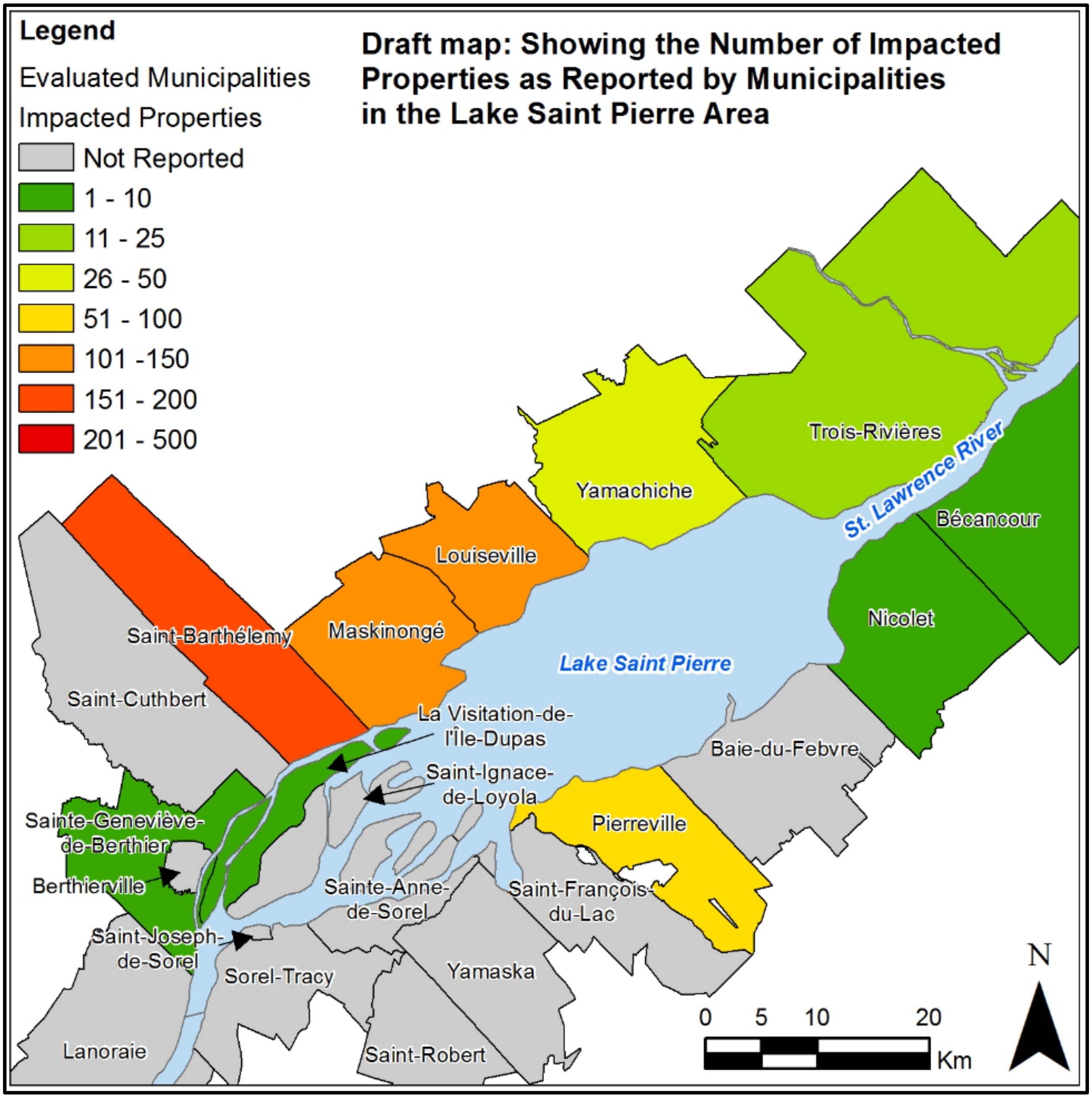


Figure 6-73: RCMs with the number of impacted properties within Regions 4 and 5. Source: Quebec Centre des Operations Gouvernementales.

Figure 6-74: High water in the Chenail-du-Moine area near Sorel on May 9, 2017. Photo credit: Transport Canada National Aerial Surveillance Program.

Similar to the impacted properties, the RCMs with the most isolated properties reported in the Centre des Operations Gouvernementales summaries are on the north shore of Lake Saint-Pierre (Figure 6-75). Maskinonge was the most impacted RCM with between 126 and 150 isolated properties. In addition to Maskinonge, RCMs located on the central shoreline of Lake Saint-Pierre had larger amounts of impacted properties relative to other areas. On the north side of the lake, Saint-Barthélemy and Louiseville had between 101 and 125 isolated properties and Yamachiche had between 26 and 50. On the south side of the lake, Pierreville had between 51 and 75 isolated properties while on the east side, Nicolet and Becancour had between one and 25 isolated properties each. Finally, on the west end of the lake, there is a notable difference when compared to the impacted properties. Sainte-Anne-de-Sorel had between 76 and 100 isolated properties whereas it had no impacted properties. It may be due to access issues reaching properties on flooded islands. La Visitation-de-l'Île-Dupas, Saint-Francois-du-Lac, and Yamaska had between one and 10 isolated properties each.

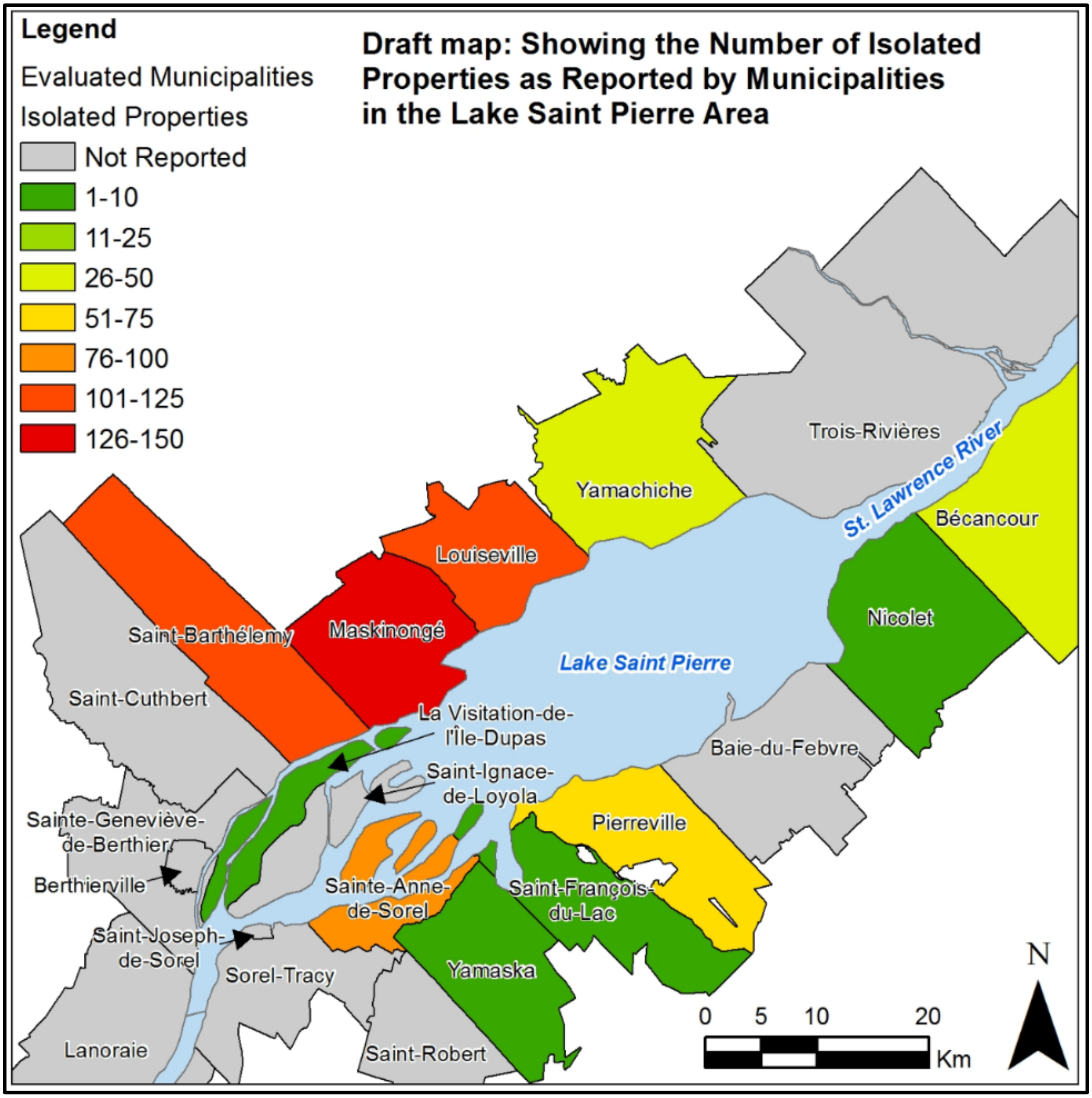


Figure 6-75: Locations of the RCMs with the number of isolated properties within Regions 4 and 5. (Source: Quebec Centre des Operations Gouvernementales)

Figure 6-76 shows that the number of affected roads in the Lake Saint-Pierre region reported in the Centre des Operations Gouvernementales summaries is fairly minor when compared to the high density Montreal region. Becancour has the largest number of impacted roads between 11 and 15, followed by Trois-Rivières and Nicolet that have between 6 to 10 impacted roads. The RCMs on the central shoreline of the lake, both north and south shore, have fewer than five impacted roads each. Roads within RCMs on the western end of the lake were generally unaffected or impacts were not reported in the summaries.

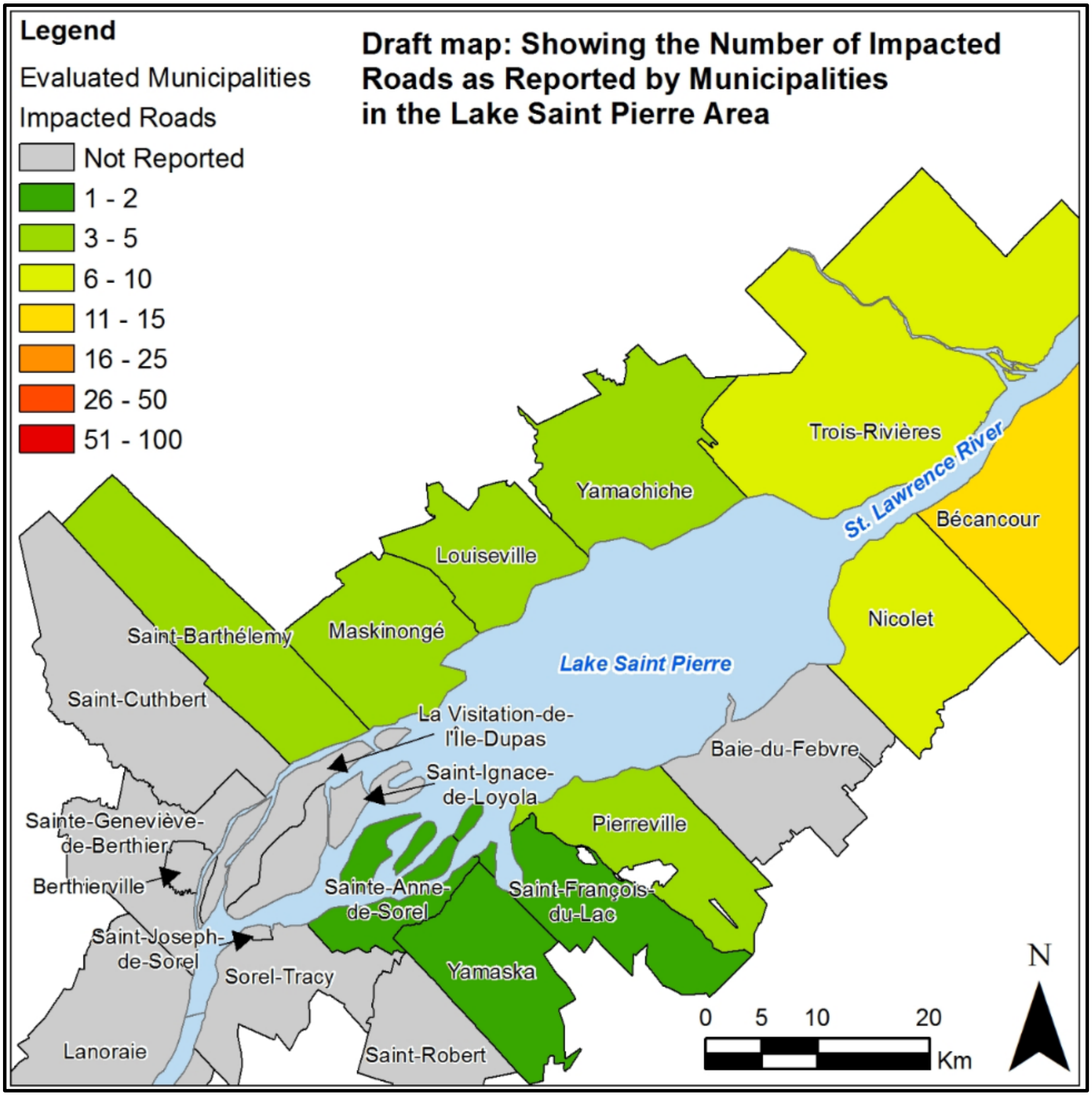


Figure 6-76: Locations of the RCMs with the number of affected roads within Regions 4 and 5 (Source: Quebec Centre des Operations Gouvernementales)

Figure 6-71 (frame 2), shown earlier, is a preliminary map displaying the locations of buildings that appear to be impacted by high water levels based on visual interpretation of analyzed reaches along the St. Lawrence River shoreline using the Transport Canada imagery. Geographic areas are highlighted where there appeared to be clusters of impacted buildings and they are colour-coded based on a count of the number of buildings that appeared to have water around their foundation. Of the reaches analyzed, there is a greater concentration of impacts in Saint-François-du-Lac, Yamaska and Sainte-Anne-de-Sorel. Impacts are less common along the central shoreline of the lake. There are several neighbourhoods on the northwestern shoreline of Lake Saint-Pierre that were impacted but not yet assessed for flooded buildings and roads (pink areas). A significant flooded neighbourhood occurred in Saint-Barthélemy and Maskinongé at the outlet of the St. Lawrence River into Lake Saint-Pierre. Also, at the outlet of the St. Lawrence River into Lake Saint-Pierre are a series of islands that also have groups of buildings impacted by flooding, including La Visitation-de-l'Île-Dupas and Saint-Ignace-de-Loyola. On the north shore, Louiseville and Yamachiche each had neighbourhoods impacted by flooding.

**Conservation Ontario/GLAM Shoreline Survey:**

The online Conservation Ontario survey was also made available to shoreline property owners in the Province of Quebec in both English and French and promoted through various sources including print and radio media. The overall number of responses was lower than for the Lake Ontario and upper St. Lawrence River shoreline. There were 41 responses received with 29 falling within the study area (the other responses were for flooding impacts not directly related to St. Lawrence River water levels and flows). Flooding impacts were reported by 25 of the 29 respondents. Like the Lake Ontario responses, the highest number of responses for the flooding category were for lawn, dock/pier and road access (Figure 6-77). For the erosion category, vegetation and beach impacts were the most commonly reported.

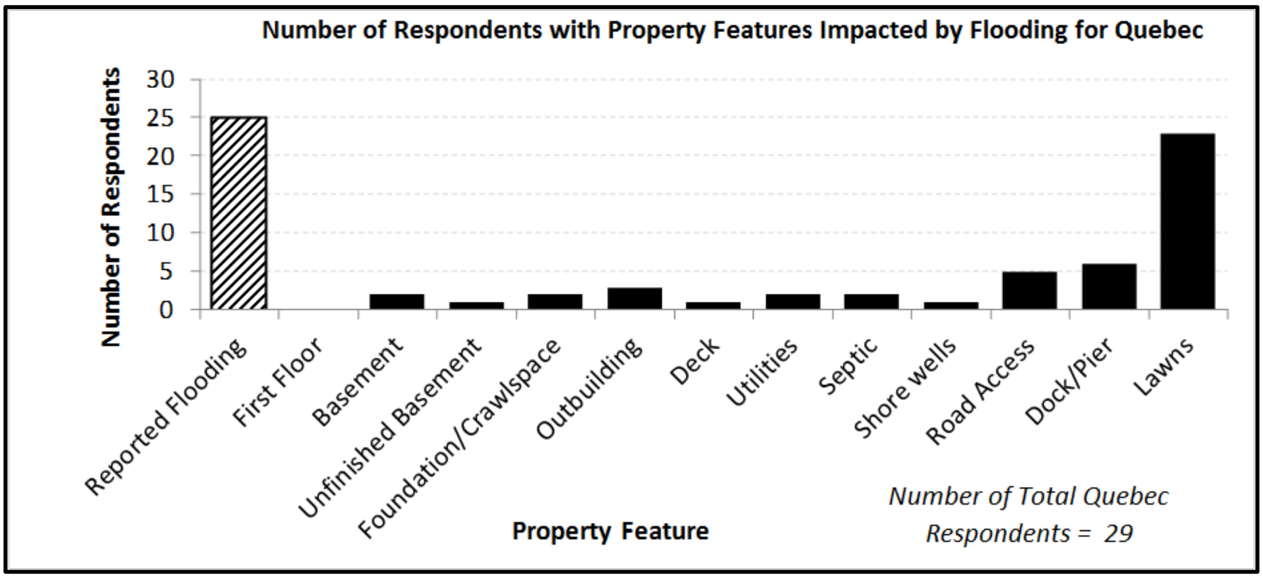


Figure 6-77: Summary of Conservation Ontario questionnaire responses for flooded property along the St. Lawrence River in Quebec. (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

## 6.4 Model/PI validation

The coastal impact category is focused on direct impacts to shoreline infrastructure, primarily residential, along the Lake Ontario and St. Lawrence River shoreline. The IJC's Plan 2014 report, dated June 2014, defines the coastal impact category as "individuals and organizations with a direct interest in the property along the shorelines of Lake Ontario and the St. Lawrence River (riparian property), particularly private property owners" (IJC, 2014). During the LOSLRS, there were three primary PIs used to represent impacts to coastal property owners along the Lake Ontario shoreline for the comparison of regulation plan options including:

- First floor flooding of residential buildings;
- Erosion to developed (i.e. with building) but otherwise unprotected land; and
- Shore protection maintenance costs.

The flooding PI was applied to all shoreline areas in the database including many of the larger embayments around the lake, while the erosion and shore protection maintenance indicators were only applied to the open coast shorelines and not those within protected embayments or the Bay of Quinte. On the upper St. Lawrence River, from the Thousand Islands through to the Moses-Saunders dam, the primary PI was first floor flooding of residential buildings. A database developed during the LOSLRS included approximately 25,000 properties directly along or within close proximity to the Lake Ontario and upper St. Lawrence River shoreline for which the PIs were applied using the evaluation models.

The GLAM Committee has not yet completed a detailed comparison of PI results to the available descriptive information of coastal impacts and this is identified as a requirement moving forward. Based on the currently available information, a wide range of coastal impacts were observed due to the high water levels in 2017 on both Lake Ontario and the St. Lawrence River system. While the types of impacts being reported were generally consistent with the primary PIs used during the LOSLRS, a number of areas were identified that may require further investigation, particularly as they relate to potential vulnerabilities at water levels in the upper end of the historic range. These impacts are discussed below in relation to the PIs.

**Lake Ontario and upper St. Lawrence Flooding**:

The PIs used during the LOSLRS relate to flooding of shoreline buildings (primarily residential) due to first floor flooding. This can be related to direct inundation or inundation due to wave impacts. The algorithm includes a basic incorporation of storm surge and direct wave impact to the buildings, but further investigation is needed regarding how the model integrates a separate wave uprush (elevation) component. Figure 6-78 and Figure 6-79 further illustrate this potential difference. The Flood and Erosion Prediction System (FEPS) model will propagate waves across a plateau if the water level plus surge exceeds the flood elevation threshold for the building (high water level in Figure 6-78). However, it is unclear if it directly accounts for the elevation a wave will reach as it dissipates up a sloped shoreline, which can lead to overtopping or spilling of water onto the plateau (Part B in Figure 6-79). Note that the overtopping of this component is included in the shore protection PI. For the flooding PI specifically, further investigation is required to verify how the model captures issues in areas where waves are spilling over the shore crest and ponding on the backshore around buildings, but where the lake level plus surge was not considered to have exceeded the building elevation. This type of flooding may not result in first floor flooding if there was some offset at the building, but it could certainly lead to basement or crawl space flooding if a significant amount of water pools around the building. In the FEPS model used during the LOSLRS, it was assumed that basements were not common in shoreline dwellings but there were many reports in the media related to basement flooding impacts, and it was much more commonly reported in the self-reporting questionnaire when compared with first floor flooding (at least for the Canadian results). Further investigation is needed to determine how common basement and crawl space areas are along the Lake Ontario and upper St. Lawrence River shoreline.

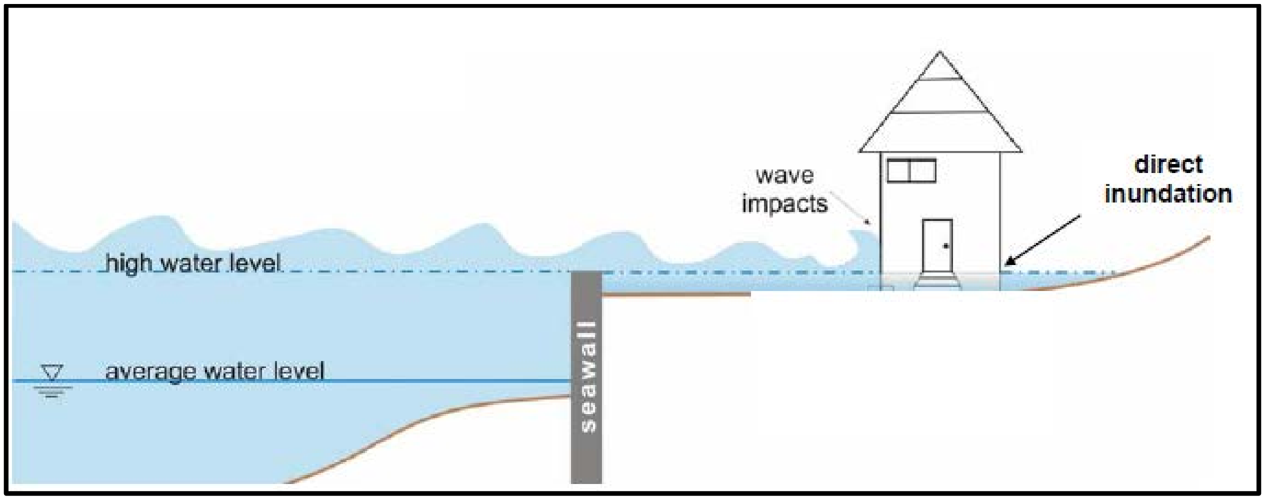


Figure 6-78: Illustration of flooding impacts in FEPS model as taken from Baird Flooding PI Summary (Source: Baird and Associates, 2005)

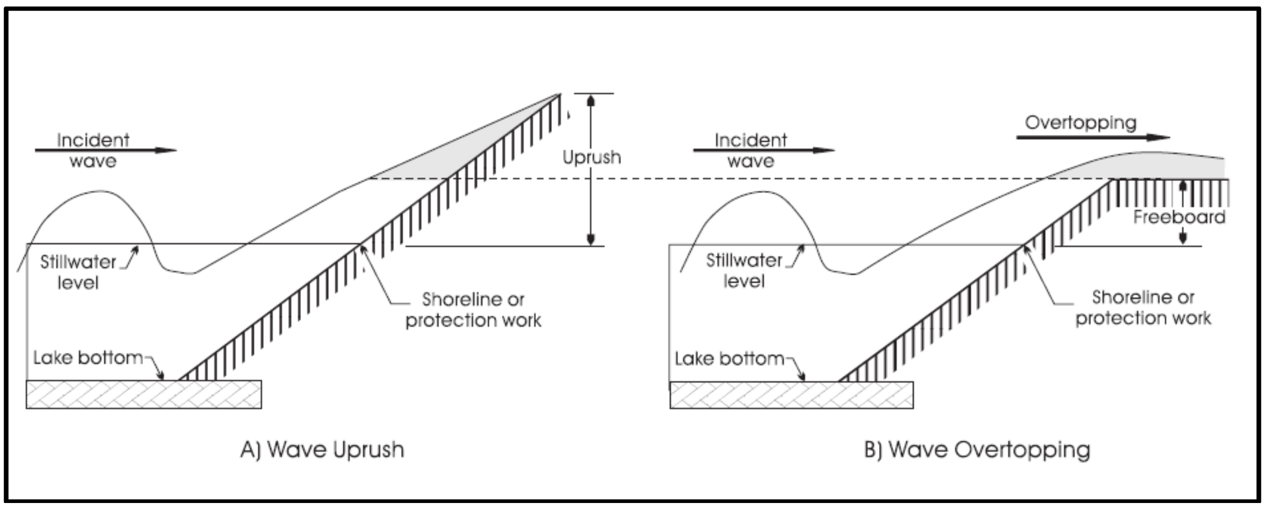


Figure 6-79: Illustration of wave uprush and overtopping where the Stillwater level is comparable to high water level (Source: Watershed Science Centre and Ontario Ministry of Natural Resources, 2001)

Based on some of the initial data review (e.g. oblique imagery review along portions of the Canadian shoreline), first floor flooding under static water conditions was not commonly observed along the Canadian shoreline. The exceptions included portions of Toronto Island, low lying marina buildings and some residential structures in the Clarington, Brighton, Prince Edward County and Thousand Islands areas. However, flooding of lawns, docks and accessory buildings (e.g. sheds, boathouses, etc.) was commonly observed in the review of the oblique imagery and was not included previously as an “impact” in the plan evaluation process. Flooding of public lands, trails and other facilities were also not included in the PI. There were also many cases where excessive rain events led to ponding of water and drainage problems that were exacerbated by the high water levels. These impacts are not currently incorporated in the flooding PI. It is important to note that no PIs are designed or able to capture all potential impacts. They are developed as indicators of response under various water level conditions and the flooding indicator is no different. The intent was not to quantify all impacts but to have an indicator that could potentially differentiate regulation plan alternatives. Recognizing this important distinction, the available information still suggests the need to review the PIs to make sure the most significant impacts observed under actual water level conditions are represented.

Finally, a number of media reports also highlighted the psychological impacts of flooding to people that live along the shoreline (e.g. https://www.theglobeandmail.com/news/hell-and-high-water-floods-are-getting-worse-failure-to-plan-ahead-is-not-an-option/article36145091/). A recent report by the Intact Centre on Climate Adaptation (June 2018) highlights both the worry and stress associated with flooding and the need to take time off to deal with flood related response (Decent and Feltmate, 2018). While the Decent and Feltmate report focuses on flooding based on short-term rainfall events in an urban environment, similar issues are likely to be experienced by flooding victims along the shoreline as illustrated by comments received through the Conservation Ontario survey. One respondent referred to it as “a truly devastating experience” and there were a couple of responses noting the stress of needing to be constantly monitoring the situation to ensure pumps were working. Another respondent said “It was also quite stressful as we didn’t know when or if the water would recede and how it would affect our property” and another noted “the length of time of the flood was a horrendous experience”. Related to the responses on stress was the personal financial toll, including the concern about the long-term implications.

Given the uncertainty around water levels and storm events, it is likely that the high water level conditions caused stress and anxiety for shoreline property owners that were almost flooded but did not actually have direct property damages. In some cases, more information on water level conditions and trends may have helped to reduce some of the uncertainty and allow for better preparation and response to the conditions. In any event, it is important to recognize that the coastal PIs used to evaluate regulation plan alternatives relate to shoreline impacts that directly impact people living along the shoreline.

**Lake Ontario and upper St. Lawrence River Erosion:**

The PI used in the LOSLRS to compare erosion impacts due to regulation plans was based on the cost to build shore protection when the bluff eroded to within a certain distance of the main building on the property (LOSLRS Board, 2006). Based on conditions in 2017, there are a few particular assumptions that may need to be re-examined to determine the impact on the plan evaluation process. In particular, the model assumes that a property owner would install shoreline protection when the bluff gets to within a certain distance of the building (typically 10 m (32.8 ft) in the simulation). However, there are examples from 2017 and previous years where this is not the case and the bluff had eroded right to the building. Under high water level conditions such as in 2017, there may be limits to what can be done to reduce bluff erosion until water levels recede, and by that point, it may be too late to protect the building. Further investigation of 2017 erosion conditions is necessary to determine how frequently the model assumption was not followed.

Another key assumption within the erosion PI that may need to be reviewed is the episodic and spatially variable nature of the observed erosion. Certainly, there were examples of significant bluff erosion that took place in 2017. However, this erosion was spatially and temporally variable. The erosion PI was not applied in the Bay of Quinte or other protected embayments, where wave energy was considered much lower than on the open lake and further review is required to determine if that assumption is still valid based on conditions from 2017.

Finally, the erosion PI was implemented in relation to protection of buildings (primarily residential). In 2017, there were clearly examples of other infrastructure impacts related to erosion. There were many instances of erosion issues affecting shoreline parks and trail infrastructure on the Canadian shoreline. For example, the City of Hamilton experienced erosion issues along the beachfront trail and undertook short term remediation efforts to install shore protection to protect the trail in specific areas with direct costs to the municipality (Figure 6-80). The general approach is very consistent with the way the PI was applied (i.e. build shore protection when erosion puts something of value at risk) but the PI only related to residential buildings and that definition may need to be broadened.

Figure 6-80: Emergency shore protection installation to protect a portion of Hamilton's waterfront trail from erosion on June 1, 2017. Photo credit: ECCC.

**Lake Ontario and Upper St. Lawrence River Shore Protection:**

As expected, high water levels and storm events were important drivers contributing to failure of shoreline protection structures along the Lake Ontario and upper St. Lawrence River shoreline. In New York State, there were numerous permit applications related to shore protection structures and the need to rebuild and it is anticipated that permit requests have continued into 2018 as the extent of damages and financial reimbursements become known. However, the failure of shoreline protection structures was not universal and it is clear that further investigation is needed to determine what factors contributed to structure failure. By undertaking further evaluation, it will allow for improvements to the models used for regulation plan evaluation to better identify the critical factors that contribute to shore protection structure instability. The GLAM Committee has received conditional approval for a project to support the investigation of shore protection failure conditions, pending availability of required funds and appropriate contracting requirements.

**St. Lawrence River Flooding:**

Flooding impacts were observed along the St. Lawrence River in 2017, particularly the late April and May freshet period. Preliminary simulations using the models developed in the LOSLRS suggested that the vast majority of the impacts on the St. Lawrence River would not be in the Montreal area but instead would be in the Lake Saint-Pierre area. This appears generally consistent with observations but there has been no validation of specific locations (municipalities) of number of buildings.

## Example Photographs Submitted by Property Owners

Figure 6-81: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted anonymously (photo date 06/03/2017, ON) and the right photo was submitted anonymously (photo date 04/30/2017, ON)

Figure 6-82: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted by Tatyana Dubay (photo date 05/28/2017, NY) and the right photo was submitted anonymously (photo date 05/25/2017, ON)

Figure 6-83: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted by George Prodanou (photo date 05/31/2017, ON) and the right photo was submitted by Rick Davis (photo date 08/01/2017, NY)

Figure 6-84: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted by Cindy Resnick (photo date 06/15/2017, NY) and the right photo was submitted by Mark Phillips (photo date 07/23/2017, NY)

Figure 6-85: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission.  The left photo was submitted by Richard Baase (photo date 05/25/2017, NY) and the right photo was submitted by Laurie Streb (photo date 04/30/2017, NY)

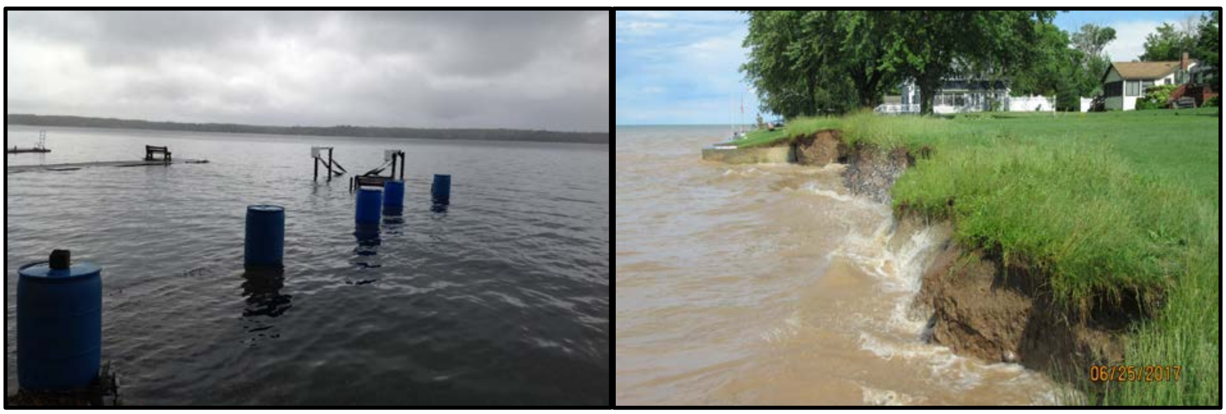

Figure 6-86: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted anonymously (photo date 05/07/2017, ON) and the right photo was submitted by Amy Thompson (photo date 06/25/2017, NY)


Figure 6-87: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission.  The left photo was submitted anonymously (photo date 05/28/2017, ON) and the right photo was submitted anonymously (photo date 05/18/2017, NY)

Figure 6-88: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted by Pete Brennan (photo date 05/01/2017, NY) and the right photo was submitted by Michael Jeffery (photo date 08/05/2017, NY)

Figure 6-89: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted anonymously (photo date 05/22/2017, ON) and the right photo was submitted anonymously (photo date 05/20/2017, NY)

Figure 6-90: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted by Tim Dixon (photo date 10/30/2017, NY) and the right photo was submitted by Cheryl and Robert Stevens (photo date 04/16/2017, NY)

Figure 6-91: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted by David Leonard (photo date 08/05/2017, NY) and the right photo was submitted anonymously (photo date 08/08/2017, NY)

Figure 6-92: Example photos submitted by property owners as part of the Conservation Ontario/GLAM online survey and used with permission. The left photo was submitted by John Pafumi (photo date 08/05/2017, NY) and the right photo was submitted by Jason Smyth, Vice Commodore, Dalhousie Yacht Club (photo date 06/01/2017, ON)

# 7.0 Ecosystem

## 7.1 Summary of GLAM work and other agency activities to assess impacts

### 7.1.1 GLAM Related Activities:

Recognizing the importance of coastal wetland plant diversity as a critical measure of ecosystem response to water level management on Lake Ontario, the GLAM Committee initiated a number of tasks to gather on-site observational wetland vegetation data in order to establish baseline conditions and to help verify and validate the wetland PIs and modelling tools developed during the LOSLRS. These data gathering efforts were fortunately in place in 2017 for wetlands on Lake Ontario and the upper St. Lawrence River through the IJC's International Watershed Initiative (IWI). Three projects in particular will help to support an understanding of vegetation response to the high water levels of 2017:

IWI Project / Monitoring of Lake Ontario wetland habitat in Ontario, Canada:

A project was initiated to collect vegetation data at 16 wetland sites on the Canadian shoreline of Lake Ontario in 2017. The data collection was supported through the IWI and in-kind contributions of the Canadian Wildlife Service (CWS) of Environment and Climate Change Canada (ECCC). The field data collection protocol has been developed by staff from the CWS over the past number of years specifically to look at the impact of water level fluctuations on Lake Ontario wetland vegetation (Grabas and Rokitnicki-Wojcik, 2015). The protocol is designed to track vegetation for a range of elevations within wetland geomorphic types. The collected data will augment existing datasets from previous monitoring undertaken by CWS-ON at Canadian wetland sites between 2009 and 2015. Initial findings of this project are summarized in 7.5.1 below.

IWI Project / Monitoring of Lake Ontario wetland habitat in NY State:

Field sampling of vegetation community information referenced to elevation was collected in sixteen Lake Ontario and St. Lawrence River coastal wetlands on the US side, replicating efforts in Canada. The field sampling was conducted by the New York Natural Heritage Program (T. Howard), State University of New York College of Environmental Science and Forestry (NYNHP) in August and September of 2017.

Outcomes at an April 2017 binational wetlands experts workshop, organized by the GLAM Committee, included recommendations to continue field monitoring so that the vegetation model (developed using vegetation data influenced by Plan 1958-D) could be refined to better model vegetation communities under Plan 2014. In addition, recommendations from the workshop will be used to refine the monitoring strategy (including study site locations) for 2017, with involvement from Canadian and US partners. Data detailed below that was collected in 2017, as well as data collected through previous US and Canadian monitoring will collectively contribute to future model verification activities as part of the GLAM Committee effort.

IWI Project/ Imagery Analysis of Lake Ontario Wetlands:

Work was initiated on this project in 2017 with imagery collection taking place in August/September 2017 and the processing of the field data carrying over into FY18. The goals of this project were to acquire high-resolution aerial imagery in maximum-vegetation condition for sixteen Lake Ontario and St. Lawrence River coastal wetlands along the US shore, use GIS to map the vegetation types within these wetlands, and then assess similarities and differences in wetland extent from equivalent mapping products from 2012 and 2014. This work will complement the collection of coastal wetland aerial imagery on the Ontario side of high resolution (8 cm Ground Sample Distance (GSD)) ortho-imagery and land elevation data collected at 17 Canadian wetland sites on Lake Ontario by the Ontario Ministry of Natural Resources and Forestry (MNRF) in 2016. This will allow the development of a lake-wide, binational assessment of the current status of Lake Ontario and St. Lawrence River coastal wetlands. These data can be used to support adaptive management of lake level dynamics and integrate into wetland vegetation community modelling of the meadow marsh extent indicator for the LOSLR area.

Other Agency Activities and Contacts:

The NYSDEC has contracted with Dr. John Farrell and the State University of New York College of Environmental Science and Forestry (SUNY-ESF) to conduct a series of environmental indicator monitoring activities for eastern Lake Ontario and St. Lawrence River. The 5-year project term is 2016 – 2021 and consists of:

- Annual assessment of northern pike community spawning success and population
- Biannual (2017 + 2019 + 2021) muskrat denning assessment with 2017 period due this winter – if conditions enable access into wetlands. High water levels limit access to wetlands to conduct surveys for a number of reasons. This could potentially affect the quality of the assessment results as it may not be possible to perform accurate counts of muskrat dens without safe access to wetlands;
- Biannual (2017 + 2019 + 2021) assessment of coastal wetland conditions, especially meadow marsh changes comparing a limited number of index sites to water level managed sites to LOSLRS sites [again, changes this year unable to attribute to Plan 2014 vs. extreme levels}.

The GLAM Committee plans to incorporate any findings based on data gathered in 2017 into this report.

Further outreach conducted by the GLAM Committee in September and October of 2017 to determine if other agencies were conducting explicit ecosystem monitoring initiated due to high water levels in 2017 yielded some results. Various governmental, academic and non-profit organizations are involved in collecting environmental data in the LOSLRS area. These can generally be divided into those monitoring for recreational safety, and those quantifying ecological metrics, such as habitat area or abundance of certain species. Groups monitoring for recreational safety are primarily focused on *E. coli* and fecal coliform, but are beginning to collect and aggregate data on enterococci and cyanobacteria as well. External groups (i.e., not USACE or ECCC) that collected ecological data during 2017 are listed in Table 7-1 below.

Table 7-1: Summary of related ecosystem efforts by external groups.

| Organization | Data Type | Region |
|---|---|---|
| Royal Botanical Gardens | • Management and restoration of a large coastal wetland at the western end of Lake Ontario (Cootes Paradise)<br>• Fish barrier installed in 1990s to keep Carp out was breached in 2017 due to high water levels<br>• Impact to vegetation due to Carp | Lake Ontario |
| 1000 Island National Park | • Manage large sections of shoreline in Kingston to Brockville area<br>• Spawning activity<br>• Wild rice<br>• Hemi-marsh | Eastern end of Lake Ontario and Upper St. Lawrence River |
| NYS DEC | • Wetland vegetation | Lake Ontario |
| Clarkson University Dr. Twiss | • Upper St. Lawrence water quality, organic and inorganic, to support adaptive management and smart infrastructure | Upper St. Lawrence River |
| The Nature Conservancy with SUNY ESF Dr. Boyer | • Sodus Bay cyanobacteria and growth model | Sodus Bay |
| SUNY ESF Dr. Farrell | • Northern pike spawning success and population<br>• Muskrat denning<br>• Coastal wetland type, including meadow marsh changes | Lake Ontario |
| Cornell Lab of Ornithology | • Annual bird counts and migratory habitat analysis<br>• NY Breeding Bird Atlas; Christmas Bird Count; North American Breeding Bird Survey; and Golden-Winged Warbler Survey | Lake Ontario and St. Lawrence River |

## 7.2 Media coverage

Media coverage related to ecosystem impacts was far less extensive than other related impacts to the coastal sector and recreational boating and tourism. Of the over 1400 articles reviewed regarding the 2017 high water levels, only 36 were identified as relating to the environment. The media attention that did occur identified a number of impacts that included a variety of examples such as poor nesting habitat for the endangered Piping Plover, a shorebird that nests on open beaches; spawning of carp and other fish in flooded roadways, parking lots and other overland areas; concerns over water quality at beaches due to the flooding and runoff from the land, causing high *E. coli* levels as well as the mixing of storm water with sewage in combined sewage outflows. There were some articles that mentioned climate changes and speculation on whether 2017 was a sign of things to come. In addition to a number of negative articles, there were also some positive ones too with anglers finding 2017 to be particularly good for Chinook Salmon and Northern Pike catches and at least one article noting 2017 high water levels as being detrimental to some species while a boon for others.

## 7.3 Impacts of 2017 water level conditions

The IWI efforts of wetland surveying by CWS-ON and NY DEC include some information on the initial impacts to wetland plant communities at elevations above typical meadow marsh communities and in other wetland areas inundated in 2017 (e.g. Figure 7-1). NYDEC and CWS-ON have committed to share data and pursue analyses using the peer-reviewed ordination method used to delineate wetland plant communities. A summary of the CWS-ON and the New York National Heritage Foundation surveillance efforts are included below. It is noted that the full extent of impacts due to inundation of these higher elevation communities were not expected to be fully realized for this year's monitoring effort, however early indications from 2017's monitoring does indeed indicate some vegetation response. Further monitoring in the coming years will be necessary to determine how these vegetation responses are reflected in future years.

Figure 7-1: Drowned upland vegetation in Braddock Bay. Photo Credit: USACE Aerial Imagery – June 3, 2017)

IWI Project / Monitoring of Lake Ontario wetland habitat in Canada:

This project involved vegetation monitoring that followed Grabas and Rokitnicki-Wojcik (2015). CWS-ON has monitored vegetation using this approach at 26 wetlands on the US and Canadian shorelines of Lake Ontario from 2009-2015. In 2017, the sites surveyed were selected to be representative of wetlands in Lake Ontario by hydrogeomorphic type, geography and level of disturbance. Four sites from each hydrogeomorphic (HGM) type were selected: dynamic barrier beach (BB), open embayment (OE), protected embayment (PE), and drowned river mouth (DRM). No new sites were surveyed in 2017, and the majority of sites had been surveyed multiple times in the past. More sites (16) were surveyed in 2017 than in previous years (8). The New York State Department of Environmental Conservation (NYSDEC) also surveyed 16 sites on the US side of Lake Ontario. To allocate the field staff, survey time and technological resources required for the additional sites, the number of transects surveyed per site was reduced from 12 (in the original study design) to six or eight depending on time available per site in 2017. Vegetation was monitored along six to eight transects at each of 20 cm elevation increments beginning at 74.0 m and ending at 76.0 m as seen in Figure 7-2. An earlier power analysis of several years' data (not shown here) indicated that differences in species composition and vegetation zonation can be adequately captured by six transects. By expanding the range of sites, the resulting dataset was more robust for the purpose of assessing wetland conditions across the Canadian side of Lake Ontario.

The sum of plant species percent cover per guild (a group of plants using the same resources, e.g. submerged aquatic vegetation) was calculated to provide a measure of the abundance of a vegetation type at each elevation within a study site. Vegetation guilds occur in a distinct zonation determined by water level and species tolerance to flooding; however, they may shift lakeward or upland as water levels fluctuate from year to year and can vary among sites. Shifts in guild extent resulting from 2017's water level conditions were not expected to be immediately evident as there is a lag time for response in some guilds. However, some notable changes in percent coverage appeared to occur at specific elevations where vegetation communities were flooded by higher water levels in 2017.

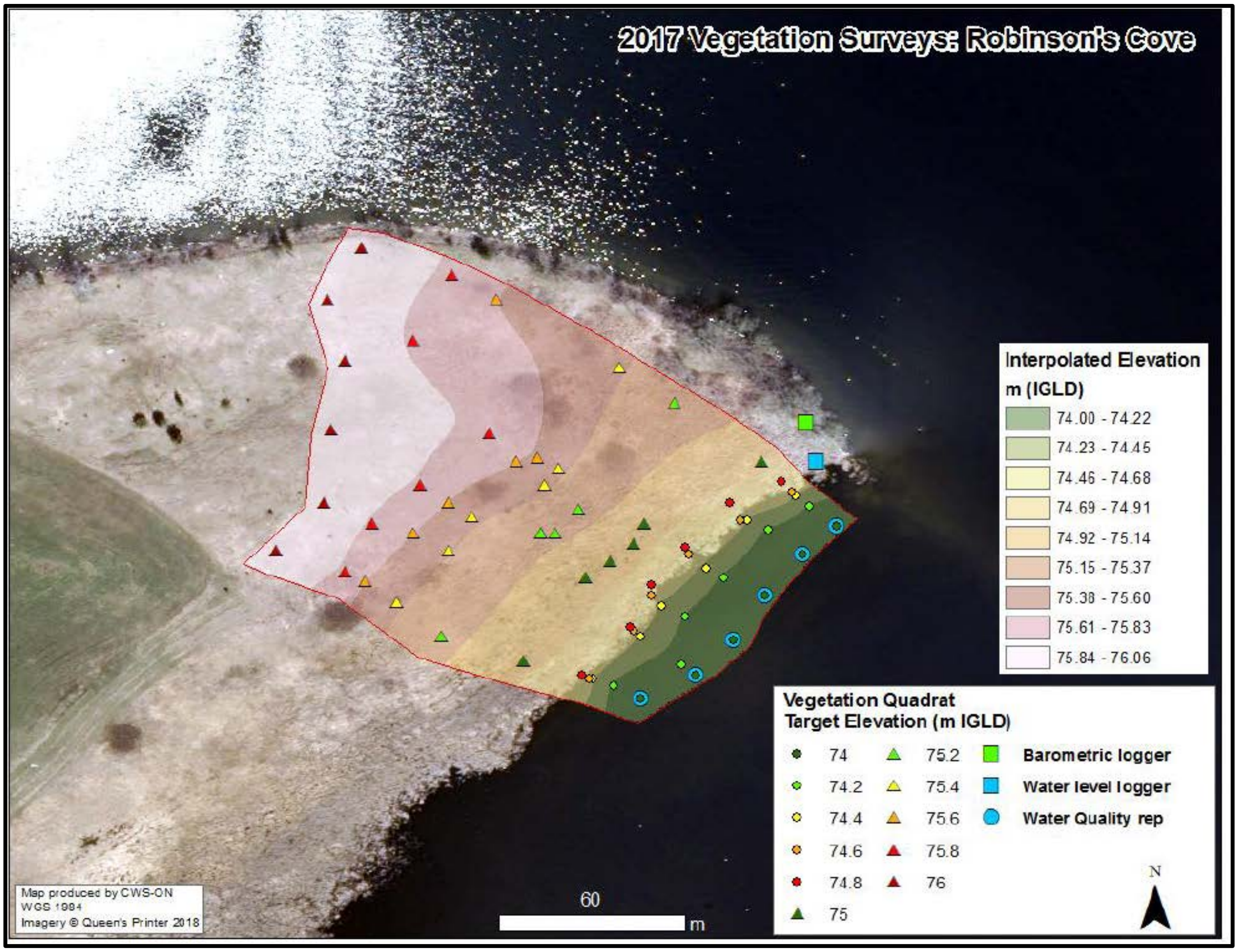

Figure 7-2: Robinson's Cove (ROC) vegetation quadrats sampled by elevation (six transects), level logger locations and water quality sampling locations in 2017. An interpolation DEM of the elevation data is overlaid. Photo Credit: ECCC - *Monitoring of Lake Ontario Coastal Wetland Habitat in Support of Adaptive Management,* March 2018.

*SAV (Submerged Aquatic Vegetation):*
In general, the percent coverage of SAV showed little change from previous years. At some sites, the elevation range of SAV may have extended upland slightly. At 75.2m, SAV was found at 53% of sites, compared to 37% in 2015 and 4% in 2014, although the coverage at these elevations is quite low where it occurs.

*SAVFF (Free-floating):* Similar to SAV, free-floating vegetation moved upland with the water level which was apparent during the field surveys. Only in 2017 were SAVFF species found at 75.6m and occasionally as high as 75.8m. At 75.4, SAVFF was found at 81% of sites, compared with less than 15% in all previous years. In many instances, these species (such as European Frogbit and Duckweed) were situated in dry areas after the water had receded.

*NPE (Non-persistent emergent):* Non-persistent emergent vegetation coverage was relatively low at all sites and was less likely to be found at the more degraded wetlands on Lake Ontario. The range and coverage of NPE appears to be fairly consistent across years, with some variability likely explained by changes in the site selection.

*Typha:* The distribution of *Typha sp*. follows the same pattern in all years, with coverage peaking at 74.8 m (245.4 ft) or 75.0 m (246.1 ft).

*MM (Meadow marsh):* The meadow marsh guild appears to have experienced the most change out of all guilds in 2017 (Figure 7-3). The average cover for meadow marsh was lower this year as these species were stressed by flooding for a large portion of the growing season. Interestingly, the elevations at which MM experienced the highest coverage have shifted; in past years, the peaks were generally at 75.2 m (246.7 ft) and 75.4 m (247.4 ft), whereas this year, the coverage was highest at 75.6 m (248 ft) and 75.8 m (248.7 ft).

*UPL (Upland):* The upland guild distinguishes vegetation that does not typically occur in wetlands. Coverage for UPL was generally lower at 75.6m and 75.8m than in previous years, except for 2015, where there were relatively few upland species found.

*Shrub:* In 2017, the average cover of shrub species at the high end of the elevation gradient was less than in previous years. This may be an artifact of site selection and the survey methodology, since areas with dense shrub cover were not always accessible and there were difficulties acquiring a GPS signal. However, observations of shrubs that were flooded or apparently had suffered from flooding early in the season were made. The effects may be more apparent in the following year.

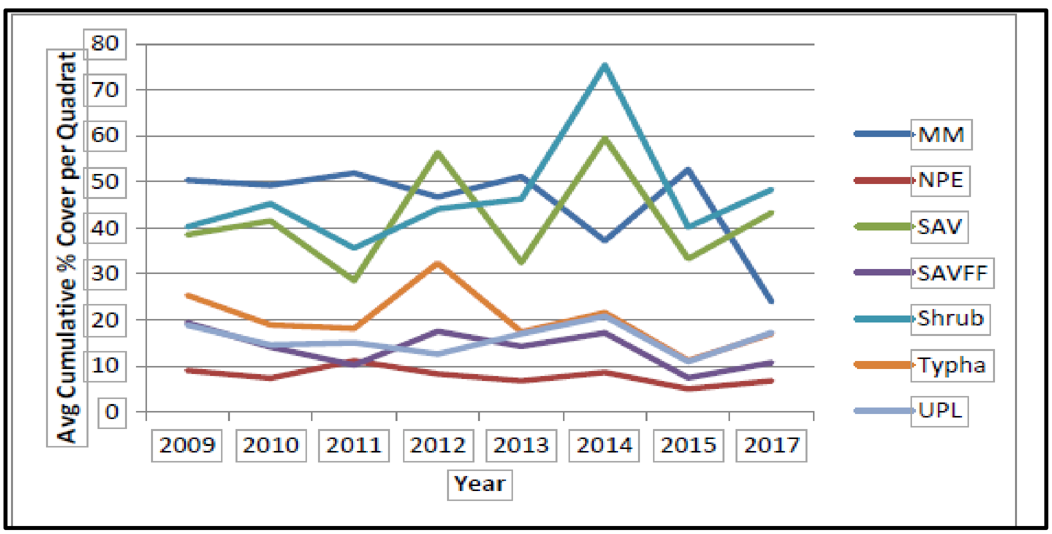


Figure 7-3: Average cumulative percent cover by quadrat per study site, by year. Source: Howard, 2018.

IWI Project / Monitoring of Lake Ontario wetland habitat in the US:

The primary purpose of this project is to report on vegetation data collected in 2017 to support wetland monitoring for adaptive management of Lake Ontario water levels. The collection methods employed were developed by the CWS and also used in the US work done in 2012 and 2014.

The US sample sites were 16 randomly-selected wetlands spanning the US side of Lake Ontario and the upper St. Lawrence River. Of those 16, there were four of each of the primary geomorphic type: barrier beach (BB), drowned river-mouth (DRM), open embayment (OE), and protected embayment (PE) (Table 7-2).

Table 7-2: Study Wetlands: Sites are identified as being in the Lake Ontario basin (LO) or St. Lawrence River (SLR), greater or less than 50 acres (Size), and by the hydrogeomorphic type (BG: barrier beach, DRM: drowned river-mouth, OE: open embayment, PE: protected embayment).

| **Wetland Name** | **Waterbody** | **Size** | **HGM** |
|---|---|---|---|
| Round Pond | LOS | Large | BB |
| Lakeview Pond | LOS | Large | BB |
| Maxwell Bay | LOS | Small | BB |
| North Pond Area | LOS | Small | BB |
| Brush Creek | LOS | Large | DRM |
| North Buck Bay Area | SLR | Small | DRM |
| Port Bay | LOS | Large | DRM |
| Sterling Creek | LOS | Large | DRM |
| Braddock Bay | LOS | Large | OE |
| Flatiron Marsh | SLR | Small | OE |
| Isthmus Marsh | LOS | Small | OE |
| Perch River | LOS | Large | OE |
| Grass Point | SLR | Small | PE |
| Muskalonge Bay | LOS | Large | PE |
| Rift Area | SLR | Small | PE |
| Sodus Bay | LOS | Large | PE |

Vegetation was sampled along transects running from the upland into the water to precisely measure the elevation of each vegetation type. High-precision GPS units were employed to sample from 76.0 m (249.3 ft) to 74.0 m (242.8 ft) of the International Great Lakes Datum (IGLD). At every 20 cm (0.66 ft) elevation within that range, percent cover information was collected for all vegetation within a 1 x 0.5 m (3.3 x 1.6 ft) quadrat sampling frame. This was repeated along five transect lines within each of the 16 wetlands. The data suggest that there was a small response of vegetation to the very high water levels in 2017, with meadow marsh decreasing in overall percent cover but also seen in increasing density at elevations higher than the highest abundance of 2012 and 2014 (Figure 7-4).

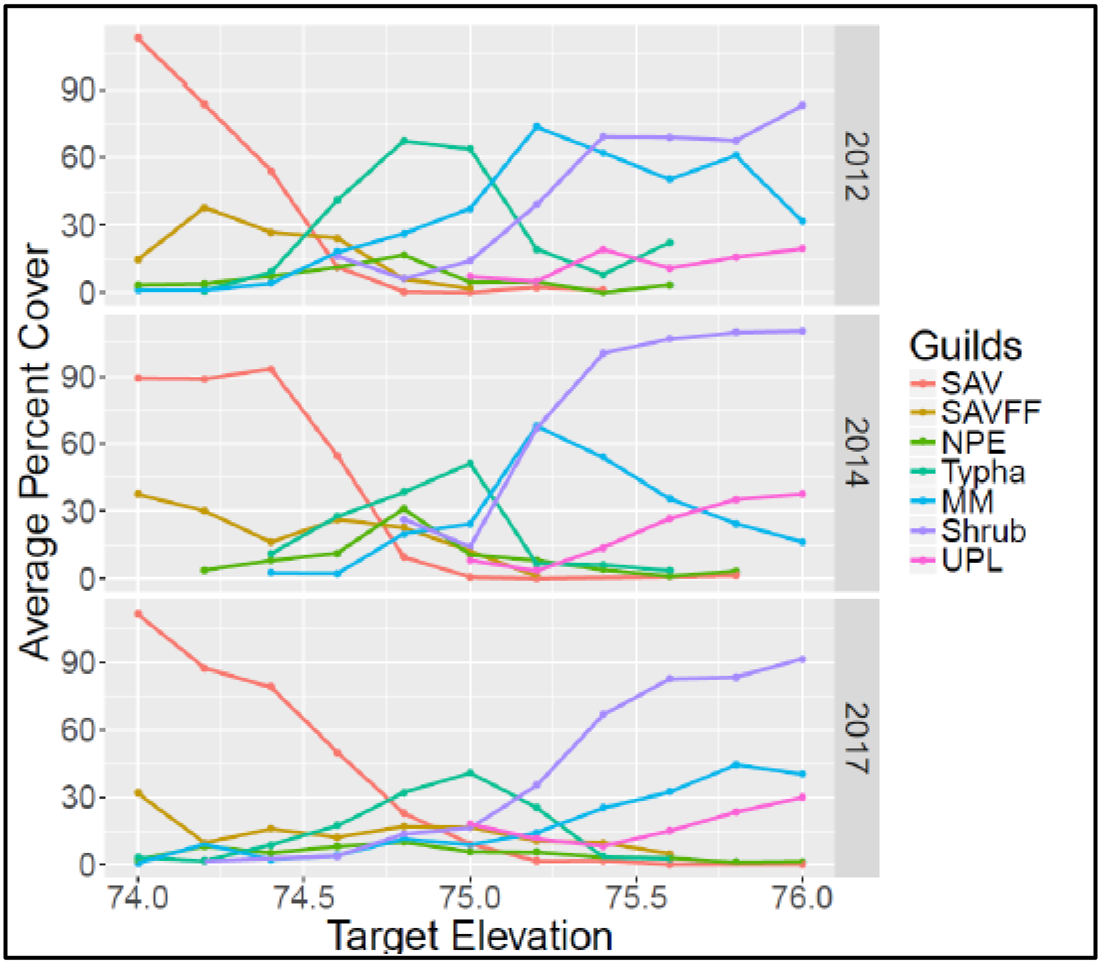


Figure 7-4: Average percent cover of species data collected in quadrats at 16 sites, plotted by targeted elevation and grouped by guilds. Guild definitions follow Grabas and Rokitnicki-Wojcik (2015): SAV = submerged aquatic vegetation, SAVFF = submerged aquatic vegetation free floating; NPE – non-persistent emergent; Typha = cattail; MM = Meadow Marsh; Shrub = Shrubs; UPL = upland species

A few observations about the similarities and differences among the three sample years are worth noting. First, recall that lake levels increased for each of the three years with maximum highs ranging from 74.9 m (245.7 ft) in 2012 to 75.17 m (246.6 ft) in 2014 and 75.82 m (248.8 ft) in 2017, and while previous year flooding levels increase the complexity, this provides a simple picture to start with. With the exception of the SAV and Shrub guilds, overall percent cover was lower for all guilds in 2017, suggesting that flooding may have compressed vegetation types within a lower band of elevation for most species in 2017.

The data collected through elevation transect surveys using Real Time Kinematic (RTK) GPS equipment are consistent and of high enough resolution to effectively capture and track vegetation changes in reference to elevation. The data allow for both qualitative and quantitative assessments of change, ranging from univariate assessments of the abundance of a single species or groups of species along the elevation gradient to multispecies assessments using multidimensional statistical techniques.

The representation of different vegetation guilds was assessed among the 2012, 2014, and 2017 sampling events and found some indications of shifting proportions (Figure 7-4). The increase in the tail of the curve to higher elevations for SAV shows that field surveyors found species grouped into the SAV guild at higher and higher elevations in 2014 and 2017. These were often individuals that were stranded in the mud from earlier season high water events. Since the summer high in 2012 was relatively low, this makes sense and might be a useful indicator of early season flooding: evidence of species from the SAV guild rooted in mud at higher elevations. Vegetation types are divided into four main groups and defined as ABC, D, EF, and G. These transects were sampled in 2003 (Wilcox et al, 2004) and ordination analysis indicated that transects A, B, and C represented the same vegetation assemblage, as did transects E and F. The ABC group generally represented the meadow marsh community, the D transect represented a transition zone between meadow marsh and cattails, the E and F transects had high percent coverage of cattails (*Typha*), while the G transect had the highest percent coverage of floating and submerged aquatic vegetation (Table 7-3).

Table 4:The estimated mean elevation in meters for the vegetation expression of each of the LOSLR transect sample groups (ABC, D, EF, G) for years 2012, 2014, and 2017. Estimates are provided for each hydrogeomorphic (HGM) type and for all HGM types combined.

| HGM | Year | ABC | D | EF | G |
|---|---|---|---|---|---|
| BB | 2012 | 75.29 | 74.67 | 74.48 | 74.19 |
| BB | 2014 | 75.61 | 74.94 | 74.69 | 74.28 |
| BB | 2017 | 75.81 | 75.12 | 74.79 | 74.29 |
| DRM | 2012 | 75.43 | 74.87 | 74.67 | 74.21 |
| DRM | 2014 | 75.45 | 74.95 | 74.75 | 74.33 |
| DRM | 2017 | 75.70 | 75.21 | 74.96 | 74.25 |
| OE | 2012 | 75.25 | 74.83 | 74.60 | 74.15 |
| OE | 2014 | 75.54 | 75.10 | 74.86 | 74.38 |
| OE | 2017 | 75.68 | 75.28 | 75.01 | 74.38 |
| PE | 2012 | 75.61 | 75.07 | 74.86 | 74.33 |
| PE | 2014 | 75.50 | 75.02 | 74.83 | 74.40 |
| PE | 2017 | 75.70 | 75.25 | 75.02 | 74.36 |
| all | 2012 | 75.51 | 74.94 | 74.72 | 74.31 |
| all | 2014 | 75.51 | 74.96 | 74.73 | 74.29 |
| all | 2017 | 75.69 | 75.19 | 74.92 | 74.33 |

## 7.4 General surveillance

The GLAM Committee was unable to identify any on-going research efforts on the lower St. Lawrence River regarding water level changes in 2017 and the impacts of those changes on the eco-system. Several additional PIs were expected to be impacted due to the 2017 conditions. At this point, no data have been collected on these PIs to corroborate the anticipated impacts from the 2017 conditions. Further efforts are being pursued to establish responses from these PIs. Additional PIs expected to be impacted due to the 2017 conditions are as follows:

- Changes in bird nesting habitat due to the availability of specific plant species sought by endangered/ threatened bird species;
- *Typha* (cattail) die-back due to long term exposure to high water as predicted in the wetlands model;
- Fish spawning increase due to expanded spawning habitat. Habitat increase can be due to any number of factors and there is not enough information available at this juncture to conclude with any degree of certainty the cause of increased spawning habitat;
- Shorelines experiencing heavy tree loss creating debris fields and the associated impacts to water quality and/or species habitat; and
- Shoreline changes such as cut back of dunes and subsequent habitat loss for dune nesting birds, and the breaching of barrier beaches causing the exposure of protected wetlands to open lake waves.

An ongoing research effort involving academic partners from Clarkson University, Middlebury College, and the River Institute (Cornwall) are assessing the impacts of water level regulation on mercury mobilization in riparian wetlands in the Upper St. Lawrence River (Twiss et al, 2018). Mercury mobilization may also be occurring in urban areas and pinpointing the driving factors is not possible at this point in time. This research is ongoing and has four objectives:

- Determine with a high degree of certainty the mass and speciation of legacy Hg and nutrients retained in St. Lawrence River riparian wetlands;
- Establish the activity of coincident Hg-methylating microbes as a method of predicting methylmercury source and potential formation;
- Confirm the potential Hg inputs from wetland sediments in the Upper St. Lawrence River to support adaptive management decisions on water level regulation; and
- Provide the necessary accurate and meaningful information needed to support improved ecosystem-based management decisions on water resources in the St. Lawrence River to the benefit of numerous stakeholders.

The USACE has been collecting hydrologic, water quality, and vegetation data for the Braddock Bay Ecosystem Restoration project since 2016. The project began in January 2016 with the excavation of approximately seven acres of channels and potholes within the existing marsh. After excavation was completed in March 2016, channel and pothole benches and habitat mounds were seeded with native seed mixes. Plugs of native wetland plants were planted in June of 2016. Cattail in the invasive species areas was mechanically removed in late July and treated chemically in late September. Phragmites stands were treated in late September and then removed mechanically in late October. Construction of the barrier beach began in August. Placement of the stone portions of the barrier beach were completed by December 2016.

Minimal progress was made towards completion of the project in 2017 due to record setting high water levels on Lake Ontario. At its June peak, water levels reached 75.88 m or 248.95 feet (+5.65 feet LWD) (Figure 7-1). This precluded the placement of beach sand on the barrier beach, placement of sand in the "new" emergent wetland, and treatment of *Typha* (cattail) and *Phragmites* (common reed). The only substantial progress made was in the placement of the low stone sill enclosing the "new" emergent marsh (USACE – Buffalo, 2018).

Additional work for 2018 will include sand placement on the barrier beach, installing live stakes and plugs on the barrier beach, additional treatment of cattail and phragmites, and filling and planting the 2.7 acre of "new" emergent marsh within Braddock Bay.

Additional vegetation data were collected by State University of New York (SUNY) Brockport between the days of 7 June 2017 and 16 August 2017, 16 months after the completion of channel and pothole excavation. Preliminary monitoring results indicate that restoration efforts have improved the diversity of the vegetation community. Comparison of data from subsequent years will be useful in monitoring whether the trends of increased vegetative diversity continue. Anecdotal evidence of potential beneficial impacts to the ecosystem are represented by a Young of Year (YOY) Northern Pike that was captured in a restored Braddock Bay Pothole on June 18$^{th}$, 2018 (USACE – Buffalo, 2018).

The GLAM Committee is currently actively engaged in the development of long term monitoring programs to collect response data on specific PIs. As part of this effort, the IWI project on state of science of remote sensing for ecosystem indicators is currently underway and should provide some specific methodologies that could be engaged in to establish long term monitoring programs that the GLAM Committee could manage with its' limited resources.

## 7.5 Model/PI validation

### 7.5.1 Lake Ontario and Upper River model efforts and Results:

In order to identify the specific PIs impacted by 2017 conditions, two approaches were employed. The first was an analysis of the original LOSLRS algorithms and comparison from the thresholds associated with those algorithms and the observed 2017 conditions indicating impacts to specific species indicators. The second was an analysis of the IERM model results employing a representative water supply year from the historic series to represent the conditions observed in 2017.

Table 7-4: Environmental PIs from LOSLRS for Lake Ontario and the Upper St. Lawrence River. * - indicates priority subsets of key environmental indicators

| |
|---|
| **Lake Ontario** |
| *Vegetation:* |
| 1. *Wetland Meadow Marsh Community - Total surface area, supply-based (ha) |
| *Fish:* |
| 2. Fish Guild (Low Vegetation, 18C) - Spawning habitat supply |
| 3. *Fish Guild (High Vegetation, 24C) - Spawning habitat supply |
| 4. Fish Guild (Low Vegetation, 24C) - Spawning habitat supply |
| 5. *Northern Pike – Young-of-year recruitment (#ha) |
| 6. Largemouth Bass – Young-of-year recruitment (#ha) |
| *Birds:* |
| 7. *Virginia Rail (RALI) - Median reproductive index (index) |
| 8. Least Bittern (IXEX) - Median reproductive index (index) (Species at risk) |
| 9. *Black Tern (CHNI) - Median reproductive index (index) (Species at risk) |
| 10. Yellow Rail (CONO) - Preferred breeding habitat coverage (ha) (Species at risk) |
| 11. King Rail (RAEL) - Preferred breeding habitat coverage (ha) (Species at risk) |
| **Upper St. Lawrence River** |
| *Fish:* |
| 12. Fish Guild (Low Vegetation, 18C) - Spawning habitat supply from Thousand Islands to Lake St. Lawrence |
| 13. *Fish Guild (High Vegetation, 24C) - Spawning habitat supply from Thousand Islands to Lake St. Lawrence |
| 14. Fish Guild (Low Vegetation, 24C) - Spawning habitat supply from Thousand Islands to Lake St. Lawrence |
| 15. *Northern Pike – Young-of-year (YOY) recruitment (#ha) from Thousand Islands to Lake St. Lawrence |
| 16. Largemouth Bass – YOY recruitment (#ha) from Thousand Islands to Lake St. Lawrence |
| 17. *Northern Pike – YOY net productivity (grams (wet wt.)/ha) in Thousand Islands area |
| *Birds:* |
| 18. *Virginia Rail (RALI) - Median reproductive index (index) on Lake St. Lawrence |
| Mammals: |
| 19. *Muskrat (ONZI) - House density in drowned river mouth wetlands (#ha) in Thousand Islands area |

The LOSLRS PI algorithms were developed with the input of various professional experts that set metrics for some of the more critical species indicators. In order to establish which species were likely impacted by the 2017 conditions, an assessment of the water level fluctuations and static quarter month levels was done with respect to the individual indicator's algorithms noted with an asterisk in Table 7-4. These algorithms define specific conditions during quarter month time frames that are expected to impact the performance of that species in that year. For example, during quarter months 18 through 26 (roughly the 2nd week of May through the 2nd week of July), Lake Ontario water level fluctuations exceeding a raise or drop of more than 0.2 m (0.66 ft) per quarter month (approximately 1 week) are expected to negatively impact wetlands birds Least Bittern and Black Tern, which are considered species at risk, as well as the Virgiana Rail (Giguere, S. et al., 2005). 2017 conditions did not exceed a 0.2 m fluctuation in any specific quarter month within the targeted timeframe, therefore there was no negative impact forecasted by the algorithm for these species. Another factor in the success rate of these wetland birds is the mean water depth below nests within the emergent marsh areas of wetlands. To be successful, nesting Least Bittern need a mean water depth between 0.2 meters and 1.0 meters below their nest. The mean elevation of emergent marsh for all types of HGM wetlands in 2017 was 74.92 m, as established in the 2017 field sampling analysis of the US wetlands. In 2017 Lake Ontario crested at 75.88 m in quarter month 21 which translates to a mean water depth of 1.04 m within the emergent marsh zone. This is slightly above the algorithm's anticipated maximum water depth below nests for Least Bittern at several different study locations in the sensitive quarter month time frames. Therefore, Least Bittern's reproductive potential was identified by the algorithm to be negatively impacted by the 2017 conditions. The Least Bittern was the only species in Table 7-4 assessed to be negatively impacted by 2017 conditions.

The second method's modeling runs performed on the ecosystem PIs revealed that a comparative high water year selected from the historic set of water supplies produced the most impacts in the PIs of the Least Bittern, Virginia Rail, Black Tern, and Upper St. Lawrence River muskrat housing density. The original study algorithm placed significant impact to these bird species related to high water events occurring during the months of May, June and July. This, of course, means that the 2017 event would be expected to significantly benefit these PIs. Though the exploratory model results indicated significant positive impacts to muskrat housing density, the study algorithm emphasized impacts to this PI during high water events from September through February. While water levels were significantly lower in the fall compared to their record high spring and early summer levels, they did remain well above average into the fall months. The NYDEC has a monitoring program ongoing for muskrat which could help validate the algorithm for this PI in future years, but data for muskrats will likely be unavailable prior to the October deadline.

Species identified as likely to have been impacted by the 2017 conditions serve as a focal point for the GLAM Committee ecosystem monitoring efforts moving forward. Data collection on the success or detriment of these indicators need to be pursued in the near future timeframe. These data will be useful to validate the study algorithms and update the IERM models.

**Lake Ontario Wetlands algorithm**

The Integrated Ecological Response Model (IERM) calculates wetland vegetation elevation response based on Lake Ontario water levels using the:

- *dewatering elevation* (highest annual peak QM water level) for vegetation response to dry conditions; and
- *flooding elevation* (fourth highest QM water level around the annual peak water level to represent the highest month of flooding) for vegetation response to wet conditions.

High water levels such as those experienced in 2017 are expected to flood and eradicate upland shrubs and trees (red area in the graph) and meadow marsh (green area in the graph) up to the flooding elevation. The flooding elevation as described above for 2017 is 75.82 m (248.75 ft) IGLD85 and the IERM algorithm predicts that Cattail-dominant meadow marsh plant community (yellow area in the graph) would rise in elevation up to 75.82 m (248.75 ft) IGLD 85. The IERM algorithm is currently programmed to have vegetation respond to water levels from the year before; in other words, the current algorithm expects the eradication of upland shrubs and trees and meadow marsh would occur in 2018, one year after the 2017 high water levels. Figure 7-5 shows that, in 2017, the IERM algorithm predicts that meadow marsh (green area) and upland vegetation (red area) will remain unaffected in 2017 by high water levels (annual flooding elevation blue line). Although it is not visible in Figure 7-5, those plant communities would be eradicated up to 75.82 m (248.75 ft) IGLD 85 in 2018 in the IERM algorithm.

At a wetlands experts workshop hosted by the GLAM Committee at the beginning of April 2017, wetland experts debated whether the vegetation response to water level conditions should be in the same year. In other words, the eradication of upland shrubs, trees and meadow marsh would occur in 2017 - the same year as the high water levels. The IERM algorithm was modified to allow the vegetation to respond to high water levels of the same year so this could be tested against the monitored data. Figure 7-6 displays the vegetation response with the modified algorithm and it shows that in 2017 the Cattail-dominant meadow marsh (yellow area) plant community has overtaken plant communities at higher elevations up to the flooding elevation of 75.82 m (248.75 ft) IGLD 85 for 2017.

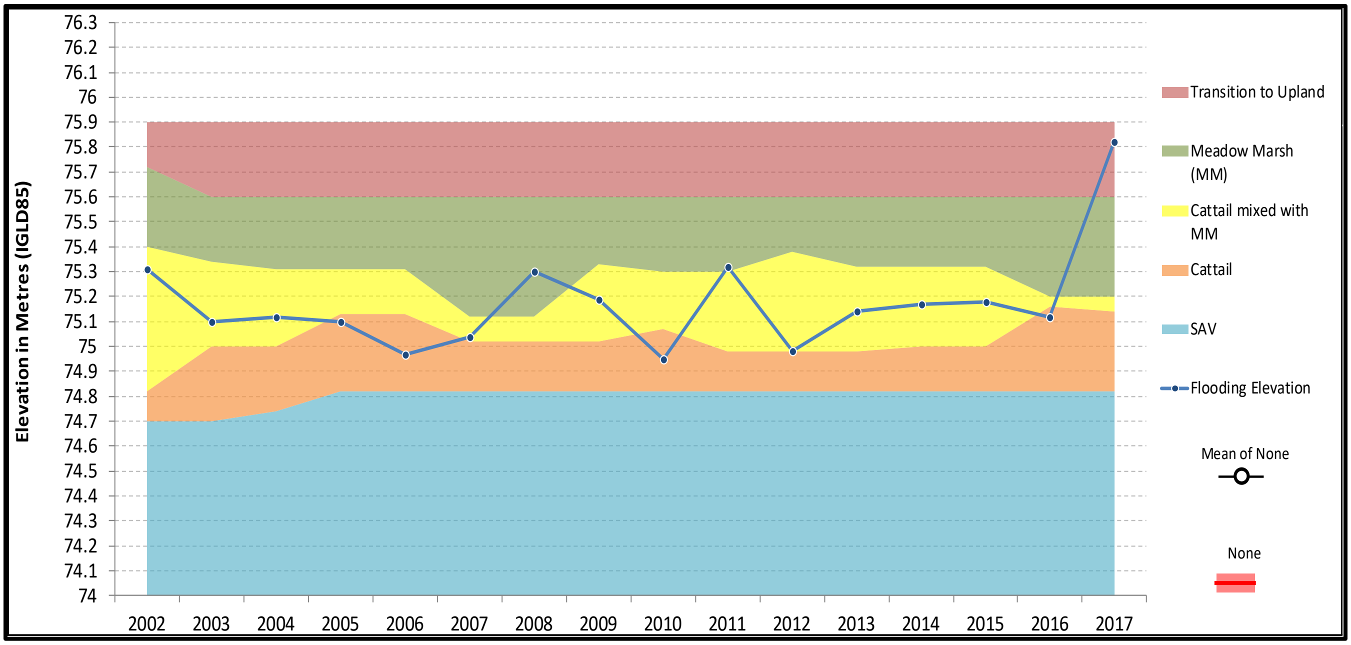


Figure 7-5: IERM algorithm vegetation response (background colours) based on water levels from 2002 to 2017.

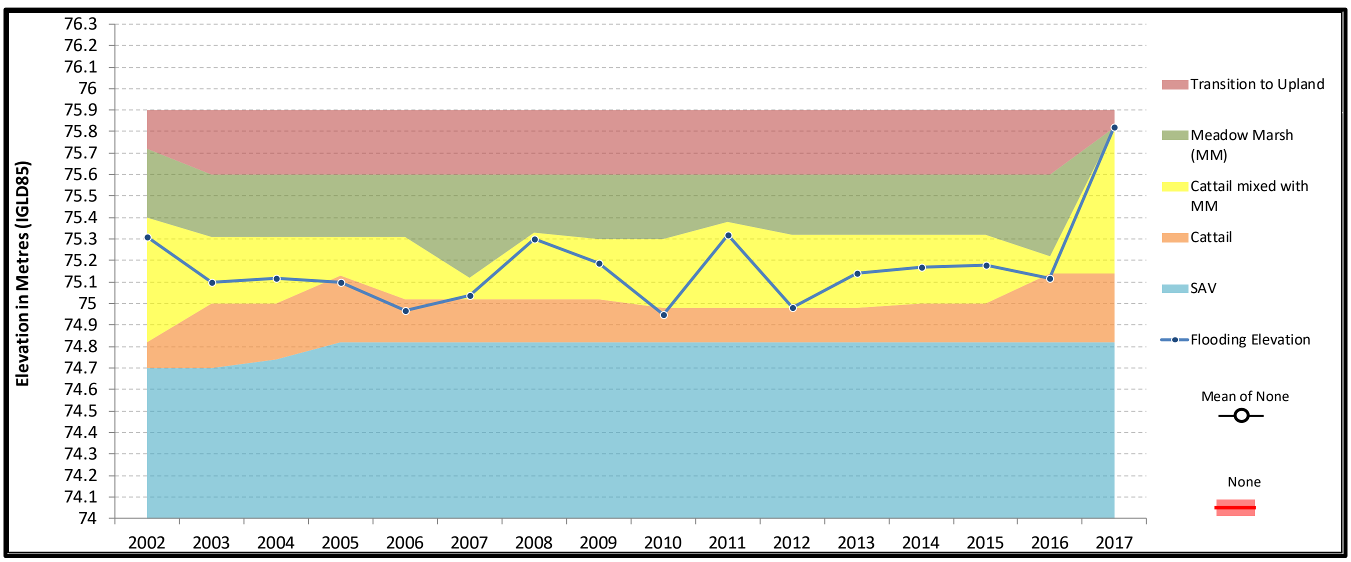


Figure 7-6: Modified IERM algorithm vegetation response (background colours) based on water levels from 2002 to 2017.

### 7.5.2 Lower St. Lawrence River model efforts and results:

As stated in the Main Report, there was no available monitoring data for 2017 for species specific PIs with which results for the lower St. Lawrence River IERM model could be verified. Therefore, the following discussion describes the IERM PIs only. Several environmental PIs were developed during the LOSLRS that aimed to quantify/qualify the impacts of discharge regulation on fauna and flora on the lower St. Lawrence River. The 11 indicators presented herein are the key indicators selected from a large number of environmental indicators (more than 200) developed for the lower St. Lawrence River that were found to be the most sensitive, significant and having the greatest level of certainty in terms of the science and model results. Table 7-5 indicates how the model predicts those PIs responded in 2017 along the various sections of the lower St. Lawrence River during a year in which an important flood occurred.

Table 7-5: Modelled Environmental PI Response on the lower St. Lawrence River

| Model | PI | St-Louis | Verchères | St-Pierre | Varennes | Sorel | Trois-Rivières | Tendency in 2017 | Comments |
|---|---|---|---|---|---|---|---|---|---|
| NOCR | Golden Shiner – suitable feeding habitat area | - | = | = | = | - | = | - | Lowest score ever |
| ANPL - | Migratory Waterfowl habitat area | = | = | + | = | + | = | + | Highest score since 2010 |
| IXEX | Least Bittern reproductive index | - | - | - | - | - | - | - | Lowest score since 2011 (0 ha) |
| RALI | Virginia Rail reproductive index | - | - | - | - | - | - | - | Lowest score since 1986 |
| ANPL - | Migratory Waterfowl productivity (nesting) | - | = | + | = | + | = | = | Little change |
| CHNI | Black Tern reproductive index | - | - | - | - | - | - | - | Lowest score since 2005 |
| ESLU | Northern Pike | = | = | = | = | = | = | = | No change |
| AMPE | Eastern Sand Darter reproductive area | = | - | - | = | - | = | - | Lowest score since 1974 |
| GRGE | Map Turtle reproductive habitat area *(replaces Spiny Softshell turtle)* | - | - | - | - | - | - | - | Lowest score since 1983 |
| NOBI | Bridle Shiner | - | - | - | - | - | - | - | Lowest score ever |

## Fish "feeding ground" habitat models

The fish feeding ground habitat models are models representing the surface area with suitable feeding and living habitat for various species. PIs have been developed for 10 fish species, the key one reported in the Plan 2014 evaluation was Golden Shiner.

The effect of the 2017 flood on the 10 fish species was not uniform. For example, the surface area obtained for this model for Walleye (STVI), is the highest since the mid-’80s as was the case for Sauger (STCA and Lake Sturgeon (ACFU) (not shown).

However, other species, such as the Golden Shiner (NOCR, Table 7-5), as well as the Pumpkinseed (LEGI), Yellow Perch (PEFL), Largemouth Bass (MISA), and Shiner (NOHU) all saw the surface area with suitable feeding ground decrease with the 2017 flood, some to the lowest levels recorded, along with a loss of habitat, particularly in the Lake Saint-Louis, Lake Saint-Pierre and Sorel regions.

Fish "reproduction habitat" model

A model to evaluate the impact of water levels on fish reproduction habitat for Northern Pike (ESLU) (shown in Figure 7-7) showed no impact to the surface area of suitable habitat for the reproduction as a result of the 2017 flood.

Table 7-6: Fish reproduction habitat model results

| Fish "reproduction habitat" model | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | **Species** | **St-Louis** | **Verchères** | **St-Pierre** | **Varennes** | **Sorel** | **Trois-Rivières** | **Tendency in 2017** | **Comments** |
| ESLU | Northern Pike | = | = | = | = | = | = | = | |
| PEFL | Yellow Perch | = | = | + | = | + | = | + | Highest score ever |

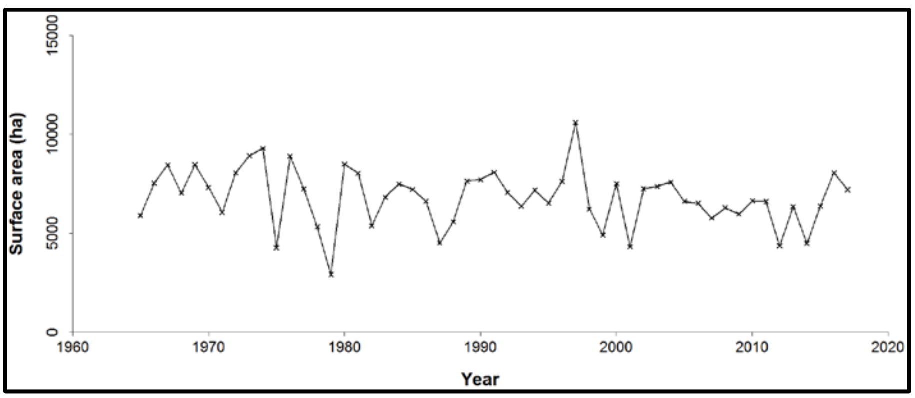


Figure 7-7: Model results of impacts of water levels on area of fish reproduction habitat.

Species at risk: reproduction habitat

A habitat model was created for four species at risk: the Least Bittern (IXEX; Figure 7-8), the Eastern Sand Darter (AMPE; Figure 7-9), the Map Turtle (GRGE) and the Bridle Shiner (NOBI; Figure 7-10). According to the model, all of these species predicts the mean surface area with suitable habitat was reduced under 2017 and this is the case in almost all sections of the St. Lawrence River (Table 7-7).

Table 7-7: Impacts to various species at risk reproduction habitat.

| Species at risk: reproduction habitat | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | **Species** | **St-Louis** | **Verchères** | **St-Pierre** | **Varennes** | **Sorel** | **Trois-Rivières** | **Tendency in 2017** | **Comments** |
| IXEX | Least Bittern | - | - | - | - | - | - | - | Lowest score since 2011 (0 ha) |
| AMPE | Sand Darter | = | - | - | = | - | = | - | Lowest score since 1974 |
| GRGE | Map Turtle | - | - | - | - | - | - | - | Lowest cost since 1983 |
| NOBI | Bridle Shiner | - | - | - | - | - | - | - | Lowest score ever |

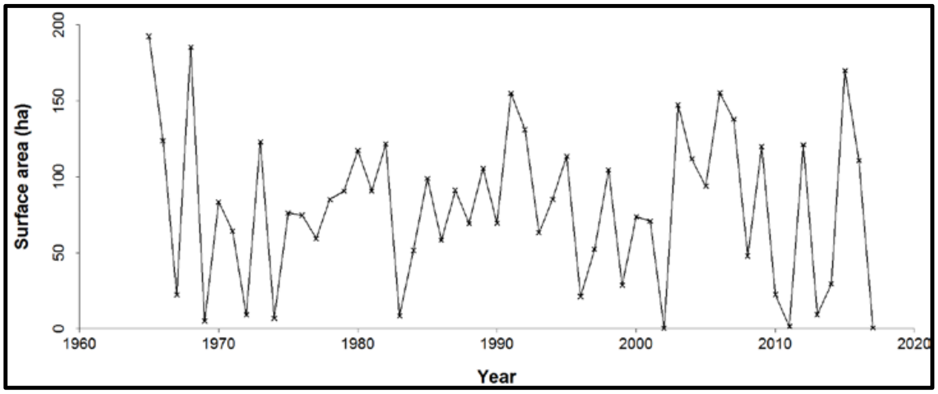


Figure 7-85: Model results of mean surface area (hectares) of the reproduction habitat of the Least Bittern between 1965 and 2017.

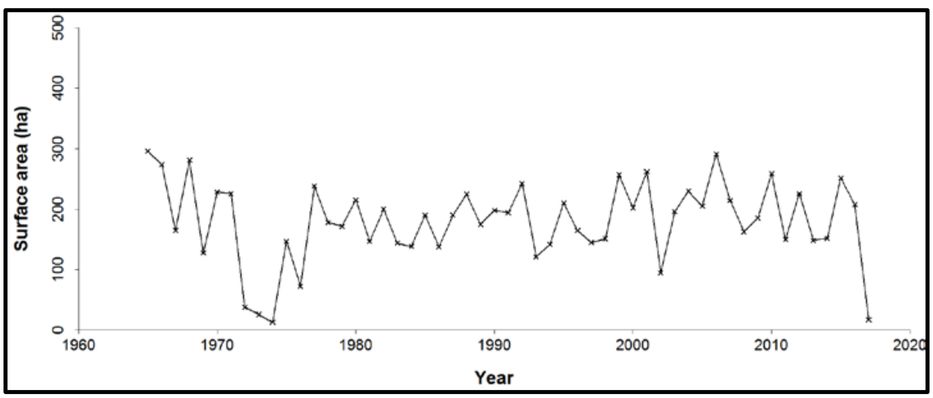


Figure 7-9: Model results of mean surface area (hectares) of the reproduction habitat of the Sand Darter between 1965 and 2017.

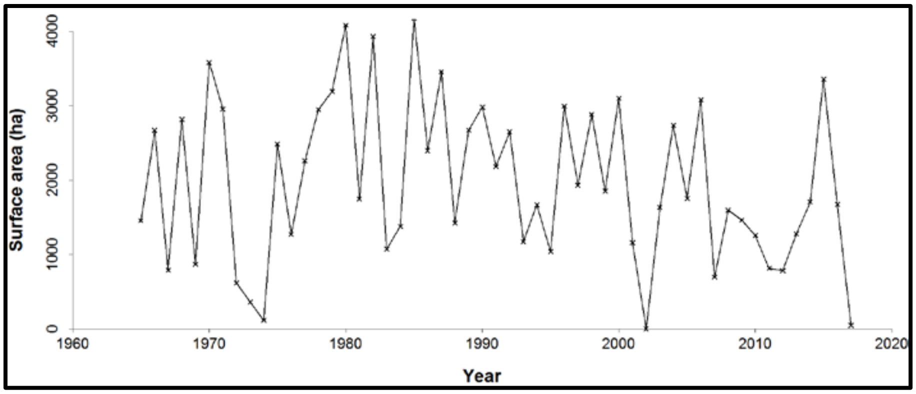


Figure 7-10: Model results of mean surface area (hectares) of the reproduction habitat of the Bridle Shiner between 1965 and 2017.

## Migratory birds

The surface area of habitat for the migration of waterfowl had increased during the 2017 flood (Figure 7-11), while the surface area for the habitat for the nesting of those birds did not change (Table 7-8). The score obtained for the migration model was the highest since 2010.

Table 7-8: Impacts on migratory birds habitat

| Migratory birds | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | **Species** | **St-Louis** | **Verchères** | **St-Pierre** | **Varennes** | **Sorel** | **Trois-Rivières** | **Tendency in 2017** | **Comments** |
| ANPL - nesting | Waterfowl | - | = | + | = | + | = | = | |
| ANPL - Migration | Waterfowl | = | = | + | = | + | = | + | Highest score since 2010 |

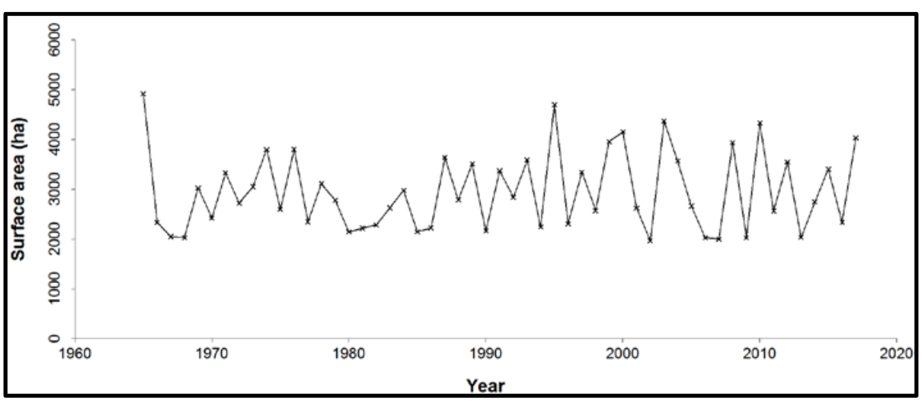


Figure 7-11: Model results of mean surface area (hectares) of the habitat suitable for the waterfowl migration between 1965 and 2017.

Wetland birds

Most of the wetland birds for which a habitat model has been developed have seen their PI scores being reduced in 2017 and this is reflected in the two wetland bird species included in the Plan 2014 evaluation including the Black Tern (CHNI) and the Virginia Rail (RALI) (Table 7-9 and Figure 7-12). They lost habitat in all sections of the St-Lawrence River. S imilar model results were seen for other wetland birds including the Veery (CAFU), the Marsh Wren, the Common Moorhen (GACH) and the Song Sparrow (MEME) (not included in Table 7-9). Most of those scores were the lowest in the past 30 to 40 years. The Swamp Sparrow (MEGE) is the only one that the model estimates to have an increase in the surface area of its habitat in 2017 (Figure 7-13).

Table 7-9: Impacts to wetland Bird's habitat.

| **Wetland birds** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | **Species** | **St-Louis** | **Verchères** | **St-Pierre** | **Varennes** | **Sorel** | **Trois-Rivières** | **Tendency in 2017** | **Comments** |
| BOLE | American Bittern | - | - | - | - | - | - | - | Lowest score since the '70 |
| CAFU | Veery | - | - | - | - | - | - | - | Lowest score since the '70 |
| CHNI | Black Tern | - | - | - | - | - | - | - | Lowest score since 2005 |
| CIPA | Marsh Wren | - | - | - | - | - | - | - | Lowest score since the '70 |
| GACH | Common Moorhen | - | - | - | - | - | - | - | Lowest score since 2007 |
| MEGE | Swamp Sparrow | + | + | + | + | + | + | + | Highest score since 2014 |
| MEME | Song Sparrow | - | - | - | - | - | - | - | Lowest score since 2002 |
| RALI | Virginia Rail | - | - | - | - | - | - | - | Lowest score since 1986 |
| | | | | | | | | | |

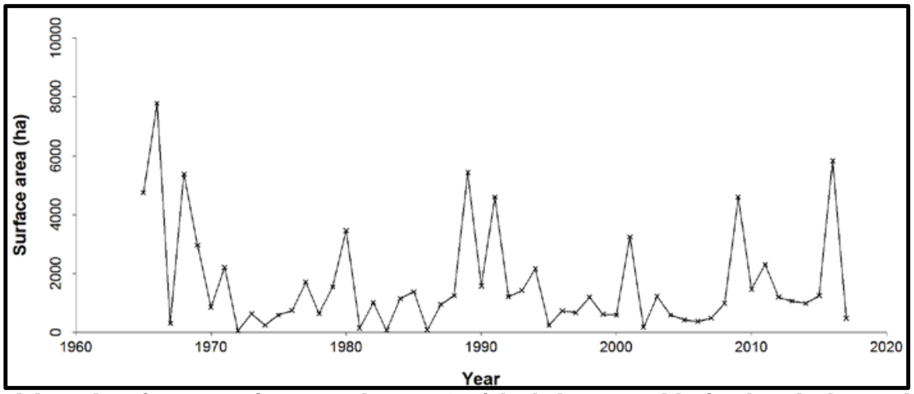

Figure 7-12: Model results of mean surface area (hectares) of the habitat suitable for the Black Tern between 1965 and 2017.

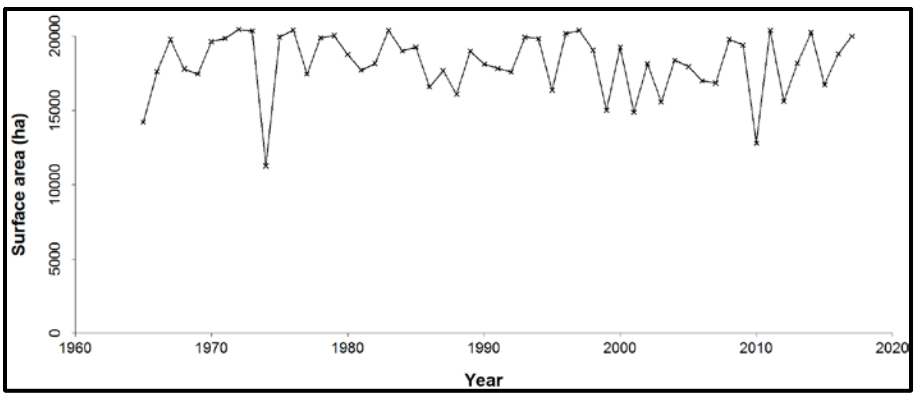

Figure 7-13*:* Model results of mean surface area (hectares) of the habitat suitable for the Swamp Sparrow between 1965 and 2017.

Muskrat

The muskrat was not impacted by the 2017 flood (Table 7-10). The season where this species is sensitive to water level fluctuation is not during the spring flood, but during fall when it builds its lodge for overwintering.

Table 7-10: Tendency of different PIs expressing the response of the muskrat in six regions of the St-Lawrence River in 2017 (=: no change in the PI value; +: increase of the PI value compared to the previous years, -: decrease of the PI value compared to the previous years).

| Muskrat | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | **Species** | **St-Louis** | **Verchères** | **St-Pierre** | **Varennes** | **Sorel** | **Trois-Rivières** | **Tendency in 2017** | **Comments** |
| ONZI | Musrat | = | = | = | = | + | = | = | |

Wetland classes

No impact on the surface area of the different wetland classes have been detected in 2017 (not shown). This is normal since the time reaction to a water level fluctuation can go from 1 to 10 years in the different models. The effect of the 2017 flood will begin to be perceptible only in 2018, especially in the Meadow Marsh.

## 7.6 Adaptive responses

The GLAM Committee identified the opportunity for Conservation Authorities or other provincial, state, or local agencies and other program managers to encourage naturalized shoreline re-development in response to detrimental impacts to the ecosystem as a result of the 2017 water level conditions. Any efforts of these agencies to pursue naturalized shoreline re-development will be tracked for report inclusion.

The GLAM Committee coastal wetland monitoring and indicator development for long-term assessment will also be considered moving forward. Initial results from the field surveys and model runs indicate that the need for development of effective, manageable long-term monitoring plans are essential. In order to validate and calibrate the existing modelling tools, verifiable field data must be collected and comparative model runs executed to ensure that the expected results align with the observed conditions. The GLAM Committee is will also be looking at how remote sensing approaches may support monitoring in the future and initiated a preliminary literature review in this area in 2017 (Ryerson, 2018).

# 8.0 Recreational Boating and Tourism

## 8.1 Summary of GLAM work and other agency activities to assess impacts

Water level impacts from the 2017 high water were gathered through:

1) efforts the GLAM Committee directly manages, and
2) efforts undertaken by outside groups and agencies independently from the GLAM Committee.

Immediate activities under GLAM control are listed in Table 8-1 and include a review of oblique photography to visually assess inundation at marina facilities and boat launches, site visit photographs at a few example marina facilities, an assessment of state boat ramps within New York and tracking of media reports. It should be noted that most information assessed within the current GLAM Committee activities relates to observations on direct impacts to recreational boating activities (e.g. inundation of docks) while the PI is willingness-to-pay, a measure of recreational boating opportunity. For this report, indicators such as apparent loss of access to facilities are being used to illustrate potential impacts. Moving forward, the GLAM Committee is engaging a contractor to undertake a marina and yacht club survey which will help gather information on the extent of business loss and use impacts. The survey was not completed in time for information to be included in this report and therefore it is not listed in the table. Figure 8-1 shows the geographic reaches used for the LOSLRS recreational boating indicator.

Table 8-1: Activities managed by the GLAM Committee that provide information on recreational boating and tourism impacts from 2017.

| **Activity** | **Lake Ontario** | | **Upper St. Lawrence** | | **Lower St. Lawrence** | **Relation to Recreational Boating and Tourism PIs** |
|---|---|---|---|---|---|---|
| | **US** | **CAN** | **US** | **CAN** | **CAN** | |
| Oblique Imagery Acquisition and Assessment | Yes | Yes | No | No | Yes | Inundation under static water level conditions of recreational boating facilities (primarily marinas and larger facilities) |
| Database of Site Visit Photographs | Yes | Yes | Yes | Yes | Partial | Site specific examples of flooding (inundation) at a selection of marina and boat launch sites |
| Closures of New York State boat launches | Yes | NA | Yes | NA | NA | Closures of boat launches operated by New York State |
| Development and Implementation of online, self-reporting questionnaire for | Yes | Yes | Yes | Yes | Yes | Allows self-reporting from property owners on impacts to docks and also for potential business impacts. ***NOTE: The questionnaire was*** |

| | | | | | | |
|---|---|---|---|---|---|---|
| coastal property owners (includes businesses) | | | | | | ***intended to allow direct input from property owners on their perspective regarding impacts but is not considered a statistically robust methodology for extrapolation purposes.*** |
| Tracking of media report | Yes | Yes | Yes | Yes | Yes | General consideration of the types, location, and magnitude of shoreline impacts commonly reported in media outlets |

Other agencies and groups are also looking at impacts associated with 2017 high water conditions for various emergency response, recovery and operational purposes (Table 8-2). Much of this information is not directly accessible to the GLAM Committee at this time as these agencies and groups have not yet released the information publicly. Efforts are underway to gain access to this impact information in support of long-term GLAM Committee activities. Examples, as they relate to the recreational boating and tourism indicators and that the GLAM Committee could access, include a survey issued by the Thousand Islands Tourism Council, an online self-reporting survey developed and implemented by the New York Sea Grant and Cornell University, information collected for the New York State flood relief/recovery program (particularly the business component) and a review of municipal or other agency documentation that may be reported for other purposes. There may be other potential sources of information to support the effort, particularly for the tourism impacts to New York and Ontario Parks related to provincial and state park impacts but that information is not currently available beyond specific site visits.

Table 8-2: Activities that are undertaken by outside groups and agencies independently from the GLAM Committee but where the results and information directly relate to GLAM Committee objectives of understanding impacts due to changing water levels

| **Activity** | **Lake Ontario** | | **Upper St. Lawrence** | | **Lower St. Lawrence** | **Relation to Recreational Boating and Tourism PIs** |
|---|---|---|---|---|---|---|
| | **US** | **CAN** | **US** | **CAN** | **CAN** | |
| Thousand Islands Tourism Council survey | NA | NA | Yes | Yes | NA | A survey of members of the Thousand Islands Tourism Council related to high water impacts |
| Cornell University/ NY Sea Grant online, self-reporting questionnaire for coastal property owners | Yes | NA | Yes | NA | NA | May include impacts to shoreline businesses and marina operators due to high water |
| New York State Flood Relief/Recovery Program | Yes | NA | Yes | NA | NA | Information on the types and extent of damages observed by business operators (if they apply) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Review of municipal and other agency documentation on impacts and costs | No | Yes | No | Yes | No | Impacts reported by Canadian shoreline municipalities related to recreational boating and tourism impacts. |

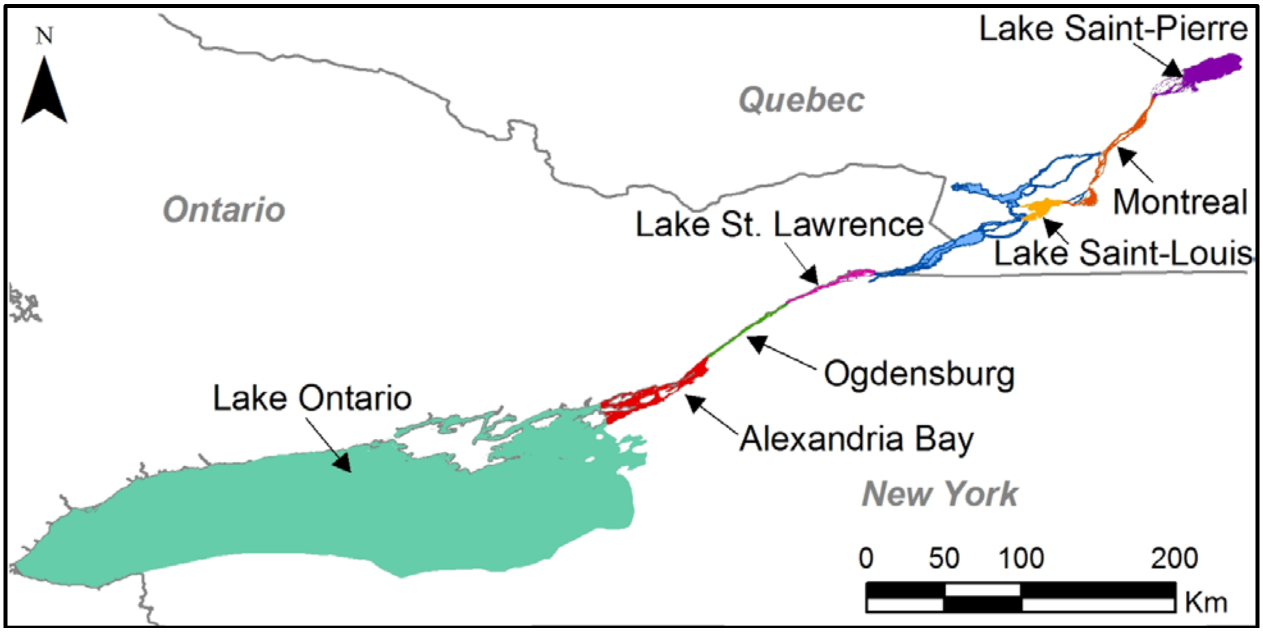


Figure 8-1: Recreational boating reaches used for LOSLRS PI

## 8.2 Media Coverage

As reported in the Coastal section (6.0), there was extensive media coverage of high water impacts throughout the Lake Ontario-St. Lawrence River system in 2017. Support staff for the GLAM Committee reviewed around 1,400 English media articles from throughout 2017 (French media was not tracked so lower St. Lawrence media is not fully represented in the assessment). The intent of the review was to get a sense of the types of impacts being reported in the media, and the relative intensity of that reporting. As part of the review, efforts were made to identify articles that included reports of specific damages or had photographs of high water impacts. These impact reports were broadly categorized by stakeholder based on the nature and extent of the described impact and a number of those impacts were classified as "recreational boating". Recreational boating impacts that were commonly impacted by flooding were marinas and/or yacht clubs that may have an impact on the recreational boating community. There were also reports of flooded boat launches which could impact boating activities on Lake Ontario. Table 8-3 shows the locations and number of impacted marinas, yacht clubs and boat launches that were captured in media reported articles for Lake Ontario and the upper St. Lawrence River.

Table 8-3: Number of English media reported flooding impacts on marinas, yacht clubs and boat launches for each US (red) and Canadian (blue) County/municipality on Lake Ontario and the upper St. Lawrence River.

| County | Marinas | Yacht Clubs | Boat Launches | Total |
|---|---|---|---|---|
| Jefferson | 7 | 5 | 5 | **17** |
| Oswego | 4 | | | **4** |
| Cayuga | 2 | | 1 | **3** |
| Wayne | 2 | | | **2** |
| Monroe | 4 | | 1 | **5** |
| Orleans | 2 | | | **2** |
| Niagara (US) | 3 | 2 | | **5** |
| Niagara (CAN) | 1 | 1 | | **2** |
| Halton | | | 1 | **1** |
| Peel | 2 | 1 | | **3** |
| Toronto | 1 | | | **1** |
| Durham | | | 1 | **1** |
| Northumberland | 1 | | | **1** |
| Hastings | | 1 | | **1** |
| **Total** | **29** | **10** | **9** | **48** |

The county with the most media-covered impacts on recreational boating facilities was Jefferson County on the eastern shore of Lake Ontario with 17 of the 48 examples identified (Table 8-3). The northern portion of Jefferson County borders the upper St. Lawrence River including the Thousand Islands area as well as a portion of the Lake Ontario shoreline. There were 21 additional media reported boating facilities on the US south shore that were impacted by flooding and identified in the media review. Of the 48 media reports related directly to recreational boating facilities, 10 were reported in Canada. The media reports only provide a sample of the types of recreational boating impacts and are only meant to supplement other sources of information that may be available. Examples of some of the reported impacts include inundation of docks, walkways, parking lots, boat launches and, in some cases, buildings. A few articles also mentioned revenue impacts due to reduced boat slip occupancy and reduced fuel sales.

# 8.3 Impacts/Benefits of 2017 water level conditions

## 8.3.1 Lake Ontario – State of New York

**Business (tourism) and recreational boating impacts:**

A majority of recreational business owners self-reported some loss of revenue when responding to the Conservation Ontario survey during the 2017 season, with some marina, boat launch and rental properties reporting a complete, 100% loss of income. Some businesses had multiple categories of service offerings, such as a business that had a restaurant, boat launch, dock and retail operations. One Conservation Ontario survey respondent noted that they could not open for the season and would be going out of business unless they received financial assistance for infrastructure. Overall, business owners generally reported some degree of revenue loss in 2017, with four out of 40 Conservation Ontario survey respondents reporting a total loss on income. Most commonly, businesses reported having access problems and unable to fully operate due to the high water. Twenty-eight of the 40 businesses reported fewer visitors and a decline in revenue. It cannot be determined whether fewer visitors and a decline in revenue are a separate problem from the decreased access and operability of the businesses, or whether these factors caused the decrease in visitors and revenue. The number of responses is contained in Figure 8-2 below.

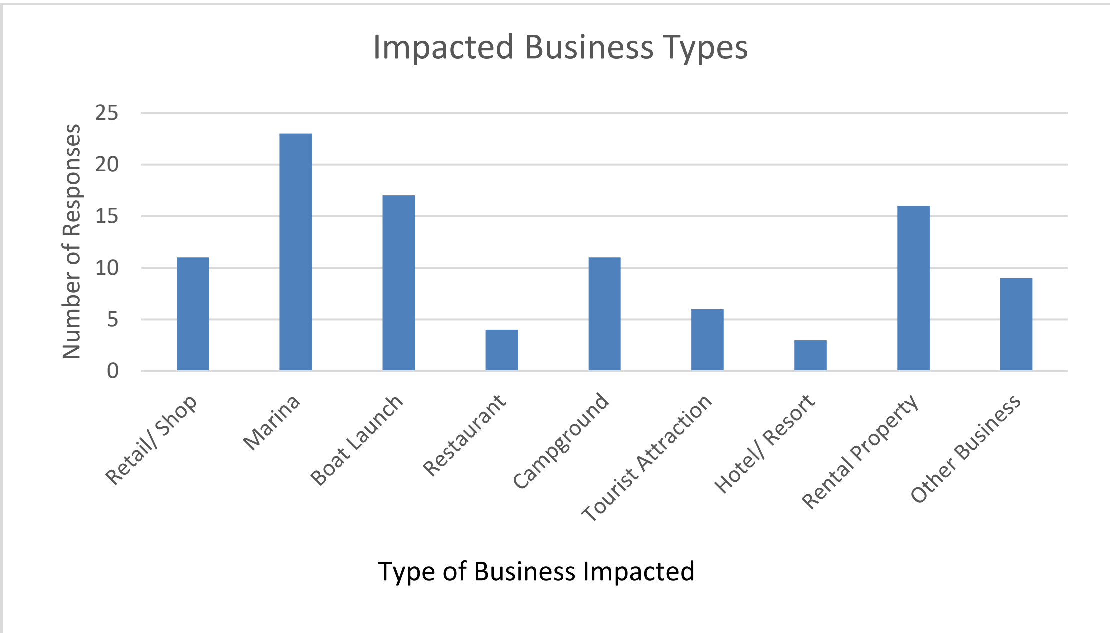


Figure 8-2: Number of reported businesses impacted as reported in the Conservation Ontario survey

New York State temporarily closed various state-owned boat ramps and boat launches at certain times during the high 2017 water level period which potentially impacted boating activities in those areas. In 2017, the NYDEC Division of Emergency Management maintained a list of 58 DEC-owned public boat launches directly affected by Lake Ontario water levels, which stated whether a launch was open, closed or partially open. This list included a reason why a launch was not fully open, was updated four times during 2017 and made available to the public on the DEC website. A review of this dataset found that the majority of launches were open during the season (Table 8-3). Approximately 10% of launches were fully closed at least once during the 2017 season. Many others had use curtailed, which included closing related facilities such as gas stations, marinas and docks, or by restricting access only to non-motorized vessels such as kayaks. Approximately 19% of launches were partially open during the season, meaning that they were open to non-motorized watercraft (i.e., kayaks and canoes) throughout the season, and access to motorized watercraft was curtailed or determined daily based on local weather conditions.

An additional 12% provided motorized boat launch access, but had reduced access to related facilities. By July 30, 2017, only three launches remained fully closed, which remained due to damaged or missing docks, for the duration of the season. Although this dataset is limited in scope to DEC-owned launches, it suggests that access to boat launches for motorized boats was curtailed in early summer at approximately one third of locations during 2017, in summing the number of launches that fully closed or were partially open and prohibited motor boat access, with motorized boat access increasing through June and July.

Fort Niagara State Park has two public boat launches. The south launch on the lower Niagara River was closed because of the high water conditions. The north launch was partially open during the season; boaters were instructed to call the park daily to confirm whether it was safe and open for launches. At North Sandy Pond, a DEC-owned launch on a narrow channel was closed to prevent boat wakes from impacting the homes abutting the channel.

Table 8-4: Summary of New York DEC boat ramp information from 2017

| Category | Percentage of Launches |
|---|---|
| Fully Closed at Least Once | 10% (6/58) |
| Partially Open<br><br>e.g., open to kayaks only, docks available but launch closed, opening is dependent on daily weather | 19% (11/58) |
| Launch Open to Boats; Related Facilities Closed*<br><br>e.g., gas sales unavailable, marina closed, docks not installed, shorefishing closed. | 12% (7/58) |

New York State also implemented a boat speed restriction for boaters close to the shoreline to reduce boat wake on shorelines that already experienced flooding from high water levels. Comments received through the survey conducted by the Thousand Islands Tourism Council (2018) suggested that some people felt the speed restrictions had a negative impact on boating activity in that region. For example, responses in that survey noted a "5 mph speed limit made boating a tiresome activity", "We were not able to operate our high-speed catamaran…due to concern for the wake it creates at slower speeds and the enforcement of speed and wake restrictions along particular sections of the river." The survey analysis stated that June 2017 saw the highest levels of perceived impacts, which decreased along with the water levels as the summer progressed.

A review of ortho-rectified imagery captured along the US shoreline of Lake Ontario collected in June 2017 and July 2017 identified a number of potential impacts to recreational boating users including flooding of docks and facilities at marinas (e.g. Figure 8-3) and inundation of private docks, boathouses and boat launches (e.g. Figure 8-4). Figure 8-5 summarizes the information on a town basis with normalized values presented to allow comparison between towns with different shoreline length (e.g. number of identified impacts in the town divided by the shoreline length within that town and reported as the rate per 10 km). Based on the imagery analysis, US recreational boating impacts were greatest within Wayne and Monroe Counties and as well as Jefferson County and Niagara County.

Figure 8-3: Example of inundation that can be identified through the USACE orthoimagery for Monroe County with particular issues highlighted (red = inundation of docks, and blue = inundation of docks, nearshore area, and sandbagging). Photo credit: USACE, June 2017.

Figure 8-4: Example of inundation that can be identified through the USACE orthoimagery for Monroe County with particular issues highlighted (red = inundation of docks, nearshore area, and sandbagging) Photo credit: USACE, June 2017.

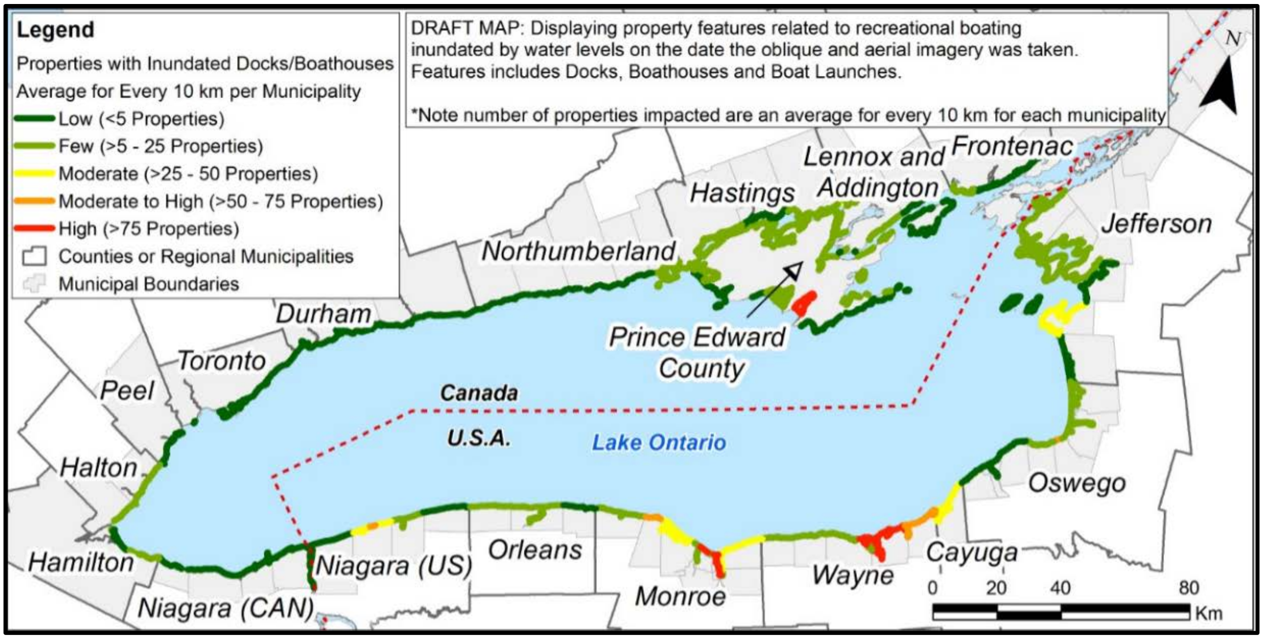

Figure 8-5: Representation of impacts identified through oblique imagery review (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

The property owner survey conducted by Conservation Ontario included questions related to flooding of dock facilities. Of the 1024 usable US survey responses, 409 indicated dock or pier flooding. The highest percentage of responses were from Wayne, Monroe and Jefferson counties (Figure 8-6).

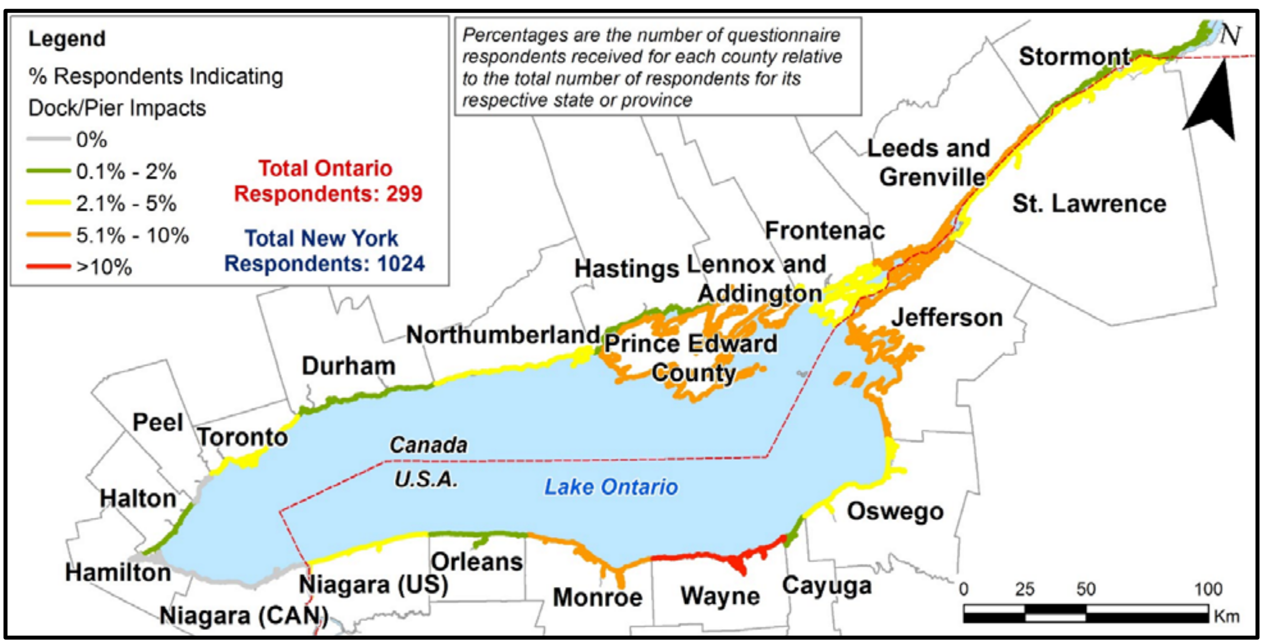

Figure 8-6: Percent of survey responses indicating dock/pier flooding (shown as a relative % by County relative to total number of that reported impact for Country) (Source: ECCC, based on data acquired through Conservation Ontario survey for IJC)

Staff from the USACE identified some recreational boating impacts during their site visits (discussed in the coastal section). In Alexandria Bay, NY two recreational boating facilities were identified as impacted by flooding: Bonnie Castle Resort and Marina and the Upper James Street Dock (Figure 8-7). Bonnie Castle Resort and Marina boat ramps had been closed due to debris and underwater hazards (Figure 8-8). The Upper James Street Dock was underwater and closed to the public (Figure 8-9). Two additional marinas in the vicinity were flooded and gas pumps had been shut down. As an adaptive action, local commercial interests constructed a floating dock adjacent to the existing dock at Upper James Street (Figure 8-10).


Figure 8-7: Impacted locations in Alexandria Bay, NY, May 26, 2017. Photo credit: USACE Buffalo.

Figure 8-8: High water at Bonnie Castle Resort Docks, Alexandria Bay, NY, May 26, 2017. Photo credit: USACE Buffalo.


Figure 8-9: Upper James Street Marina flooding, Alexandria Bay, NY, May 26, 2017. Photo credit: USACE Buffalo.

Figure 8-10: Upper James Street floating dock addition, Alexandria Bay, May 26, 2017. Photo credit: USACE Buffalo.

### 8.3.2 Lake Ontario – Province of Ontario

#### *8.3.2.1 General*

Information from various sources indicated that marina impacts due to high water levels in 2017 varied along the Canadian shoreline of Lake Ontario and the St. Lawrence River based on site specific characteristics, but there were a number of common themes based on information gathered through facility websites and posted notices. In general, marinas with floating docks were more adaptable to high water conditions than those with non-floating docks. Even with floating docks, there were challenges including where portions floated above their attachment to the shoreline and temporary ramps were required. In some cases, electrical and gas docks were closed so the marinas might have been open to usage but lacked electrical hook-ups at the docks, or access to gas facilities. In addition to dock problems, a number of marinas experienced building damage due to flooding, along with property, parking lot and dock flooding. Shoreline flooding and erosion created instability on shorelines and required some marinas to close off certain portions of their properties, roads leading to buildings, and even certain walkways and docks, which reduced access to boats. Limited facility space due to high levels (some areas of marina areas flooded and unusable) forced some clubs to shrink certain programs like sailing camps for children and cancel or postpone reciprocal yacht club benefits to later summer dates due to challenges to safely accommodate boats. Recreational boating opportunities were delayed in a number of areas in late April and early May. It was typical for put-in dates for larger vessels to be pushed back a number of weeks until the end of May or early June and even when they did occur, additional precautions had to be taken due to flooded boat launches. In some cases, even later dates were reported where marinas were dominated by non-floating docks. Where recreational boating was occurring, there were safety concerns around additional debris in the water and also that a number of inundated features (e.g. non-floating docks) created navigation hazards.

#### *8.3.2.2 Region of Niagara to Region of Peel:*

Based on information from a review of oblique imagery, site visits, municipal reports, shoreline survey results, and media reports, boating facilities appear to be generally concentrated in larger protected harbours and embayments in the western end of Lake Ontario (including the Region of Niagara through Peel Region). Direct impacts to marina facilities were observed or reported at a number of locations including, but not limited to, Port Dalhousie (Figure 8-11), Foran's Marine in Grimsby and 50 Point Marina in Stoney Creek. Smuggler's Cove Boat Club in Niagara-on-the-Lake reported closures through their respective website calendar for June and July due to high water level conditions and only reopened in August with limited capacity. In Hamilton Harbour, websites or other social media platforms for various marinas reported problems such as impacted gas facilities, reduced dock access and impacts to electrical supply. Despite the direct impacts, marinas and yacht clubs appeared to undertake efforts to mitigate some of the impacts by adjusting dock and electrical facilities, modifying access to some docks and adjusting boat launch timing. For example, Lasalle Marina in Burlington noted on their Facebook page that they continued to operate despite high water levels resulting in a late launch.

The City of Oakville reported issues with boat launching at marinas operated by the City and a shortened boating season impacting slip rentals (Figure 8-12) (City of Oakville, 2017). In addition, various boating infrastructure repairs were required by the City of Oakville including dock rebuilding, bracket replacement, boardwalk replacement and, most significantly, the replacement of the Bronte boat launch ramp which suffered significant structural damage requiring closure and a complete rebuild (currently planned for 2018) with a large capital expenditure (City of Oakville, 2018). In Mississauga, repairs and hydro relocations had to be carried out at Credit Village Marina and Lakefront Promenade Marina to mitigate service disruption while operating costs and revenue impacts have not yet been reported by the City (City of Mississauga, 2017). Marina Park boat launch, charter boat docks and portions of gravel and asphalt parking lots remained inaccessible. Some seasonal slip charter boats relocated to Credit Village Marina, while others cancelled their slip for the season (City of Mississauga, 2017).

Figure 8-11: Inundation of docks at Lakeside Park in Port Dalhousie (left) and a set of floating docks in the same area (right). Photo credit: ECCC, May 24, 2017.


Figure 8-12: Bronte Harbour Marina (City of Oakville), May 17, 2017. Photo credit: City of Oakville – May 23, 2017 staff report.

A preliminary review of the oblique photography taken June 8, 2017 in the Region of Niagara through the Region of Peel illustrated a range of impacts to recreational boating facilities such as flooding of marina property, docks, buildings, decks, parking lot, roads, boat launches and the facility in general. To attempt to identify how high water levels may impact the boating facilities' business, inundated boat docks/slips were identified from the oblique imagery and are represented in Figure 8-5 on a relative scale across the Lake Ontario shoreline area covered by the oblique photography. The identified locations include private docks, boathouses and boat launches. The imagery review process is highly subjective so the results are intended to be descriptive, and not absolute. Of the fifteen marinas from Niagara to Peel that could be viewed using the June 8, 2017 oblique imagery, five were considered to have boat slips or docks inundated (e.g. Figure 8-14), seven additional marinas had other property features that appeared to be impacted by flooding such as property, boat launches and buildings (e.g. Figure 8-13), and three did not have direct impacts to docks or other facilities that could be readily observed from the imagery (e.g. Figure 8-14).

One marina in this region completed the shoreline impacts survey by Conservation Ontario in 2017. That respondent indicated the marina had dock flooding, damage to docks and stairs/ramp due to erosion and noted a loss of memberships due to boats not being launched.

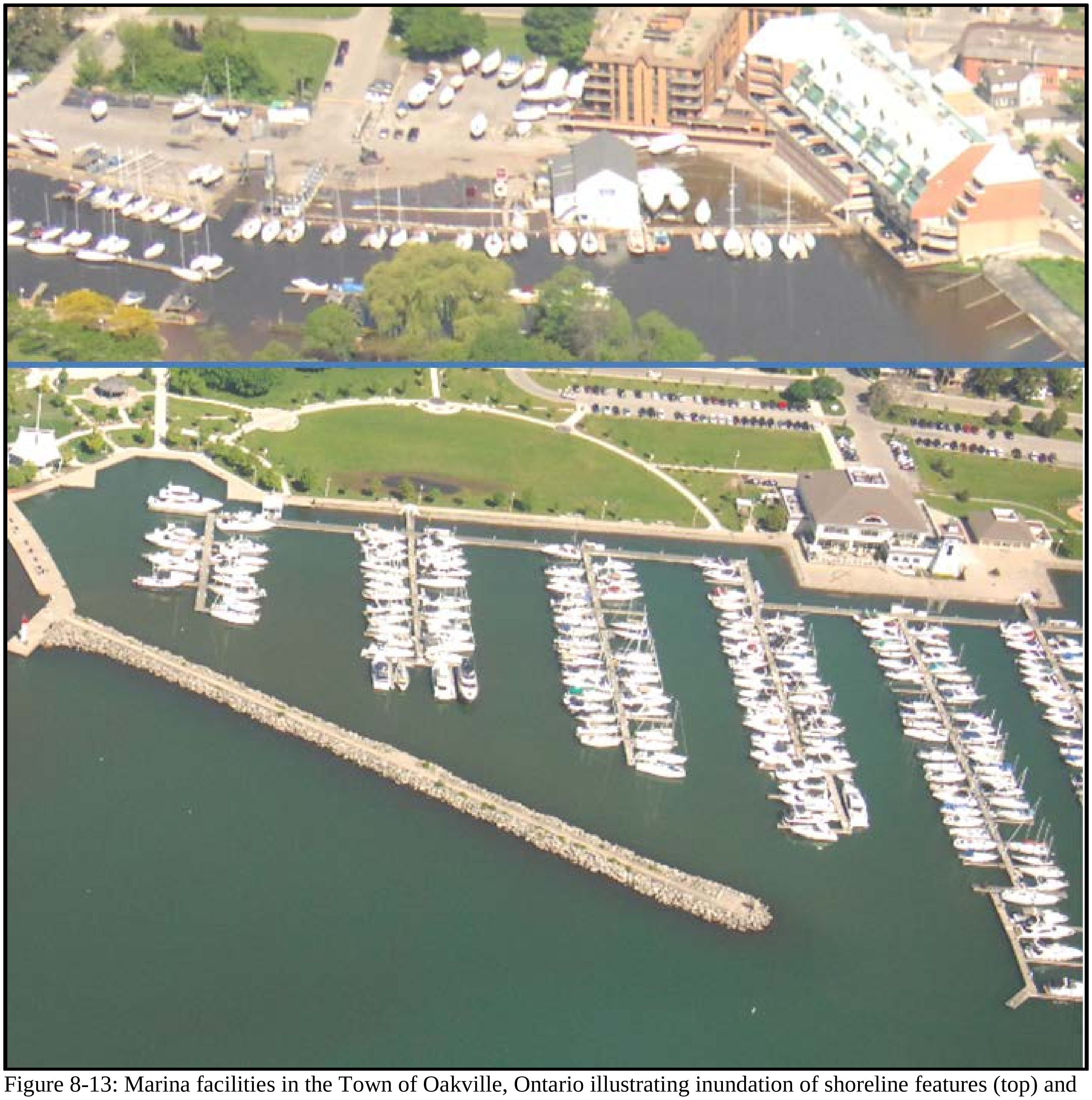

Figure 8-13: Marina facilities in the Town of Oakville, Ontario illustrating inundation of shoreline features (top) and nearby facilities that appear to have limited impacts (bottom). Photo credit: Transport Canada - National Aerial Surveillance Program, June 8, 2017.

Tourism impacts beyond recreational boating were also observed in this coverage area. The most common impact was related to loss of use for public lands such as parks. Lakeside Park in Port Dalhousie, which had been undergoing upgrades and renovations, was impacted for much of the summer, including limited access, and required the relocation of events typically held at the site such as Canada Day festivities (link). The beach area of Burlington Beach park was closed for much of the summer (link), although the trail and other park facilities remained open. In Mississauga, the city notes in a staff report from June 1 that waterfront parks and shoreline such as St. Lawrence Park, J.C. Saddington Park, and J.J. Plaus Park received significant damage as a result of multiple storm events from April 30 to May 30 2017 and continued unprecedented high Lake Ontario water levels (City of Mississauga, 2017). There were direct impacts to restaurant facilities such as the Snug Harbour restaurant in Port Credit (link) which was closed for a period of time due to basement flooding. In Oakville, numerous city parks had damage to the shoreline or other park facilities estimated at $1.69 million with the most significant costs associated with the repair and replacement of damaged shoreline protection structures (City of Oakville, 2018) and there were impacts to bookings and special events that were scheduled for some of the parks (City of Oakville, 2017).

#### *8.3.2.3 City of Toronto and Durham Region*

There were recreational boating impacts in the City of Toronto and further east in Durham Region. A review of yacht club and marina websites and social media sources indicated numerous marinas and private clubs reported some form of high water impacts such as flooding of docks and gas pumps, inundation of storage areas, closing of facilities to visiting (transient) vessels (due to lack of docking space), significant changes in social events schedules and adaptive actions to maintain limited access to some dock facilities. It was also common for boat put-in dates to be delayed. The most significant reporting of impacts occurred in May and June. Similar problems were reported at marinas further east in Durham Region. It should be noted that not all marinas were impacted as significantly. For example, a post on the Frenchman's Bay Marina Facebook page noted that they remained relatively unharmed as of May 8 and the adjacent Fairport Yacht Club also posted that they were largely unaffected as of May 31.

Oblique imagery from June 8, 2017 was reviewed for Toronto and Durham, where available. The review of oblique imagery is the same approach as discussed in the previous Niagara to Peel section. An example is provided in Figure 8-14 which shows two different marinas in a portion of Bluffer's Park in Scarborough with the docks on the right hand side of the image being inundated, but with many slips still utilized, while the docks on the left hand side do not appear to be inundated. A total of 20 marinas could be observed within Toronto and Durham using the oblique imagery. There were two facilities with evidence of boat slips or docks that appeared to be flooded and unoccupied and a further 13 facilities where there appeared to be flooding of property, boat launches or other buildings. There were also seven facilities where direct impacts to docks or other features were not apparent in the oblique imagery.

Four marinas in Toronto completed the shoreline survey impacts by Conservation Ontario in 2017. All the marina respondents indicated dock and utility infrastructure flooding impacts as well as some deck and outbuilding impacts. One respondent noted that power to the docks was turned off due to safety concerns and submerged electrical boxes.

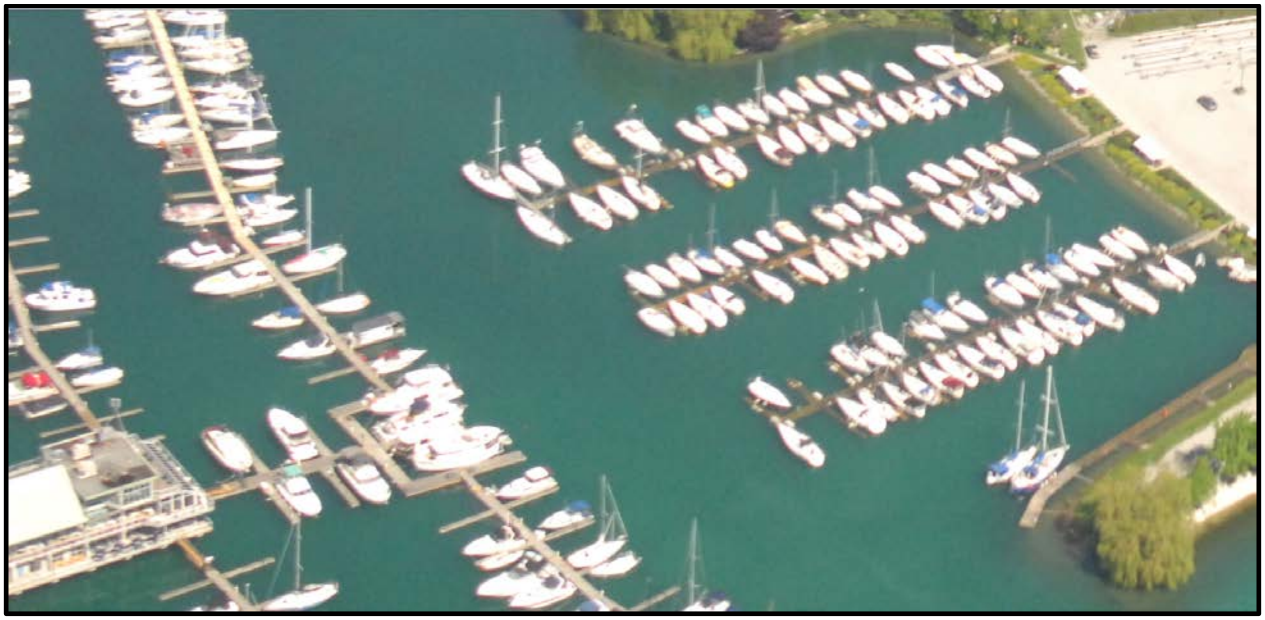

Figure 8-14: Marina facilities in Scarborough, Ontario illustrating inundation of docks (right) and docks that appear to not be inundated (left). Photo credit: Transport Canada - National Aerial Surveillance Program, June 8, 2017.

Tourism impacts were particularly significant in Toronto and more specifically on Toronto Island. The City of Toronto estimates that the closure of the Island from May 4 to July 30 led to an estimated reduction in ferry revenue of $4.5 million (City of Toronto, 2018). Centerville Island's amusement park reported an $8 million in lost revenue due to the closure of the island (https://www.theglobeandmail.com/news/toronto/toronto-islands-reopen-after-nearly-three-month-closure-due-to-flooding/article35841189/) and a number of other island businesses also suffered from loss of access such as the Rectory Café which was ultimately forced to close (link). Special events and concerts that were scheduled for the island had to be rescheduled or re-located to other nearby locations. Given the impact of the park closure and ferry shut down, the City of Toronto was considering reducing rent and license fees for some island businesses, marinas and yacht clubs (City of Toronto, 2018). Flooding at nearby Ashbridge's Bay beach led to significant impacts on beach volleyball facilities that then also impacted scheduled events (link). In Durham Region, the closure of parks impacted local activities (e.g. volleyball, general beach use) while Darlington Provincial Park saw impacts to some of its beach and other shoreline activities (link).

#### *8.3.2.4 Northumberland County:*

Oblique imagery from June 8, 2017 and Google Earth imagery from June 2, 2017 were reviewed for Northumberland County, where available. The review of oblique imagery is the same approach as discussed in the earlier Niagara to Peel section. There were seven marinas within Northumberland County that were identified using the oblique imagery. Of those facilities, two had boat slips or docks that appeared to be flooded and unoccupied and those two as well as four others had other features that were flooded such as property and boat launches.  One facility did not have apparent impacts in the oblique imagery and one facility was totally unoccupied but further follow-up through the facility's website indicated they were undergoing renovations to replace their docks with floating docks in order to adapt to changing conditions.

One marina in Northumberland County completed the shoreline impacts survey by Conservation Ontario in 2017.  The marina respondent did not indicate any damages to the marina.  Based on site visits to a number of locations, impacts to recreational boating facilities varied across the region. Figure 8-15 shows a portion of Cobourg Harbour on June 14, 2017 with floating docks (left) and boat launch (right) that, while impacted by high water levels, appeared to remain operational.  In contrast, a municipal boat launch in nearby Brighton was closed on the same day and some fixed docks remained underwater on July 25, although floating docks in the background illustrate the potential difference in vulnerability based on the type of facility (Figure 8-16).

Figure 8-15: Cobourg Harbour and boat ramp, June 14, 2017. Photo credit: ECCC.

Figure 8-16: Flooded boat ramp at the Municipality of Brighton Bay Street Marina on June 14, 2017 (left).  Photo credit: ECCC and flooded docks (right), also in the Brighton area on July 25, 2017. Photo credit: ECCC.

Media articles and review of available oblique imagery and Google Earth images have shown that several private property owners on Lake Ontario had their docks flooded or had the docks pulled out of the water during the high water levels in 2017 within Northumberland County.  Of the 37 respondents to the Conservation Ontario questionnaire, there were 10 reports of dock flooding.

Tourism is an important component of activities in Northumberland County. Presqu'ile Provincial Park, an important destination near Brighton Ontario, was closed to all visitors for a portion of May 2017 (partly high water levels, partly significant rainfall) (link). No camping or day visitor access was available during this period which had direct impact on the park and spinoff impacts for surrounding businesses.

#### *8.3.2.5 Prince Edward, Hastings and Lennox and Addington Counties*

Impacts were observed or reported at a number of marinas. For example, the Prince Edward Yacht Club's May 2017 newsletter shows the building of a significant dock addition to allow unrestricted (dry) access to the otherwise operational floating dock segments (Prince Edward Yacht Club, May 2017).

A combination of oblique imagery from June 8, 2017 and Google Earth ortho-rectified imagery from June 2018 was reviewed for Prince Edward, Hastings, and Lennox and Addington Counties, where available, using a similar approach as discussed in the earlier Niagara to Peel section and impacts are illustrated in Figure 8-20. A total of twelve marinas within those counties were observed in the available imagery. Of those facilities, two had boat slips or docks that appeared to be flooded and unoccupied while nine facilities had other features that appeared to be impacted such as flooding of property, boat launches or buildings. A further facility did not have obvious signs of direct impacts to docks or other features in the imagery.

Two marinas in this region completed the shoreline survey impacts by Conservation Ontario in 2017. Both marina respondents indicated docks, utility infrastructure, outbuilding and lawn flooding. One marina respondent indicated the facility's breakwall had to be rebuilt. Flooding of private docks was commonly reported in the Conservation Ontario survey. Of the 119 responses in the area, over 60 respondents identified dock or pier flooding as an impact and these counties (particularly Prince Edward) had the majority of this impact type for the responses within the province of Ontario (Figure 8-20). Like other areas of shoreline, there were also examples of boat launches impacted by the high waters (Figure 8-17). A number of its local boat launches within Prince Edward County had to be closed or their access modified due to high water. Launch locations and their status as of May 19, 2017 and August 5, 2017 are identified in Table 8-5 based on reports on the Prince Edward County website.

Figure 8-17: Boat launch in the Belleville area, June 15, 2017. Photo credit: ECCC.

Table 8-5: Prince Edward County boat launch status as of May 19, 2017 (http://thecounty.ca/news--notices/update-county-boat-launch-dock-access-limited-or-closed-due-to-high-water-level.php) and August 5, 2017 (http://www.thecounty.ca/news--notices/notice-update-on-county-boat-launch-and-dock-access.php)

| Launch | Status as of May 19th, 2017 | Status as of Aug 5th, 2017 |
|---|---|---|
| Wellington Beach Boat Launch – Beach Street | **CLOSED** | **Boat launch and docks open** |
| Wellington Marina Boat Lunch – Belleville Street | **CLOSED** | **Boat launch and docks open** |
| Picton Marina Boat Launch – Bridge Street | **OPEN** | **No update provided** |
| Mabel Kleinsteuber Boat Launch – County Rd 12 | **CLOSED** | **Boat launch open, but high water levels hindering access to docks** |
| Consecon Boat Launch – Novotny Court | **CLOSED** | **No update provided** |
| Northport Launch – Boat Centennial Park, County Rd 15 | **CLOSED** | **Boat launch and docks open** |
| Prinyers Cove Boat Launch – County Rd 7 | **CLOSED** | **Boat launch and docks open** |
| Wellers Bay Boat Launch – Edward Drive | **CLOSED** | **Boat launch open, but high water levels hindering access to docks** |
| Rossmore Launch – Ridley Street | **RESTRICTED ACCESS TO DOCK** | **Boat launch open, but docks closed** |
| Glendon Green Launch – Off County Rd 18 | **OPEN** | **Boat launch and docks open** |

Tourism impacts were reported, particularly at Sandbanks Provincial Park which had operational and visitor experience impacts (e.g. Sandbanks had to close one of their popular public beaches for much of the summer which limited visitor access by restricting the number of day use visitors to the park because there was no available beach space).

### 8.3.3 Upper St. Lawrence River – State of New York and Province of Ontario

Recreational boating is particularly important in the upper St. Lawrence River, both with regards to general recreational use and also to access numerous island properties. High water impacts were identified at marina and yacht club facilities throughout the region. The Cataraqui Region Conservation Authority highlighted marina and boat ramp problems associated with flooding in the Kingston area. For example, they note the boat ramp and gas dock at the Kingston Yacht Club were closed due to flooding as of May 31 and the boat ramp at Kingston Penitentiary/Portsmouth Olympic Harbour was closed. Further east towards Gananoque and the Thousand Islands, the Ivy Lea and Mallorytown public docks and boat ramps were closed and a number of marinas were inundated (e.g. Andress Boat Works in Rockport as identified during site visits). A Cataraqui Region Conservation Authority boat ramp was also closed in the Brockville area. Figures 8-18 and 8-19 document some of these impacts.

Figure 8-18: Kingston Yacht Club, June 14, 2017. Photo credit: ECCC.


Figure 8-19: Marina facilities in the Gananoque area of the Thousand Islands, May 7, 2017. Photo credit: International Joint Commission.

In the Lake St. Lawrence area, there were no aerial photos to assess impacts in May and June. However, record high outflows starting in late May continued through July and caused a drawdown of water levels in the Lake St. Lawrence area throughout the summer and fall (ILOSLRB, 2018). As Lake Ontario levels continued to decline through the summer and outflows remained very high, low water level problems were observed on Lake St. Lawrence which required a short-term flow reduction October 6 through 8 to allow for boat haul-out.

Oblique imagery from June 8, 2017 was only available for Frontenac and therefore only that county was reviewed. The review of oblique imagery is the same approach as discussed in the Niagara to Peel section earlier in the report. A total of six marinas within Frontenac County were assessed using oblique imagery as illustrated in Figure 8-20. Of the identified facilities, slip inundation was not apparent from the aerial imagery although three of them (including Kingston Yacht Club in Figure 8-18) appeared to have flooding of property or other features. Figure 8-20 illustrates all the facilities reviewed using the aerial or oblique imagery and the approximate percentage of inundated slips. Only the Lake Ontario shoreline is included on the map because the upper St. Lawrence River shoreline was not captured by the orthoimagery or oblique imagery acquisition in 2017.

Three marinas in this region completed the shoreline impacts survey by Conservation Ontario in 2017. One marina did not experience any impacts, but the other two marina respondents indicated fixed docks and utility infrastructure flooding. One marina respondent indicated flooding up to the building foundation. One indicated that the club house built on cribs almost flooded and that the marina’s gas dock was flooded and forced to close. One respondent noted a disruption to the marina’s floating docks system noting that chains were broken and anchors were moved. A number of private shoreline residents in this area also reported impacts to docks (see Figure 8-21).

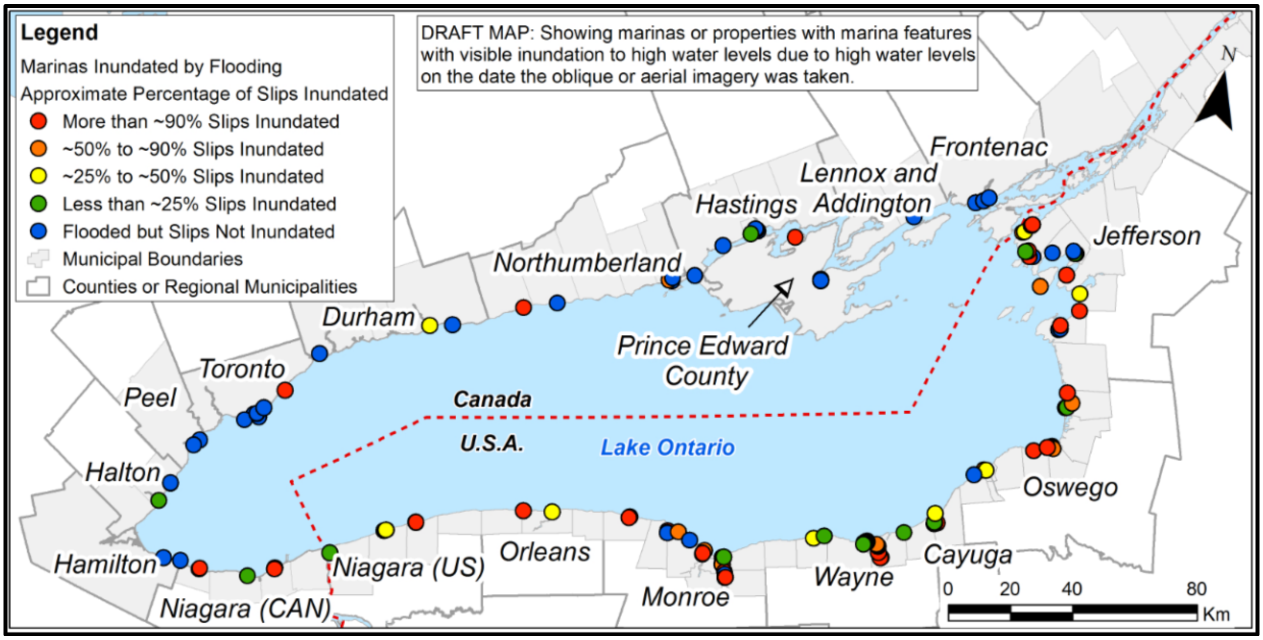


Figure 8-20: Lake Ontario marinas that were assessed based on ortho/oblique imagery collected during 2017 and appeared to be impacted by high water levels. (Source: ECCC and USACE)

Tourism is a very important component of the local economy in the upper St. Lawrence River including the Thousand Islands area. The Thousand Islands International Tourism Council released a report that indicated a range of high water impacts to businesses and an overall decrease in activity (Thousand Islands International Tourism Council, 2017). They sent an email to 680 contacts and received 109 responses from the Thousand Islands region of the St. Lawrence River. Most businesses in this report indicated a 10-40 percent loss in business. Business respondents suggested that high water levels discouraged visitors and high water levels impeded operations (Thousand Islands International Tourism Council, 2017). The type of businesses in the Thousand Islands region that reported impacts included lodging, restaurants, retail, marinas, fishing/hunting operations, attractions and events (Thousand Islands International Tourism Council, 2017). For example, tour boat operations in the Thousand Islands area were negatively impacted in some locations due to challenges with docking facilities (Figure 8-21). Based on the responses to the Thousand Islands International Tourism Council survey, there were more businesses negatively impacted in the US relative to Canada (Thousand Islands International Tourism Council, 2017).

Figure 8-21: Example from tour boat operations in the Thousand Islands area, May 7, 2017. Photo credit: International Joint Commission.

Some of the higher profile operations reported impacts, particularly early on as levels rose rapidly and reached their peak. For example, Boldt Castle reported negative impacts such as flooding when water levels peaked and required dock modifications to allow proper boat access. Boldt Castle closed for a week from May 5 to May 12 due to the high water levels. During this period, a safety platform was constructed to allow boats to continue ferrying tourists to Heart Island. However, high waters prevented the opening of their Yacht House and Power House. Boldt Castle sells tickets to the Yacht House separate from the main castle admission. The Thousand Islands National Park had restricted access to a number of their sites and several campsites were closed for various lengths of time (John Haselmayer, personal communication).

### 8.3.4 Lower St. Lawrence River – Montreal to Trois-Rivières

High water impacts to marinas and other recreational boating facilities were observed in the lower St. Lawrence River from Montreal downstream through Trois Rivières. Fifty-one marina and yacht club locations were identified as potential impact areas (Figure 8-22, top left image) and, like the Lake Ontario and upper St. Lawrence River assessment, many of those sites were captured in the May 2017 imagery from Transport Canada and associated Google Earth imagery around the same time (44) and efforts were made to review facilities' websites and social media presence to identify impacts. There were numerous examples of impacts that could be observed from the oblique imagery at the specific sites during the peak of the lower river flooding in early May (Figure 8-22). In general, the types of impacts to facilities were similar to those observed on Lake Ontario and the upper St. Lawrence River and included issues like flooding of property in and around the marinas, buildings, boat launches (Figure 8-23, top right image) and breakwalls. Many of the facilities still had some of their docks out of the water or appeared to rely on floating docks to adapt to water level fluctuations in the St. Lawrence River that are typically more variable than observed on Lake Ontario, so there were few examples where non-floating docks were inundated in the available imagery (Figure 8-25).

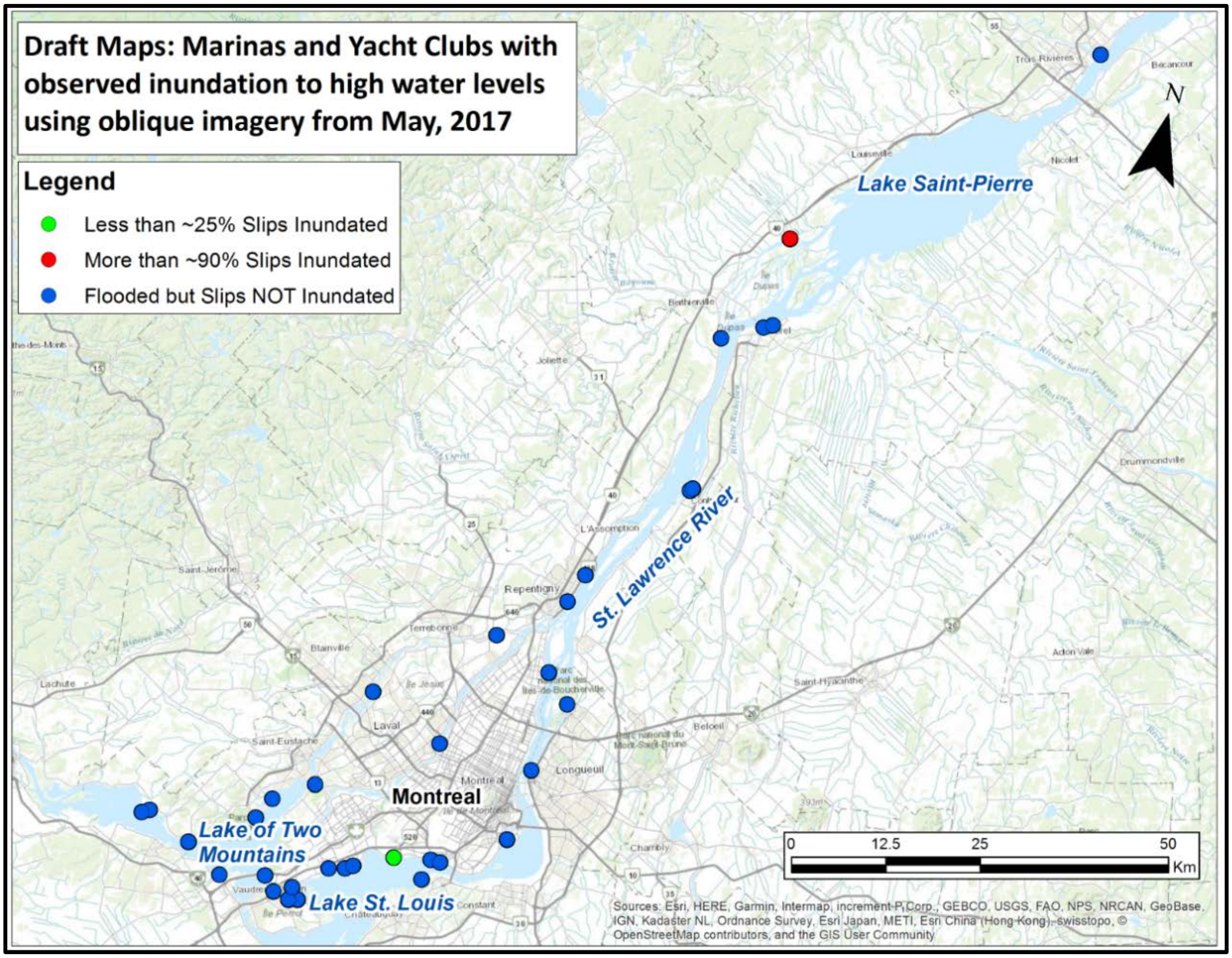

Figure 8-22: Locations of marinas and yacht clubs with observed inundation. (Source: ECCC).

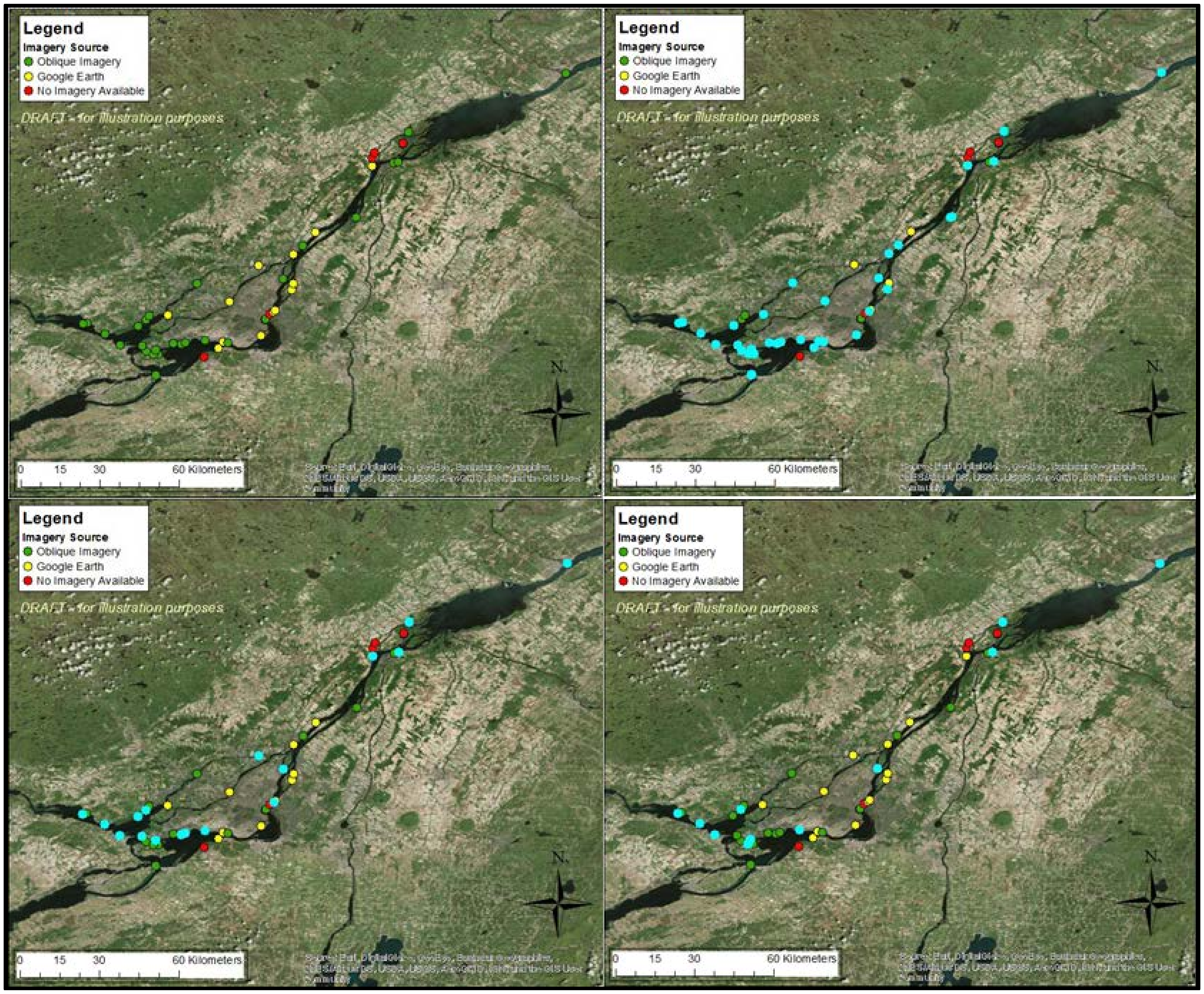

Figure 8-23: Marina and yacht club facilities on the lower St. Lawrence River (top left) and assessment of impacts using oblique imagery (blue highlights) for property (top right), boat launches (bottom left) and buildings (bottom right). (Source: GLAM Committee)

In the Lake Saint-Louis area, inundation of boating facilities was observed in May and corroborated by site visit photos in the area or by earlier imagery as available through Google Earth and other sources (Figure 8-24 to 8-26). The available sources are not considered to provide a comprehensive reflection of impacts. A number of the marina and yacht club facilities updated their members through websites and social media updates. The majority of the updates on impacts took place during late April and early May as water levels peaked. Various marinas indicated they were pushing back their put-in dates for installing their floating docks due to the high levels and inundation of necessary facilities (e.g. anchor points for floating docks were inundated or it was unsafe for staff to work near the shoreline). Since the peak flooding occurred relatively early in the boating season, few boats were in the water at the time the oblique imagery was taken and there were examples where floating docks did not appear fully set up for the season yet. Similar observations were made using the available imagery along the St. Lawrence River between Montreal and just upstream of Sorel (e.g. Figure 8-27).

Figure 8-24: Beaconsfield Yacht Club showing inundation to a portion of the shoreline facilities on May 7, 2017. Photo credit: (left) Transport Canada - National Aerial Surveillance Program, (right) ECCC, May 5, 2017.

Figure 8-25: Baie-d'Urfe Yacht Club showing inundation of shoreline areas on May 8, 2017 (left) relative to lower water level conditions in September 2013 (right). Photo credit: (left) Transport Canada - National Aerial Surveillance Program, (right) Google Earth, September 17, 2013.

Figure 8-26: Club de Voile Ile Perrot on May 12, 2017 illustrating shoreline inundation. Photo credit: Transport Canada - National Aerial Surveillance Program.


Figure 8-27: Marina de la Rive Nord on May 11 (left) and September 10, 2017 (right) Photo credit: Transport Canada - National Aerial Surveillance Program (left) and Google Earth (right)

Marinas and recreational boating facilities in the Lake Saint-Pierre area were also impacted by the high water conditions in early May. Like areas further upstream, a number of locations delayed their put-in date and there was flooding of boat ramps and other facilities. This was evident through the oblique imagery (e.g. Figure 8-28 and 8-29). There were also reports of a high amount of debris getting pushed up onto the shoreline for various facilities based on the combination of high water levels and waves. Due to the resolution of the available imagery, it was not always possible to clearly identify shoreline erosion issues but some of the facilities identified this issue on their websites or social media sites.


Figure 8-28: Marina Le Nid D'aigle on May 11 (left) and August 19, 2016 (right) for reference. Photo credit: Transport Canada - National Aerial Surveillance Program (left) and Google Earth (right)


Figure 8-29: Marina de Trois-Rivières on May 9 (left) and June 16, 2016 (right). Photo credit: Transport Canada - National Aerial Surveillance Program (left) and Google Earth (right).

The available imagery suggests that there were site-specific facility impacts during the peak flooding period on the lower St. Lawrence River but there remains considerable uncertainty as to the impact of high water levels to overall lower St. Lawrence River recreational boating activity of 2017. As reported on numerous facility websites, it appears that put-in dates were delayed until later in May. However, there is very little information about what kind of impact (or perhaps even benefit) prolonged high Lake Ontario outflows in June, July and into August would have had on overall recreational boating activity along the lower St. Lawrence River. As well, there has not been an assessment of impacts to private docks due to the high water levels. As with Lake Ontario and the upper St. Lawrence River, the GLAM Committee has initiated a contract for further follow up with marinas on the lower St. Lawrence River to better understand overall impacts in 2017. It is expected that the additional information from that contract will support the GLAM Committee's long-term objectives for improving available PIs.

## 8.4 Model/PI validation

The recreational boating PI established during the LOSLRS used data collected from 2001 and 2002. Data includes survey data as well as physical depth measurements at some private docks, boat launches, and marinas. The study area was divided into six reaches:

a. Lake Ontario
b. Upper St. Lawrence River, Alexandria Bay
c. Upper St. Lawrence River, Ogdensburg
d. Lower St. Lawrence River, Lake St. Louis
e. Lower St. Lawrence River, Montreal-Contrecoeur
f. Lower St. Lawrence River, Lake St. Pierre

Water level impact relationships (stage-damage curves) were created for each reach using the PI of net economic value lost (see Figure 8-30 as an example for one reach). There are monthly curves for each reach due to the variability in boater activity throughout the season (i.e. between April where activity is low compared with July and August where activity is at its peak). Generally speaking, the impact curves identified some loss of recreational boating activity under very high water levels but a greater impact was observed under very low water level conditions. It is important to note that these curves consolidate impacts across broad geographic areas.

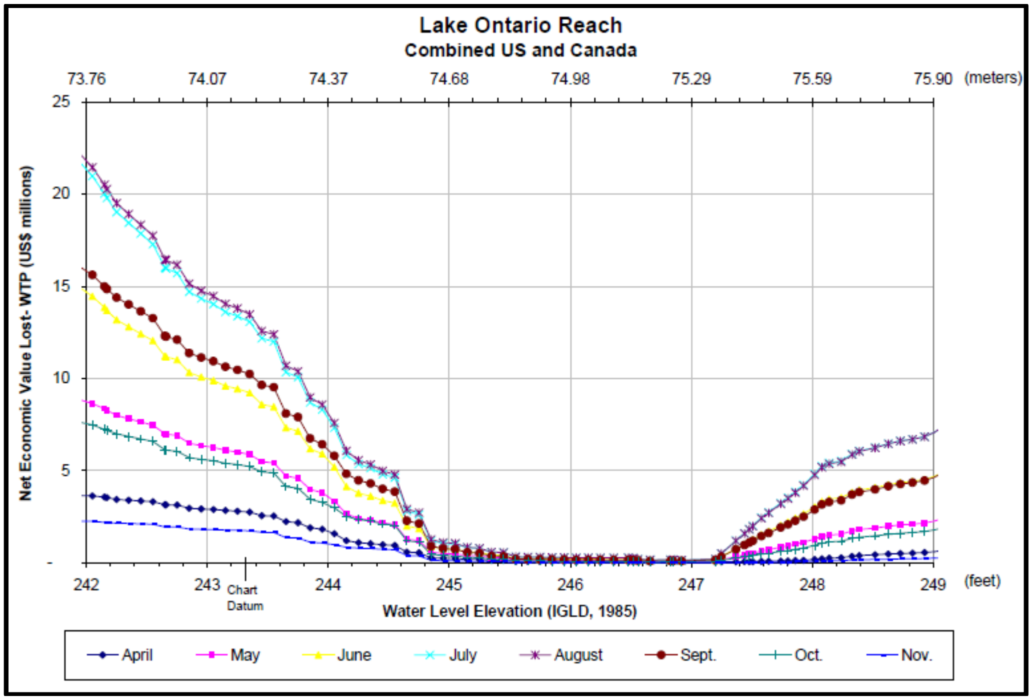


Figure 8-30: Water level impact relationship using net economic values lost by month for all US and Canadian Lake Ontario Reach users. (Source: LOSLRS Board, 2006, Annex 2)

Most of the information currently available on recreational boating impacts during the 2017 high water period relate to direct impacts to recreational boating facilities. This information alone does not directly support the validation of the willingness-to-pay PI, which is a measure of the social benefit of recreational boating activities, by month. However, the information may be appropriate as an indicator of reduced recreational boating opportunities and activity. For example, inability to access non-floating docks that are inundated or the closure of a boat ramp limiting the ability to launch boats in certain areas are indicators of reduced boating opportunity. The challenge for validating the PI will be to determine whether recreational boating was reduced (i.e. some boaters chose not to go at all) or was moved to other locations either within the Lake Ontario-St. Lawrence River system (so no net impact) or was moved completely outside the system. The GLAM Committee will continue to pursue options to acquire economic estimates of the 2017 impacts on recreational boating in order to compare with estimates using the PI, including the survey of recreational boating facility owners.

## 8.5 Adaptive responses

Based on ECCC staff site visits, a review of media reports and examples from numerous marina and yacht club websites, it is apparent that many marinas took steps to adjust to extreme levels and maintain some, albeit reduced, access to their facilities. This included sandbagging buildings, placing additional wood or other material on top of docks to have a pathway that was out of the water and adjusting electrical hookups. Media articles reported that several marinas sandbagged to protect their property and facilities throughout Lake Ontario and upper St. Lawrence River.

Some facilities appeared more resilient than others. Fixed docks primarily saw many slips inundated whereas some floating docks appeared fairly usable with modifications installed where the floating docks met the shoreline. For example, while conducting the imagery assessment of the Presqu'ile Yacht Club in Brighton, ON, their website was visited and a news bulletin on the website discussed a project to adapt to high water level conditions, such as those experienced in May and June by switching all the fixed docks to floating docks. Figure 8-31 is a picture of the new floating docks installed to adapt to changing water level conditions.

Figure 8-31: New floating docks installed at the Presqu'ile Yacht Club in Brighton, ON. Action taken to adapt to extreme water levels such as those experienced in May and June 2017. Photo credit: http://presquileyc.com/high-water-project-update/

# 8.6 Surveillance

The survey data from the LOSLRS, along with the associated depth measurements taken of docks, boat slips and boat launches used to establish the impact-relationship curve for the recreational boating PI will need to be reviewed if the raw data are still available. Until it can be determined if the raw data are available, it will be difficult to deconstruct the PI in order to test and validate beyond what is available in the impact-relationship curve. A beach access PI was developed during the LOSLRS, but not used based on advice received by the economic advisors during the study.  This PI may have to be revisited to establish a tourism PI.  There are a few other factors that may have impacted recreational boating and tourism behavior in 2017 but are probably difficult to assess given available information, including:

1. Did boat speed (and wake) restrictions negatively impact recreational boating activities?
2. Did transient boaters choose other lakes to visit (e.g. Finger Lakes, Kawartha Lakes, etc.)?
3. Did reports of debris in the water due to erosion along the shoreline impact boating behavior?
4. Did flooded breakwalls, groins or other water hazards pose a safety risk for boaters unable to see them?
5. Did poor weather such as several rainy days coupled with high water levels discourage boating activities?
6. Did negative press on high water impacts and closures discourage visitors to the region? This was suggested by some responses in the Thousand Islands Tourism Council Survey report (Thousand Islands International Tourism Council, 2017), speculating visitors did not go to the Thousand Islands region because it was assumed tourism services were not operating due to high water level conditions.
7. Did better weather and higher water level conditions in the fall make up some of the losses caused by water levels in the spring?

All of these factors may have had some role in the recreational boating and tourism impacts in the Lake Ontario-St. Lawrence River region, although it may be difficult to assess their importance with available data.

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