June 2019

High Water Impacts Research on Lake Ontario and St. Lawrence River – Municipal and Industrial Water Users FINAL RESULTS

Prepared for the International Joint Commission
by LURA Consulting

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1. EXECUTIVE SUMMARY

2017 presented challenges for industry and businesses located along the shorelines of Lake Ontario and the St. Lawrence River. A very wet spring led to record high water levels on both Lake Ontario and the St. Lawrence River which resulted in flood and erosion damage to a variety of shoreline properties.

The IJC's Great Lakes - St. Lawrence River Adaptive Management (GLAM) Committee has prepared a review of impacts across all sectors that were affected by high water levels in 2017 as well as an assessment of how the regulation of outflows from Lake Ontario impacted levels throughout the system, available here. Based on the availability of impact information for the GLAM Committee's report on 2017 conditions, the need for additional data collection was identified for a number of sectors. The GLAM Committee retained LURA Consulting to gather relevant information about 2017 high water impacts through surveys for two target groups: 1) recreational boating interests (marinas and yacht clubs), and 2) municipal water and wastewater operators and industrial facilities on the shorelines of Lake Ontario and the St. Lawrence River (downstream to Trois-Riviere).

The objectives of the research regarding high water level impacts on municipal and industrial facilities were:

1. To better understand the types of impacts municipal and industrial water users on Lake Ontario and the Upper and Lower St. Lawrence River experienced due to high water levels in 2017, the extent of these impacts, and critical water level thresholds for these users;

2. To understand the adaptive responses taken by municipal and industrial water users during and after 2017 high water levels; and

3. To accumulate data that will be used to help validate and/or improve existing models and support long-term activities to review regulation plans guiding water levels and flows in the Lake Ontario–St. Lawrence River System.

An exhaustive search was undertaken to identify potential respondents (municipal water/wastewater treatment plants, industrial facilities that take and/or return water, and power generating stations) within the Lake Ontario-St. Lawrence River System. A total of 207 potential respondents were identified, with 71 facilities identified in New York State, 99 in Ontario, and 37 in Quebec. The target sample size was met or exceeded for all facility types and locations, except for the overall target set for industrial facilities. This audience may require special consideration and additional outreach efforts for any future research of a similar nature.

Data collection occurred through a two-pronged approach: either a 30-minute telephone call, or through an online survey. It was found however that most facilities preferred being given the link for the survey to complete on their own. The study was promoted through various means such as an official invitation (and later on, reminder) letter/email from the GLAM Committee, direct phone calls to potential respondents, a web page on the GLAM Committee website. When undertaking outreach to invite these facilities to participate in the survey, the active approach of calling them proved to be far more effective in soliciting responses than the passive approach of letters or emails. One challenge that was often encountered however was identifying the appropriate individual to respond to the survey. This information was often not readily accessible in the public domain, and required considerable effort to identify while the study was ongoing.

This report details the findings of the municipal and industrial survey, to which 73 facilities responded. Key findings from the survey include:

- The majority of facilities (56.2%) reported no impact to their facility's operations from the 2017 high water levels. An additional 30.1% of facilities reported a negative impact on their facility's operations.
- Of those reporting impacts, "other impacts", "flooding of sewer manholes" and, "shoreline erosion affecting pipes near shoreline" were the most commonly cited impacts.
- When reviewing the total number of impacts reported by month, the highest number of impacts were reported in May (63 impacts reported), followed by April and June (42 impacts reported in each month). The overall number of impacts reported decreases throughout the late summer and into fall.
- Of those facilities identifying a source of flooding for the aforementioned impacts, the most frequently cited source was overland flow from Lake Ontario and/or the St. Lawrence River.
- The vast majority (86%) of facilities did not experience any loss of service due to the 2017 high water levels. Of those facilities that did experience a loss of service, the largest number were municipal wastewater treatment plants on Lake Ontario, of which there were four. Of those indicating a loss of service, a number cited a reduced capacity to treat wastewater during peak (wet weather) flows. A small number of facilities (n=2) indicated that this situation lasted for a few months.
- The majority of facilities (86%) indicated that they did not experience any improvements. Of those facilities that did experience improvements, the largest number were municipal water treatment plants from the Lower St. Lawrence River and Lake Ontario.
- While the majority (79%) of facilities did not report water quality concerns, twenty-one percent (21%) did experience water quality concerns. Water quality concerns were most often cited in municipal wastewater treatment plants on Lake Ontario and municipal water treatment plants on the Lower St. Lawrence River.
- Two-thirds of facilities (67%) reported taking no actions in 2017 in response to the high water levels. Conversely, 33% or twenty-four facilities did take action during the high water levels. Seventy-three percent (73%) of facilities reported no actions since the 2017 event, while 27% reported taking some action.
- Fourteen (14) facilities reported costs associated with actions taken in 2017, while 59 reported no cost. Of those that did incur costs, the average cost of actions taken in 2017 was $71,028.57, with cited costs ranging from $100 to $220,000.
- Twelve (12) facilities reported costs associated with actions since 2017, while 61 reported no cost. In terms of twelve facilities that had taken actions since 2017, the average cost was $624,416.67. In this case, costs ranged from $10,000 to $3,000,000.
- While the majority of facilities (79%) did not identify any new vulnerabilities from the 2017 event, twenty-one percent (n=15) indicated the identification of new vulnerabilities.
- On a scale of 1 (low) to 10 (high), nearly half of facilities (47.8%) rated the overall impact as a "1". The average rating was 2.7. Three-quarters of facilities (75.4%) rated the overall impact as a 1, 2 or 3.

2. INTRODUCTION

2.1. Background

2017 was a challenging year for industry and businesses located along the shorelines of Lake Ontario and the St. Lawrence River. A very wet spring led to record high water levels on both Lake Ontario and the St. Lawrence River which resulted in flood and erosion damage to a variety of shoreline properties.

The IJC's Great Lakes St. Lawrence River Adaptive Management (GLAM) Committee has prepared a review of impacts across all sectors that were affected by high water levels in 2017 as well as an assessment of how the regulation of outflows from Lake Ontario impacted levels throughout the system, available here. The GLAM Committee was established by the IJC in 2015 to examine the effectiveness of the existing rules for regulating the outflows from Lake Superior and Lake Ontario. It is also charged with looking at the impacts of past, present and potential future weather and climate conditions on water levels and outflow regulation, and how these factors affect different user groups throughout the Great Lakes-St. Lawrence River system. The International Lake Ontario – St. Lawrence River Board urges everyone to be prepared to live within the full range of levels that have occurred in the past and of those that may occur in the future, recognizing that future climate conditions are uncertain, and more extreme water levels may be reached.

Based on the availability of impact information for the GLAM Committee's report on 2017 conditions, the need for additional data collection was identified for a number of sectors. The GLAM Committee retained LURA Consulting to gather relevant information about 2017 high water impacts from two target groups: 1) recreational boating interests (marinas and yacht clubs), and 2) municipal water and wastewater operators and industrial facilities on the shoreline.

From past and recent research with municipal and industrial water users, there was indication that high water impacts could affect facilities through flooding and that sewage overflows can be an issue for wastewater treatment systems. It was however identified that there was insufficient information on the breadth and severity of impacts, and that an improved understanding is needed regarding: a) loss of service or cost to maintain service at these facilities due to high water levels; b) water quality concerns; and c) impact on the function of municipal water infrastructure near the shoreline.

To enhance this understanding, extensive efforts were undertaken by LURA Consulting between January and March 2019 to survey municipal and industrial facilities on the shorelines of Lake Ontario and the St. Lawrence River, who take water from and/or discharge water to the two water bodies. The survey was open from January 23, 2019 to March 31, 2019 (extended from the initial deadline of March 8, 2019). This report details the findings of this survey. Ultimately, the information collected will be used by the GLAM Committee to help improve the models used to assess the regulation of Lake Ontario outflows under a range of actual and potential future climate conditions.

2.2. Research Objectives and Questions

The objectives of the research regarding high water level impacts on municipal and industrial facilities were:

1. To better understand the types of impacts municipal and industrial water users on Lake Ontario and the Upper and Lower St. Lawrence River experienced due to high water levels in 2017, the extent of these impacts, and critical water level thresholds for these users;

2. To understand the adaptive responses taken by municipal and industrial water users during and after 2017 high water levels; and

3. To accumulate data that will be used to help validate and/or improve existing models and support long-term activities to review regulation plans guiding water levels and flows in the Lake Ontario–St. Lawrence River System.

Key overarching questions that guided the research included:

1. How were facilities and operations affected by the high water levels in 2017 (positive and negative, month-by-month)?
2. What were the impacts of the high water levels on the function of municipal water infrastructure near the shoreline (e.g. any water quality concerns)?
3. What adaptive responses did the facility take <u>during</u> the 2017 high water conditions to maintain operations?
4. What adaptive responses has the facility taken <u>after</u> the 2017 high water conditions to protect against future impacts?
5. Did the impacts of the high water levels in 2017 result in the facility identifying any additional vulnerabilities to either high or low water conditions?

The full approach to the survey and full set of questions within it is available as Appendix A.

2.3. Target Survey Audience

The key groups that were targeted for this survey included:

Municipal Water Treatment Plants	Facilities that take water from Lake Ontario or the St. Lawrence River and treat that water to provide drinking water to a specific service area.
Municipal Wastewater Treatment Plants	Facilities that process wastewater from a specific service area and return clean treated water to Lake Ontario or the St Lawrence River.
Industrial Water Users	Facilities that take water from or return water to Lake Ontario or the St. Lawrence River as part of the facility's operation activities.
Power Generating Stations	Facilities that use water from Lake Ontario or the St. Lawrence River specifically for the generation of power, which may include the intake and outflow of water for cooling purposes.

The geographic scope of these target audiences includes facilities located on the Canadian and United States shorelines of:

Lake Ontario	One of the five Great Lakes, bordered on the north and west by the Province of Ontario, and the south and east by the State of New York.
Upper St. Lawrence River	The portion of the St. Lawrence River upstream of the Moses-Saunders Dam at Cornwall, ON and Massena, NY is called the upper St. Lawrence River. It includes the entire river from Kingston/Cape Vincent to the power dam and locks at Cornwall-Massena, including Lake St. Lawrence.
Lower St. Lawrence River	The portion of the St. Lawrence River downstream of the Moses-Saunders Dam is called the lower St. Lawrence. It includes Lake St. Francis, Lake Saint-Louis, Montreal Harbour, Lac St. Pierre and the portions of the River connecting these lakes as far downstream as Trois-Rivieres, Quebec.

2.3.1. Sample Selection

A list of municipal and industrial water users on Lake Ontario and the St. Lawrence was compiled by updating a pre-existing list from 2005 CDM research on the impacts of changes in source water elevation on water supply infrastructure, commissioned by the U.S. Army Corps of Engineers Institute for Water Resources[1]. This was complemented with a number of other documents and sources, including:

- A summary of municipal and industrial facilities approached by the U.S. Army Corps of Engineers (Buffalo) in 2018;
- A summary of New York State water intakes and discharges on Lake Ontario and the St. Lawrence river, provided by the New York State Department of Environmental Conservation;
- Publicly available lists of permits to take water in Ontario;
- Publicly available environmental compliance reports in Quebec;
- Publicly available mapping on water taking in New York;
- 'Ground truthing' via publicly available mapping software; and
- Internet searches to confirm whether a facility was still operational, and the completeness of previously documented information.

The number of identified facilities is summarized in Table 1, stratified by the three main geographic areas included in the study – the shorelines of Lake Ontario, the upper St. Lawrence River, and the lower St. Lawrence River. A total of 71 facilities were identified in New York State, 99 in Ontario, and 37 in Quebec.

Table 1: Total number of municipal and industrial water users in the study area

		Shoreline Location			
		Lake Ontario	Upper St. Lawrence	Lower St. Lawrence	Total Number
Type of Facility	Municipal Water and Waste Water Treatment Plants	85	23	31	139
	Industrial	31	9	11	51
	Power	11	3	3	17
	Total	127	35	47	**207**

[1] U.S. Army Corps of Engineers. (2005). *Impacts of Changes in Source Water Elevation on Water Supply Infrastructure: Lake Ontario and the St. Lawrence River.* Institute for Water Resources.

Table 2 displays the originally proposed target sample size for the survey. The number of facilities in each category were first assigned proportionally across the shoreline zones, and then adjusted to fill in known information gaps (e.g. nuclear facilities, industries, Lower St. Lawrence). It is important to note that the information presented below does not represent a statistically representative sample, and the project scope never intended to generate a statistically significant sample. However, the sample identified below allowed for in-depth exploration of impacts on the diversity of facilities in the target group across the three geographical zones.

Table 2: Originally proposed sampling of municipal and industrial water users

<table>
<tr><th></th><th></th><th colspan="3">Shoreline Location</th><th></th></tr>
<tr><th></th><th></th><th>Lake Ontario</th><th>Upper St. Lawrence</th><th>Lower St. Lawrence</th><th>Total Number</th></tr>
<tr><td rowspan="6">Type of Facility</td><td>Municipal Water Treatment</td><td rowspan="2">13</td><td rowspan="2">5</td><td rowspan="2">5</td><td rowspan="2">23</td></tr>
<tr><td>Municipal Wastewater Treatment Plant</td></tr>
<tr><td>Industrial</td><td>7</td><td>5</td><td>3</td><td>15</td></tr>
<tr><td>Power</td><td>3</td><td>1</td><td>1</td><td>5</td></tr>
<tr><td>Total</td><td>23</td><td>11</td><td>9</td><td>43</td></tr>
</table>

2.4. Methodology

2.4.1. Data Collection Approach

Specific facilities from the developed list of 207 were randomly selected until the sample number was reached (or in many cases, exceeded). Data collection occurred through a two pronged approach: 1) 30-minute telephone calls conducted in the language (English or French) preference of the respondent once the most appropriate individual to answer the questions was identified; 2) facility operators/supervisors were provided the option of completing the questions online once the most appropriate individual was identified.

If done by telephone, the interviewer documented the responses in the online survey platform. GPS coordinates were also documented in the database to connect responses to their geographical location. French responses were documented in a separate online platform, translated, and entered into the database in English for ease of analysis.

2.4.2. Promotion and Outreach Efforts

Official Letter/Email from GLAM Committee Introducing the Project

A formal letter/email was the first contact with municipal and industrial water users and was sent to the full list of identified facilities (207) via LURA Consulting, addressed specifically to facility supervisors or managers. The letter/email included the GLAM Committee logo and outlined the importance of collecting the data about high water impacts in 2017 to support long-term activities to review existing regulation plans. It notified facilities that someone from LURA would be contacting them at a later date to schedule an interview time by phone or Skype, and that their participation would be appreciated. Letters/emails were sent in both English and French, as appropriate, on January 23, 2019.A copy is provided in Appendix A.

Phone Contact

Attempts were made to reach all facilities on the list of 207 by phone between January 23, 2019 and March, 25 2019 – ahead of the closing date of March 31, 2019. Once the appropriate individual at a facility had been identified, the purpose of the survey and its importance were outlined for them, and they were invited to do the survey by phone or online, both at a time of their convenience. Calls were made in both English and French, as appropriate. GLAM Committee members also assisted in contacting potential respondents by email and phone.

GLAM Committee Website

Details of the survey were posted on the GLAM Committee website, inviting interested potential facilities to contact the GLAM Committee for information on doing the survey.

Official Reminder Letter/Email from GLAM Committee

A formal reminder letter/email was sent to the full list of identified facilities who had yet to complete the survey, reminding them to please do so, and that the closing date had been extended.

Letters/emails were sent in both English and French, as appropriate, on March 4, 2019. A copy is provided in Appendix A.

2.4.3. Data Analysis Methods

Responses were collected via SurveyMonkey, in both English and French, as outlined above. Upon closure of the survey, all responses were exported into both MS Excel and PDF format. Responses included both quantitative and qualitative data.

First, data was reviewed in Excel to ensure completeness and consistency (i.e. removed duplicate or entirely incomplete responses, adding additional summary columns to aid in analysis). GPS coordinates (latitude and longitude) were entered for each facility. GPS coordinates were located using Google Maps, based on the addresses provided by facilities.

Quantitative analysis was conducted in Excel, maintaining a “Master” tab with the complete dataset, and adding additional tabs for each question posed in the survey. Analysis was completed using a series of pivot tables to calculate count and percentage data, as applicable. Pivot charts were then used to present the data graphically. In some cases, multiple graphs were generated in order to best present the resulting information. Where applicable and appropriate, further analysis was conducted into correlations, exploring the data by month, facility type, location, and shoreline zone.

Qualitative analysis was conducted in NVivo – a purpose-built software for qualitative and mixed-methods[2] research. NVivo assists in managing and analyzing large datasets, and streamlines the identification of key themes emerging from qualitative data. First, the complete PDF of response data from SurveyMonkey was uploaded into NVivo software, and qualitative (open-ended) responses were categorized by question number. Again, working question-by-question, responses were “coded”, manually identifying and highlighting key themes using thematic analysis techniques. Thematic analysis[3] is a method of data reduction, which involves summarizing and categorizing qualitative data such that the important concepts within the data set are captured. Once the thematic analysis was completed for each question, the collection of themes was used to formulate descriptive text to accompany the appropriate graphs (described above). The results of the coding are available in Appendix B.

The final step in the process was to present the quantitative and qualitative results together. Within this report, graphs have been presented with accompanying qualitative description, which builds upon the interpretation of the results.

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[2] Where researchers analyze both qualitative and quantitative data in the same study

[3] Given, L. M. (Ed.). (2008). *The Sage encyclopedia of qualitative research methods*. Sage Publications.

2.4.4. Interpreting the Data

The overall approach taken to collect data for this project is referred to as purposive sampling[4]. This involves identifying a population of interest (facility operators in this case) and developing a systematic way to obtain responses that is not based on any predetermined knowledge of what the responses or outcomes would be. The purpose of the research and data collection is to increase credibility, not to foster statistical representativeness.

It is important to note that the information presented below does not represent a statistically representative sample. This was not the intent of the research. However, the sampling approach described in Section 2.3.1 allowed for in-depth exploration of impacts on diverse respondents in the target audience across the three geographical zones. Further, it enabled a mix of quantitative and qualitative analysis on the extent and types of impacts experienced by marina and yacht club operators along Lake Ontario and the St. Lawrence River.

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[4] Lavrakas, P. J. (2008). *Encyclopedia of survey research methods*. Sage Publications.

3. OVERVIEW OF RESPONSES

3.1. Response Rate

As shown in Table 3 (below), the overall response rate for the municipal and industrial water users survey was seventy-three (n=73), exceeding the original target sample of 43. All sampling targets were met or exceeded, with the exception of industrial facilitates on the Upper and Lower St. Lawrence River.

Table 3: Response rate for municipal, industrial and power users.

Type of Facility		Lake Ontario (Target)	Lake Ontario (Actual)	% of Target	Upper St. Lawrence (Target)	Upper St. Lawrence (Actual)	% of Target	Lower St. Lawrence (Target)	Lower St. Lawrence (Actual)	% of Target	Total Number (Target)	Total Number (Actual)	% of Target
	Municipal Water/ Wastewater Treatment	13	27	208%	5	8	160%	5	21	420%	23	56	243%
	Industrial	7	7	100%	5	1	20%	3	1	33%	15	9	60%
	Power	3	6	200%	1	1	100%	1	1	100%	5	8	160%
	Total	23	40	**174%**	11	10	**91%**	9	23	**256%**	43	73	**170%**

Figure 1 (below) displays the response rate compared to the target sample. Geographically, the largest number of facilities were located on Lake Ontario (n=40). In terms of facility type, municipal water and wastewater treatment plants were the most frequent facilities (n=56).

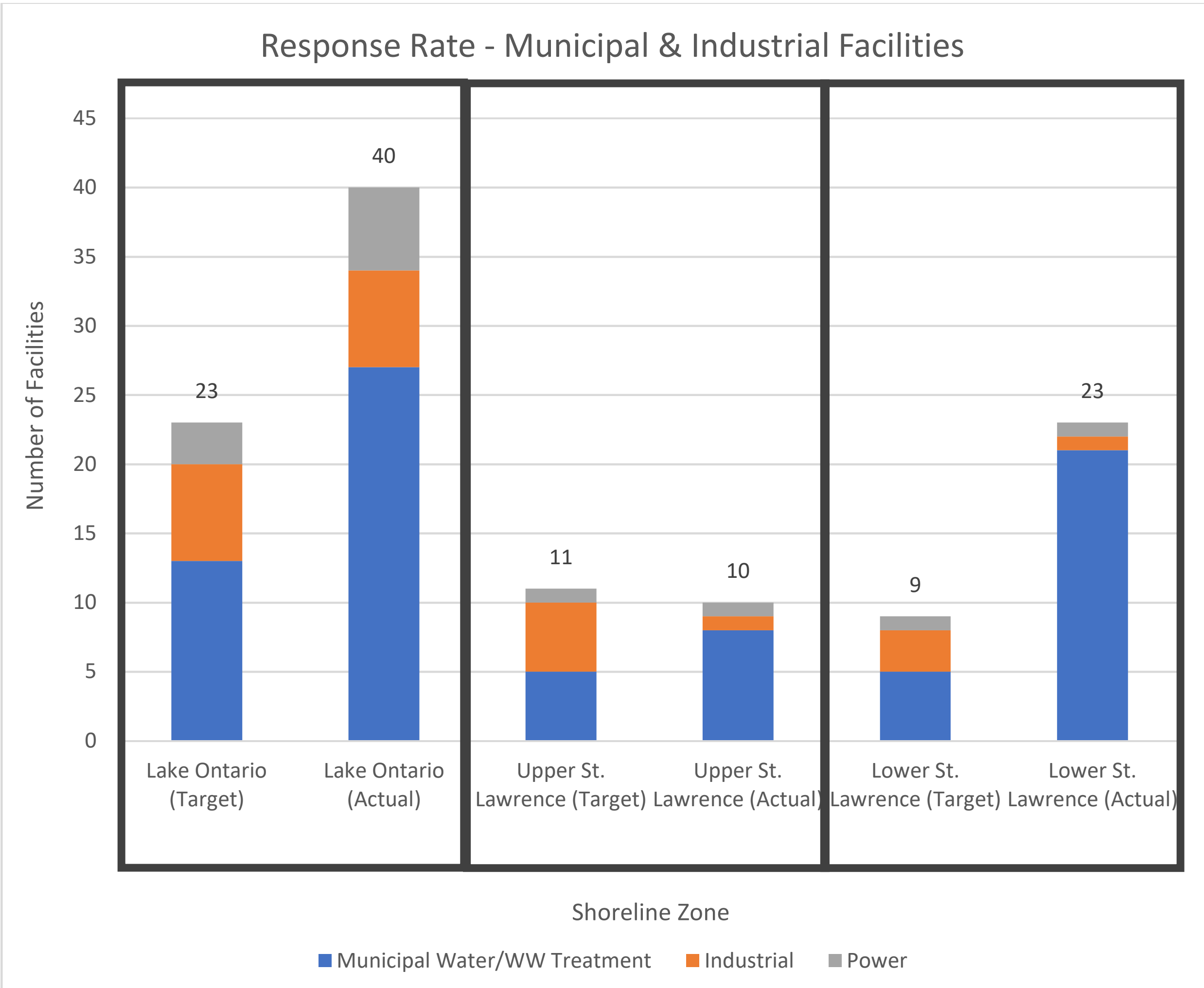


Figure 1: Response rate by facility shoreline zone and facility type (n=73)

4. CHARACTERISTICS OF FACILITIES

4.1. Facilities by Location

Figure 2 (below) shows each of the participating facilities based on their geographic location. Facility types are distinguished by colour.

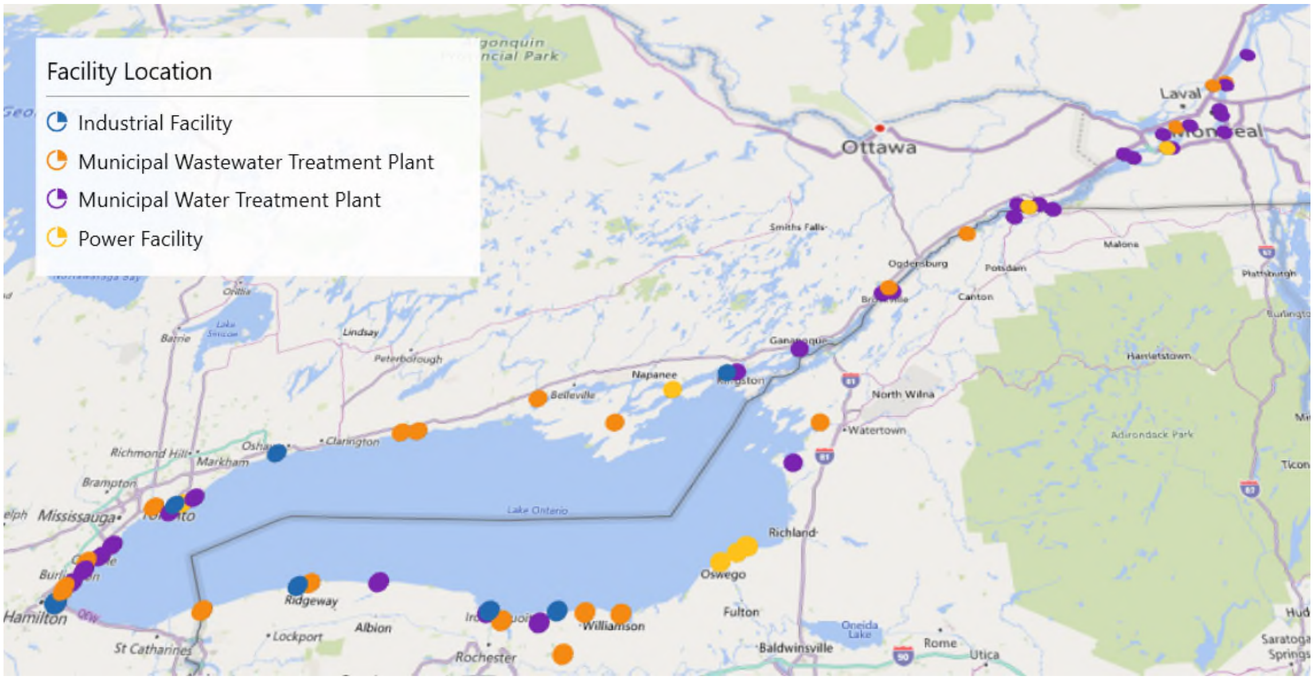
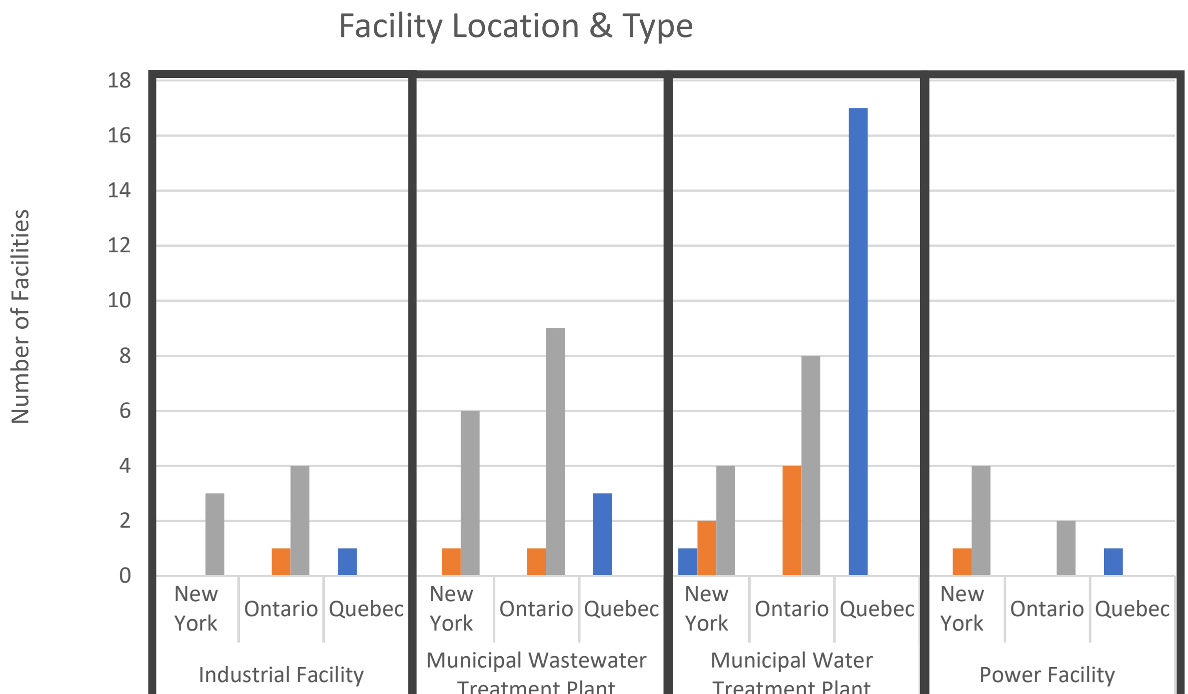


Figure 2: Map showing facilities by location and type

As shown in Figure 3 (below), the largest proportion of facilities were from municipal water treatment plants in Quebec, located on the Lower St. Lawrence River. In comparison, the smallest number of responses came from power and industrial facilities in Quebec. These facilities were also located on the Lower St. Lawrence River. The largest number of responses from Ontario and New York came from municipal water and wastewater facilities, with fewer responses from industrial and power facilities.



	Industrial Facility – New York	Industrial Facility – Ontario	Industrial Facility – Quebec	Municipal Wastewater Treatment Plant – New York	Municipal Wastewater Treatment Plant – Ontario	Municipal Wastewater Treatment Plant – Quebec	Municipal Water Treatment Plant – New York	Municipal Water Treatment Plant – Ontario	Municipal Water Treatment Plant – Quebec	Power Facility – New York	Power Facility – Ontario	Power Facility – Quebec
Lower St. Lawrence River			1			3	1		17			1
Upper St. Lawrence River		1		1	1		2	4		1		
Lake Ontario	3	4		6	9		4	8		4	2	

Figure 3: Facilities by facility location and facility type (n=73)

4.2. Municipal Plants by Population

In terms of municipal facilities, the highest number of responses were received from those serving populations under 50,000, as shown in Figure 4. A greater number of responses was received from water treatment plants compared to wastewater treatment plants. Facilities are also shown on the map below (Figure 5).

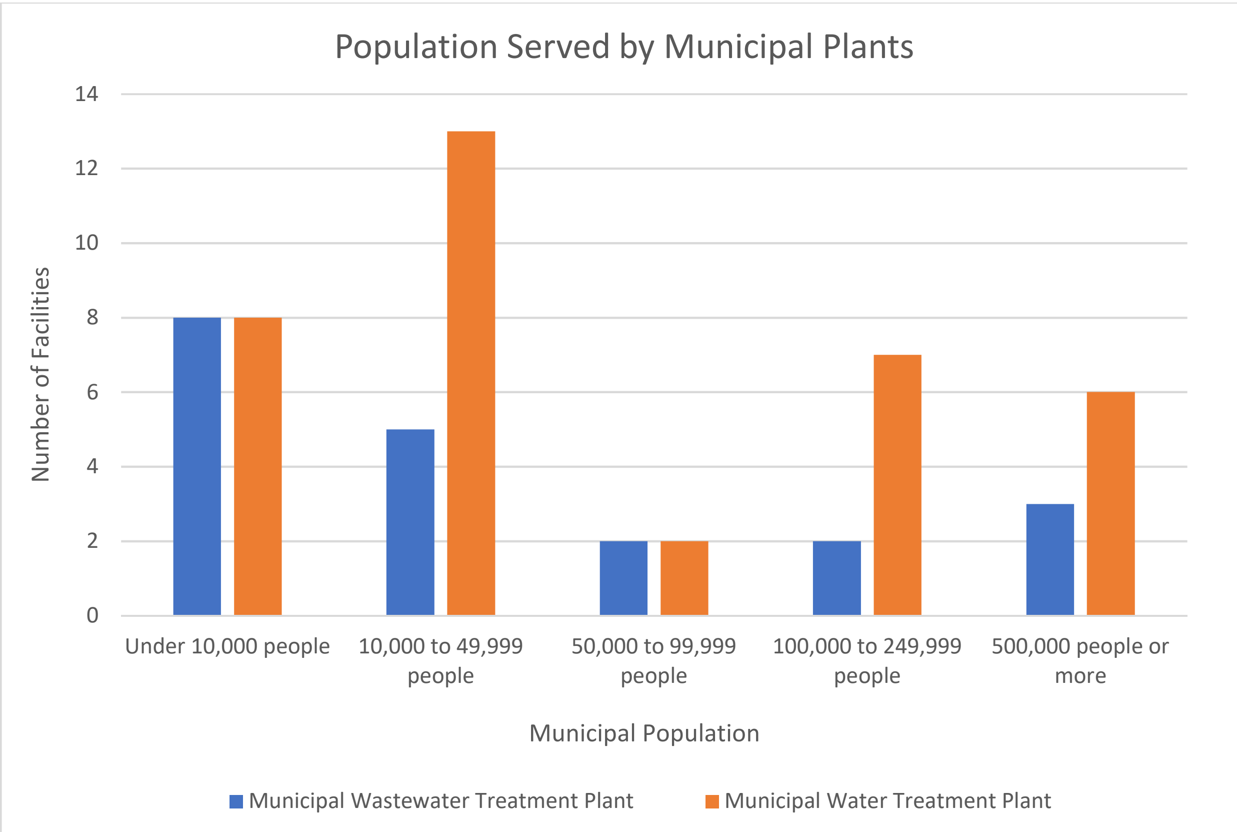


Figure 4: Population served for Municipal plants in study area (n=56)

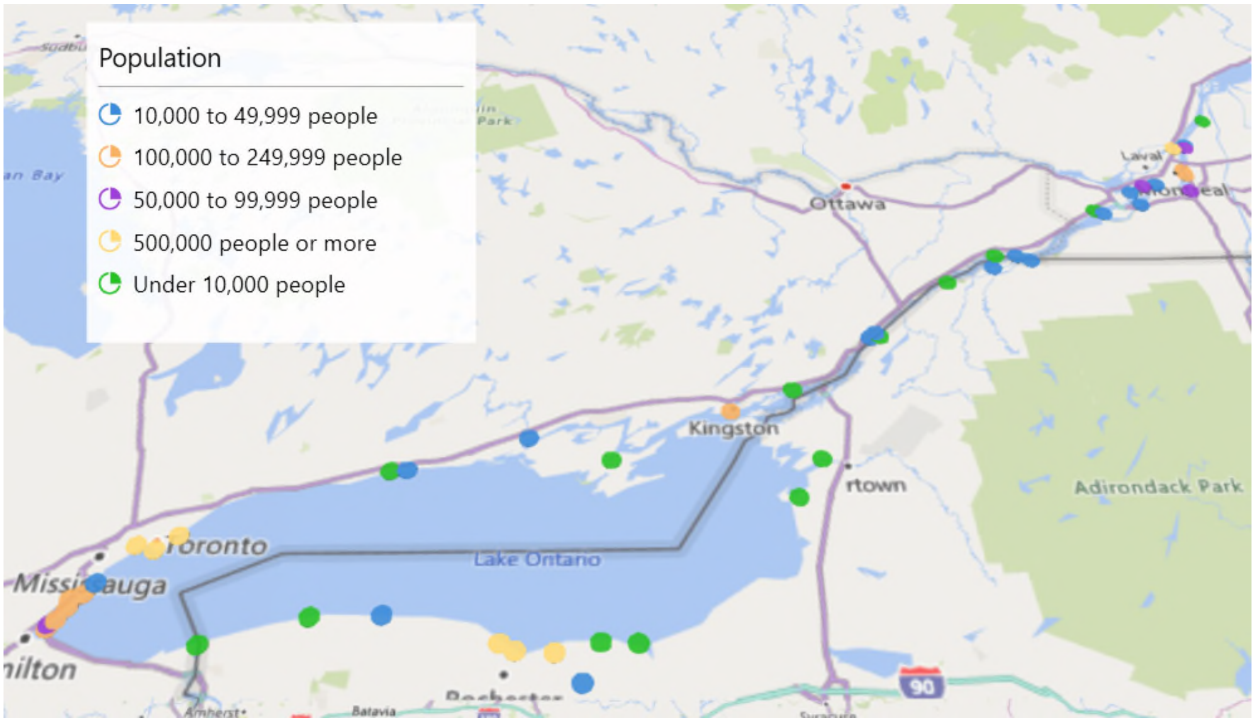


Figure 5: Map of municipal plants by population served

5. IMPACTS OF HIGH WATER LEVELS

5.1. Degree of Impact by Shoreline Location

Facilities were asked to identify the degree of impact that the 2017 high water levels had on their facility's operations. As shown in Figure 6 (below), the majority of facilities (56.2%) reported no impact to their facility's operations. An additional 30.1% of facilities reported a negative impact on their facility's operations. The largest proportion of those reporting positive or both negative and positive impacts were located on the Lower St. Lawrence River. None of the facilities from the Upper St. Lawrence River reported positive impacts to their operations.

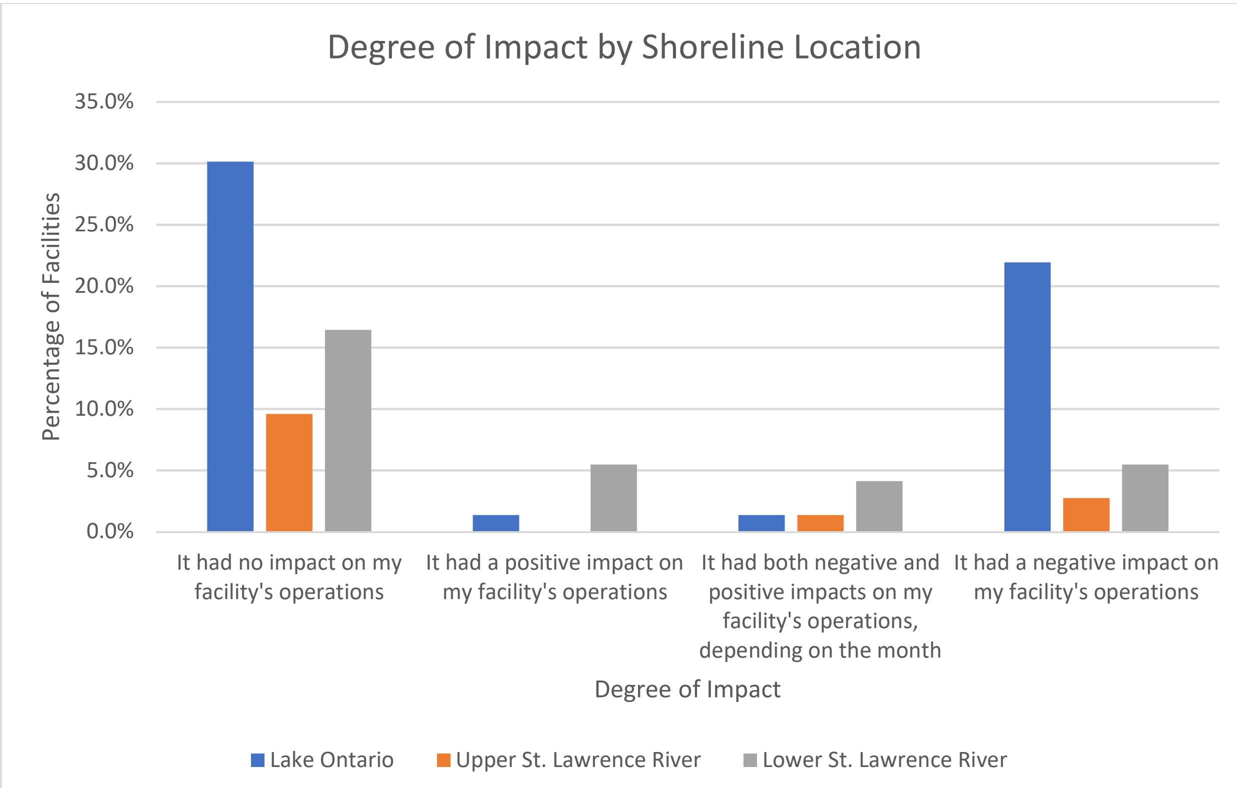


Figure 6: Degree of impact on facilities by shoreline location (n=73)

5.2. Experience of Physical Impacts

Next, facilities were asked to identify any physical impacts experienced during the 2017 high water levels. Figure 7 (below) displays the number of facilities reporting specific impacts at any point during the peak 2017 high water level period (April to October). The majority of facilities reported no impacts or indicated that the suggested impacts were not applicable to their operations. Of the 31 unique facilities that reported impacts, "other impacts", "flooding of sewer manholes" and, "shoreline erosion affecting pipes near shoreline" were the most commonly cited impacts.

Physical impacts were attributed to both storm events and static water levels. One respondent noted that the impacts occurred during static water levels, but were amplified by storm events.

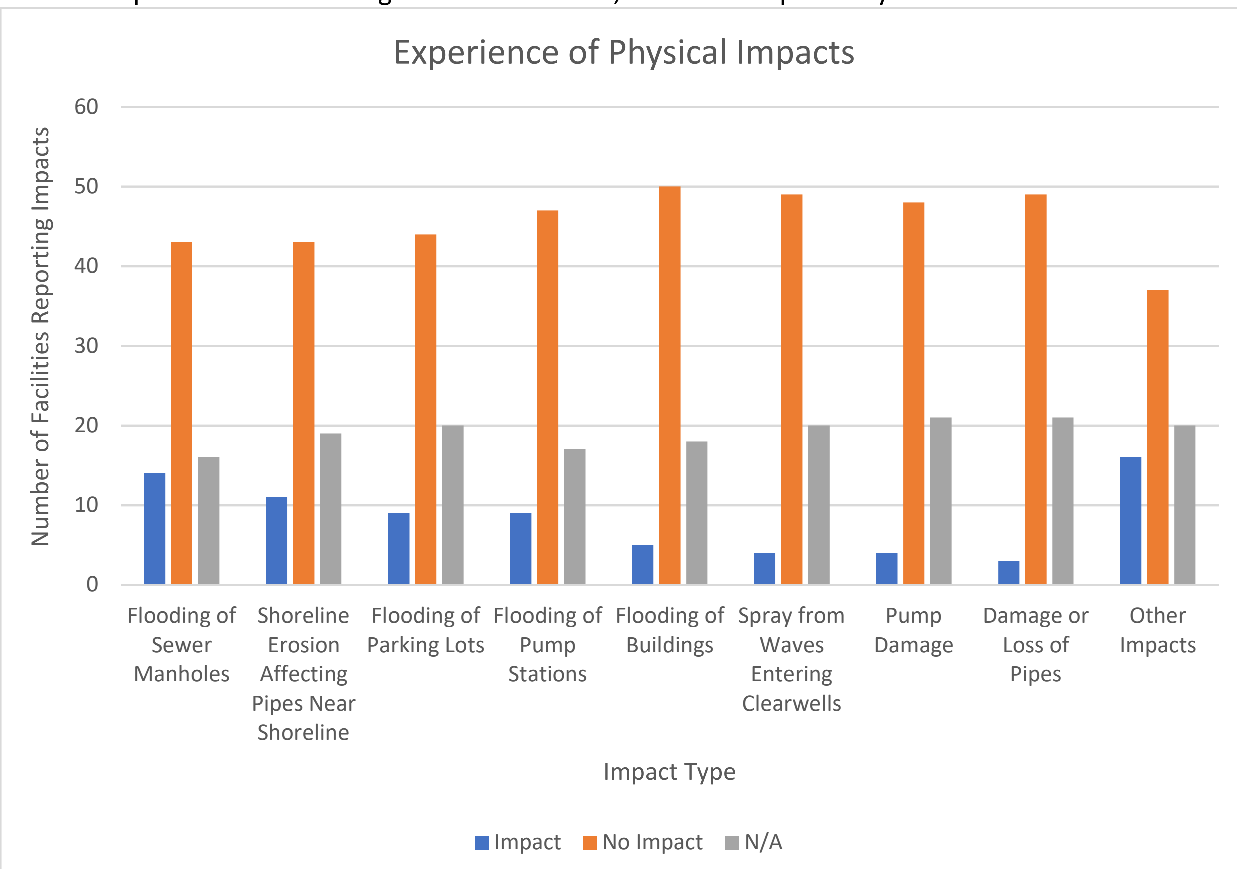


Figure 7: Experience of physical impacts on facilities (n=73)

Figure 7a (below) displays the experience of physical impacts by location. Facilities in New York and Ontario reported “other impacts” most often, while facilities in Quebec reported “flooding of sewer manholes” most often. “Other impacts” are further explained in Section 5.2.9 (below).

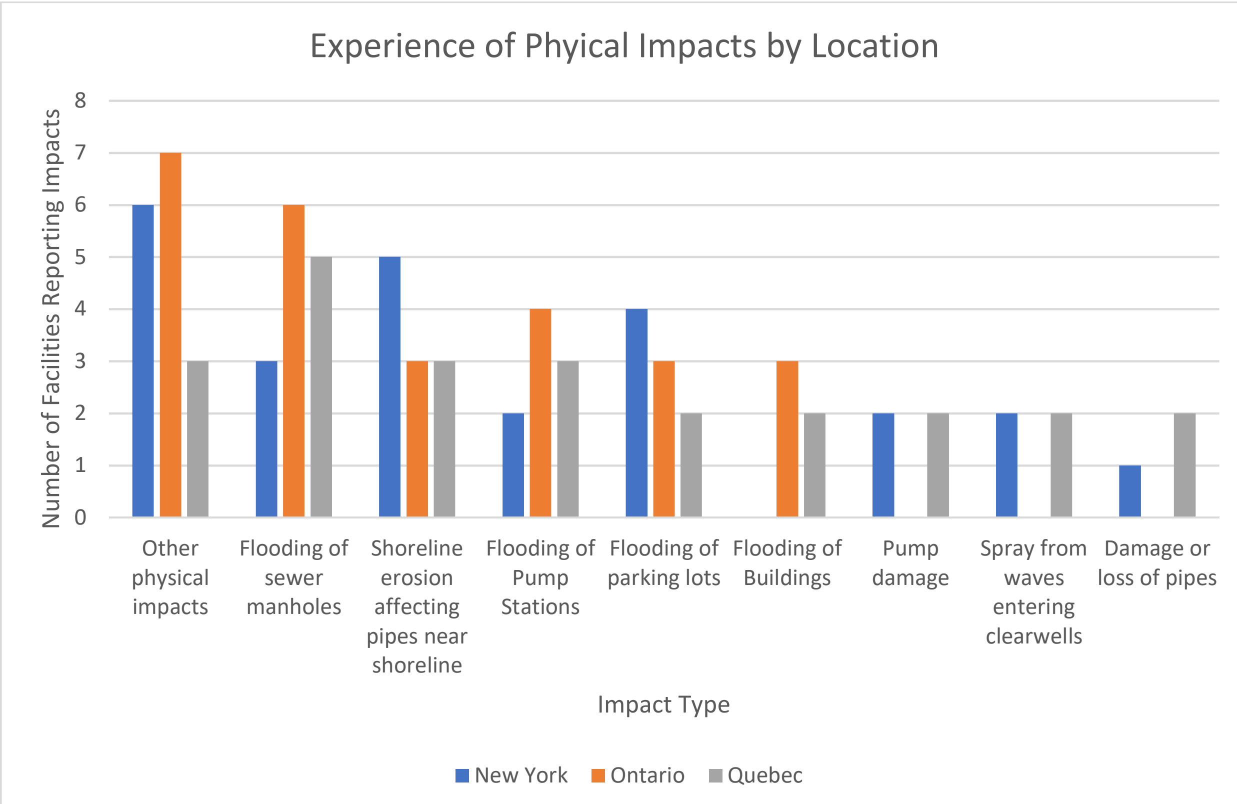


Figure 7a: Experience of physical impacts by location (n=73)

As shown in Figure 8 (below), the majority of facilities (57.5%) did not report any impacts. Thirty-four percent (34.2%) of facilities reported one, two or three impacts. Figure 9 (below) shows that of all facility types, municipal wastewater treatment plants reported the largest average number of impacts.

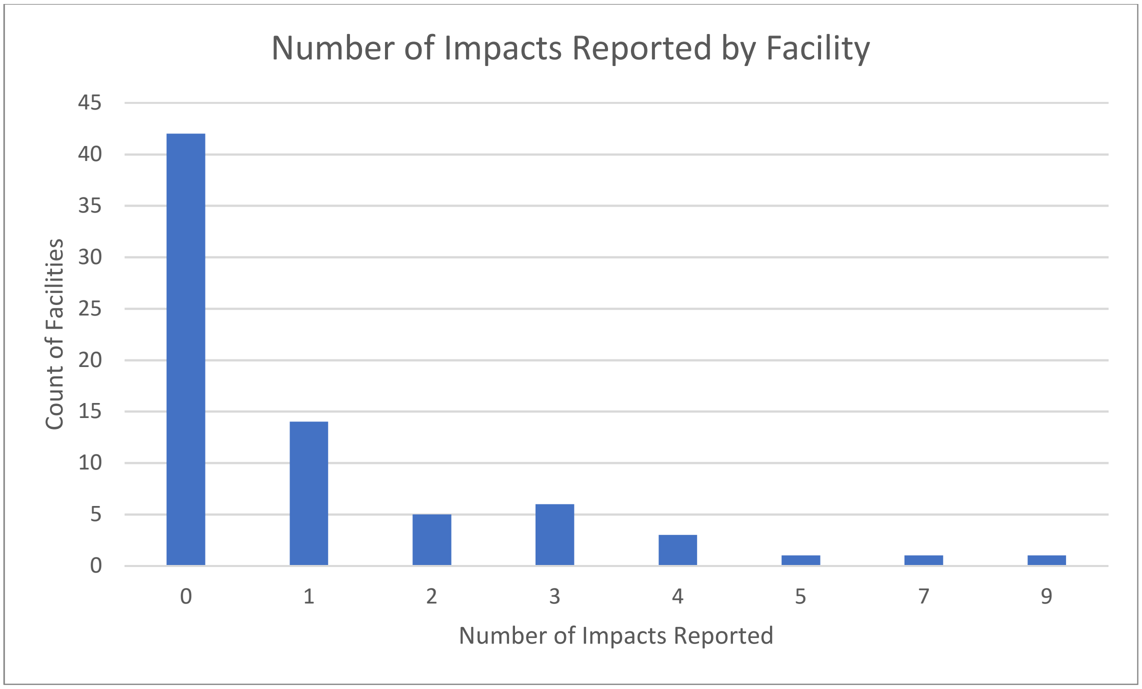


Figure 8: Number of impacts reported by facility (n=73)

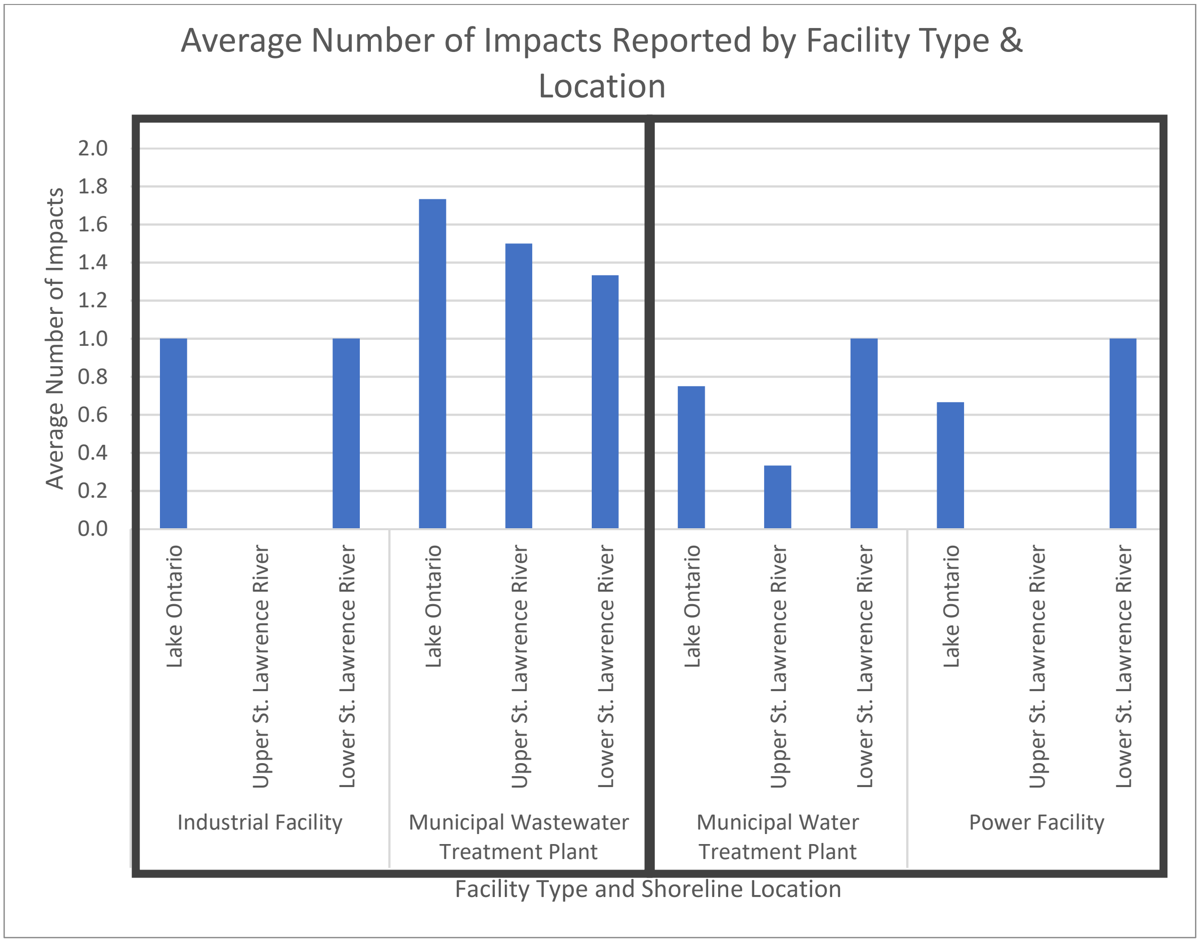


Figure 9: Average number of impacts reported by facility type and location (n=73)

The figures in the following sections look at a specific impact (i.e. flooding of sewer manholes) and presents the number of facilities reporting that impact by month.

5.2.1. Flooding of Sewer Manholes

Of the 57 facilities answering this question, 14 unique facilities reported impacts in one or more months and, 43 reported no impacts associated with the flooding of sewer manholes. This impact was most often reported in May, followed by April and June.

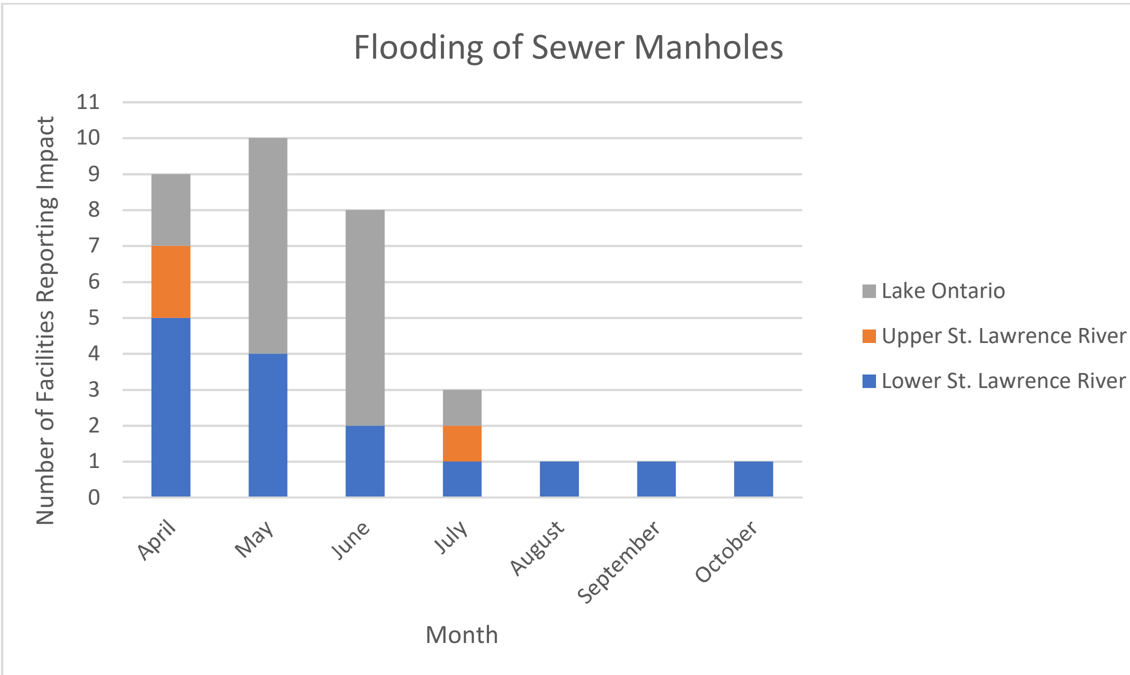


Figure 10: Flooding of sewer manholes by month (n=57)

5.2.2. Shoreline Erosion Affecting Pipes Near Shore

Similar to the above, shoreline erosion affecting pipes near the shoreline was most often reported in May, followed by April and June respectively. No impact was reported for October. Of the 54 facilities answering this question, 11 unique facilities reported impacts in one or more months and, 43 reported no impacts associated with shoreline erosion affecting pipes near shore.

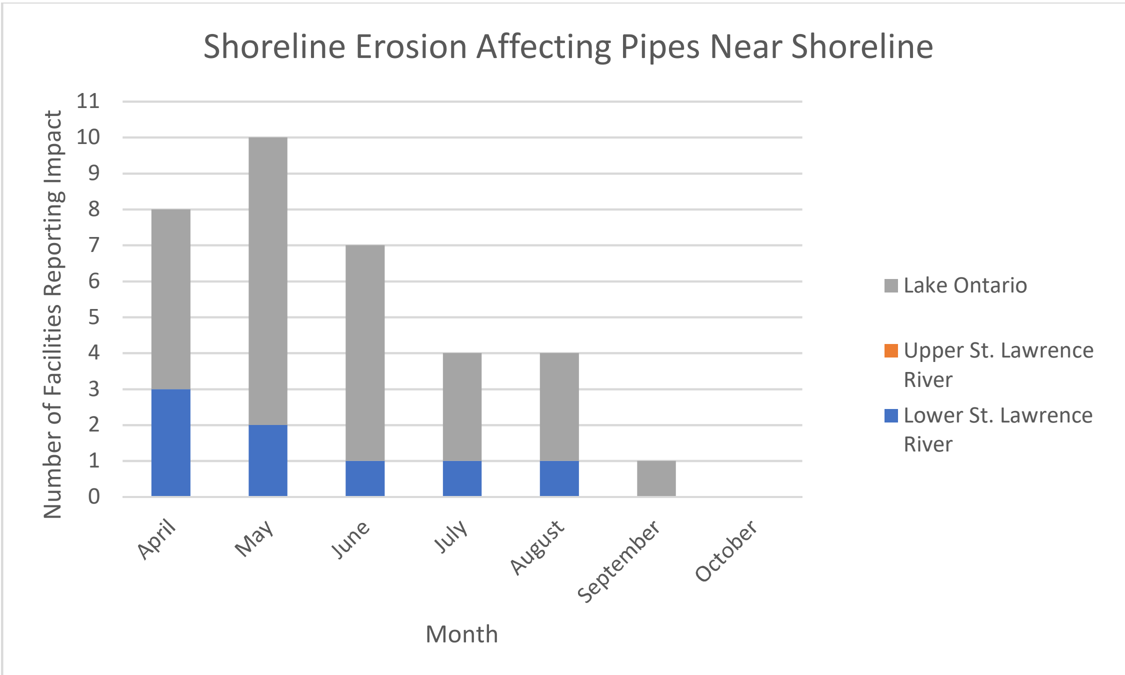


Figure 11: Shoreline erosion affecting pipes near shore by month (n=54)

5.2.3. Flooding of Parking Lots

The flooding of parking lots was most often reported during the month of May. No flooding of parking lots was cited during August or September. Of the 53 facilities answering this question, 9 unique facilities reported impacts in one or more months and, 44 reported no impacts associated with the flooding of parking lots.

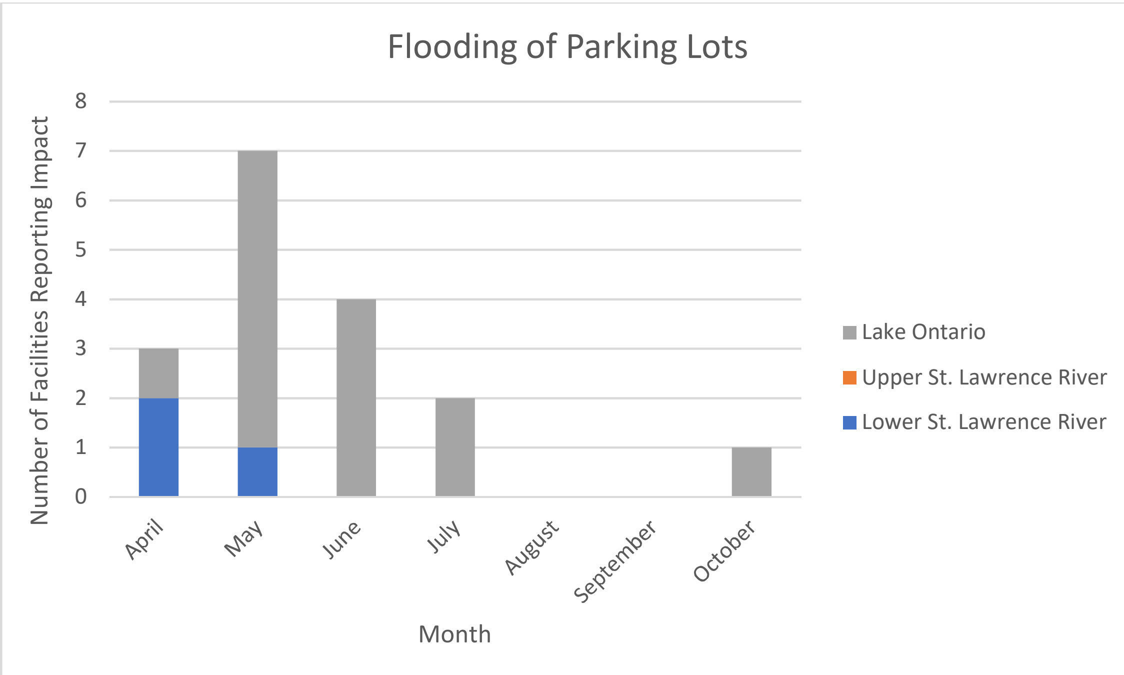


Figure 12: Flooding of parking lots by month (n=53)

5.2.4. Flooding of Pump Stations

In comparison to the impacts highlighted above, flooding of pump stations appeared to be more evenly distributed across the three shoreline zones. Again, the most impacts were felt during the month of May, followed by April and June. Of the 56 facilities answering this question, nine unique facilities reported impacts in one or more months and, 47 reported no impacts associated with the flooding of sewer manholes.

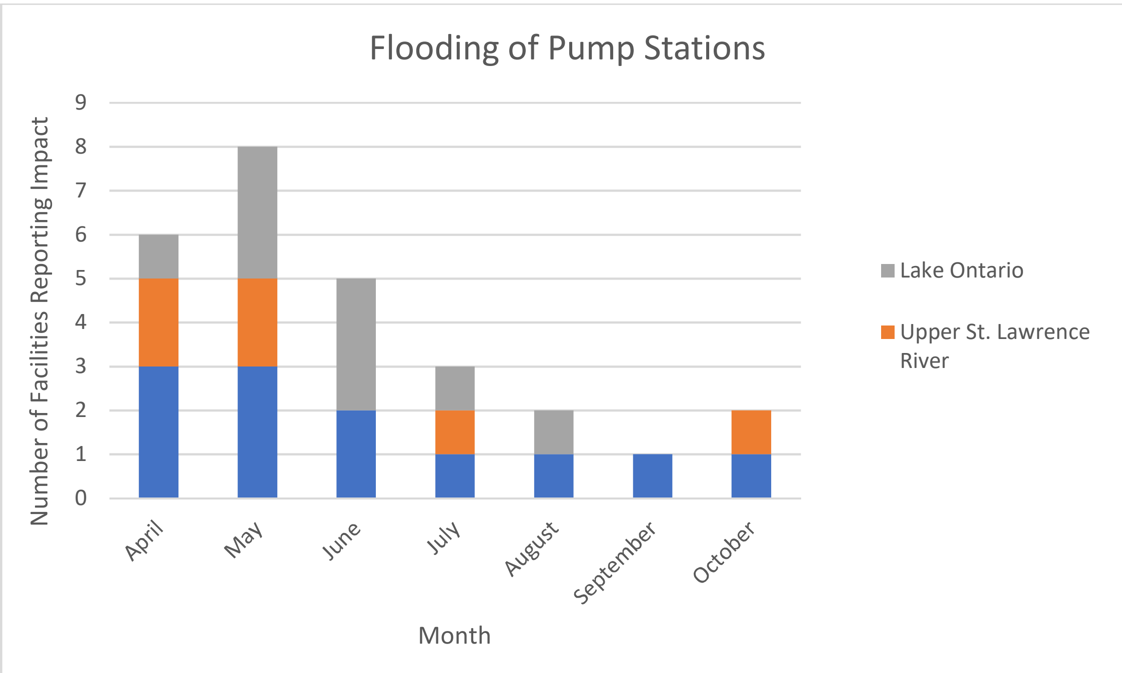


Figure 13: Flooding of pump stations by month (n=56)

5.2.5. Flooding of Buildings

A small number of facilities experienced flooding of buildings in April and May, as shown in Figure 14 (below). Of the 55 facilities answering this question, five unique facilities reported impacts in one or more months and, 50 reported no impacts associated with the flooding of buildings. One facility on Lake Ontario reported flooding of buildings in each month.

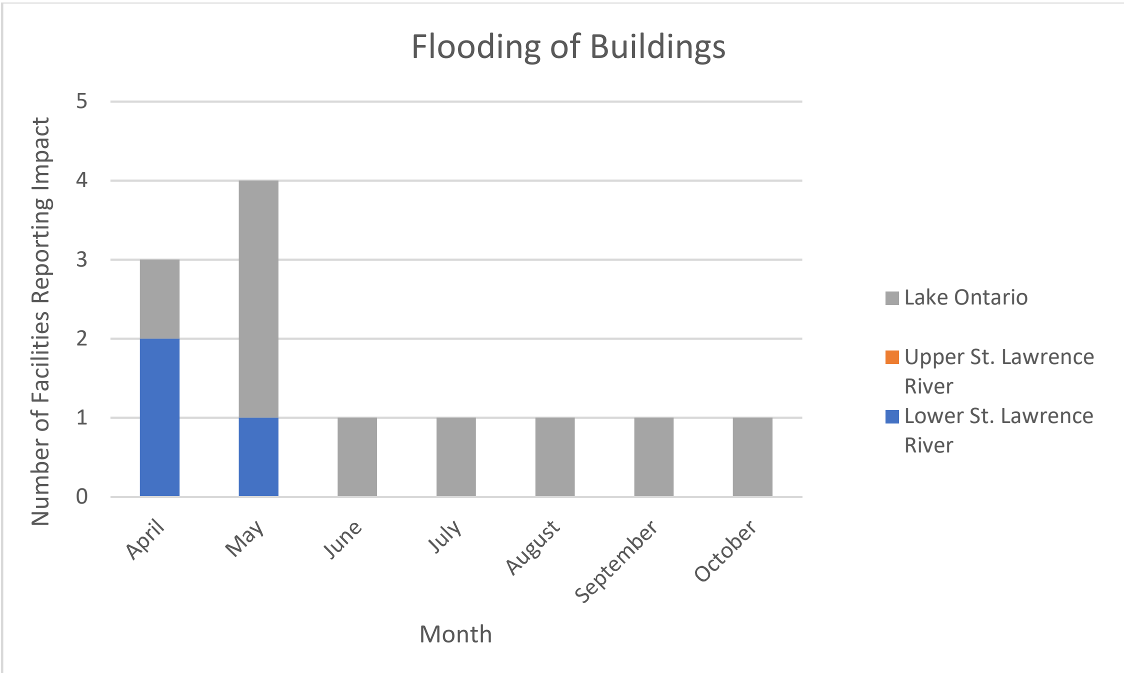


Figure 14: Flooding of buildings by month (n=55)

5.2.6. Spray from Waves Entering Clearwells

Four facilities reported spray from waves entering clearwells in May and June, as shown in Figure 15 (below). No impacts were reported in September or October. Of the 53 facilities answering this question, four unique facilities reported impacts in one or more months and, 49 reported no impacts due to spray from waves entering clearwells.

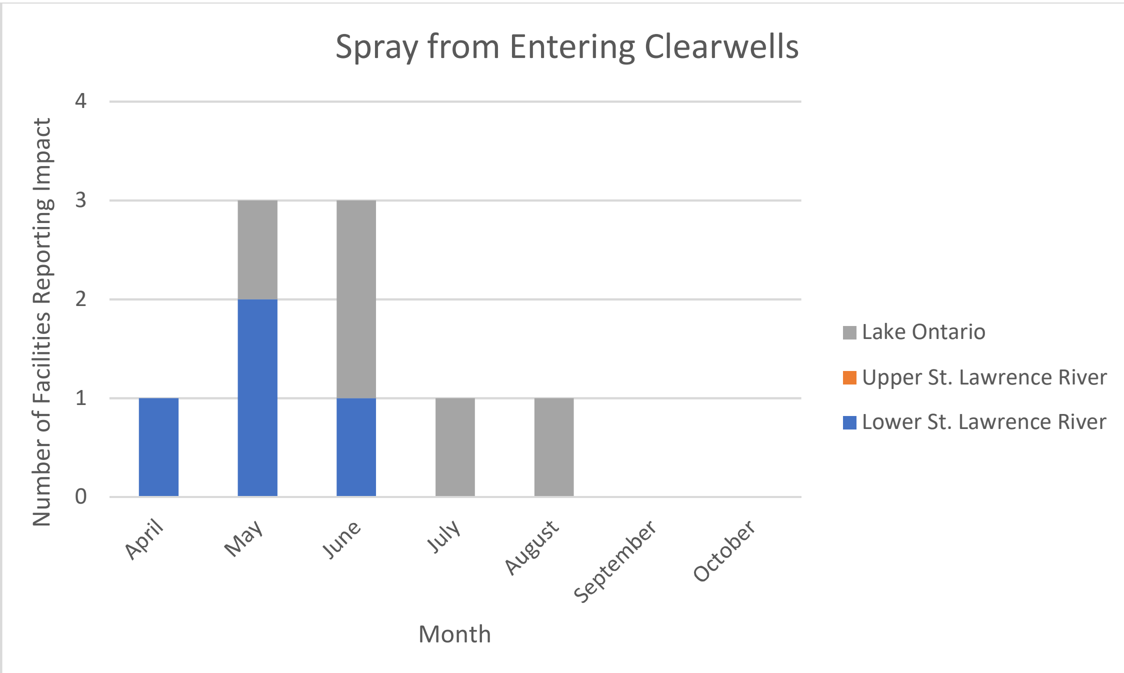


Figure 15: Spray from entering clearwells by month (n=53)

5.2.7. Pump Damage

Four facilities reported pump damage between April and August, with the majority occurring in May, June and July, as shown in Figure 16 (below). No impacts were reported in September or October. Of the 52 facilities answering this question, four unique facilities reported impacts in one or more months and, 48 reported no impacts associated with pump damage.

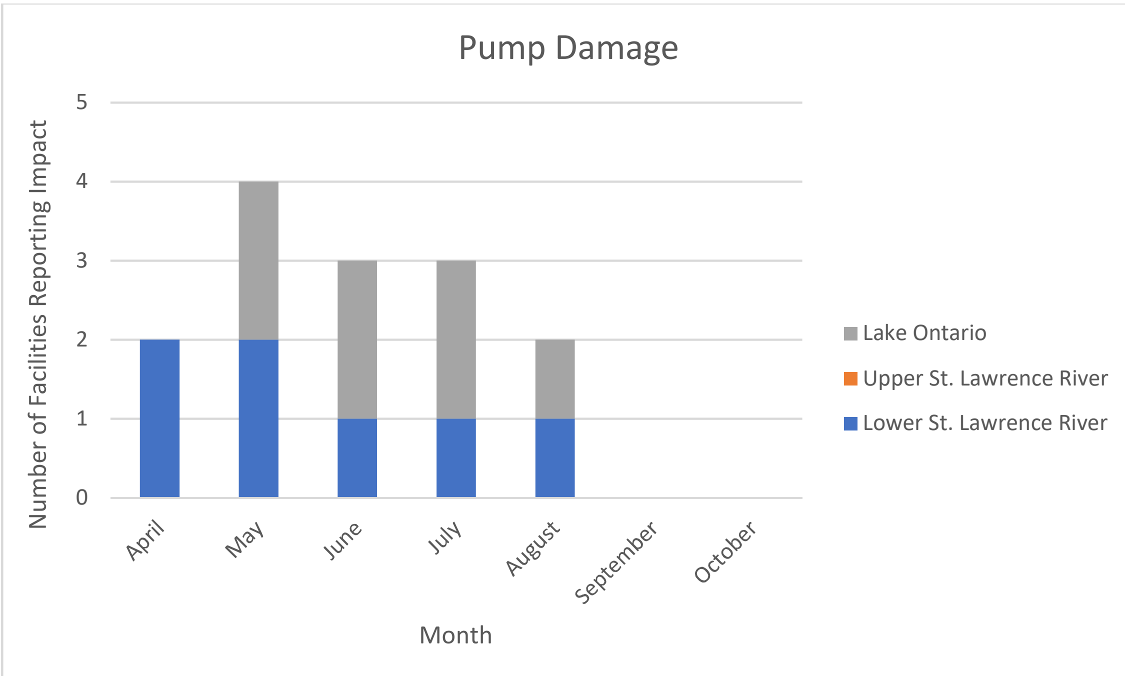


Figure 16: Pump damage by month (n=52)

5.2.8. Damage or Loss of Pipes

Three facilities reported damage to or loss of pipes between April and August, as shown in Figure 17 (below). No impacts were reported in September or October. Of the 52 facilities answering this question, three unique facilities reported impacts in one or more months and, 49 reported no impacts associated with the damage or loss of pipes.

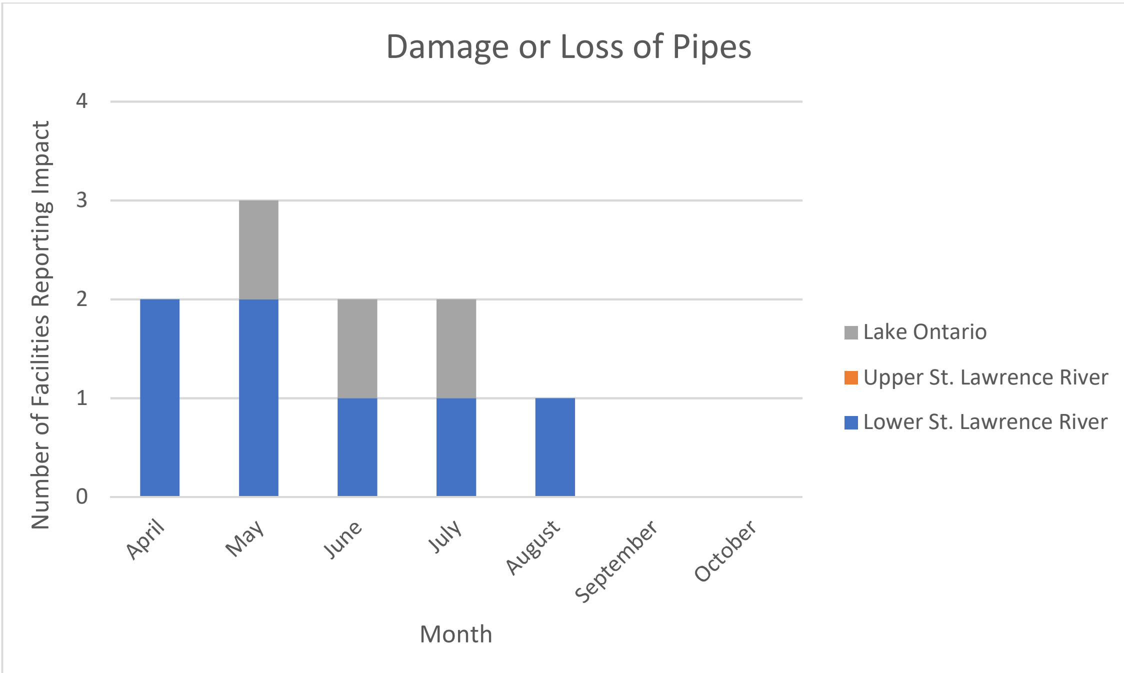


Figure 17: Damage or loss of pipes by month (n=52)

5.2.9. Other Physical Impacts

Other physical impacts, were most often reported in May, followed by June and April. No other impacts were reported in September or October. Of the 53 facilities answering this question, 16 unique facilities reported impacts in one or more months, and 37 reported no other physical impacts.

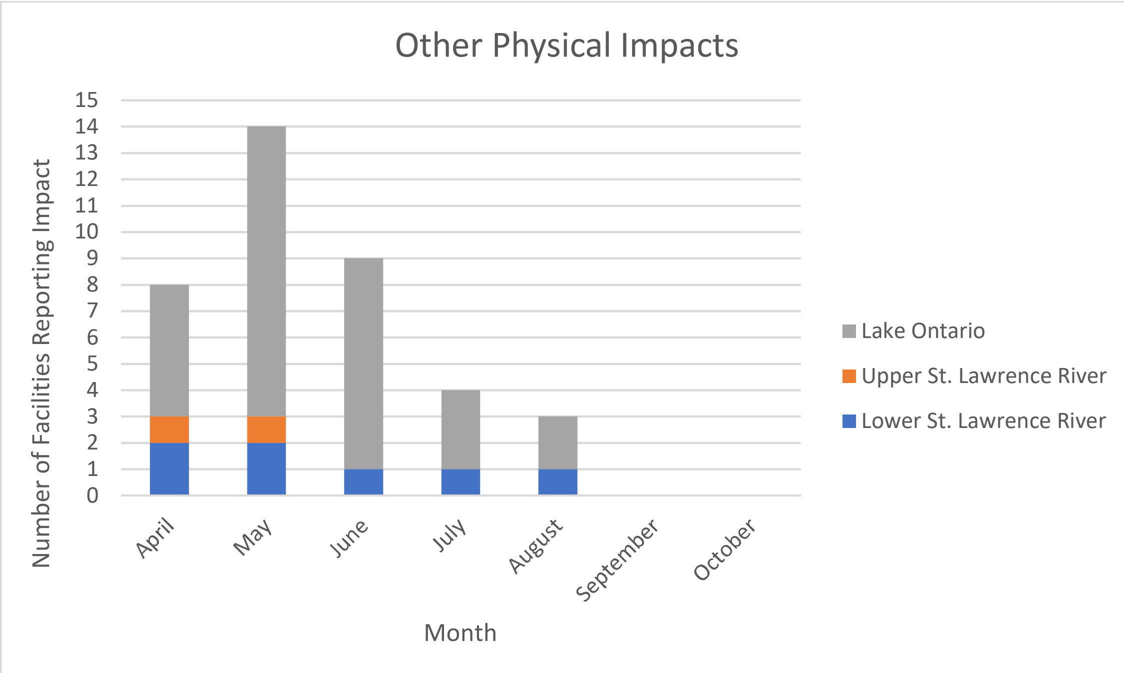


Figure 18: Other physical impacts by month (n=53)

Sixteen facilities (n=16) identified other impacts to their facilities. These facilities identified a number of additional physical impacts, including: infrastructure damage; shoreline erosion (in general); blockage of pipes and/or pumps; and, flooding of facilities (basements and equipment). A few facilities referenced difficultly in accessing certain parts of their facilities due to road wash outs.

In terms of water quality, facilities noted that water treatment was more difficult and required more chemicals, due to high turbidity, increased organic load and suspended matter. For some facilities, the high water levels reduced the treatment capacity, leading to combined sewer overflows and/or backup of the sanitary system.

5.3. Total Impacts by Month

When reviewing the total number of impacts reported by month, the highest number of impacts were reported in May (63 impacts reported), followed by April and June (42 impacts reported in each month). The overall number of impacts reported decreases throughout the late summer and into fall.

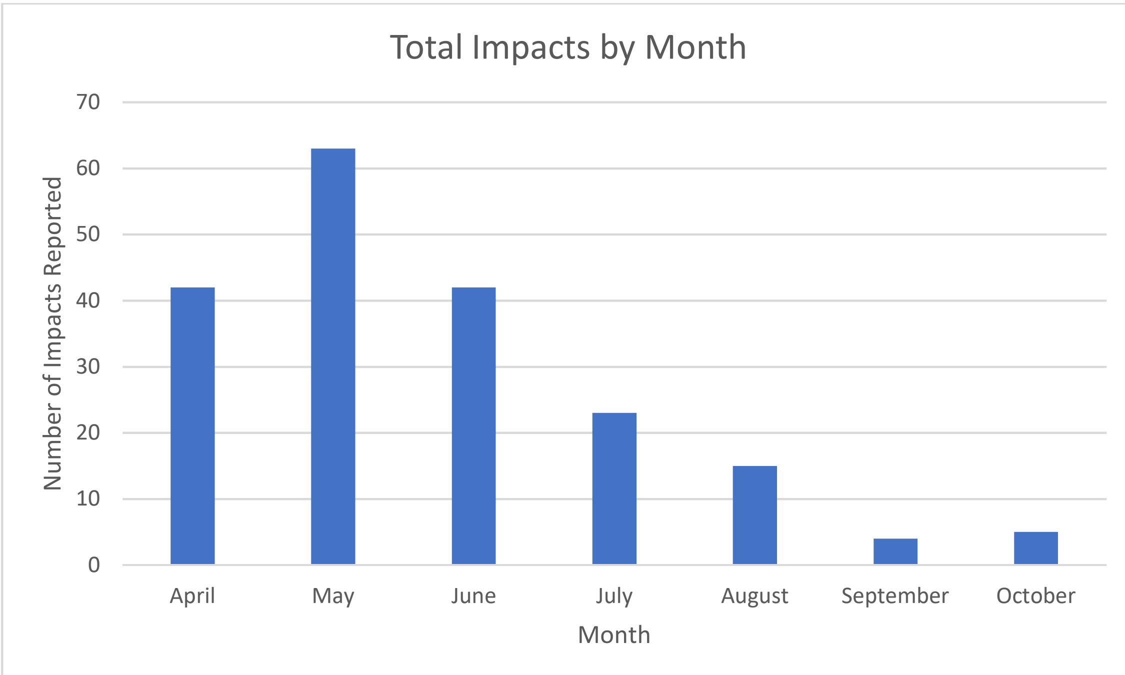


Figure 19: Total impacts per month (n=63)

The number of unique facilities reporting impacts varied by month and shoreline zone, as shown in Table 4 below. For example, twenty-five individual facilities reported some impact during the month of May.

Table 4: Number of unique facilities reporting impacts per month

Month	April	May	June	July	August	September	October
Lake Ontario	8	18	14	8	6	2	2
Upper St. Lawrence River	2	2	0	1	0	0	1
Lower St. Lawrence River	5	5	4	2	2	1	1
Number of Unique Facilities	15	25	18	11	8	3	4

Table 5 displays the total number of unique facilities for each shoreline zone reporting at least one impact, across all months.

Table 5: Number of unique facilities reporting at least one impact, by shoreline zone

Zone	Lake Ontario	Upper St. Lawrence River	Lower St. Lawrence River
Number of Unique Respondents	22	2	7

5.4. Source of Flooding Identified

Next, facilities were asked to identify the source of the flooding for the impacts outlined above[5]. As shown in Figure 20, below, the majority of facilities did not know the source of the flooding or the question was not applicable (i.e. no impacts were identified). Twelve facilities identified a source for the flooding of sewer manholes. The specific sources of flooding are identified in Figure 21 (below).

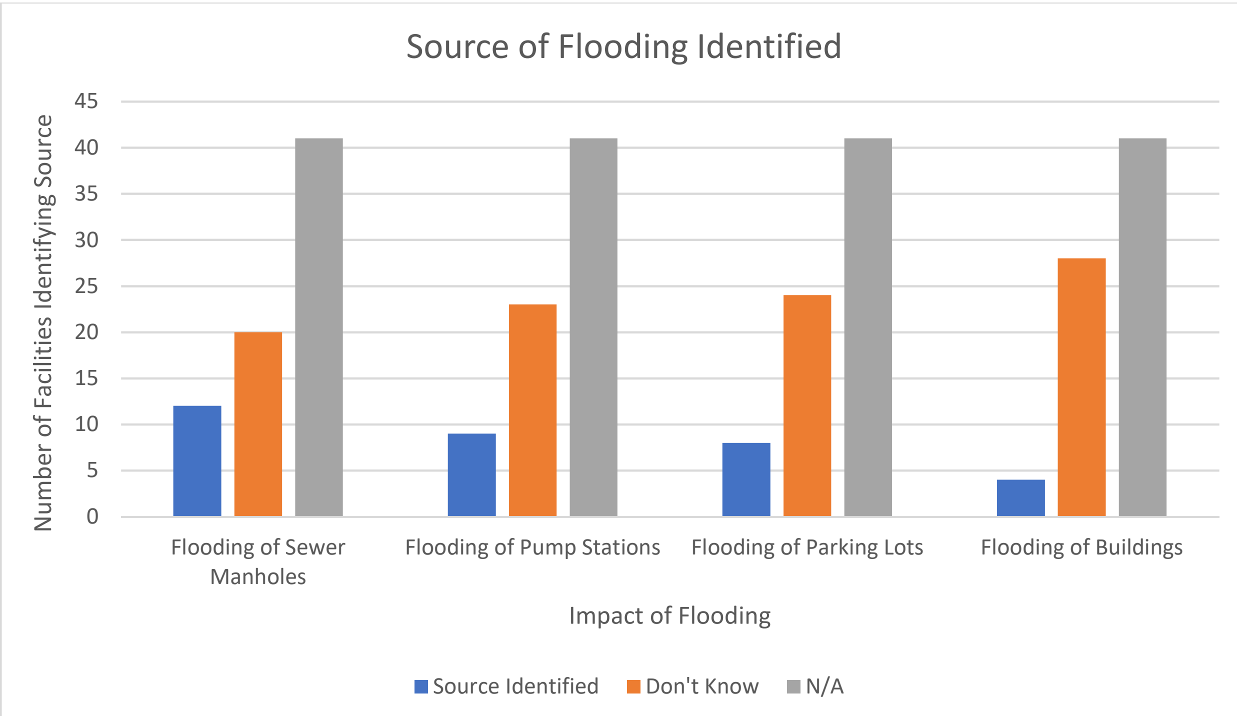


Figure 20: Source of flooding identified (n=73)

[5] This question was posed to all facilities, with the option to either indicate one of three sources of flooding (overland flow from Lake Ontario or the St. Lawrence River, overland flow from high precipitation, or backup flow) or that they did not know the source of flooding. In hindsight, this in essence forced facilities that did not experience any flooding to indicate they did not know the source of the flooding. For the purpose of this reporting, if a facility answered “no impact” to the previous question regarding flooding and indicated “don’t know” as their response regarding the source of flooding, we have presented this data as “N/A”.

5.4.1. Source of Flooding Impacts

Of those facilities identifying a source of flooding for the aforementioned impacts, the most frequently cited source was overland flow from Lake Ontario and/or the St. Lawrence River. When looking at specific impacts, “flooding of sewer manholes” and “flooding of parking lots” were most often attributed to overland flow from Lake Ontario and/or the St. Lawrence River. In contrast, “flooding from buildings” and “flooding of pump stations” were attributed to all three sources of flooding.

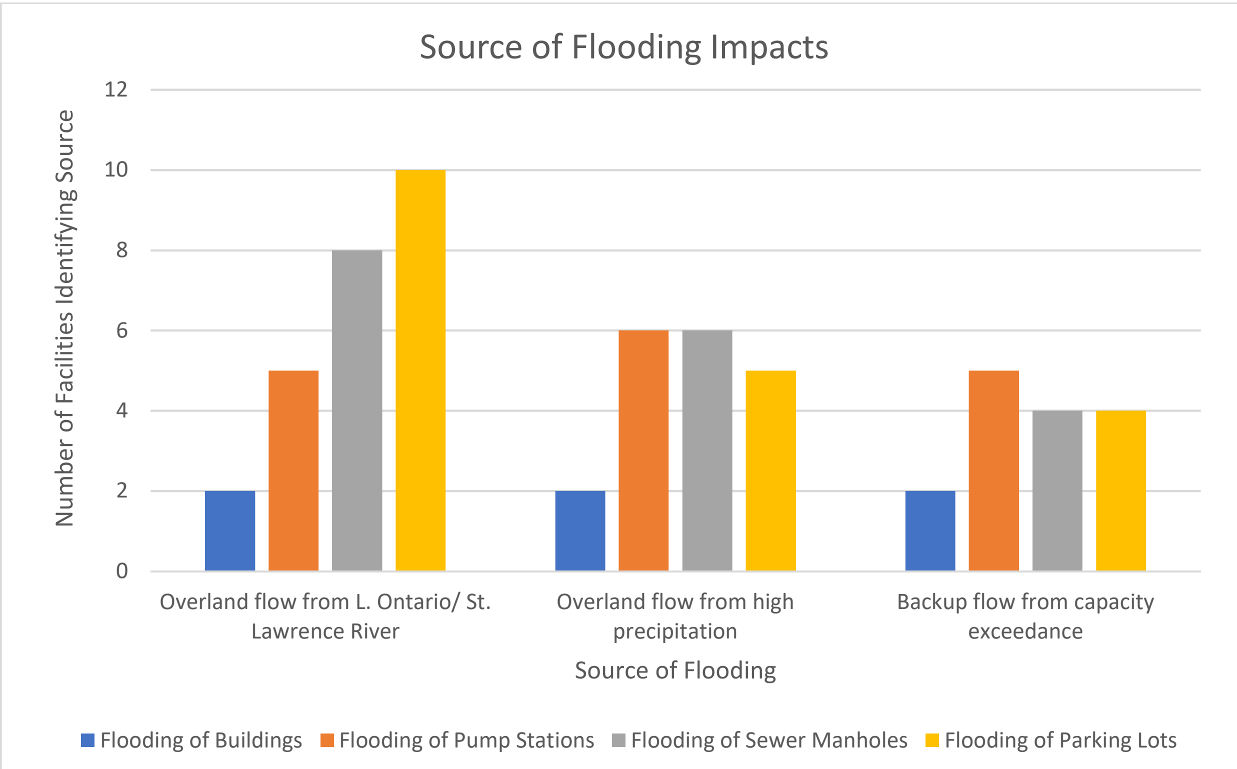


Figure 21: Source of flooding impacts (n=32)

5.5. Loss of Service

Facilities were asked if they experienced any loss of service, reduced service capacity, or negative operational impacts due to the high water levels in 2017. As shown in Figure 19, below, the vast majority (86%) of facilities did not experience any loss of service. Of those facilities that did experience a loss of service, the largest number were municipal wastewater treatment plants on Lake Ontario, of which there were four. Overall, municipal wastewater treatment plants reported a loss of service most often.

Of those indicating a loss of service, a number cited a reduced capacity to treat wastewater during peak (wet weather) flows. A small number of facilities (n=2) indicated that this situation lasted for a few months. In some cases, this resulted in combined sewer overflows. Some facilities required repairs to outfall structures. Others did not experience a loss in service, but indicated a need to increase the amount of water treatment chemicals, as mentioned above.

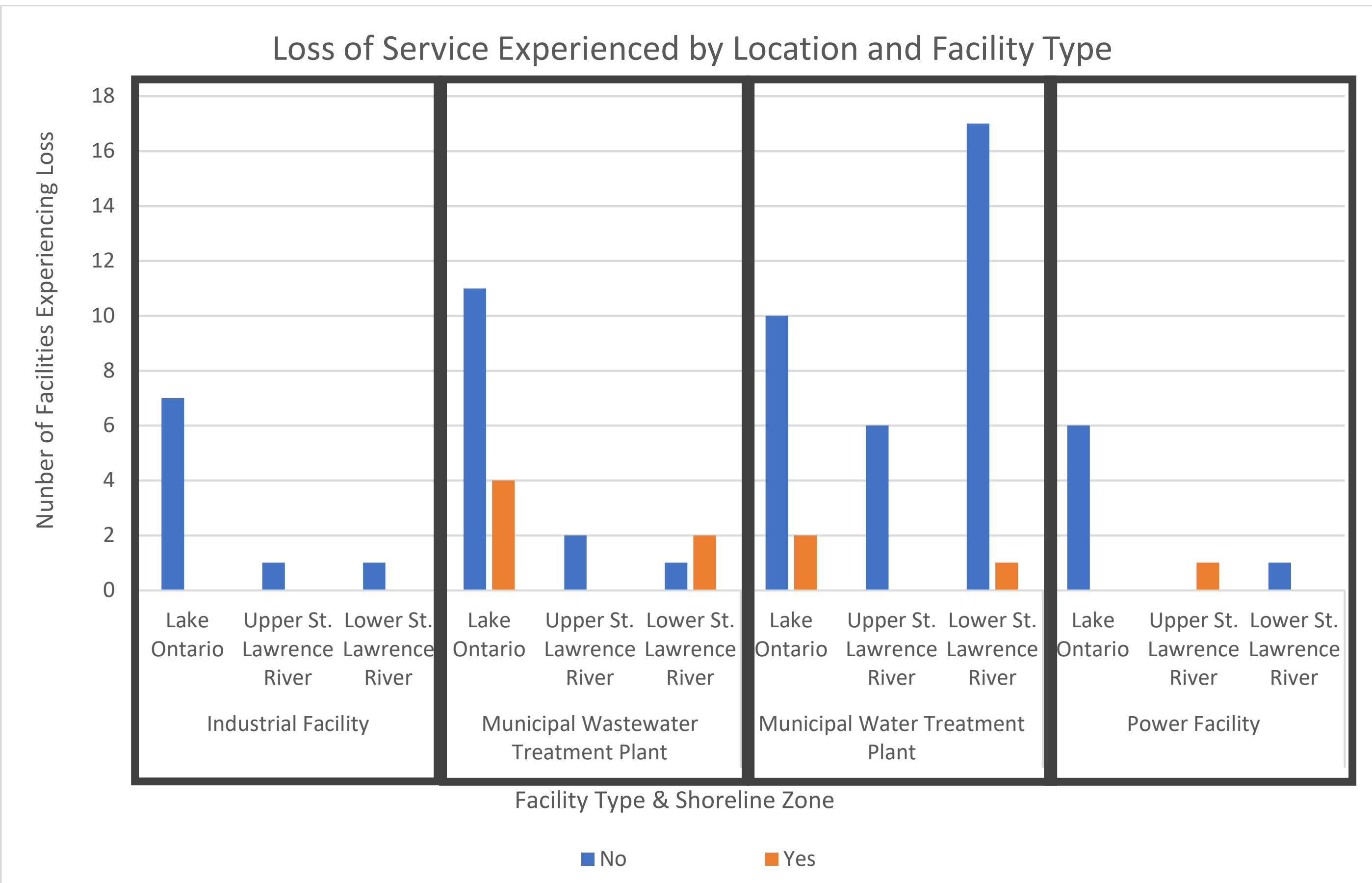


Figure 22: Loss of service experienced by location and facility type (n=73)

5.6. Improvements in Service

Next, facilities were asked if they experienced any improvements in service and/or operations due to the high water levels in 2017. Again, the majority of facilities (86%) indicated that they did not experience any improvements. Of those facilities that did experience improvements, the largest number were municipal water treatment plants from the Lower St. Lawrence River and Lake Ontario, of which there were five in total.

Of those identifying service improvements, the most commonly identified was the increased pumping efficiency due to the increased water volumes and reduced static head. A number of facilities also undertook repairs or other improvements, which positively impacted operations.

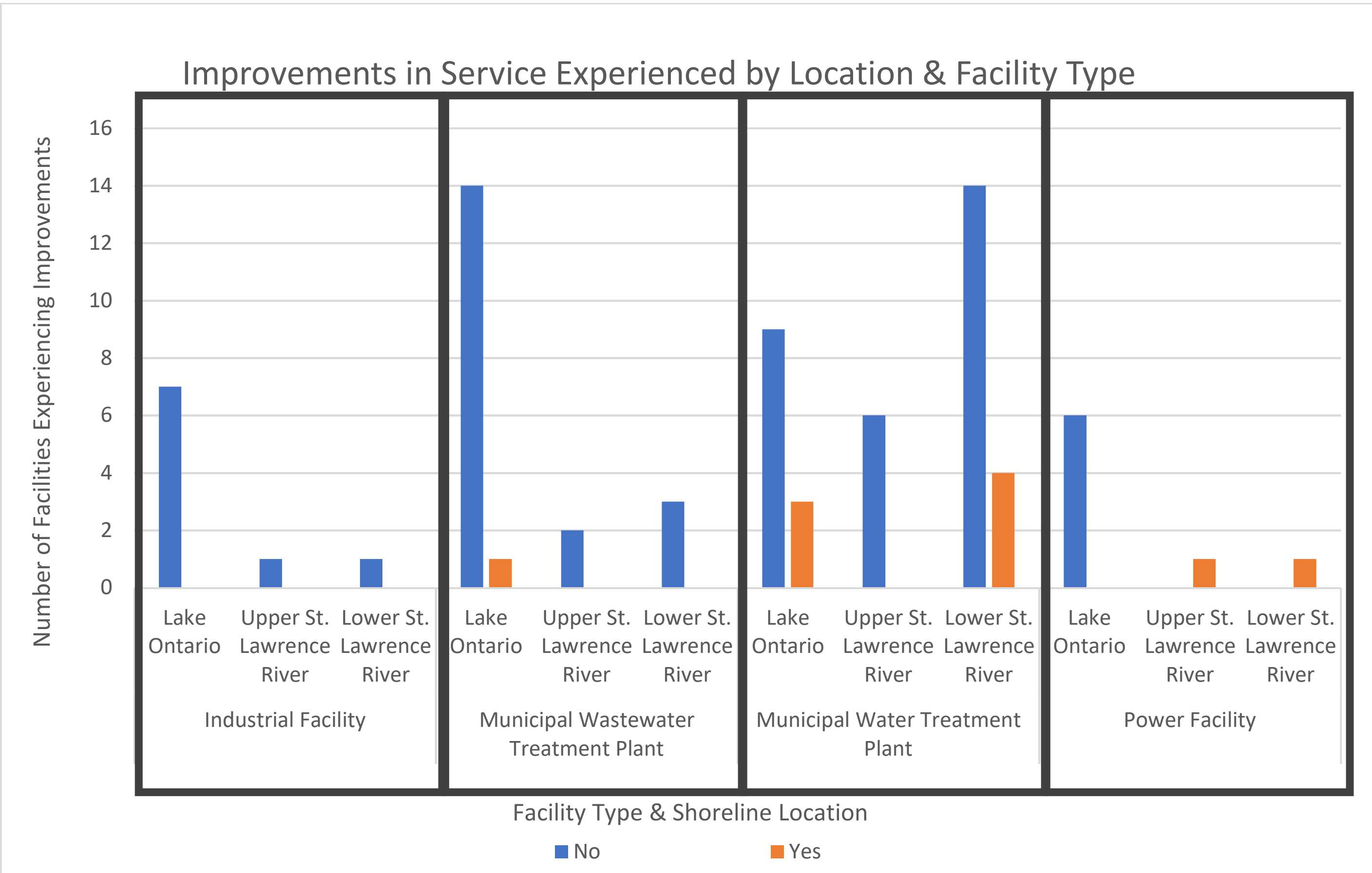


Figure 23: Improvements in service experienced by location and facility type (n=73)

5.7. Water Quality Concerns

Facilities were asked if they experienced any water quality concerns at their facility associated with the 2017 high water levels. While the majority (79%) of facilities did not report water quality concerns, twenty-one percent (21%) did experience water quality concerns. Water quality concerns were most often cited in municipal wastewater treatment plants on Lake Ontario and municipal water treatment plants on the Lower St. Lawrence River, of which there were nine in total.

Of those experiencing water quality concerns, a number mentioned the need for increased treatment dosing due to increased organic load and suspended matter. As mentioned above, a number of facilities also encountered issues with treatment capacity. In some cases, this resulted in combined sewer overflows and associated water quality concerns.

Figure 24: Water Quality Concerns experienced by location and facility type (n=73)

5.1. Critical High and Low Water Levels

There was a question in the survey asking about facilities' critical high and critical low water thresholds. They asked the following:

- Threshold above/below which there is some concern of impacts on the facility or operations;
- Threshold above/below which there is substantial concern of impacts on the facility or operations; and,
- Threshold above/below which the facility can no longer operate.

Due to how these questions were worded, respondents interpreted them differently and thus answered them differently, resulting in considerable variability in responses. Some facilities provided an *absolute* water level (e.g. 75 metres), others provided an *increase* above typical water levels (e.g. 1 metre), some said water levels were not a concern, some stated they did not know, and others did not answer at all.

Given the variability in responses, representatives from the GLAM Committee reviewed individual responses to these questions to establish a methodology for interpreting the results. For those that provided an increase above typical water levels, the number they provided was then added to chart datum to provide comparability and consistency with those who reported an absolute water level. Some individual responses to both questions were noted as being uncertain (i.e., the reported water levels were not realistic/logical relative to chart datum) and have been excluded from this analysis at the advice of the GLAM Committee. It is suggested that the GLAM Committee follow-up with facilities in the future to collect standardized responses to these questions.

5.1.1. Critical High Water Levels

The qualifying results from facilities on Lake Ontario were grouped together, as there is a reasonable level of comparability across the Lake. For those qualifying respondents on Lake Ontario, the results of their responses are presented below in Table 6. For reference, Lake Ontario chart datum is 74.2 metres. The maximum value reported in each instance is for a power facility that is approximately 500 metres offshore at an elevation well above lake level.

Table 6: Critical high water levels for Lake Ontario facilities

	Average Water Level (metres)	Minimum Value Reported (metres)	Maximum Value Reported (metres)
Threshold above which there is some concern of impacts on the facility or operations (n=16)	76.62	75.20	81.82
Threshold above which there is substantial concern of impacts on the facility or operations (n=16)	77.02	75.59	81.82
Threshold above which the facility can no longer operate (n=14)	78.46	75.70	89.44

The values from those facilities located on the Upper and Lower St. Lawrence River are more difficult to analyze together, as the point of reference (elevation) changes over the course of the river (upstream to downstream). As such, qualifying responses have been compared to nearby chart datum reference points along the River, and results have been presented in Table 7 as a net increase in water level, as opposed to an absolute water level. The maximum value reported in each instance is from a facility located at an elevation well above nearby chart datum.

Table 7: Critical high water levels for Upper and Lower St. Lawrence River facilities, shown as a net increase in water level

	Average Change in Net Water Level (metres)	Minimum Change in Net Water Level (metres)	Maximum Change in Net Water Level (metres)
Threshold above which there is some concern of impacts on the facility or operations (n=6)	4.18	0.74	15
Threshold above which there is substantial concern of impacts on the facility or operations (n=6)	4.74	1.40	15
Threshold above which the facility can no longer operate (n=8)	4.89	1.90	15

5.1.2. Critical Low Water Levels

The qualifying results from facilities on Lake Ontario were grouped together, as there is a reasonable level of comparability across the Lake. For those qualifying respondents on Lake Ontario, the results of their responses are presented below in Table 8. For reference, Lake Ontario chart datum is 74.2 metres.

Table 8: Critical low water levels for Lake Ontario facilities

	Average Water Level (metres)	Minimum Value Reported (metres)	Maximum Value Reported (metres)
Threshold below which there is some concern of impacts on the facility or operations (n=10)	72.07	69.20	73.82
Threshold below which there is substantial concern of impacts on the facility or operations (n=9)	70.97	68.20	72.68
Threshold below which the facility can no longer operate (n=8)	70.28	66.58	72.07

The values from those facilities located on the Upper and Lower St. Lawrence River are more difficult to analyze together, as the point of reference (elevation) changes over the course of the river (upstream to downstream). As such, qualifying responses have been compared to nearby chart datum reference points along the River, and results have been presented in Table 9 as a net decrease in water level, as opposed to an absolute water level.

Table 9: Critical low water levels for Upper and Lower St. Lawrence River facilities, shown as a net increase in water level

	Average Change in Net Water Level (metres)	Minimum Change in Net Water Level (metres)	Maximum Change in Net Water Level (metres)
Threshold below which there is some concern of impacts on the facility or operations (n=7)	-2.06 metres	0.27 metres	-8.24 metres
Threshold below which there is substantial concern of impacts on the facility or operations (n=7)	-2.95 metres	-0.60 metres	-8.24 metres
Threshold below which the facility can no longer operate (n=6)	-4.10 metres	-0.30 metres	-9.16 metres

In addition to the quantitative questions referenced above, respondents were also asked how the high water levels in 2017 affected the designation of critical surface water level thresholds at their facility. Most facilities indicated that there were no changes made to their identified critical water levels following the 2017 event; however, critical water levels were reviewed and/or modified in a handful of cases.

6. ADAPTIVE ACTIONS

6.1. Actions Taken in 2017

Facilities were next asked to identify actions taken during the high water level impacts to maintain services and/or minimize impacts. As shown below, approximately three-quarters of facilities (67%) reported taking no actions in 2017. Conversely, 33% (or twenty-four total) of facilities did take action during the high water levels. Specific actions are outlined below, in Figure 25.

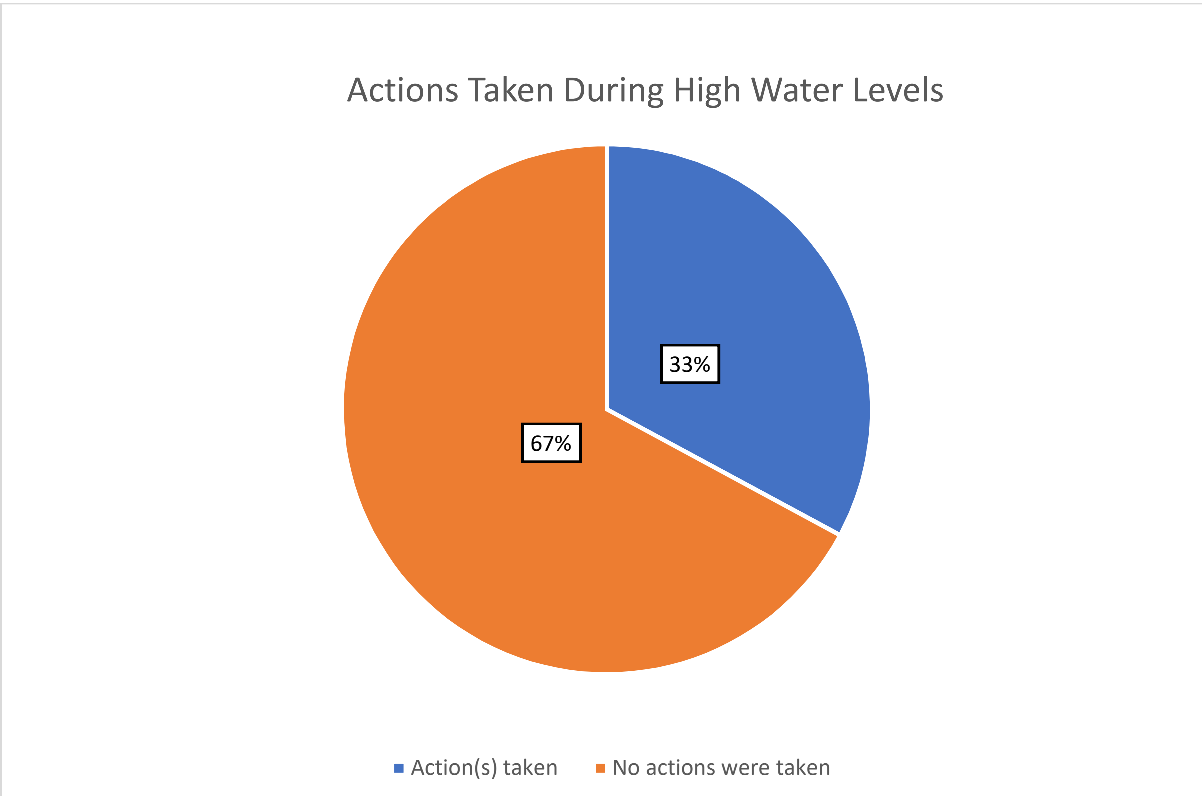
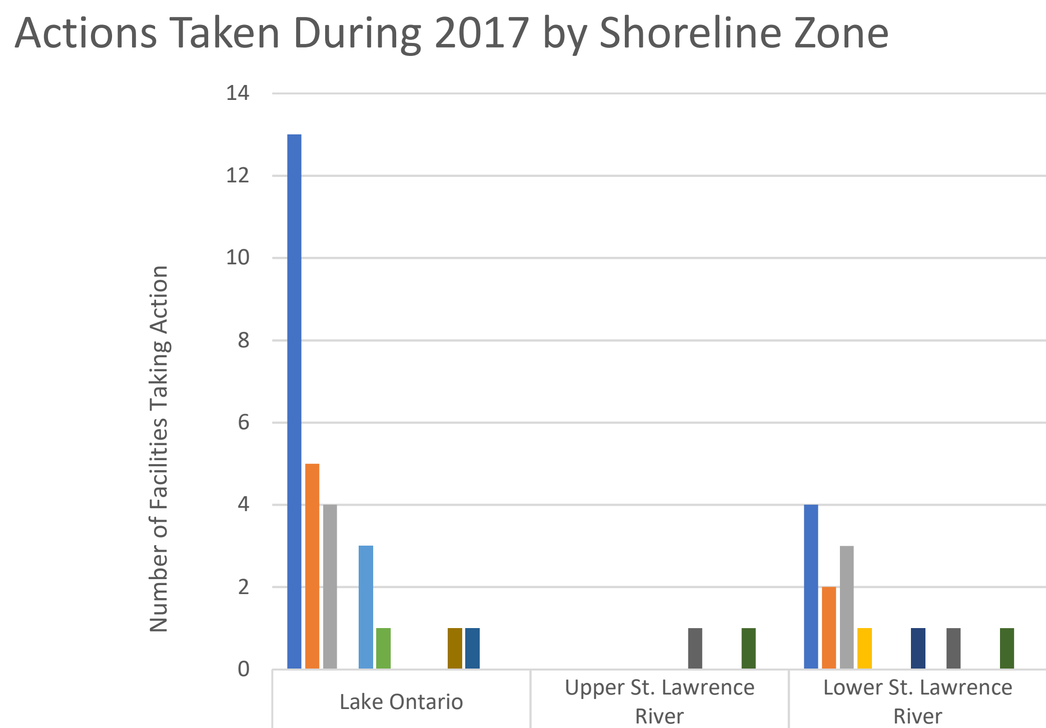


Figure 25: Actions taken in 2017 (n=73)

Of those facilities on Lake Ontario reporting actions taken, the most commonly reported actions were “other actions”, “using sandbags to protect infrastructure from flooding” and, “pumping water to remove standing water”. Among those facilities on the Lower St. Lawrence River “other actions”, “pumping water to remove standing water” and, “using sandbags to protect infrastructure from flooding” were also the most commonly cited. For the Upper St. Lawrence River, one respondent “shut down the whole facility”, while another “opened additional outflow pipes”.

Of those reporting other actions, facilities cited a mix of physical or process-related actions. Physical actions included: infrastructure repairs; discharging or pumping excess water; and, installing/improving weirs and temporary flood barriers. Process-related actions included: increased monitoring and maintenance; manually backwashing filters; and keeping stormwater management ponds low to increase capacity to tolerate high rain events.



	Lake Ontario	Upper St. Lawrence River	Lower St. Lawrence River
Other actions	13		4
Using sandbags to protect infrastructure from flooding	5		2
Pumped water to remove standing water	4		3
Activated shut-off valves			1
Constructed berms	3		
Closed inflow pipes	1		
Opened additional inflow pipes			1
Closed outflow pipes			
Opened additional outflow pipes		1	1
Relocated waste outflows	1		
Installed additional riprap to support shoreline pipes	1		
Shut down sections of the facility		1	1
Shut down whole facility			

Shoreline Zone

Figure 26: Type of actions taken by shoreline zone (n=24)

6.2. Actions Taken Since 2017

Next, facilities were asked if their facility has taken actions since the high water levels of 2017 to protect against future possible impacts. Seventy-three percent (73%) of facilities reported no actions since the 2017 event, while 27% reported taking some action.

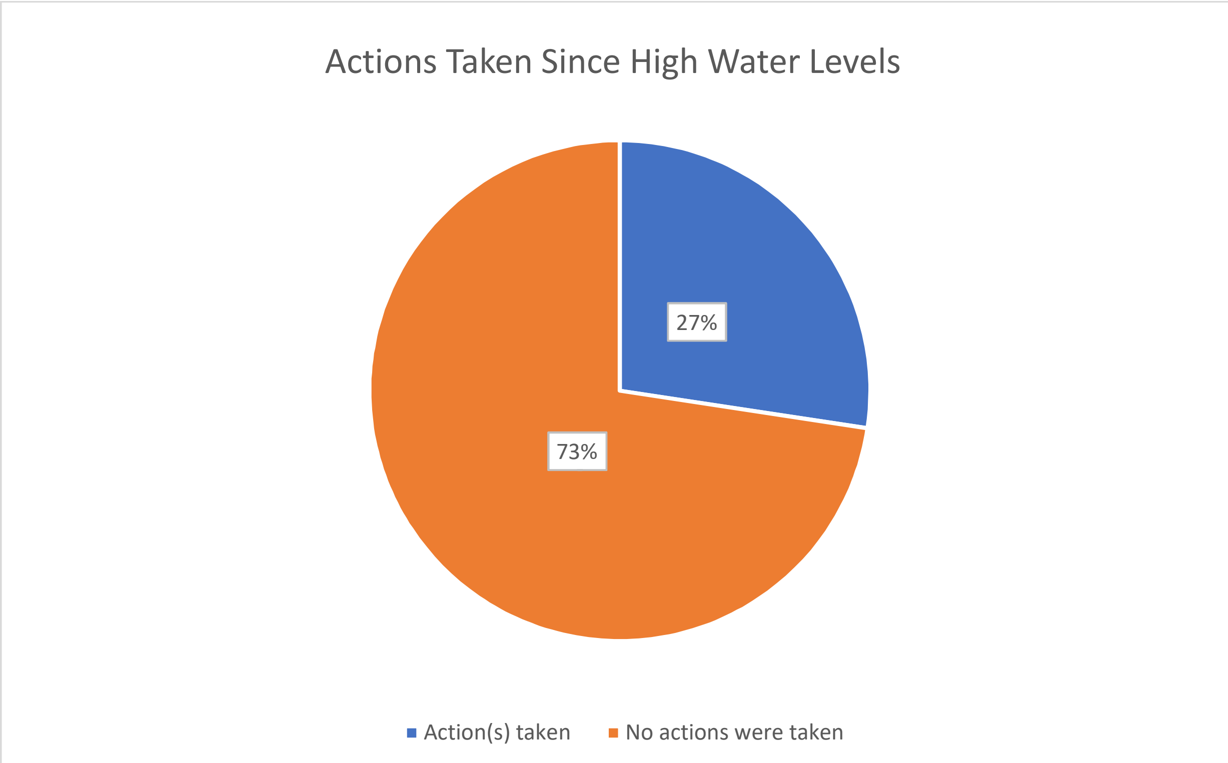
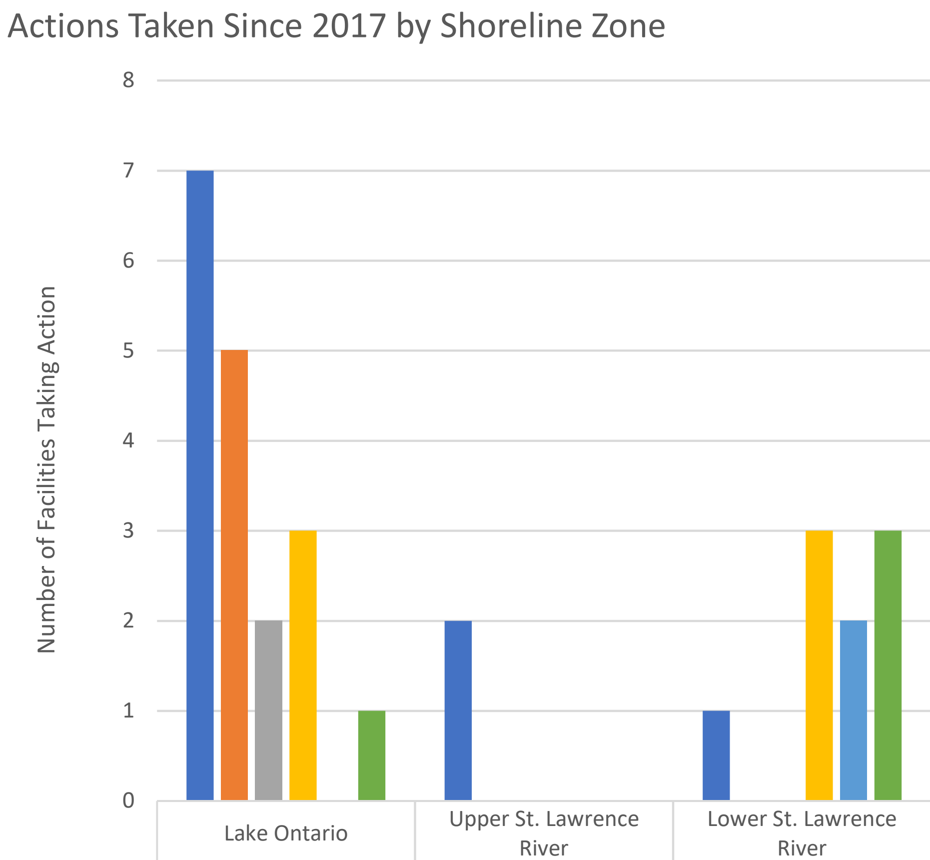


Figure 27: Actions taken since 2017 (n=73)

The most commonly cited action for those on Lake Ontario and the Upper St. Lawrence River were "other actions", with "improved shoreline protection" also being popular for facilities on Lake Ontario. For those facilities on the Lower St. Lawrence, "purchasing flood-proof equipment" and "upgrading facility" were the most common actions.

Of those reporting other actions, facilities again cited a mix of physical or process-related actions. Physical actions included: infrastructure repairs and upgrades and, implementing shoreline improvements. Process-related actions included: increased monitoring and maintenance; initiating vulnerability studies and emergency planning measures; and, recording lessons learned.



	Lake Ontario	Upper St. Lawrence River	Lower St. Lawrence River
Other Actions	7	2	1
Improved shoreline protection	5		
Installed additional riprap to support shoreline pipes	2		
Upgraded facility	3		3
Re-designed outflow or intake pipes			2
Purchased flood-proof equipment	1		3

Figure 28: Actions taken since 2017 by location and facility type (n=20)

6.3. Cost of Actions

Facilities were asked to report the cost of implementing the actions above, both during and after the 2017 high water event[6]. The majority of facilities did not report a cost – likely since the majority of facilities did not report taking any actions. Fourteen (14) respondents reported costs associated with actions taken in 2017, while 59 reported no cost. Of the 14 facilities that provided a cost for actions taken during 2017, the average cost of actions taken was $71,028.57, with cited costs ranging from $100 to $220,000. In terms of actions taken since 2017, 12 respondents reported costs associated with actions since 2017, while 61 reported no cost. Of the 12 reporting a cost for actions taken since 2017, the average cost was $624,416.67. In this case, costs ranged from $10,000 to $3,000,000. This suggests that more costly actions and improvements were taken following the 2017 event.

As shown in Figures 29 and 30 (below), the majority of facilities reported no costs. Of those that did report costs, the costs were more likely to be “medium” or above.

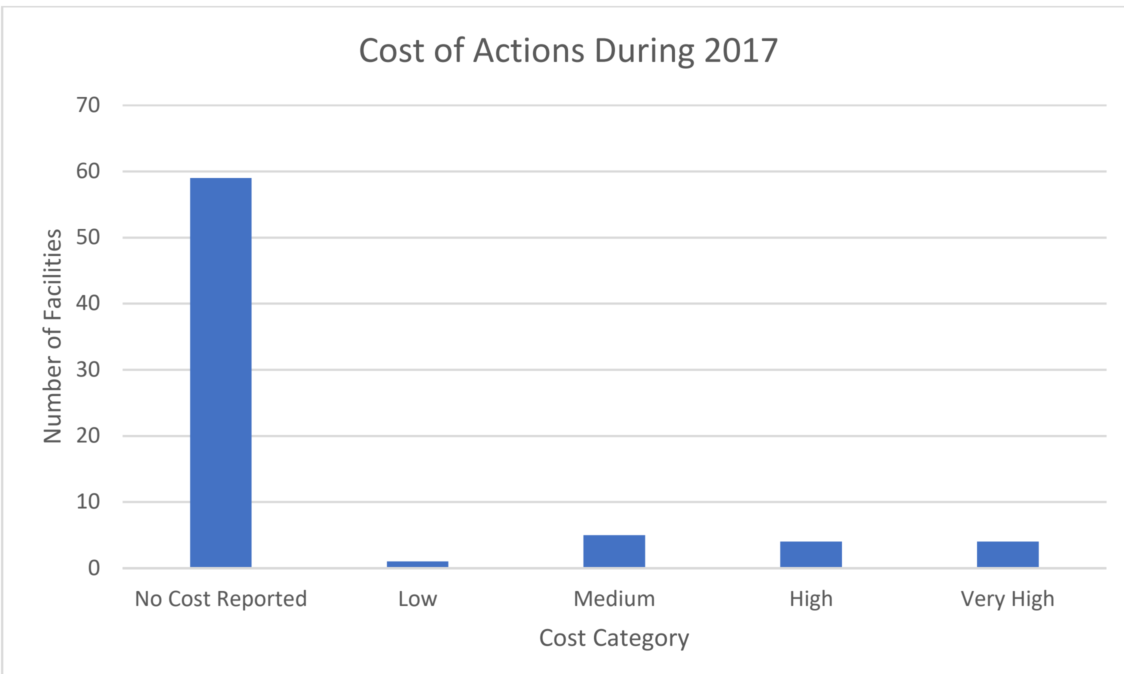


Figure 29: Cost of actions taken during 2017 (n=73)

[6] Costs were categorized as: “No Cost Reported” ($0 or blank); “Low” ($1 to $1,000); “Medium” ($1,001 to $10,000); “High” ($10,001 to $100,000); or, “Very High” (Over $100,000).

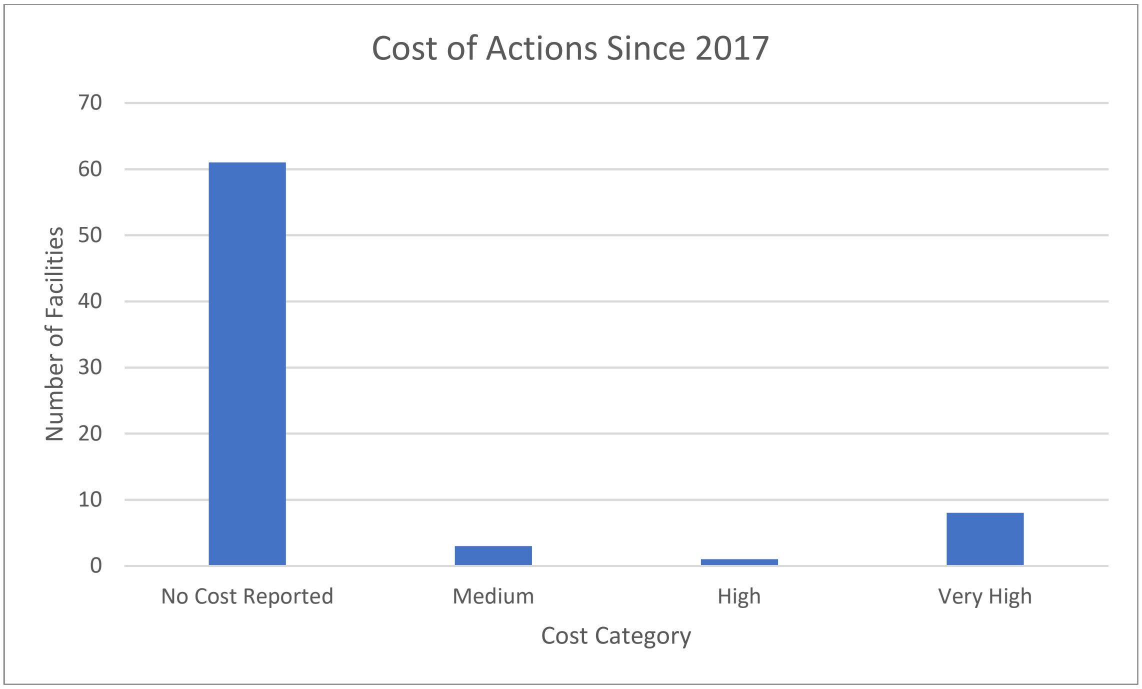


Figure 30: Cost of actions taken since 2017 (n=73)

6.4. New Vulnerabilities Identified

Facilities were asked if the 2017 high water levels resulted in the identification of new or unknown vulnerabilities to either high or low water levels. While the majority of facilities (79%) responded "no", 21% (n=15) indicated the identification of new vulnerabilities. Figure 31 (below) outlines the number of new vulnerabilities outlined by facility type and location. Half of those who identified new vulnerabilities (n=7) were municipal wastewater treatment plants on Lake Ontario.

Of those who identified new vulnerabilities, commonly cited included: inflow and infiltration issues and, increased vulnerability to storm events during high water levels.

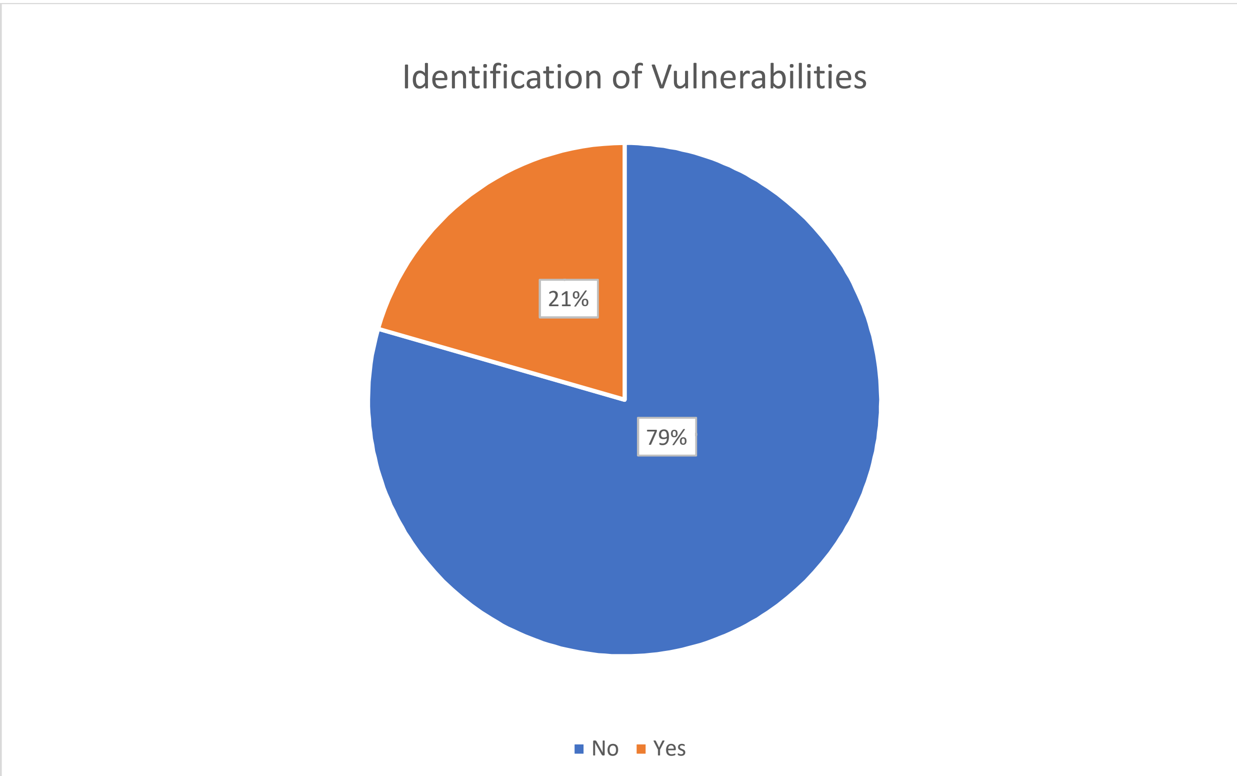


Figure 31: Vulnerabilities identified at facilities (n=73)

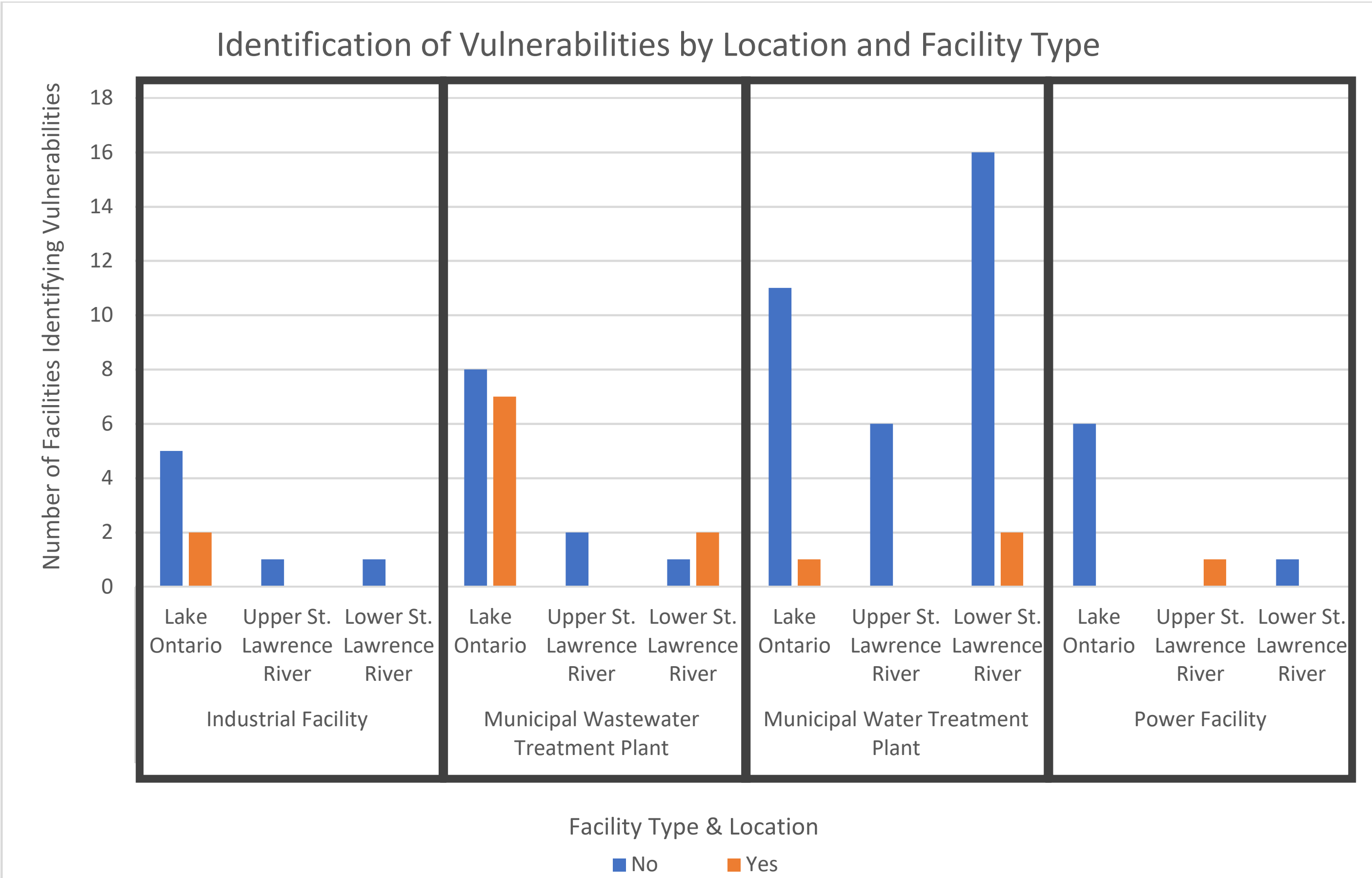


Figure 32: Number of facilities identifying vulnerabilities (n=73)

7. OTHER COMMENTS AND CORRELATIONS

7.1. Scale of Impact by Location

In closing, facilities were asked the following question: "On a scale of 1 to 10, 1 being very little impact and 10 being high degree of impact, how would you rate the overall impact of the 2017 high water levels on your facility and operations?". As shown in Figure 28 (below), nearly half of facilities (47.8%) rated the overall impact as a "1". The average rating was 2.7. Three-quarters of facilities (75.4%) rated the overall impact as a 1, 2 or 3.

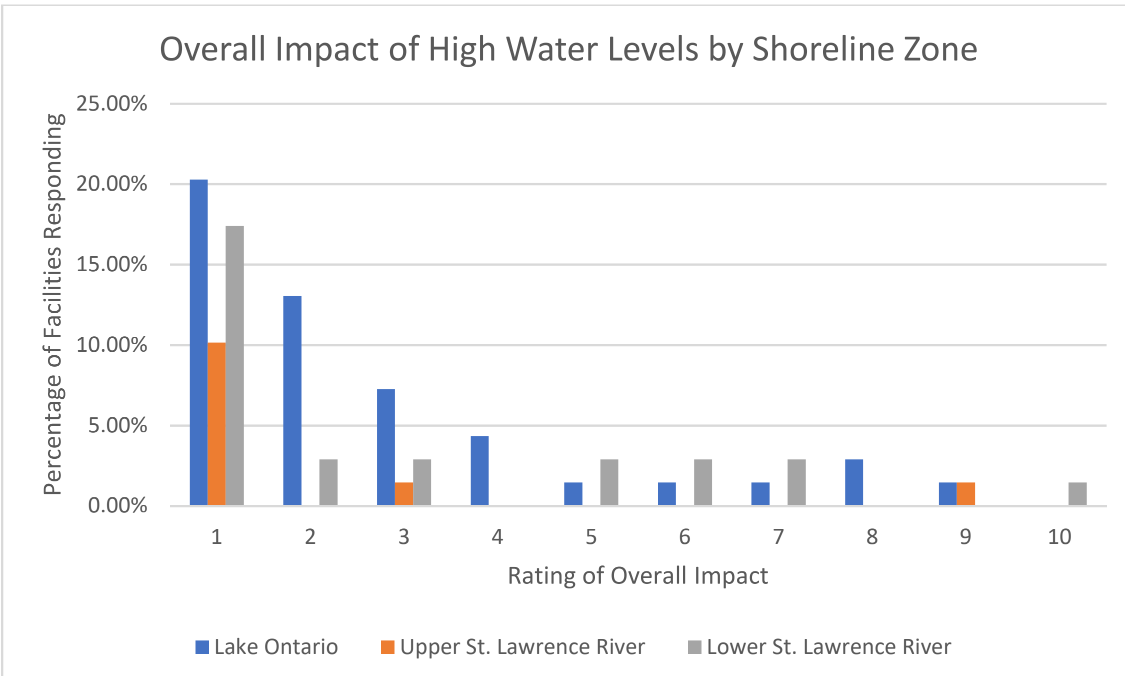


Figure 33: Overall impact of high water levels by shoreline zone (n=69)

Figure 33a (below) shows the overall impact by location. As shown, the highest percentage of facilities from New York, Ontario and Quebec rated their overall impact as a 1. Responses were concentrated in the 1, 2, and 3 ratings. Impact ratings from all three locations were fairly evenly spread across values from 4 to 10.

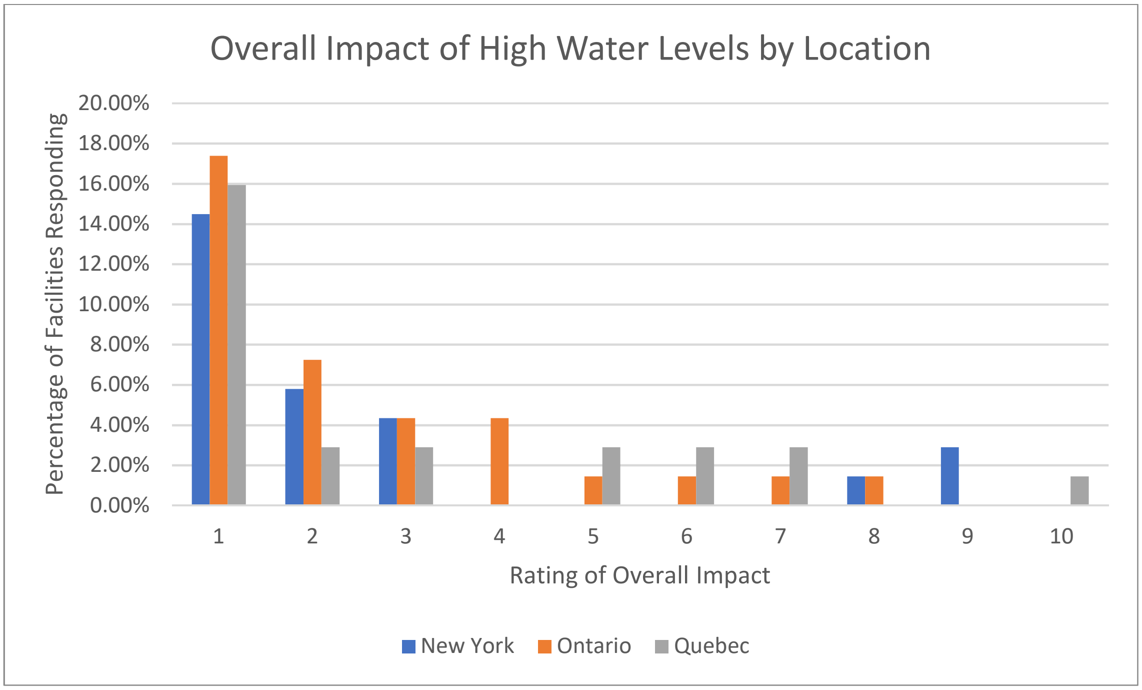


Figure 33a: Overall impact of high water levels by location (n=69)

Figure 34 (below) depicts the overall impact ratings geographically. A larger bar indicates a greater reported impact. Each facility that responded is represented by its own bar.

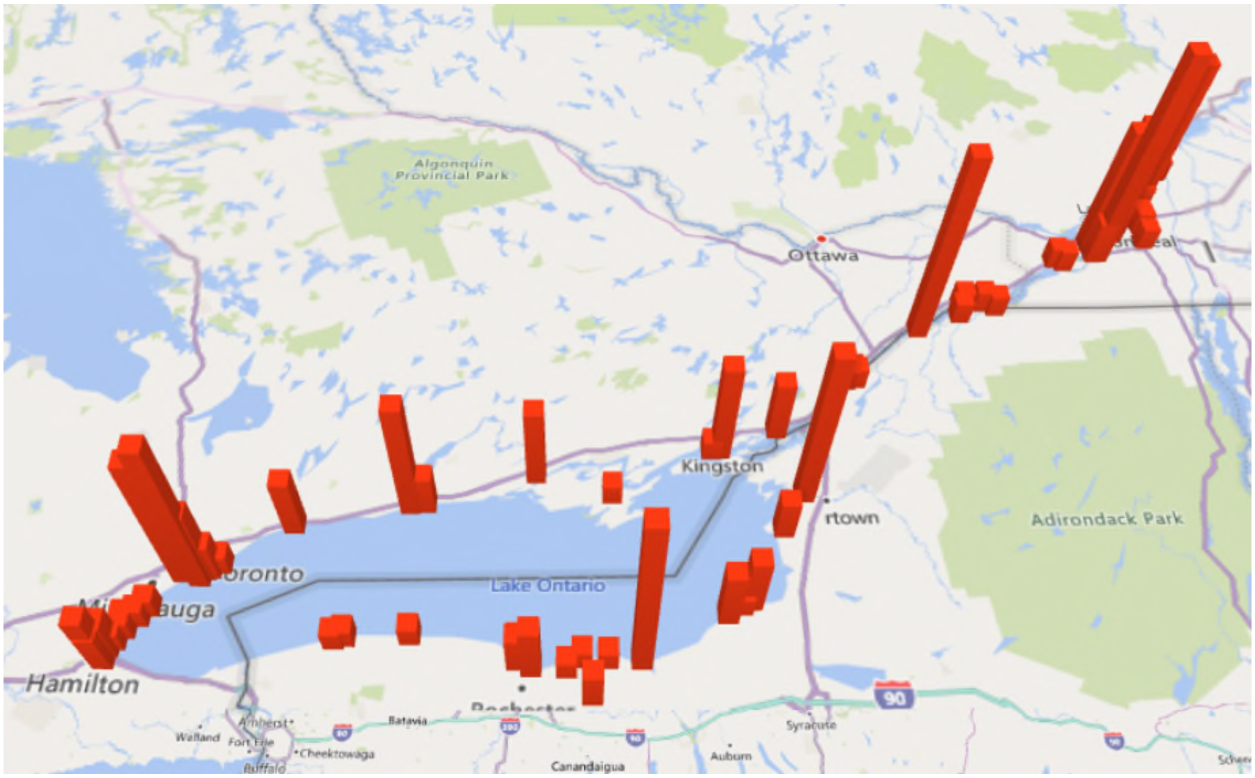


Figure 34: Map showing overall impact of high water levels by location and type (n=69)

7.2. Impact by Location

Figure 35 displays the average reported impact on a scale of one to ten (represented by the bars and referenced to the primary y-axis) and number of responses (represented by the dots and referenced to the secondary y-axis) by shoreline zone and facility type. The highest average reported impact (6.0) is seen among the three responding municipal wastewater treatment plants on the Lower St. Lawrence River. The lowest average reported impact (1.0) was seen amongst industrial facilities on the Upper and Lower St. Lawrence River, though this represents only one facility each.

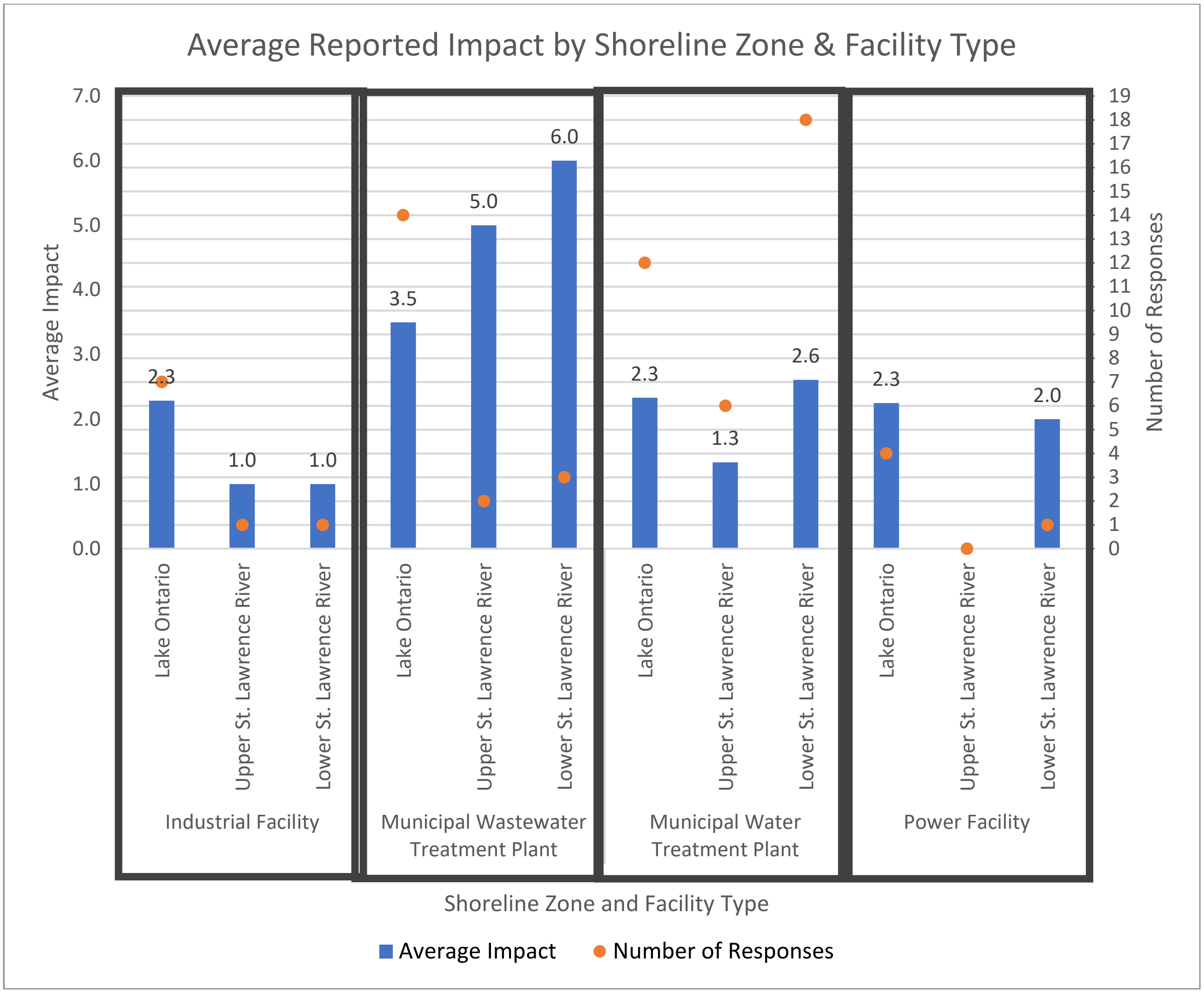


Figure 35: Average reported impact by shoreline zone and facility type (n=69)

7.3. Final Comments

In the final comments section, a few facilities indicated that with a small amount of additional water and/or storm event, their facilities could have seen more significant impacts. A few facilities mentioned that others (i.e. suppliers, local residents) experienced greater impacts than their facilities. Additionally, facilities were invited to provide photographs from the 2017 high water event – these are available in Appendix C.

8. KEY FINDINGS

The majority of municipal and industrial facilities reported no impact to their facility's operations from the 2017 high water levels. On a scale of 1 (low) to 10 (high), nearly half of respondents rated the overall impact as a "1". The average rating was 2.7. Three-quarters of respondents rated the overall impact as a 1, 2 or 3.

Of those reporting impacts, "other impacts", "flooding of sewer manholes" and, "shoreline erosion affecting pipes near shoreline" were the most commonly cited impacts. The highest number of impacts were reported during the month of May, with the overall number of impacts reported decreasing throughout the late summer and early fall.

The majority of facilities did not experience any loss of service or any improvements due to the 2017 high water levels. The majority of facilities also did not report any water quality concerns or identify any new vulnerabilities from the 2017 event.

Approximately one-third of respondents reported taking action during the high water levels of 2017. Just over one-quarter of respondents reported taking some action since 2017. Of those facilities who reported a cost for actions taken during 2017, the average cost was just over $71,000, with cited costs ranging from $100 to $220,000. In terms of facilities having reported a cost for actions taken since 2017, the average cost was over $624,000. In this case, costs ranged from $10,000 to $3,000,000.

9. LESSONS LEARNED

With respect to the process for undertaking a survey of municipal and industrial facilities, the following lessons were learned and should be considered when undertaking future work of a similar nature:

- When undertaking outreach to invite these facilities to participate in the survey, the active approach of calling them proved to be far more effective in soliciting responses than the passive approach of letters or emails. Both however played a role, but a passive approach cannot be relied upon solely.
- Though the option was given to facilities to complete the survey over-the-phone, only one chose to do it that way. Once contact had been made with the appropriate individual to respond to the survey, most facilities preferred being given the link for the survey to complete it on their own.
- Given the nature of the survey and the questions within it, facilities found it valuable to be able to review the questions in advance. This allowed them to understand the types of information they needed for their responses, and to compile this information in advance of responding to the survey.
- At the outset, a letter/email was sent to all facilities indicating the survey was happening and that we may be in touch for them to complete it. This original correspondence did not include a link to the survey. The rationale for this was that specific facility types within each shoreline zone would be targeted for completing the survey to ensure sample targets were achieved. In hindsight, the link should have been provided at the outset to all identified facilities in the original correspondence. The correspondence should have also included an offer to provide the survey questions for review in advance. These matters were indeed corrected when the reminder letter/email was sent to municipal and industrial facilities.
- Though correspondences indicated that the survey was for facilities that were negatively impacted or fared well, many facilities expressed in conversation that they did not feel the survey was for them as they experienced no negative impacts. The survey outreach team addressed this in conversation with these facilities, and ultimately secured responses from many facilities that were not impacted. However, any future efforts for similar endeavours should ensure that all facilities on the spectrum of not impacted to highly impacted clearly understand their experiences and insights are equally valued.
- The questions regarding critical high and low water thresholds were answered in a wide variety of ways by facilities. To have allowed for more consistency, it may have proved beneficial to provide them with more context and an example of the desired format of their response. It is suggested that the GLAM Committee follow-up with respondents at a future date and again pose this question, but do so in such a way so as to ensure consistency in responses.
- In a small number of cases, there was confusion amongst potential facilities from Hamilton Harbour. It was perceived that Hamilton Harbour was a separate entity from Lake Ontario, rendering the survey inapplicable. In future endeavours, communications should be worded in such a way as to overcome this potential source of confusion.
- The target sample size was met or exceeded for all facility types and locations, except for the overall target set for industrial facilities. This audience may require special consideration and additional outreach efforts for any future research. One facility indicated that completing surveys was against corporate policy, which may be a contributing factor for others.