



INTERNATIONAL LAKE ONTARIO-  
ST. LAWRENCE RIVER BOARD

# OBSERVED CONDITIONS & REGULATED OUTFLOWS IN 2017

Report to the International Joint Commission



## International Lake Ontario- St. Lawrence River Board

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### Observed Conditions and Regulated Outflows in 2017

*May 25, 2018*

*All images and figures contained in this report are from the International Lake Ontario-St. Lawrence River Board's files unless otherwise noted.*

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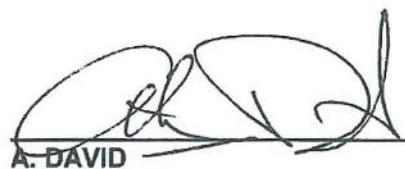
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## INTERNATIONAL LAKE ONTARIO - ST. LAWRENCE RIVER BOARD MEMBERSHIP

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Joan Frain, Member	Frank Sciremammano, Jr., Member
Patricia Clavet, Member	Thomas Brown, Member
Jean Aubry-Morin, Member	Anthony M. "Tehera'tats" David, Member
Marc Hudon, Member	Robert Campany, Member
Jacob Bruxer, Regulation Representative	LTC Adam Czekanski, Regulation Representative
Jamie Dickhout, Alternate Regulation Representative	Keith Koralewski, Alternate Regulation Representative
Rob Caldwell, Secretary	Arun Heer, Secretary

### NOTE

The International Lake Ontario - St. Lawrence River Board was established by the International Joint Commission (IJC) and is comprised of an equal number of members from the United States and Canada. Members of the Board serve at the pleasure of the IJC and are expected to be full participants in all activities of the Board. As with all IJC Boards and Committees, the Lake Ontario - St. Lawrence River Board members serve in their personal and professional capacity, not as a representative of their agencies or employers.

## EXECUTIVE SUMMARY

This report by the International Lake Ontario - St. Lawrence River Board (the Board) describes the causes of the record high water levels in 2017 on Lake Ontario and the St. Lawrence River, as well as the regulation of outflows by the Board during this event. The Board is appointed by the International Joint Commission (IJC), an organization created as part of the 1909 Boundary Waters Treaty between the United States and Canada to regulate shared water uses and resolve transboundary water conflicts. The Board is responsible for regulating the outflow from Lake Ontario through an international dam located on the St. Lawrence River at Cornwall, Ontario and Massena, New York, according to orders issued by the IJC. Water levels on Lake Ontario and the St. Lawrence River are thereby influenced, though not completely controlled, by these actions. The IJC has also appointed members to the Great Lakes - St. Lawrence River Adaptive Management (GLAM) Committee, which is responsible for an on-going evaluation of the regulation of outflows from Lake Ontario and Lake Superior as a body of the three Great Lakes Boards. The GLAM Committee will produce a report later this year that will provide a detailed synthesis of the hydroclimatic conditions and their effects on the high water levels in 2017, and document the related effects of high water levels on the various stakeholders and interests throughout the Great Lakes– St. Lawrence River system.

The record high water levels experienced in 2017 can be attributed to a variety of factors, as well as timing and interaction, but simply put, the high water was mainly due to record precipitation received across the Lake Ontario and St. Lawrence River basin. From January through May of 2017, many locations recorded more precipitation than during the same five-month period of any previous year dating back to at least 1942, including Toronto, Ontario and Rochester, New York on the shores of Lake Ontario, as well as the cities of Ottawa, Ontario and Montreal, Quebec near the confluence of the Ottawa and St. Lawrence Rivers. The wet weather also extended upstream to the Lake Erie basin, where for example, Buffalo, New York recorded its second highest January to May total since 1938. This increased the level of Lake Erie, and the amount of water entering Lake Ontario via the Niagara River.

As a result, the combined total inflow of water to the Lake Ontario and St. Lawrence River system was well above average, and at times unprecedented. From January through March, the net total inflow to Lake Ontario was the 13th highest for this three month period since records began in 1900. April and May were the wettest of all, and with Lake Erie also nearing its seasonal peak, the total inflows to Lake Ontario were even more severe. April 2017 saw the second highest total inflow on record for this month, while total inflows set a new record high for the month of May. In fact, inflows to Lake Ontario during April and May of 2017 were two of the four highest months recorded since 1900, and combined this was the wettest two month period ever recorded for Lake Ontario. As a result, levels of Lake Ontario rose rapidly, setting new record highs by the end of May,

exceeding the highest levels recorded since at least 1918 when reliable records began.

As this was occurring upstream, the watersheds of the Ottawa and St. Lawrence Rivers were experiencing similar conditions downstream. Record precipitation in April combined with snow melt caused flow to rapidly increase in the Ottawa River. By April 20, flows in the Ottawa River reached a record peak for this date and were the highest Ottawa River flows since 1998, only to be exceeded at the start of May as two back-to-back storms further inundated the system resulting in the highest peak flow in the Ottawa River in over 100 years. Because the Ottawa River flows into the St. Lawrence River near Montreal, this meant the Board was releasing water from a flooding Lake Ontario into a flooded St. Lawrence River.

The extreme, and at times, unprecedented hydrologic conditions were not the only notable events to occur in 2017. At the beginning of January, the Board also implemented a new regulation plan, called Plan 2014, which was developed and approved by the IJC with the concurrence of governments. Plan 2014 establishes a new set of rules used to determine the outflows from Lake Ontario, and replaces the former regulation plan, known as Plan 1958-D, which had been in use since 1963.

It is clear that Plan 2014 did not cause, or meaningfully exacerbate, the flooding and associated damages that occurred in 2017. A review of the rules of Plan 2014 and how they responded to the hydrologic conditions that occurred, as well as the factors the Board had to consider when it deviated from those rules, indicates that the outflows released in 2017 under the new regulation plan would have been very similar to those that would have been released had the Board still been operating under the old regulation plan. Moreover, while the Board had greater authority to deviate and release flows other than those that the rules of Plan 1958-D would have prescribed, it is unlikely that this greater authority would have changed the outcome in 2017 in any significant way. Essentially, the extreme weather and water supply conditions that occurred largely dictated the outflows that were released during 2017, and this would have been the case under either regulation plan. For most of January through May and from September through December 2017, outflows were set according to rules within Plan 2014 that were largely designed to mimic how the Board had operated under similar conditions in the past when operating under Plan 1958-D, including deviations. Starting at the end of April, the Board had authority to deviate from Plan 2014, and it did so from the end of May to the start of September, considering the effects that higher outflows would have on lowering the water level of Lake Ontario as well as the impacts that this would have on multiple interests throughout the Lake Ontario – St. Lawrence River system, which would be the same considerations it would have faced under the old regulation plan.

More specifically, the wet conditions and highly variable temperatures from January through March required outflows to be nearly continuously adjusted as ice cover repeatedly

came and went in the St. Lawrence River. Such actions would have been required under any regulation plan to avoid disturbing the fragile ice cover and potentially causing it to collapse. Furthermore, these actions were done according to rules built into Plan 2014, which are based Board operations during similar conditions in the past. Next, during the extremely wet weather in April, as water levels rose rapidly throughout the Lake Ontario – St. Lawrence River system, outflows were again repeatedly adjusted to balance the impacts of high water conditions, which were occurring both upstream and downstream. Outflows during this time were also set according to rules of Plan 2014 which were designed to mimic past Board strategies.

By the end of April, water levels of Lake Ontario exceeded the threshold set within Plan 2014 known as criterion H14 which identifies the water levels at which the Board is granted authority to perform major deviations from the rules of Plan 2014 and set outflows to provide all possible relief to riparian interests upstream and downstream while considering all other interests in the system. However, during most of May, the Board chose to provide that relief by setting outflows identical to those stipulated in Plan 2014's rules, which were designed to balance high water impacts throughout the system.

As the Ottawa River gradually declined from the record highs at the start of May, outflows from Lake Ontario were gradually increased, and by the last week of May, the amount of water entering the lower St. Lawrence River from the Ottawa River had subsided enough that it provided the opportunity for the Board to begin major deviations and release higher flows than the rules of Plan 2014 would have otherwise allowed in an attempt to lower the level of Lake Ontario. Starting May 24, the outflow was increased above Plan 2014, to a rate that equaled the highest weekly mean outflow on record for Lake Ontario. Those records were broken when the outflow was further increased on June 14, and from this date through the first week of August, outflows were maintained at a rate that exceeded the highest amounts ever previously released from Lake Ontario on a sustained basis.

Finally, starting August 8, the Board began to gradually reduce outflows, setting them at the maximum possible rates to lower the level of Lake Ontario, while still ensuring safe navigation could continue in the upper St. Lawrence River. While the Board's priority in 2017 was to reduce the impacts from high water upstream and downstream, the Board also had to consider the degree of relief that could be provided as well as the consequences to all other interests. Conditions in the St. Lawrence River are more immediately and significantly impacted by outflows from Lake Ontario than the lake itself. The record-high flows released in 2017 increased the velocity of currents in the St. Lawrence River. In the international section of the river, between Lake Ontario and Moses-Saunders Dam, the currents continued to increase as Lake Ontario's water level declined throughout the summer. If higher flows than those set by the Board continued to be released, this would have increased currents to such an extent that it would have put the safety of ships at risk and potentially forced the stoppage of commercial navigation.

Such an action, while providing only small amounts of additional relief to Lake Ontario shoreline properties, would have further impacted people's lives and the economy throughout the Great Lakes region.

Water levels continued to decline thereafter due to the combined effects of continuing high outflows and generally dry conditions at the end of August and throughout September. The Board returned to setting outflows according to the rules of Plan 2014 at the start of September, which at the time continued to maximize outflows in consideration of the continuing high levels of Lake Ontario and the upper Great Lakes, while ensuring safe navigation could continue. These rules within Plan 2014 are also based in part on rules within the old regulation plan. Outflows were set at or near the maximum possible rate consistent with safe navigation through December 25 in order to lower Lake Ontario levels as quickly and safely as possible.

In summary, the extreme weather and water supply conditions were the primary factors in causing Lake Ontario water levels to rise a record breaking 1.38 meters (m) (4.53 feet (ft)) from the beginning of January to the end of May. Conversely, this was followed by a record decline of 1.11 m (3.64 ft) from the start of June through December, in part due to record outflows and deviations by the Board during the summer and continuing high outflows prescribed by the Plan itself thereafter. Declining inflows, including a much needed dry spell at the end of August through September were also major contributing factors to the record decline.

The high water caused severe damage and distress along the Lake Ontario shoreline and along the St. Lawrence River, both above and below the dam. The former Plan 1958-D and the new Plan 2014 were both designed to manage these impacts to the extent possible given the physical capacities of the system and the varying effects that water levels and flows have on different interests. Trade-offs between important objectives are unavoidable, perhaps none more obvious than when both Lake Ontario and the St. Lawrence River are flooded, or when efforts to reduce Lake Ontario flooding conflict with the conditions required to maintain safe navigation. Are the regulation plans based on an accurate representation of these trade-offs? Under the directive established by the IJC, the GLAM Committee is charged with assisting the Board to assess the ongoing performance of the regulation plan under a range of conditions, such as those experienced in 2017, and whether the plan is meeting its intended objectives. It must also assess how the Great Lakes – St. Lawrence River system may be changing and how that might alter decisions made on how to best regulate flows. At the time of this report, the GLAM Committee is at work gathering information on a wide variety of 2017 impacts, and relating that information to modeled estimates used to develop Plan 2014. The GLAM Committee is also assessing the degree to which modifications of the rules of Plan 2014 might have affected the outcomes during the high supply conditions of 2017. The GLAM Committee will submit the results of that investigation to the Board and IJC later this year, as part of their efforts to establish an annual reporting process to support its long-term adaptive management effort.

## 1.0 INTRODUCTION

On December 8, 2016, after 16 years of study and consultation, the International Joint Commission (IJC), with the concurrence of the governments of the United States and Canada, announced it was moving forward with the implementation of Plan 2014 for Lake Ontario and the St. Lawrence River, as a modern regulation plan replacing a nearly 60 year old plan. The updated order and regulation plan replaced the 1952 and 1956 orders, and Plan 1958D. The IJC directed their International Lake Ontario - St. Lawrence River Board (the Board) to implement the plan rules and ensure that releases at the Moses-Saunders Dam comply with the IJC's December 8, 2016 Supplementary Order which took effect on January 7, 2017, the day Plan 2014 was officially implemented.

At the time that Plan 2014 was implemented, conditions were not unusual: water levels of Lake Ontario were 5 centimeters (cm) (2.0 inches (in)) below their long-term average at the start of January 2017, the upper Great Lakes water levels were above average but similar to recent years, and ice was starting to form in critical areas of the St. Lawrence River. However, as chance would have it, the events that unfolded over the coming months would test the new regulation plan and the Board with perhaps the most extraordinary conditions to ever occur in the Lake Ontario – St. Lawrence River system.

While similar high water conditions and associated impacts have occurred in the past, the events of 2017 were exceptional in a number of ways. Highly variable winter weather and unprecedented ice conditions were

followed by a series of massive spring storms that brought an exceptional amount of rainfall to the basin, culminating in record high water levels, flooding, and coastal damages throughout the Lake Ontario – St. Lawrence River system. The unprecedented conditions were followed by an equally exceptional response, as record outflows were released from Lake Ontario in an attempt to provide relief to those shoreline communities, home owners, and local businesses that were severely impacted, both upstream and downstream, while at the same time considering the effects on multiple interests throughout the basin.

The purpose of this report is to thoroughly document what transpired over the course of 2017 in terms of observed hydrologic conditions (water supplies, water levels and flows), and how the regulation plan and the Board responded to those conditions. This report also serves as a foreword to a future report by the Board's Great Lakes - St. Lawrence River Adaptive Management (GLAM) Committee which will include further information on the weather and hydrological conditions of 2017 and will report on observed, reported, and anecdotal evidence of impacts of the high water levels and flows on various interests throughout the Lake Ontario – St. Lawrence River system in 2017. The GLAM annual report will also include some preliminary tests to further examine the effects and limitations of outflow management under the extreme conditions of 2017. The GLAM Committee's annual report for 2017 is still under development with submission to the Boards and the IJC expected in October 2018.

## 2.0 LAKE ONTARIO - ST. LAWRENCE SYSTEM AND HOW IT FUNCTIONS

The Lake Ontario – St. Lawrence River system (Figure 2.1) straddles approximately 500 kilometers (km) (300 miles (mi.)) of the Canada-US border, covering an area that runs all along the southern and eastern portions of the province of Ontario and the western and northern parts of the state of New York. From there, it continues even further through the province of Quebec before it eventually meets and ends at the Atlantic Ocean. To understand the events of 2017, it is important to understand the physical and hydrological characteristics of Lake Ontario and the St. Lawrence River, the role and limits of outflow regulation, and the influence these factors have on flows and water level fluctuations throughout the system.

Lake Ontario is a massive water body. Its surface measures 18,960 square kilometers (km<sup>2</sup>) (7340 square miles (sq. mi.)), making it one of the largest freshwater lakes in the world but the smallest of the Great Lakes in terms of surface area. Lake Ontario's surrounding drainage basin is also relatively large at 63,970 km<sup>2</sup> (24,700 sq. mi.), and being the furthest downstream of the Great Lakes, Lake Ontario also

receives water from all of the upper Great Lakes and their surrounding basins.

The primary factors affecting Lake Ontario levels are the uncontrolled, naturally occurring water supplies that the lake receives. Water from the upper Great Lakes flows out of Lake Erie and into Lake Ontario via the Niagara River and Welland Canal. On average, Lake Erie supplies approximately 85% of the net total inflow to Lake Ontario. The rest of the inflow Lake Ontario receives comes from its own drainage basin, in the form of over-lake precipitation and runoff from the surrounding drainage basin, minus evaporation from the lake's surface. Combined, precipitation plus runoff minus evaporation are known as net basin supplies. In terms of magnitude, on average net basin supplies provide a smaller proportion of the total inflow to Lake Ontario than Lake Erie, but the variability in net basin supplies can be much greater, particularly on shorter time scales (weeks to months), which makes net basin supply conditions – particularly extremes – less predictable.



**Figure 2.1**

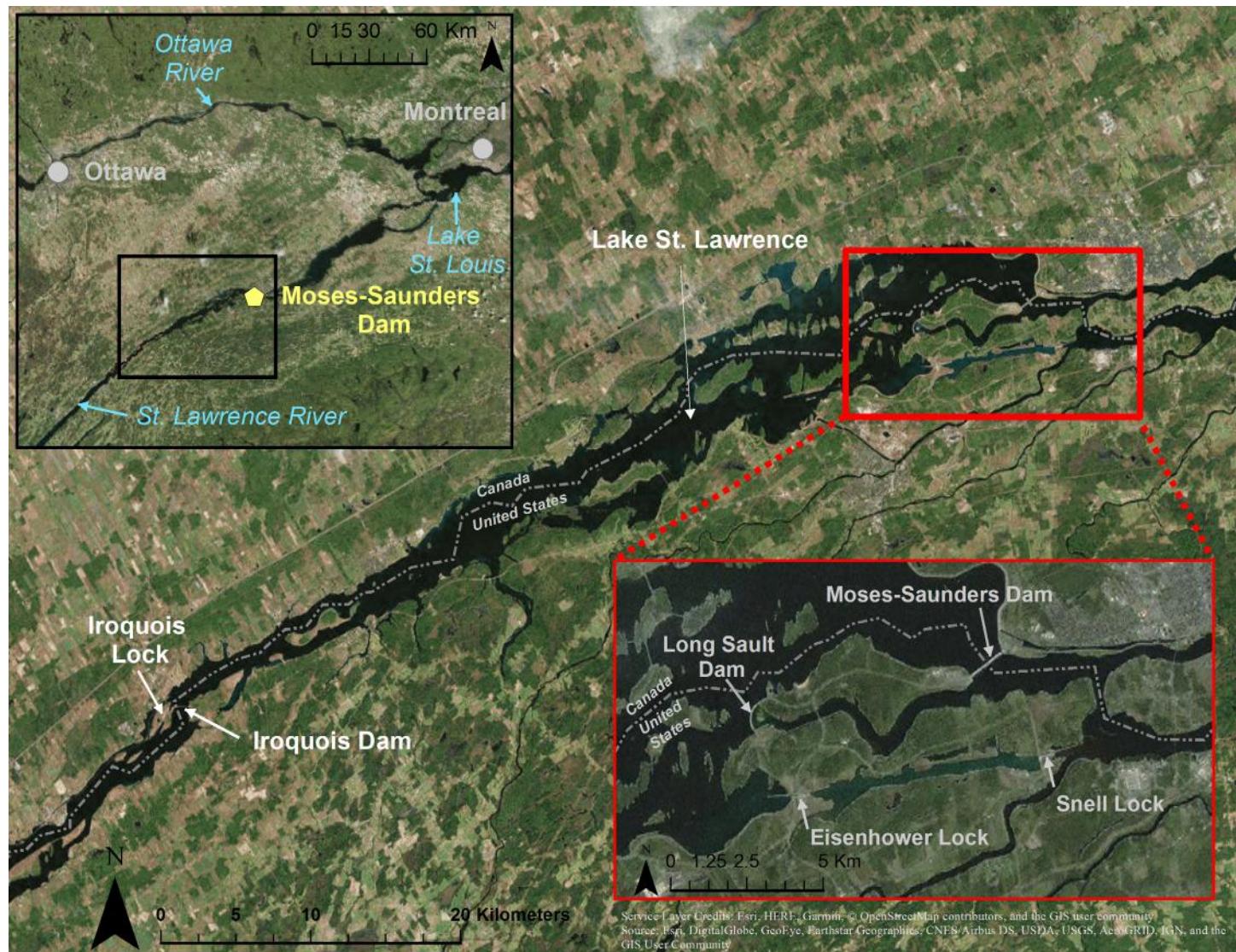
Lake Ontario and St. Lawrence River drainage basin.

While Lake Ontario is the most downstream of the Great Lakes, it represents the most upstream location of the Lake Ontario – St. Lawrence River system. Water flows out of Lake Ontario into the upper St. Lawrence River at the east end of the lake, near Kingston, Ontario and Cape Vincent, New York, where it passes the Thousand Islands. Water levels in this part of the upper St. Lawrence River are largely dependent on Lake Ontario levels and experience similar fluctuations as the lake.

As water moves further downstream in the St. Lawrence (Figure 2.2), the water levels become less dependent on the level of Lake Ontario, and more closely related to the outflow that is released through the hydropower project known as Moses-Saunders Dam near Cornwall, Ontario and Massena, New York. The area immediately upstream of Moses-Saunders Dam is known as Lake St. Lawrence. Lake

St. Lawrence was created when the Moses-Saunders Dam went into operation in 1958 and serves as a forebay for the dam, measuring 259 km<sup>2</sup> (100 sq. mi.). Large increases in outflows cause large and rapid drops in water levels on Lake St. Lawrence. Conversely, large reductions in outflows result in large and rapid water level rises on Lake St. Lawrence. The effects of hydropower operations and wind events can also result in significant, short-term (hourly basis) water level fluctuations on Lake St. Lawrence.

Figure 2.2 also includes the location of Iroquois Dam, a gated structure located at the upstream end of Lake St. Lawrence. This structure does not control flow, but can be used to suppress high levels of Lake St. Lawrence and help facilitate ice management during the winter. Locks are located adjacent to each dam in the river to permit vessels to bypass the dams.



**Figure 2.2**

A map of Lake St. Lawrence from Ogdensburg to Cornwall.

Lake Ontario outflows have been regulated since 1960 through the Moses-Saunders Dam (Figure 2.3). This facility is jointly owned and operated by Ontario Power Generation and the New York Power Authority. The nearby Long Sault Dam in New York acts as a spillway when outflows are greater than the capacity of the power dam (Figure 2.4). These structures define the downstream extent of Lake St Lawrence.

Downstream of the Moses-Saunders Dam begins what is referred to as the lower St. Lawrence River (Figure 2.5). The lower St. Lawrence River first flows past a group of islands that are part of the lands of the Akwesasne First

Nation, before widening again to form Lake St. Francis. This relatively small lake is 233km<sup>2</sup> (91 sq. mi.). Hydro-Quebec hydropower facilities located at Beauharnois and Les Cedres/Coteau are also a critical area of the system. They are operated as “run-of-river” facilities, meaning that there is very little storage capacity on Lake St. Francis and therefore the Hydro-Quebec hydropower facilities must release similar outflows to those released from the Moses-Saunders Dam. As a result, there is some control of water levels in this relatively short stretch of the St. Lawrence River. The Beauharnois Canal and a lock adjacent to the Beauharnois Dam allow vessels to transit through this area of the St. Lawrence River.



**Figure 2.3**

Moses-Saunders Dam located near Cornwall, Ontario and Massena, New York, is the main control structure on the St. Lawrence River used to regulate outflows from Lake Ontario.

Downstream of the Beauharnois Dam, along the western shore of the Island of Montreal, is another widening in the river known as Lake St. Louis. At just 148 km<sup>2</sup> (58 sq. mi.), it is the smallest lake in the St. Lawrence River, but it is also here that the enormous quantity of water released from Lake Ontario through the St. Lawrence River is augmented significantly by the vast amounts of water that enter from the Ottawa River basin.

Two outlets of the Ottawa River discharge into the St Lawrence River at Lake St. Louis, while another two Ottawa River outlets (Rivière des Milles-Îles and Prairies River)

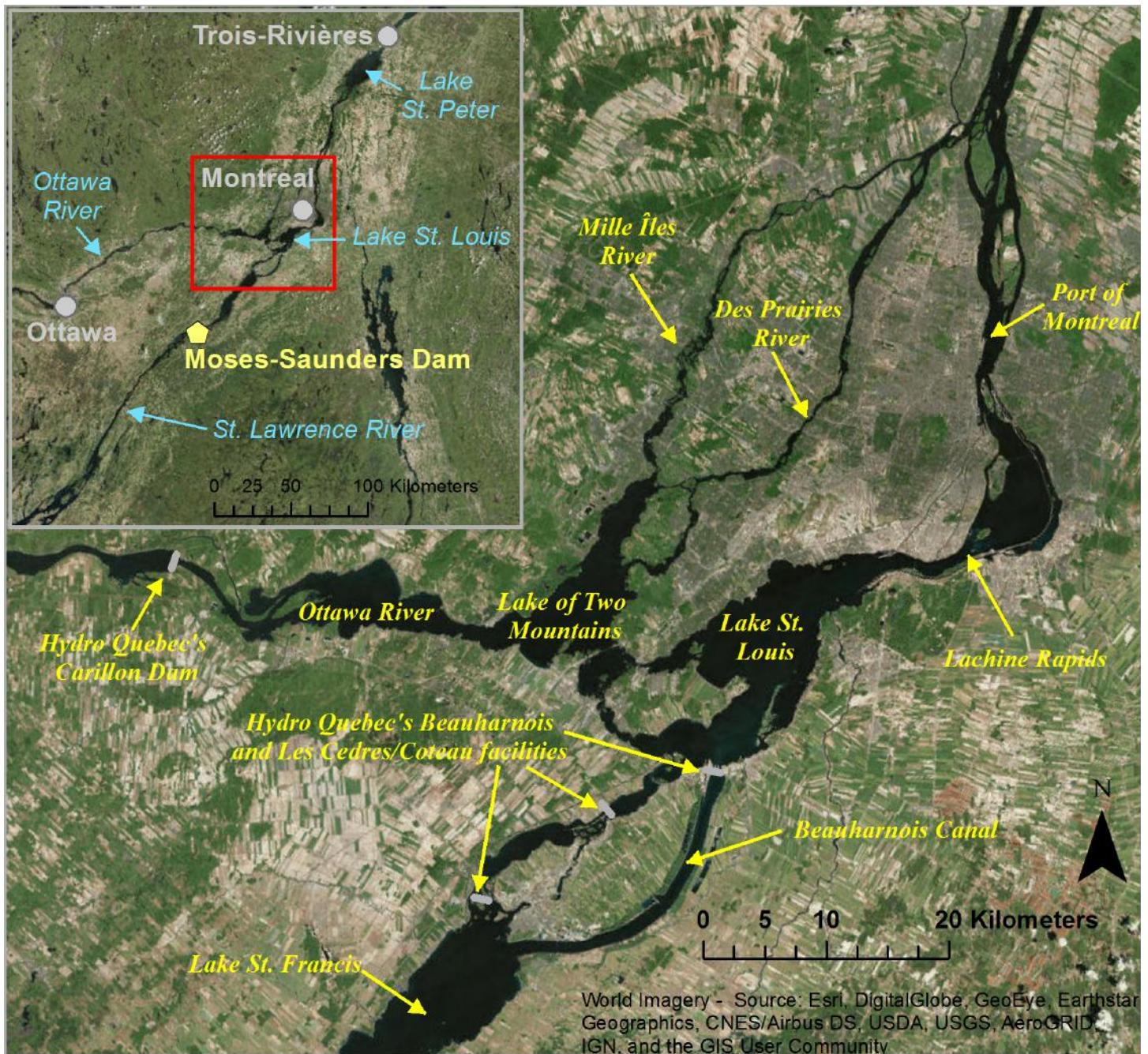
flow north around the Island of Montreal and join the St Lawrence River further downstream. As a result, Lake St. Louis receives just less than half of the total Ottawa River flow in addition to all of the water released from Lake Ontario, and this then cascades into the Lachine Rapids, and makes its way further downstream.

It's also at the Lachine Rapids that the system of locks and canals known as the St. Lawrence Seaway begins, enabling vessels to navigate through the St. Lawrence River and allowing access to Lake Ontario and the upper Great Lakes via the Welland Canal.



**Figure 2.4**

Long Sault Dam, located near Massena, New York, acts as a spillway when outflows are greater than the capacity of the adjacent Moses-Saunders Dam, as they were on June 10, 2017 when this photo was taken.



**Figure 2.5**

The lower St. Lawrence River downstream of the Moses-Saunders Dam with a focus on the area around the Island of Montreal.

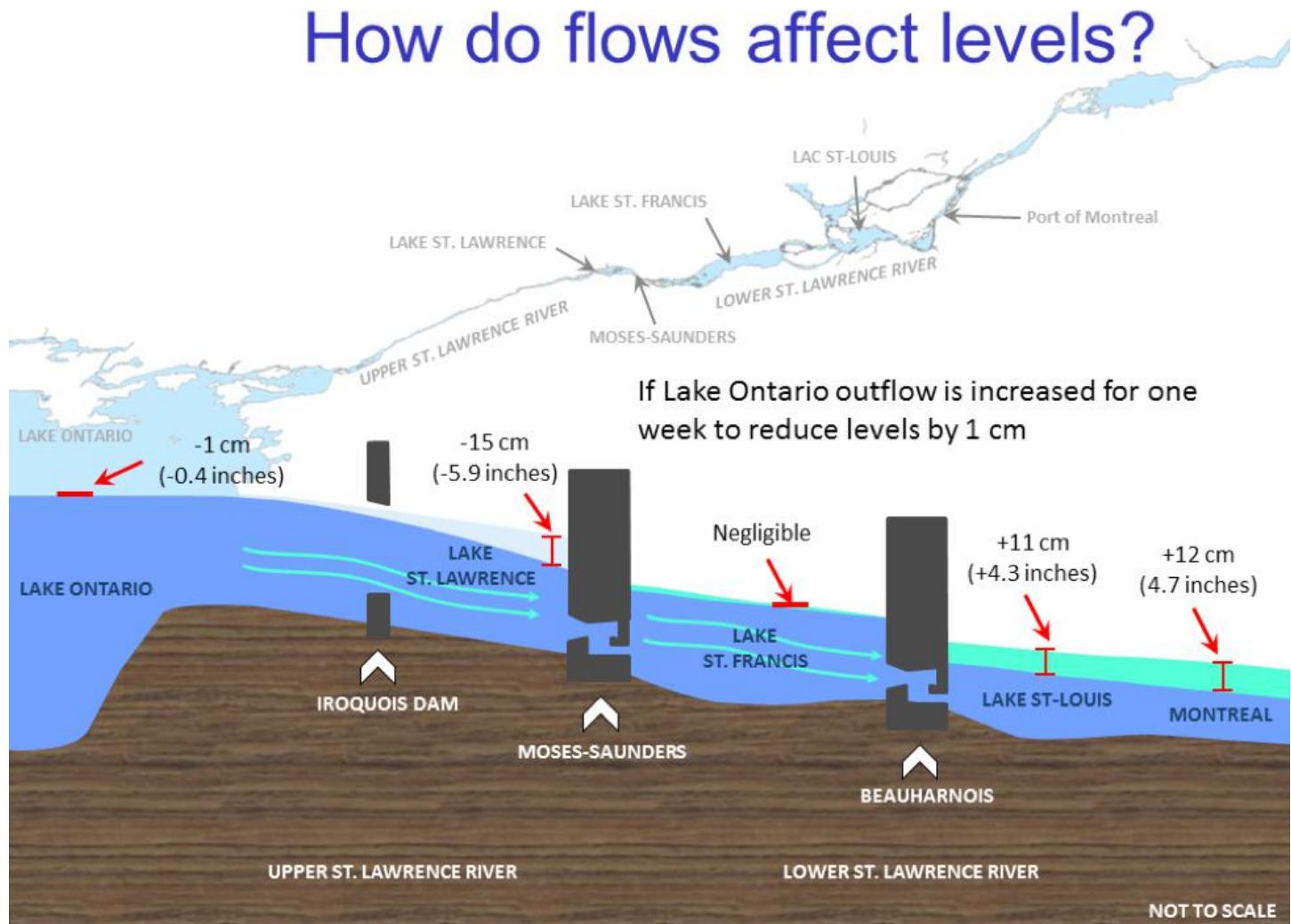
The lower St. Lawrence River next passes the Port of Montreal, which stretches 26 km (16 mi.) along the city waterfront. Just downstream of here is where the northern two outlets of the Ottawa River discharge into the St. Lawrence River, and as a result, areas further downstream receive the full discharge of both the entire Great Lakes system, including the outflow from Lake Ontario, as well as the full discharge out of the Ottawa River system.

Lastly, further downstream is the final widening of the St. Lawrence River, which is 353 km<sup>2</sup> (138 sq. mi.) and is known as Lake St. Peter. Lake St. Peter represents the furthest point downstream in which the impacts of Lake Ontario outflow regulation are measurable.

The regulation of outflows from Lake Ontario through the Moses Saunders Dam on the St. Lawrence River must consider the effects on water levels throughout the entire system, the limited physical capacity of the control structures and channel, as well as the need to balance multiple, and sometimes conflicting, objectives for a range of users that might benefit or be impacted by changing water levels and flows. Municipal and industrial water users, hydropower production, commercial navigation, people that live and work along the shoreline, recreational boaters, along with various ecosystem functions all represent some of the critical interests that must be considered in outflow management, both on Lake Ontario and along the St.

Lawrence River. While Lake Ontario is the smallest of the Great Lakes, it's still enormous and holds a huge volume of water. This is especially true when compared to the capacity of the St. Lawrence River, which receives the full discharge out of Lake Ontario. As a result, changes in outflow have much more rapid and large impacts on the water levels of the St. Lawrence River than they do on Lake Ontario. For example, to achieve a 1 cm (0.4 in.) change in Lake Ontario water levels in a week requires outflows to be changed by about 322 m<sup>3</sup>/s (11,400 cfs). This same volume

of water released through the St. Lawrence River results in more than a 10 times greater change in water levels in critical areas of the St. Lawrence River, with the effects differing upstream and downstream of the Moses-Saunders Dam. Figure 2.6 depicts these relative changes. These physical constraints and the differing effects that outflows have on water levels throughout the system are a critical consideration when regulating the outflow of Lake Ontario through the St. Lawrence River.



**Figure 2.6**

Hydraulic profile (not to scale) of the St. Lawrence River illustrating the effects that a release of water needed to achieve a 1 cm (0.4 in.) decline in Lake Ontario levels has on water levels at critical areas of the St. Lawrence River. Plan view of the system is shown in the upper portion in the figure for reference.

### 3.0 THE ROLE OF THE INTERNATIONAL LAKE ONTARIO - ST. LAWRENCE RIVER BOARD

The IJC is a binational body charged with preventing and resolving disputes over water along the Canada-US border and has oversight over the outflows from the Moses-Saunders hydropower project at Cornwall, Ontario and Massena, New York. The IJC approved this project in 1952. With the concurrence of the United States and

Canadian Governments, the 1956 IJC Supplementary Order of Approval for the project included requirements to reduce the range of Lake Ontario water levels to provide dependable flow for hydropower, adequate navigation depths, and protection for shoreline and other interests on Lake Ontario and downstream in the Province of Quebec.

The International Lake Ontario - St. Lawrence River Board, originally known as the International St. Lawrence River Board of Control, was established in 1952 by the IJC to regulate outflows to meet the Order of Approval and to monitor levels and flows in the St. Lawrence River. The Board was renamed when the IJC issued the December 8, 2016 Supplementary Order effective January 7, 2017. The IJC appoints 10 members to the Board, equally from the United States and Canada, with a broad diversity of experience and expertise who act in their personal and professional capacity.

## 4.0 A NEW REGULATION PLAN

On December 8, 2016, the IJC, with the concurrence of the governments of the United States and Canada, issued a Supplementary Order, replacing Plan 1958-D and adopting Plan 2014 as the new regulation plan. Plan 2014, which became effective on January 7, 2017, prescribes a new set of rules that the Board must ordinarily follow in setting the outflows from Lake Ontario through the St. Lawrence River.

As reported by the IJC in their June 2014 report on Plan 2014 (IJC, 2014), the objective of Plan 2014 is to return the Lake Ontario - St. Lawrence River system to a more natural hydrological regime, while limiting impacts to other interests. The old Orders' criteria under Plan 1958D did not explicitly address contemporary considerations such as environmental and recreational boating needs, and were designed using historically observed water supply conditions, which consisted of a shorter period of record and did not include several more extreme supply sequences occurring since its development. The result, according to the IJC and with the concurrence of governments, is a more balanced approach that considers objectives in different ways and degrees for all interests. New criteria were defined on this premise, using longer periods of record, and state-of-the-art uncertainty and potential future hydroclimate and water supply conditions.

Plan 2014 begins with a sliding rule curve based on the pre-project stage-discharge relationship such that as water levels of Lake Ontario rise, outflows also increase and as water levels decline, outflows decrease. The rule curve flow is also adjusted higher or lower depending on whether total inflows (i.e., the net total supply of water flowing into Lake Ontario) during the past year have been relatively high or low, respectively. Total inflows include the supply of water received from the Lake Ontario basin and also from Lake Erie, and helps provide some indication of the water supplies that Lake Ontario may receive in the foreseeable future.

A number of secondary rules are also applied to the rule curve flow, which are dependent on whether the level of Lake Ontario is high or low. Notably, if Lake Ontario is high at the start of September, then Plan 2014 includes a rule that applies through the rest of the year and tries to reduce the risk of high levels in the following spring and summer by linearly increasing the rule curve flow by the amount needed to reach a level of 74.80 meters (m) (245.41 feet

The Board's main duty is to ensure that outflows from Lake Ontario meet the requirements of the IJC order. The Board also has responsibilities to communicate with the public about water levels and flow regulation, and work with the GLAM Committee to monitor and assess the performance of the regulation plan. It is important to note that while the regulation plan establishes the rules used to determine the outflows from Lake Ontario, the regulation plans and the Board are limited in their ability to alter lake levels especially under extreme conditions which are driven by natural factors of precipitation, evaporation and wind.

(ft)) by January 1. Another secondary rule, which applies throughout the year whenever Lake Ontario's average water level over the past 52 weeks is less than or equal to 74.60 m (244.75 ft), reduces the rule curve flow by 200 m<sup>3</sup>/s (7,100 cfs).

Plan 2014 then checks the adjusted rule curve flow against a series of maximum and minimum flow "limits" to address specific conditions.

The "I" limit, also referred to as the "ice" limit, defines the maximum flow that can be released during ice formation at critical locations on the St. Lawrence River. During periods of ice formation, either downstream on the Beauharnois Canal or on Lake St. Lawrence and the International Section of the St. Lawrence River upstream of Moses-Saunders Dam, the maximum flow is reduced to 6,230 cubic meters per second (m<sup>3</sup>/s) (220,011 cubic feet per second (cfs)) to reduce velocities in the channel and avoid disturbing the fragile ice cover, which could potentially cause it to collapse and greatly increase the risk of causing an ice jam, which could lead to downstream flooding. Once a complete ice cover has formed and is stable on these sections of the river, the I-limit generally allows flows to be increased, though it also prescribes a maximum flow that will prevent the river level at Long Sault Dam from falling lower than 71.80 m (235.56 ft). This limit prevents low levels that might impact municipal water intakes on Lake St. Lawrence, and also acts to limit the shear stress and maintain stability of the ice cover. The I-limit also limits the maximum flow with an ice cover present in the Beauharnois and/or international channels to no more than an absolute maximum of 9,430 m<sup>3</sup>/s (333,000 cfs).

The "F" limit defines the maximum flow to limit flooding on Lake St. Louis and near Montreal in consideration of the Lake Ontario level. It is a multi-tiered rule that applies during periods of high water, normally during the Ottawa River's spring freshet when snowmelt and rainfall increase flows into the lower St. Lawrence River. The rule attempts to balance upstream and downstream flooding damages by keeping the level of Lake St. Louis below a given stage for a corresponding Lake Ontario level (Table 4.1).

**TABLE 4.1**

Lake St. Louis levels (measured at Pointe Claire) corresponding to Lake Ontario levels for balancing upstream and downstream flooding damages (F limits).

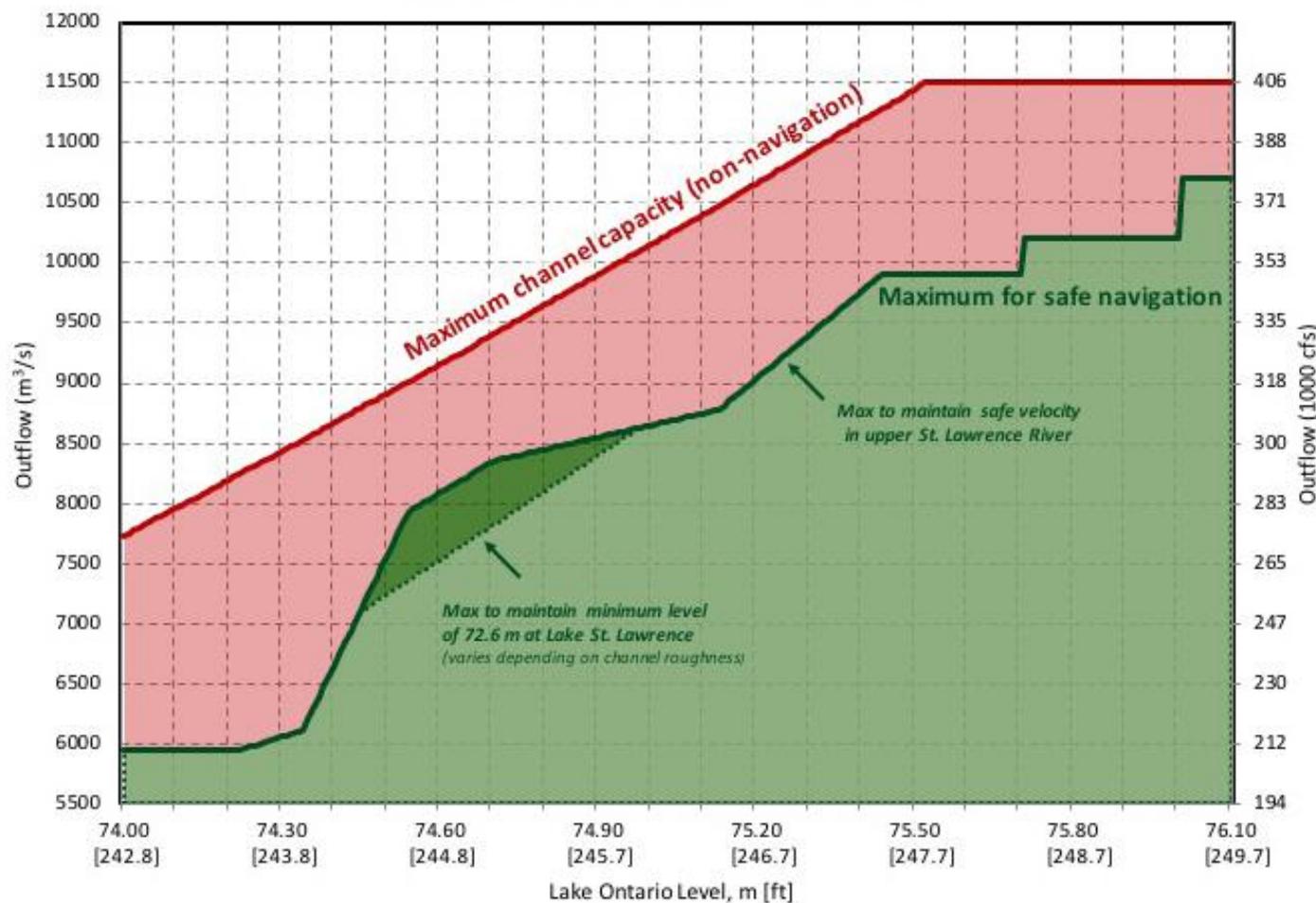
LAKE ONTARIO WATER LEVEL	LAKE ST. LOUIS (AT POINTE CLAIRE) WATER LEVEL
< 75.30m (247.05 ft)	22.10 m (72.51 ft)
≥ 75.30 m (247.05 ft) and < 75.37 m (247.28 ft)	22.20 m (72.83 ft)
≥ 75.37 m (247.28 ft) and < 75.50 m (247.70 ft)	22.33 m (73.26 ft)
≥ 75.50 m (247.70 ft) and < 75.60 m (248.03 ft)	22.40 m (73.49 ft)
≥ 75.60 m (248.03 ft)	22.48 m (73.75 ft)

Water levels expressed in meters/feet International Great Lakes Datum (IGLD) 1985

The “L” limit defines the maximum outflow that can be released from Lake Ontario while still maintaining adequate levels, safe velocities, and other conditions for navigation in the St. Lawrence River. As shown in Figure 4.1, this maximum flow limit varies according to water levels of Lake Ontario: when levels are high, outflows can also be very high while still permitting safe navigation; as levels of Lake Ontario

decline, so do levels in the upper St. Lawrence River, and this increases velocities and requires flows to be reduced to ensure safe conditions are maintained. Plan 2014’s L-limit defines the flow of 10,200 m<sup>3</sup>/s (360,200 cfs) as the maximum that can be released for a level of Lake Ontario from above 75.70 m to 76.00 m (248.36 ft. to 249.34 ft) during the navigation season.

### Plan 2014 - Maximum L-limit Flow

**Figure 4.1**

Depending on the water level of Lake Ontario, Plan 2014's L-limit prescribes the maximum outflow that will maintain adequate levels and safe conditions in the St. Lawrence River during the navigation season and the maximum capacity of the river during the non-navigation season.

The “M” limit defines the minimum flow required to balance low levels of Lake Ontario and Lake St. Louis. Similar to the F-limit that applies during periods of high water, this limit is also a multi-tiered rule that adjusts the outflow depending

on the levels observed both upstream and downstream: during periods of dry conditions, as levels of Lake Ontario decline, the levels that this rule maintains at Lake St. Louis are also allowed to decline (Table 4.2).

**TABLE 4.2**

**Lake St. Louis levels (measured at Pointe Claire) corresponding to Lake Ontario levels for balancing low levels (M Limits).**

LAKE ONTARIO WATER LEVEL	TOTAL FLOW FROM LAKE ST. LOUIS	(APPROXIMATE CORRESPONDING LAKE ST. LOUIS (AT POINTE CLAIRE) WATER LEVEL)
> 74.20m (243.44 ft)	6,800 m3/s (240,100 cfs)	20.64 m (67.72 ft)
> 74.10 m (243.11 ft) and ≤ 74.20 m (243.44 ft)	6,500 m3/s (229,500 cfs)	20.54 m (67.39 ft)
> 74.00 m (242.78 ft) and ≤ 74.10 m (243.11 ft)	6,200 m3/s (219,000 cfs)	20.43 m (67.03 ft)
> 73.60 m (241.47 ft) and ≤ 74.00 m (242.78 ft)	6,100 m3/s (215,400 cfs)	20.39 m (66.90 ft)
≤ 73.60 m (241.47 ft)	Minimum of (5,770 m3/s (203,800 cfs) or pre-project fixed at year 2010)	20.27 m (66.50 ft) or less

*Water levels expressed in meters/feet International Great Lakes Datum (IGLD) 1985*

The “J” limit defines the maximum change in flow from one week to the next unless another limit takes precedence. Flows are permitted to increase or decrease by a maximum of 700 m3/s (24,700 cfs). This limit ensures more consistent and predictable flows for hydropower operators and ships during the navigation season, and in the winter complements the I-limit by ensuring relatively consistent conditions for ice formation. If the lake is above 75.20 m (246.72 ft), and ice is not forming, then the flow may increase by up to 1420 m3/s (50,100 cfs) from one week to the next.

The maximum and minimum flow limits within Plan 2014 were designed and are applied based largely on how the Board has operated under similar conditions in the past when operating under Plan 1958D with deviations. If the Plan 2014 adjusted rule curve flow falls within the range of these maximum and minimum limits, then none of them are applied, and the adjusted rule curve flow becomes Plan flow. Alternatively, if the adjusted rule curve flow is less than the maximum of the minimum limits or higher than the minimum of the maximum limits, the appropriate limit becomes the plan flow.

Since weather and hydrologic conditions often define when Plan 2014 limits are applied, and these conditions are difficult to accurately predict and can change rapidly, the plan allows for operational adjustments. Operational adjustments allow Plan 2014 outflows to be adjusted when necessary to address inaccurate forecasts employed by the plan or short-term changes in conditions within the week. For example, adjustments may be needed when ice first begins to form, during periods of rapidly increasing Ottawa River flows and downstream water levels, or to ensure adequate river depths or safe velocities for ship transits in

the upper St. Lawrence River. In the past, the Board would, through deviations from Plan 1958-D, often provide similar adjustments to flows to achieve similar objectives, so in this way the new plan functions in much the same way as the previous plan. However, Plan 2014 was designed to include such considerations directly in the rules of the plan itself as operational adjustments. Therefore, unlike deviations, no offsetting or compensatory restoration of water stored or released from Lake Ontario is necessary following operational adjustments.

In addition to the limits and operational adjustments of Plan 2014, the plan also includes provisions that allow the Board to deviate from the rules under certain circumstances, including major and minor deviations that may be used under special circumstances such as short-term needs on the St. Lawrence River, or under extreme water level conditions.

As per the IJC's December 8, 2016 Directive on Operational Adjustments, Deviations and Extreme Conditions, major deviations from the plan may be allowed when levels of Lake Ontario rise above or below a set of established Lake Ontario threshold levels as defined by criterion H14 (Appendix A).

As detailed in the IJC's Directive, the high water level triggers are those levels that would be expected to be exceeded 2 percent of the time and the low triggers are defined as the levels expected to be exceeded 90 percent of the time under the rules of Plan 2014. Similar to lake levels, these thresholds follow a seasonal cycle and vary throughout the year. They were established by simulating water levels using the rules of Plan 2014 with 50,000 years of potential stochastically generated water supply sequences.

When the thresholds are exceeded, criterion H14 allows the Board to set outflows according to an alternative strategy in order to provide relief to those interests impacted by extreme high or low water level conditions. During times that the high threshold is exceeded, as was the case in 2017, criterion H14 requires that the Board release outflows in an attempt to provide all possible relief to riparian areas along the shorelines of the entire system, including upstream on Lake Ontario and downstream on the St. Lawrence River. There are four high and four low threshold levels per month, totaling 48 of each threshold per year.

Minor deviations are also addressed in the 2016 Directive on Operational Adjustments, Deviations, and Extreme Conditions and can be implemented by the Board for contingencies such as hydropower maintenance, assistance for commercial vessels, boat haul-outs, emergencies, etc. Minor deviations are to be restored by equivalent offsetting adjustments from the plan flows as soon as conditions

permit. Thus, cumulative impacts and changes to the balance of the plan's benefits are minimal.

The rules of Plan 2014 are designed to respond to weather and water supply conditions, which are the primary drivers of water level fluctuations over time. Moreover, the Plan's maximum and minimum limits as well as its provisions for deviations under criterion H14 are designed to address extremes. As a result of the extraordinary conditions that occurred in 2017, including highly variable ice conditions, record rainfall, and the simultaneous occurrence of extreme water levels on both Lake Ontario and downstream on the St. Lawrence River near Montreal, all of Plan 2014's maximum limits were applied at some point during the year (only the minimum M-limit was not applied), and major deviations were also performed when Lake Ontario levels exceeded criterion H14 high thresholds. A detailed summary of the hydrologic conditions and regulated outflows is presented in the following section.

## 5.0 SUMMARY OF OBSERVED CONDITIONS AND REGULATED OUTFLOWS IN 2017 ON LAKE ONTARIO AND THE ST. LAWRENCE RIVER

### 5.1 INITIAL CONDITIONS

When Plan 2014 was implemented on January 7, 2017 conditions were not out of the ordinary. The previous year began with relatively wet weather and gradually rising water levels from January through March 2016. However, the spring and summer of 2016 were quite dry, as a severe and prolonged drought took hold in the Lake Ontario basin (Figure 5.1), causing water levels of Lake Ontario to decline below average during the summer months. Water levels remained near or below average through fall, and by the start of January 2017, Lake Ontario's water level was 74.49 m (244.39 ft), 5 cm (2.0 in.) below its long-term (1918–2016) average, and at about the same level as was recorded at the start of each of the previous two years in 2015 and 2016.

Upstream of Lake Ontario, the upper Great Lakes were all above their seasonal average levels, but not significantly so. Lake Erie, which, on average, supplies about 85 percent of the net total inflow of water to Lake Ontario via the Niagara River and Welland Canal, was 18 cm (7.1 in.) above average at the start of 2017, but well below record highs, and like Lake Ontario, at similar levels as were recorded at the start of both 2015 and 2016.

Downstream of Lake Ontario on the St. Lawrence River, water levels on Lake St. Lawrence were well above average, largely due to the fact that ice, which typically suppresses water levels at this location during winter, had not started forming. Further downstream near Montreal, water levels were below average in early 2017 owing to below-average

Ottawa River flows and near average outflows from Lake Ontario.

Finally, at the start of January, ice was beginning to form on the St. Lawrence River in the Beauharnois Canal (refer to map Figure 2.5). The Board had already reduced outflows from Lake Ontario to the rate required for ice formation, which applied under both the old and new regulation plans, supporting a seamless transition to Plan 2014.

In summary, at the start of 2017, ice was forming in the St. Lawrence River as it typically does, and levels of Lake Ontario were slightly below average. The upper Great Lakes were above-average, but close to where they were in recent years. All indications were that 2017 would be a fairly unremarkable year.

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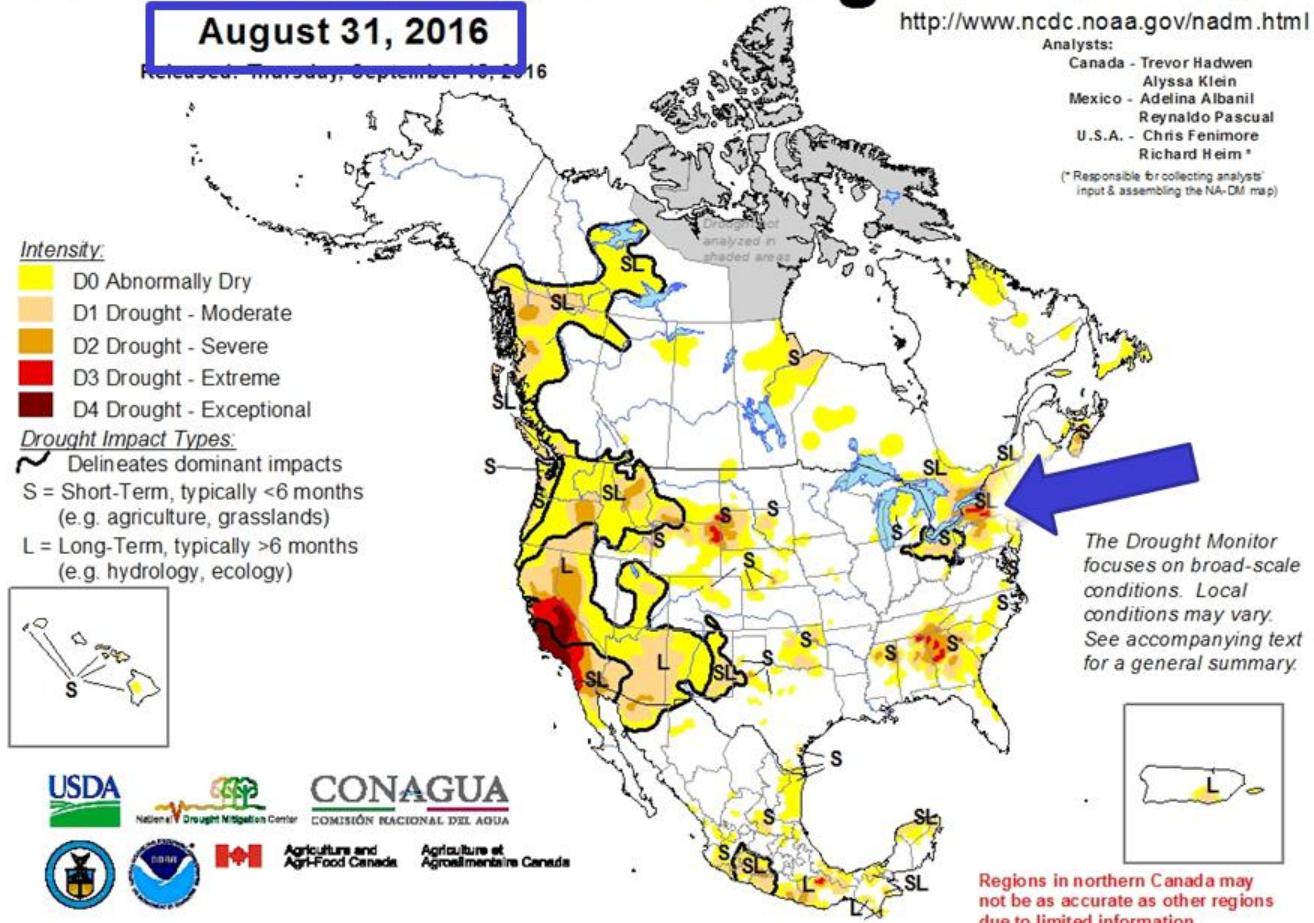
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# **North American Drought Monitor**

August 31, 2016

Released: Thursday, September 15, 2016



**Figure 5.1**

The Lake Ontario basin experienced severe to extreme drought conditions during the summer of 2016, as highlighted in the North American Drought Monitor at the end of August that year. Source: North American Drought Monitor (<https://www.ncdc.noaa.gov/temp-and-precip/drought/nadm/maps>).

## 5.2 WET WEATHER AND HIGHLY VARIABLE WINTER TEMPERATURES (JANUARY TO MARCH)

The first three months of 2017 were marked by generally wet weather (Figure 5.2), and highly variable temperatures and ice conditions, which impacted Lake Ontario water levels and outflows during this period.

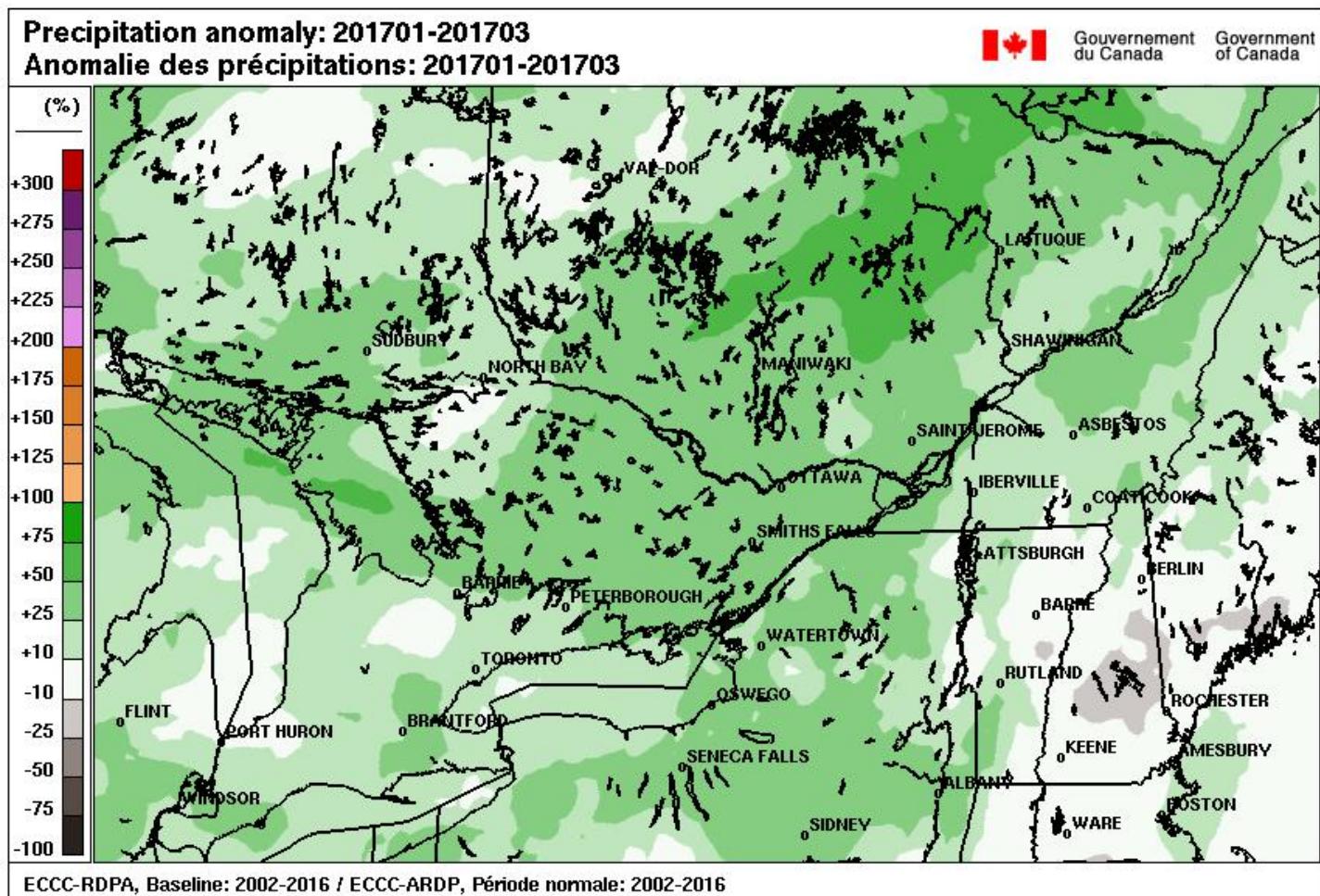
Above-average precipitation was recorded over the Lake Ontario and St. Lawrence River basin in January and February. Moreover, unusually mild temperatures during these two months meant that much of the precipitation fell as rain rather than snow. As a result, much of the snow that fell melted saturated the land surface, and along with the rain this increased streamflows into Lake Ontario. Furthermore, above average precipitation was also observed on the Lake Erie basin, which increased water levels in that lake and led to rising flows in the Niagara River, which discharges into Lake Ontario.

While not entirely unusual, the generally wet conditions led to above average water supplies. The total inflow to Lake Ontario, known as the “net total supply” and which includes the inflow from Lake Erie as well as precipitation that falls directly onto the lake’s surface, the runoff (streamflow) from the surrounding drainage basin, minus evaporation from the

lake, was above average during both January and February. In fact, the net total supply during the months of January and February combined was the 7th highest recorded during this two month period, with records dating back to 1900.

As inflows to Lake Ontario were increasing at a greater than normal rate for the time of year, Lake Ontario water levels also rose at above average rates during the first two months of 2017. Lake Ontario rose 26 cm (10 in) in January, which was the 4th highest January rise recorded during this month since 1918, and then rose another 17 cm (6.7 in) in February, the 7th highest rise recorded in that month.

In response to the rising level of Lake Ontario and increasing water supplies, including those from Lake Erie, the regulated outflow from Lake Ontario also began to generally increase, as prescribed by Plan 2014. Similar to water levels, outflows also generally follow a seasonal cycle. Plan 2014, like the previous regulation plan, generally results in increased outflows early in the year and through the spring as Lake Ontario levels rise in response to increased rainfall, snowmelt, and tributary streamflows. Conversely,



**Figure 5.2**

Precipitation anomaly for January through March 2017 measured as a percentage departure from normal precipitation amounts for these three months. Green areas depict a 10 to 100 percent departure from normal. Source: Environment and Climate Change Canada (ECCC).

outflows generally begin to decrease later in summer, and continue to decrease through the fall and start of winter as water supplies decrease and water levels decline. This is comparable to many other unregulated lake and river systems in North America which tend to follow similar seasonal patterns.

However, on the Lake Ontario – St. Lawrence River system, a critical difference is the manner in which outflows are regulated to manage risks that ice conditions on the St. Lawrence River may cause during the winter months. As ice starts to form in the St. Lawrence River, including at the Beauharnois Canal and Lake St. Lawrence, outflows must be temporarily reduced to facilitate the formation of a safe and stable ice cover. Reducing outflows slows the current and reduces the stress that this puts on the ice cover, and this helps reduce the risk that a newly formed, fragile ice cover could collapse and potentially cause damage. In addition, fast moving water with frigid temperatures generates what is known as frazil ice, ice crystals suspended in water that is too turbulent to freeze solid. Frazil ice can result in ice jams along the St. Lawrence River which can cause flooding and property damages. Prior to regulation, ice jams occurred frequently in the St. Lawrence River. If one were to occur today, the ice-clogged channel would reduce outflows significantly and for an extended period, potentially causing immediate flooding upstream along portions of Lake St. Lawrence and the St. Lawrence River, and leading to rapidly declining levels in the St. Lawrence River downstream of the jam. Ice jams also limit the Board's ability to vary flow until the jam dissipates.

In contrast, by carefully monitoring ice conditions and temporarily reducing flows when necessary, the Board creates flow conditions that help form a stable ice cover. Once the ice cover has formed and as the ice cover strengthens, the Board can safely increase outflows. The flow management strategies employed during ice formation are built into the rules of Plan 2014, specifically the "I-limit" (i.e., maximum flow for ice formation). These rules were developed from past Board operational ice management practices that were employed under the previous regulation plan. In other words, managing flows according to ice conditions is required under any regulation plan and the implementation of the new regulation plan did not change how this occurs. Furthermore, it is important to note that ice forms when weather conditions dictate; the management of outflows does not cause ice to form or prevent it from forming, rather it simply helps ensure that the ice forms in a safe and stable manner.

From January through March 2017, unusual temperature fluctuations resulted in highly variable ice conditions in the St. Lawrence River. Ice started forming the first week of January in the Beauharnois Canal, which is about an average start date for this location, and outflows were reduced accordingly. However, by January 16, the Beauharnois Canal was only half covered with ice (Figure 5.3) and the unusual winter weather began.

Unseasonably mild temperatures, with daily highs above freezing, occurred from January 16 through January 23.

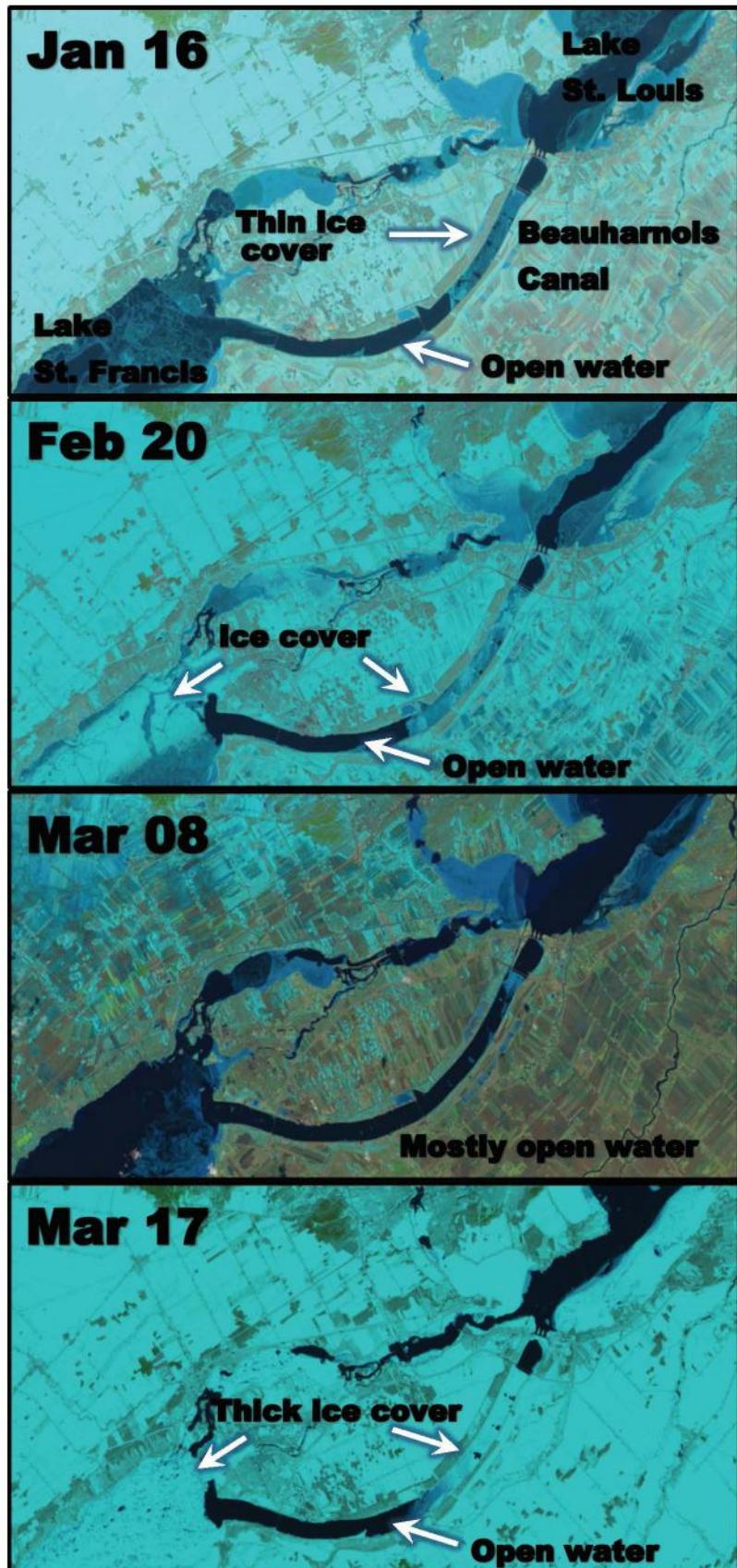
During this week long thaw, the ice that had formed in the Beauharnois Canal receded to the point that the Lake Ontario outflow was safely increased back to values previously passed during the open water season. By January 25, following another period of colder weather, ice had started to form again and the flow needed to be reduced on January 28. However, mild weather returned, ice conditions deteriorated, and flow was again increased on January 31.

This cycle of freezing and thawing continued in February, and flows were adjusted six times that month in response to fluctuating temperatures and ice conditions. A few days of typically cold winter weather at the start of February were followed by several days of milder, but below freezing temperatures, that allowed ice to slowly form at the Beauharnois Canal. On Lake St. Lawrence, ice finally began to form on February 11, the third latest date that ice formation has begun in this area since regulation began in 1960.

However, the last half of February was exceptionally warm. Daily high temperatures recorded at Dorval, Quebec, near Beauharnois, were above freezing for 13 days from February 18 through March 2, and reached 14.5 °C (58 °F) on February 25. Similar conditions were observed at Massena, New York (Figure 5.4), including a record high of 16.7 °C (58 °F) on February 23. The ice was entirely gone from Lake St. Lawrence by this date, less than two weeks after it started forming, and it did not return. The ice cover at Beauharnois was gone by February 26, which permitted the Board to increase the flow several times through the end of the month.

During this time, water levels throughout the system continued to increase gradually. Lake Ontario rose more than normal in February, as inflows were above average and outflows were restricted by the varying ice conditions. St. Lawrence River levels near Montreal also gradually edged upwards until suddenly rising above average on February 26 as snowmelt combined with rare February thunderstorms and rainfall.

Typically by February, a solid ice cover has formed on the St. Lawrence River and remains in place. Occasionally mild temperatures cause the ice cover to melt during February. Both of these conditions allow Lake Ontario outflows to be safely increased. Furthermore, at no time since ice records began had an ice cover started to form in March. However, after the mild and near record warm temperatures in January and February, temperatures became unusually cold in March. At Massena, New York (Figure 5.4), the month of March was colder on average than any of the previous three months of December through February, something not seen since temperature records began at this location in 1960. In fact, two of the coldest stretches of weather all winter occurred in March: from March 2 through 6, overnight lows were less than -10 °C (14 °F), and this was followed by an extended period of unseasonable cold weather from March 10 through 26, in which low temperatures of less than -10 °C (14 °F) were recorded on ten days and temperatures twice fell below -18 °C (0 °F).



### Timeline of Beauharnois Canal Ice Formation Cycles in 2017

#### 1<sup>st</sup> cycle: Jan 08 – Jan 21

The first period of ice formation began in the Beauharnois Canal on Jan 8, 2017, but two stretches of mild weather between Jan 10-23 caused formation to stall and ice cover to diminish, and by Jan 21, it was gone.

#### 2<sup>nd</sup> cycle: Jan 25 – Jan 28

A second brief cycle began Jan 25, but mild temperatures limited progress and it ended Jan 28.

#### 3<sup>rd</sup> cycle: Jan 31 – Feb 26

Ice resumed forming a third time on Jan 31. Steady, but slow progress was made as temperatures fluctuated just below freezing, but an extended period of warm weather from Feb 18 – Mar 1 caused the ice to diminish rapidly. By Feb 26, no ice remained.

#### 4<sup>th</sup> cycle: Mar 04 – Mar 08

A brief, but severe cold snap at the start of March caused ice to resume forming on Mar 4, but milder weather followed and formation again ended Mar 8.

#### 5<sup>th</sup> cycle: Mar 11 – Mar 31

Extreme cold temperatures returned and ice resumed forming for an unprecedented 5<sup>th</sup> time starting on Mar 11. Progress was rapid. On Mar 18 an ice breaker arrived, but ice breaking was slow due to thick ice and continued cold. Starting on Mar 24, overall milder, but still variable temperatures allowed the ice to diminish slowly, and last ice was finally observed Mar 31.

**Figure 5.3**

Timeline of ice formation in the Beauharnois Canal with satellite imagery illustrating conditions on the dates indicated. Source: European Space Agency Sentinel [January 16 and March 17] and NOAA/USGS Landsat [February 20 and March 08]; all images obtained from EarthExplorer (<https://earthexplorer.usgs.gov/>).

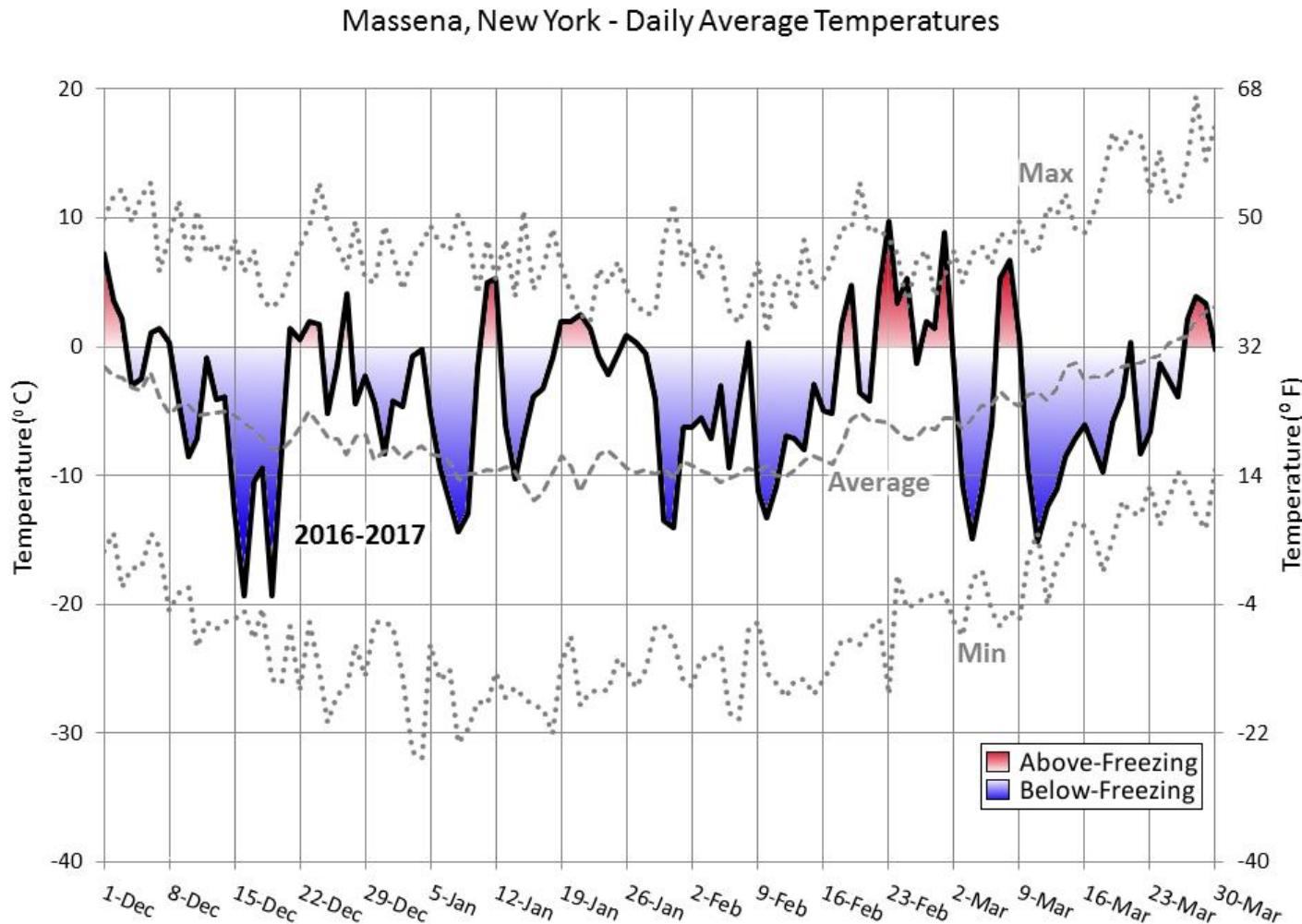
As a result, substantial ice cover formed and disappeared twice in the Beauharnois Canal during March 2017, both unprecedented events. Lake Ontario outflows varied considerably during this time, being reduced as ice formed during the first half of March, and then increased four times thereafter, by a total of 18 percent from March 17 through 22. Once increased, flows remained relatively stable for the rest of the month. Figure 5.5 presents the outflows for 2017 with the winter ice operation from January through March highlighted by a dashed, teal rectangle. A complete list of outflow changes can be found in Appendix B.

Overall, from January through March 2017 the critical areas of the St. Lawrence River experienced five periods of ice formation punctuated with thaw cycles in between (Figure 5.3). This was the most freeze/thaw cycles ever seen in the St. Lawrence River in one winter season.

These highly variable ice conditions required reduced outflows at times, and made regulating outflows challenging

throughout January through March. However, the main component that caused the rising water levels throughout the Lake Ontario - St. Lawrence River system during the first three months of 2017 was the above normal amount of water the basin received. This water came from precipitation, snowmelt, and runoff from within the basin, and above average and increasing inflows from Lake Erie, which also experienced wet conditions and generally rising water levels throughout this period. From January through March, the net total water supply (i.e., total inflow) to Lake Ontario was above average, and the 13th highest for this three month period since records began in 1900.

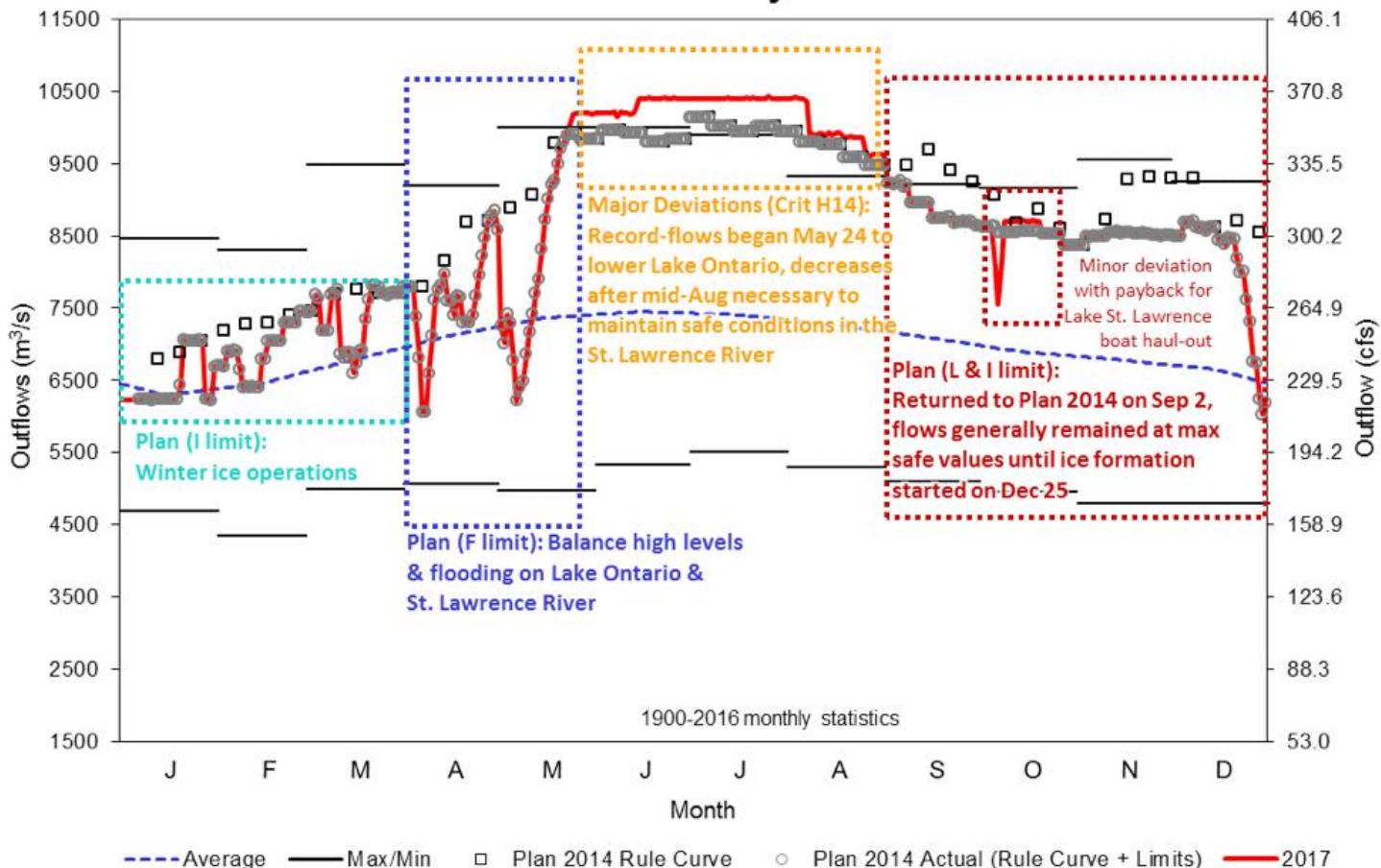
During the first three months of 2017, Lake Ontario's water level rose 59 cm (23 in), reaching 75.08 m (246.33 ft) by the end of March, which was 32 cm (13 in.) above average and very close to the level recorded at the same time in 2016.



**Figure 5.4**

Temperatures recorded at Massena, New York (USW00094725) from December 2016 through March 2017, with freeze and thaw cycles indicated. Source: National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI).

## Lake Ontario Daily Outflows 2017



**Figure 5.5**

Lake Ontario daily outflows for 2017 (red), highlighting particular operational periods within the year. Also shown are the 1900–2016 long-term seasonal average outflows (blue dashed line), the monthly minimum and maximum outflows (dark grey bars), the Plan 2014 weekly rule curve flows (black squares), and the actual Plan 2014 weekly outflow that applied after application of the maximum and minimum flow limits.

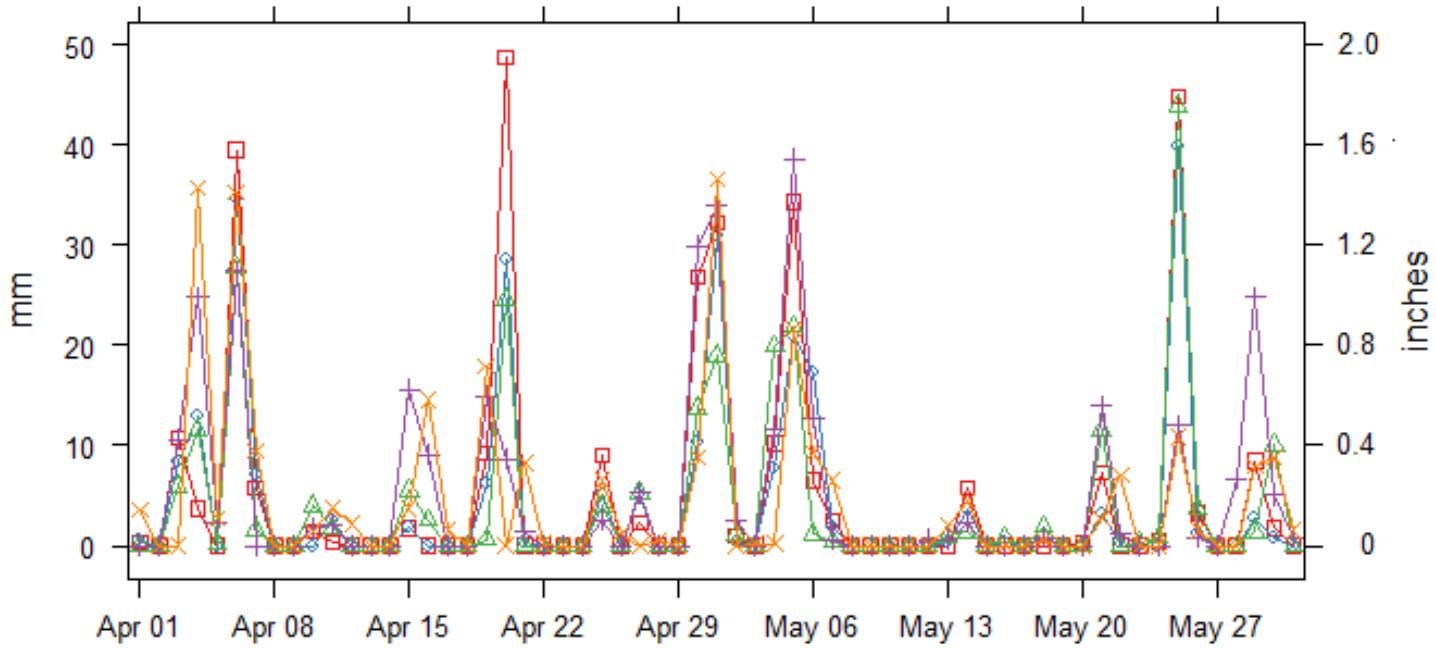
### 5.3 UNPRECEDENTED RAINS AND RECORD OTTAWA RIVER FLOWS (APRIL AND MAY)

The unusually wet winter transitioned quickly to an exceptionally wet spring. Starting on March 29 and continuing through the first week of May, a series of heavy, widespread storm events passed through the Great Lakes basin (Figure 5.6). These storms deposited significant volumes of water directly onto the surface of Lake Ontario and its surrounding drainage basin, which saturated the ground surface, melted the remaining snowpack, and led to significant increases in runoff and stream flows with each storm. The wet weather extended upstream to the Lake Erie basin, as well as downstream to the watersheds of the Ottawa and St. Lawrence Rivers, where some additional snowfall was also recorded during April. Reports of flooding on smaller inland watercourses were frequent and widespread, and all of this extra water flowed quickly and persistently into the Lake Ontario – St. Lawrence River system.

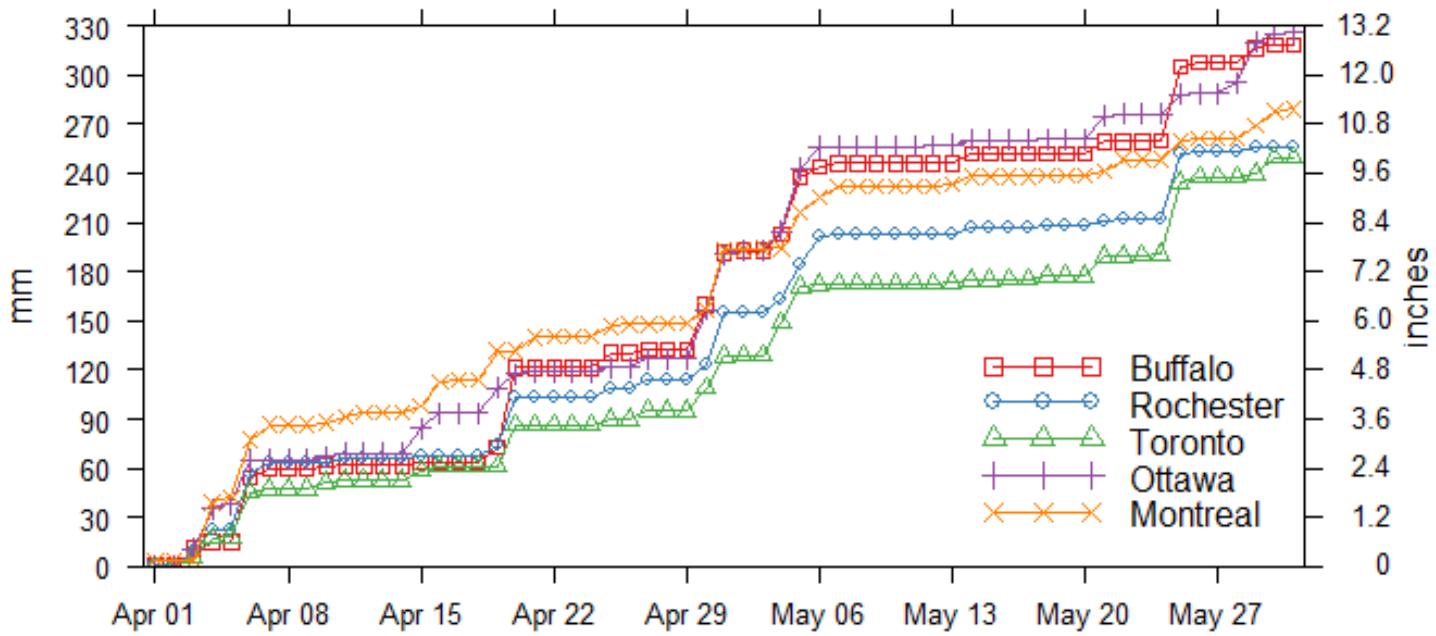
Lake Ontario's water level, which had been steadily increasing since the start of January, began to rise much more rapidly at the start of April in response to the rapidly increasing inflows. Likewise, water levels on Lake St.

Louis also rose quickly throughout the first three weeks of April as heavy precipitation, combined with unseasonably warm temperatures, and a significant thaw event when temperatures were recorded at  $23.5^\circ\text{C}$  ( $74^\circ\text{F}$ ) on April 10. The increasing water levels at Lake St. Louis were not entirely unusual, as typically snowmelt and rainfall tend to temporarily increase flows out of the large Ottawa River basin and into the lower St. Lawrence River during the spring. However, the unusually heavy rainfall in April 2017 coincided with melting snow that had already saturated the ground and swollen waterways, causing the Ottawa River to rise rapidly and well above normal. At Carillon Dam, the most downstream station in the Ottawa River system, the peak flow of  $6,877 \text{ m}^3/\text{s}$  (242,900 cfs) on April 20 was a record for this date and the highest Ottawa River flow for any time of year since 1998 (Figure 5.7), and these high flows began to cause significant flooding in some areas in the southern parts of the Ottawa River system.

## 24-Hour Precipitation



## Cumulative Precipitation



**Figure 5.6**

April and May 2017 precipitation totals (daily at top, cumulative at bottom) recorded at locations around the Lake Ontario – St. Lawrence River basin. The multiple storm events that occurred in April through the first week of May resulted in significant and widespread precipitation totals, while another significant event later in May was more confined to Lake Ontario. Data Source: NOAA National Centers for Environmental Information (US stations), Environment and Climate Change Canada (Canadian stations).

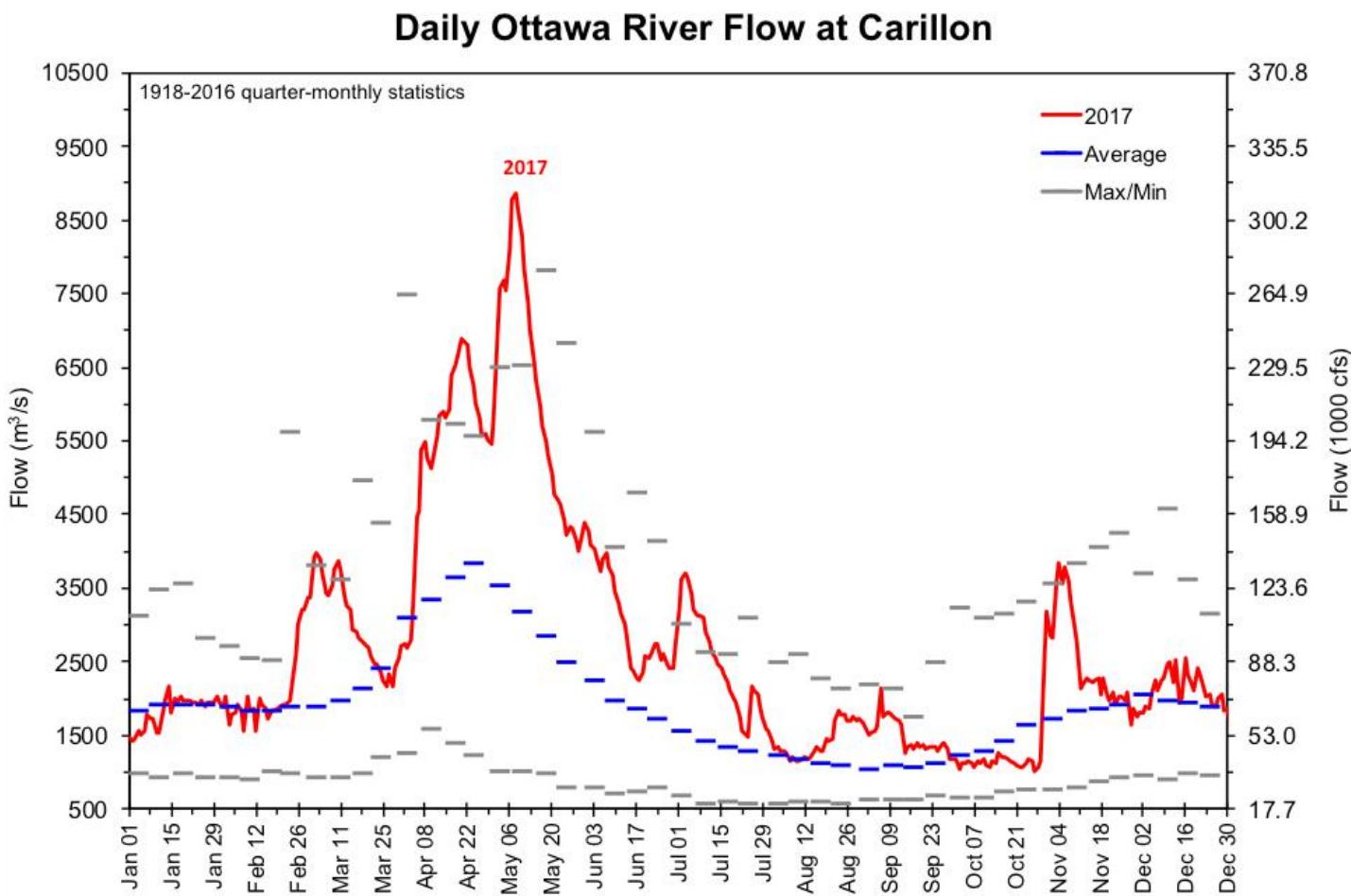
During this time, outflows from Lake Ontario continued to be regulated according to Plan 2014 and in consideration of the wet weather, high inflows, and increasing water levels throughout the system. Continuing from March 22 until noon on April 5, the Plan 2014 adjusted “rule curve” flow was followed. The rule curve of Plan 2014 is based entirely on the level of Lake Ontario and the inflows from the upper Great Lakes, and is normally the flow that Plan 2014 will release if no other limitations in the system are being applied (see section 4.0).

Significant rainfall was received during this time, which caused Ottawa River flows and St. Lawrence River levels around Montreal to rise rapidly. Outflow from Lake Ontario was first reduced on April 5 in order to maintain Lake St. Louis levels below the flood alert level of 22.10 m (72.51 ft). Thereafter, as a series of rainstorms continued to pass through the region, two dozen adjustments to Lake Ontario outflows (highlighted by the dashed blue rectangle in Figure 5.5) were facilitated during the month of April in response to the rapidly rising, highly variable Ottawa River, and local tributary flows.

The Lake Ontario outflows were adjusted in accordance with the Plan 2014 “F-limit” rule, which prescribes the

maximum flow to balance upstream and downstream flooding damages by keeping the level of Lake St. Louis below a given stage for a corresponding Lake Ontario level. This rule was designed to mimic the Board’s decision making strategies under the previous regulation plan. For example, during high water events in the 1990s, flooding and erosion risks, and impacts upstream on Lake Ontario and in the Thousand Islands were balanced with those downstream from Lake St. Louis through Lake St. Peter. During periods of wet spring conditions, as levels on Lake Ontario reach higher and more critical values, this multi-tiered rule also allows increased levels downstream at Lake St. Louis (refer to Table 4.1). Water levels at Lake St. Louis also act as a flood risk indicator for other areas of the St. Lawrence River downstream, and consequently are used to determine and adjust outflows from Lake Ontario.

Starting April 5, the Plan 2014 F-limit was employed continuously throughout the rest of the month to set Lake Ontario outflows. Ottawa River flows were generally high throughout the month of April, and with the ground fully saturated, each storm led to rapid increases in flows into Lake St. Louis. Lake Ontario outflow adjustments were required to maintain the level of Lake St. Louis in accordance with the F-limit rule.



**Figure 5.7**

Daily Ottawa River flows at Carillon Dam in 2017 (red line) compared to the 1963-2016 long-term average (blue bars) and the minimum and maximum flows (dark grey bars).

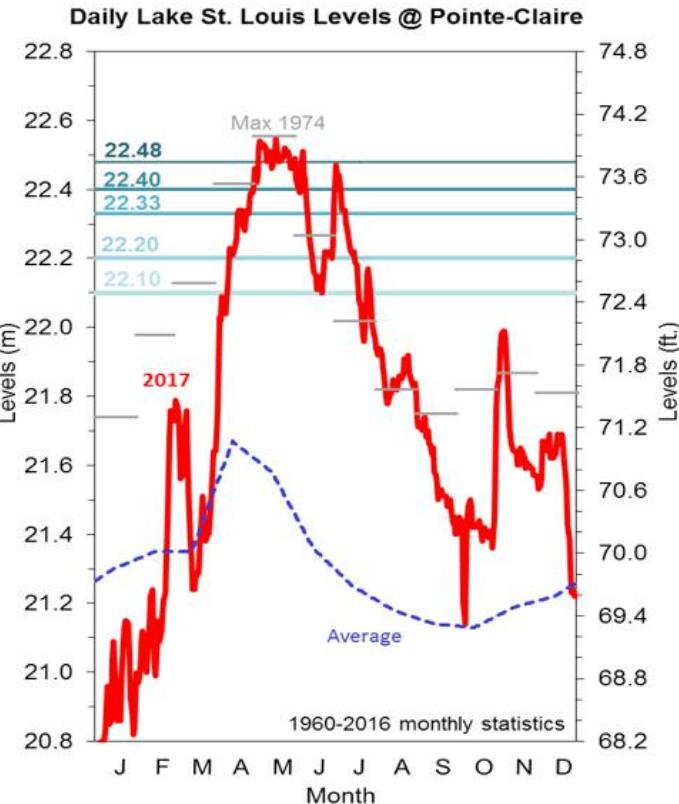
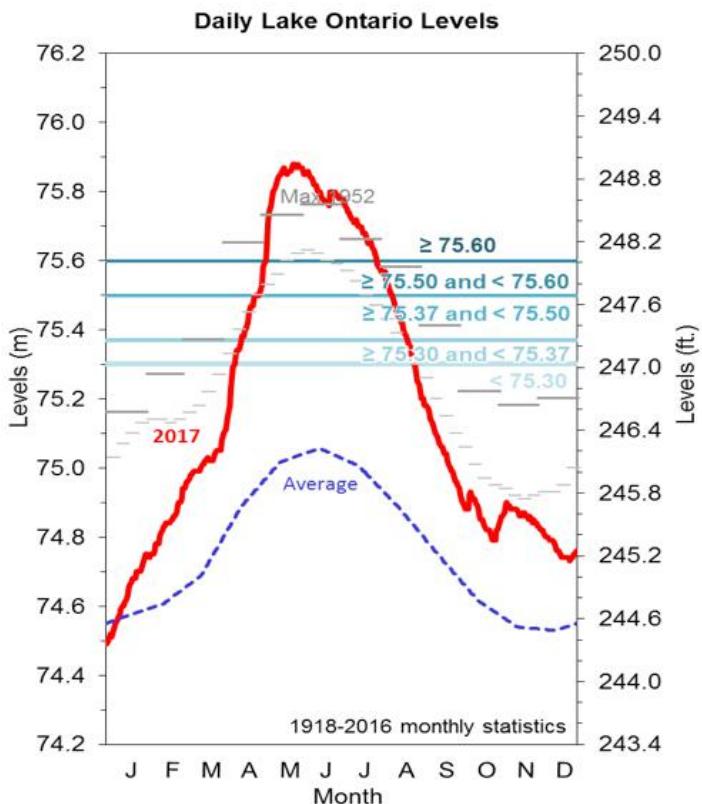
At the same time, many of the same storms inundated areas around Lake Ontario, which caused the lake levels to rise. The net total inflow to Lake Ontario during the month of April was the second highest recorded since 1900. This was due to a combination of well above average inflows from Lake Erie and extremely high precipitation and basin runoff. As examples of how extreme and widespread the wet weather was, the city of Rochester, New York, recorded 125.7 millimeters (mm) (4.95 in) of precipitation in April, the 3rd highest total since 1926, Toronto Ontario recorded 110.8 mm (4.36 in), its 5th highest total since 1938, while Ottawa, Ontario recorded 159 mm (6.26 in), its highest total for the month of April dating all the way back to 1890.

While the wet weather continued to inundate the system, Lake Ontario and St. Lawrence River levels continued to rise (Figure 5.8). Despite above average outflows, Lake Ontario rose 44 cm (17.32 in.) during the month of April, which is the third highest April rise recorded since 1918 (tied with 1940). Lake Ontario's level reached the criterion H14 upper threshold level during the week ending April 28, giving the Board authority to undertake major deviations from Plan 2014 and set outflows to provide all possible relief to riparian interests upstream and downstream.

However, the rules of Plan 2014 respond to extreme water level and supply conditions long before criterion H14 trigger levels are reached, and indeed Lake Ontario outflows were adjusted according to the extreme precipitation received and the rapidly rising water level conditions that occurred throughout most of April. Flows generally increased during the month. However, the increased outflows

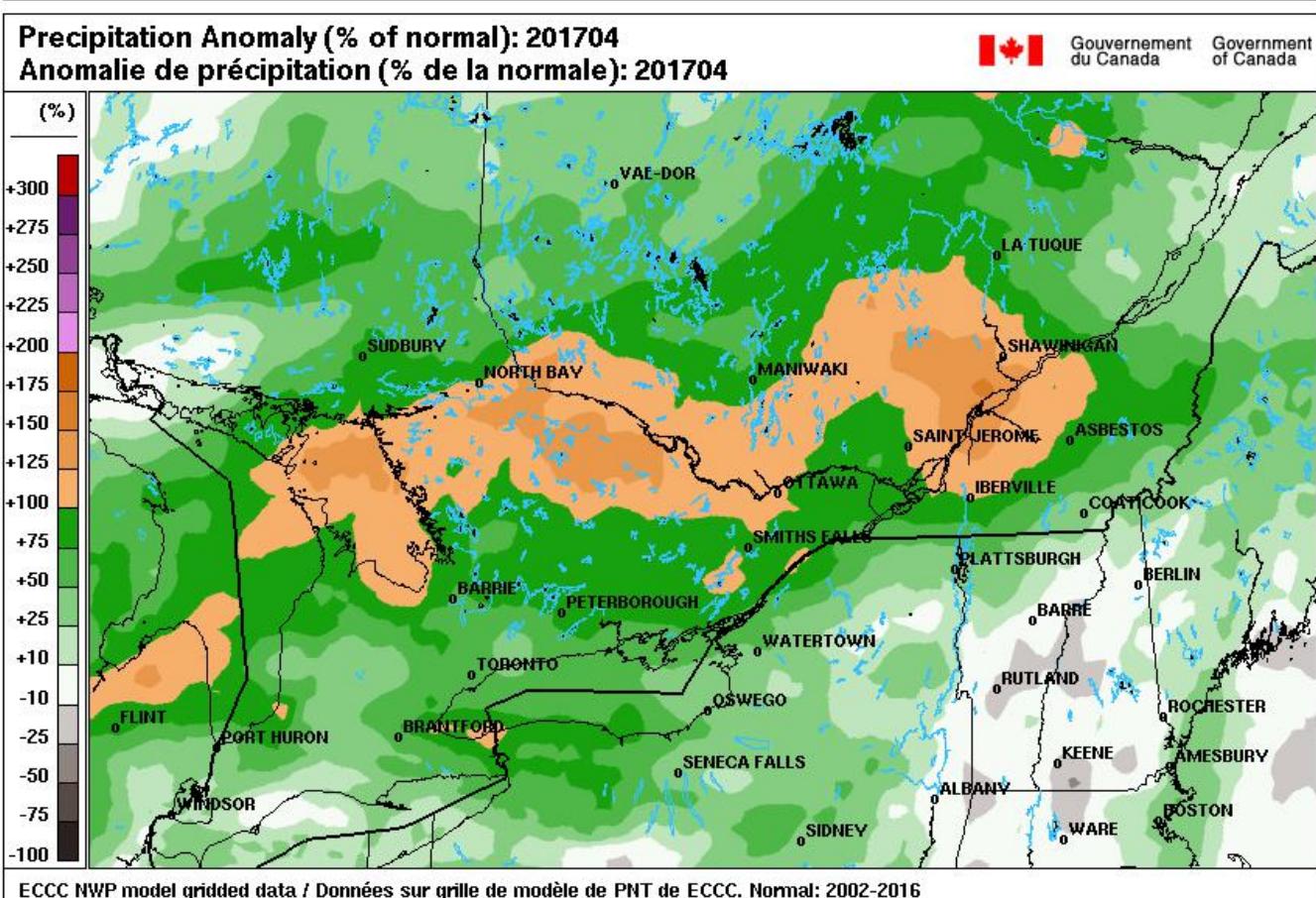
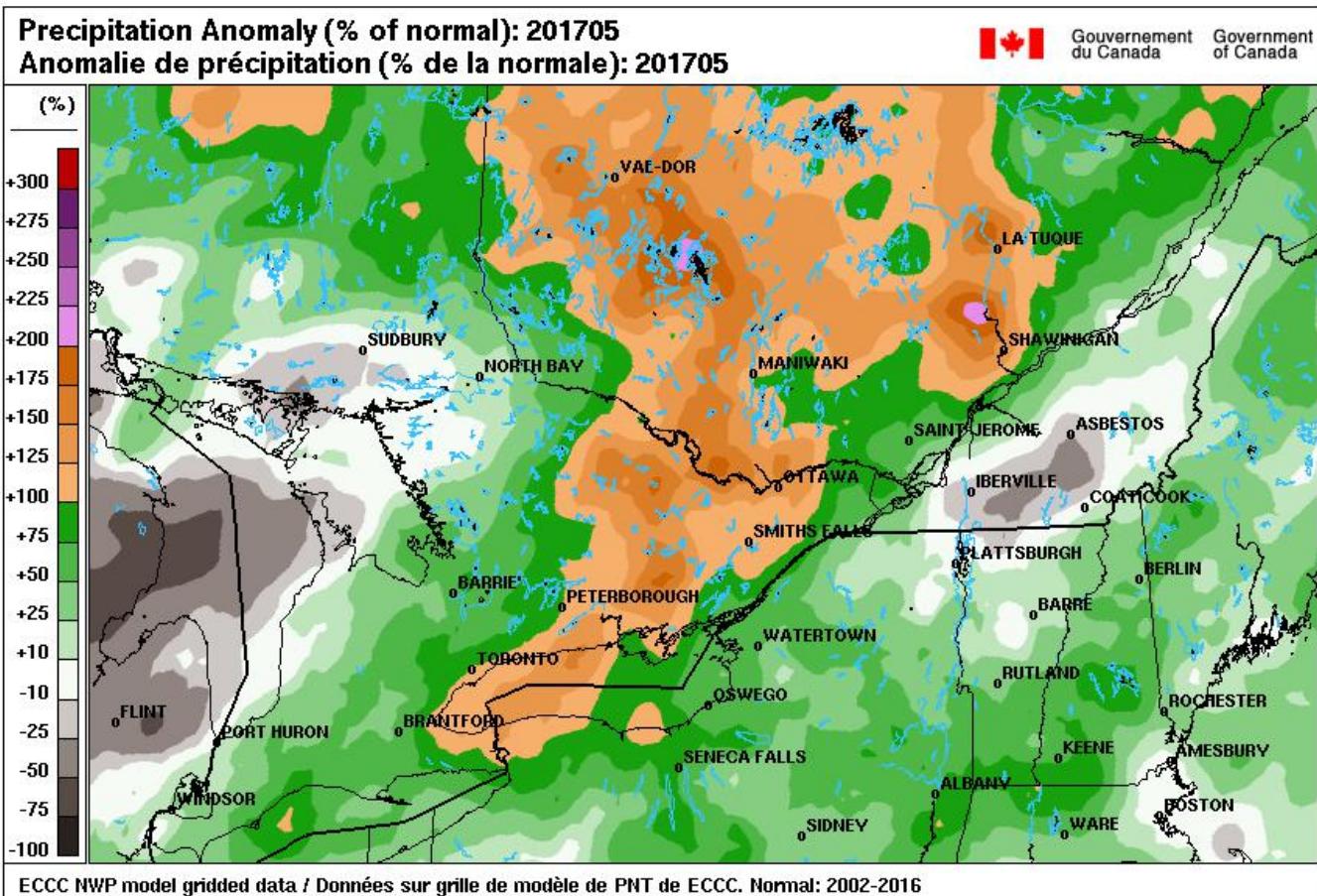
were temporarily, but frequently, interrupted and flows were reduced following the multiple heavy rain events that caused Ottawa River flows and Lake St. Louis levels to rise even more rapidly. This was done in accordance with the Plan 2014 F-limit rule. Furthermore, as conditions subsided downstream, outflows were increased again in response to the rising levels upstream, and this process was repeated throughout the month.

While levels of Lake Ontario eventually exceeded criterion H14 at the end of April, by that time Plan 2014 was already setting outflows in response to the exceptional conditions and severe impacts that had been steadily increasing throughout the month. The Board consensus was that the best way to continue to balance the effects of water levels upstream and downstream, and minimize flood and erosion impacts to the extent possible throughout the system, was to continue to follow Plan 2014's F-limit rules. In fact, during the month of April even prior to exceeding the criterion H14 levels, the extreme weather conditions and the regulation plan's built-in response to the extreme weather conditions meant the Board had very little discretion or ability to take additional measures to alleviate the flooding conditions upstream or downstream. When criterion H14 was eventually exceeded and the Board did have authority to undertake major deviations, the Board had even less discretion because conditions were critical both upstream and downstream. Essentially, the Board was releasing water from a flooding Lake Ontario into a flooded St. Lawrence River.



**Figure 5.8**

April and May 2017 precipitation totals (daily at top, cumulative at bottom) recorded at locations around the Lake Ontario – St. Lawrence During most of April and May, outflows were set according to Plan 2014's multi-tiered F-limit rule, which attempts to balance high water levels on Lake Ontario (left) with those on Lake St. Louis (right).



**Figure 5.9**

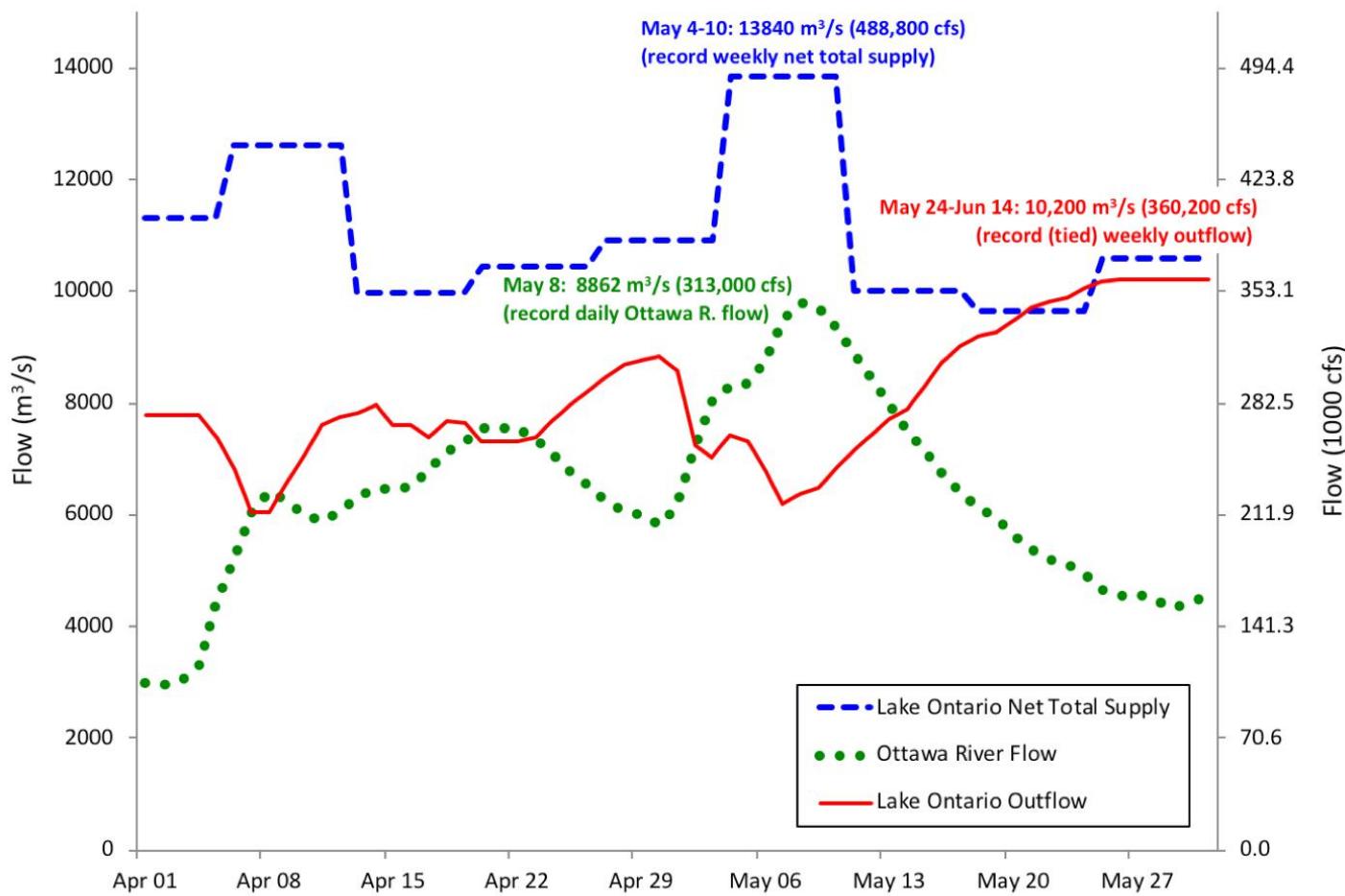
Precipitation anomalies for April (top) and May (bottom) 2017 measured as a percentage departure from normal precipitation amounts for these months. Green areas depict a 10 to 100 percent departure from normal, orange areas depict a 100 to 200 percent departure from normal. Source: ECCC.

As April ended and conditions remained critical, the wet weather only worsened in May (Figure 5.9). The month began with a so-called “perfect storm”. Two extremely large and slow moving storm systems passed through the region on April 30 through May 2 and from May 4 through 8. These storms combined produced at least 75 mm (3 in.) of rain over most of the Lake Ontario, Ottawa River and St. Lawrence River basins, while some areas around Lake Ontario received twice that amount. Heavy rain also fell upstream of Lake Ontario on Lake Erie, where water levels were also rising and inflows to Lake Ontario increased to well above average values.

As a result of the very wet weather, during the first week of May water flowed into Lake Ontario at record rates so exceptional that they were in fact about 25 percent higher than any release the Board can physically discharge through the St. Lawrence River. Furthermore, had it been physically possible to release this amount of water from Lake Ontario during this period, the increase outflow would have had much more severe impacts on areas of the lower St. Lawrence River which were already flooded.

At the same time inflows to Lake Ontario were rapidly increasing, the Ottawa River flow into the St. Lawrence River was as well (Figure 5.10). During the first week of May, the Ottawa River flow (at Carillon Dam) peaked for a second time during the spring, higher than the first peak in April which had already initiated major flooding (Figure 5.7). The daily flow in the Ottawa River of 8,862 m<sup>3</sup>/s (313,000 cfs) on May 8 was a new record and resulted in significant flooding in many parts of the Ottawa River basin and Lake of Two Mountains in the Montreal area where the Ottawa River empties into the St. Lawrence River. Combined with the outflow from Lake Ontario, the record Ottawa River flows caused flooding around Lake St. Louis, Montreal Harbour, and in many areas of the St. Lawrence River further downstream, including Lake St. Peter. The high levels and flooding downstream occurred despite the fact that outflows from Lake Ontario were reduced quickly and significantly over the first week of May to moderate the sharp rise in St. Lawrence River levels near Montreal. As outflows were reduced and inflows to Lake Ontario and the St. Lawrence River increased significantly, this caused Lake Ontario to rise rapidly towards its record peak that occurred later in May.

### Lake Ontario - St. Lawrence River: Inflows and Outflows, Apr-May 2017



**Figure 5.10**

During April and May 2017, as total inflows to Lake Ontario (blue dashed) and Ottawa River flows (green dotted) into the St. Lawrence River both increased during each precipitation event, outflows from Lake Ontario (red solid) were temporarily reduced to maintain Lake St. Louis levels according to the Plan 2014 F-limit. Following each storm event, Lake Ontario outflows were again increased as the Ottawa River subsided.

Following the second-wettest April in terms of total inflows, the total inflow to Lake Ontario was the highest recorded during the month of May since 1900. In fact, April and May were the fourth and second highest, respectively, of any months recorded since 1900 (Table 5.1). Taken together, April and May were the highest two month total inflow on record. This was due to the combination of both well-above-average inflows from Lake Erie (the 11th highest April/May total since 1900), as well as unprecedented amounts of precipitation recorded across the basin (Figure 5.10). According to precipitation data from Environment and

Climate Change Canada's (ECCC) Historical Climate Data archives and from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) in the US, the total precipitation recorded during April and May 2017 combined set a record for this two-month period at Toronto, Ontario (where records start in 1938) and at Ottawa, Ontario (where records start in 1890), was the second wettest ever at Watertown, New York (records starting in 1893), and third wettest on record for both Rochester, New York (starting in 1940) and Montreal, Quebec (starting in 1942).

**TABLE 5.1**

Highest monthly total inflows (net total supply) to Lake Ontario since 1900.

RANK	YEAR	MONTH	TOTAL INFLOW (M3/S) (CFS)	
1	1993	April	11700	413,000
2	2017	May	11040	390,000
3	1976	March	10970	387,000
4	2017	April	10830	382,000
5	1973	April	10800	381,000
6	1973	March	10680	377,000
7	1943	May	10670	377,000
8	1951	April	10630	375,000
9	1974	April	10590	374,000
10	2014	April	10550	373,000

The precipitation records for the five-month period of January through May were even more widespread (Table 4.4). Many locations within the basin received a record amount of precipitation, including the cities of Rochester,

New York, Toronto and Ottawa, Ontario, and Montreal, Quebec. Upstream, in the Lake Erie basin, Buffalo recorded its second highest January to May total since 1938.

**TABLE 5.2**

Total precipitation from January through May broke records at a number of locations around Lake Ontario and the St. Lawrence River.

LOCATION (STATION NAME)	STATION ID(S)	PERIOD OF RECORD	JANUARY - MAY TOTAL PRECIPITATION			
			2017 TOTAL	HISTORICAL RANK	PREVIOUS RECORD	YEAR
Buffalo (Buf. Niagara Intl)	USW00014733	1938-2017	565.7 mm (22.27 in)	2nd	595.1 mm (23.43 in)	2011
Rochester (Roc. Greater Intl)	USW00014768	1926-2017	507.5 mm (19.98 in)	1st (RECORD)	450.6 mm (17.74 in)	1950
Toronto (Toronto Intl A)	6158733	1938-2013	448.6 mm	1st (RECORD)	447.9 mm (17.63 in)	1942
	6158731	2013-2017	(17.66 in)			
Ottawa (Ottawa CDA)	6105976	1890-2017	546.9 mm (21.53 in)	1st (RECORD)	526.3 mm (20.72 in)	1916
Montreal (Montreal Intl A)	7025251	1942-2017	577.8 mm (22.75 in)	1st (RECORD)	529.1 mm (20.83 in)	2006

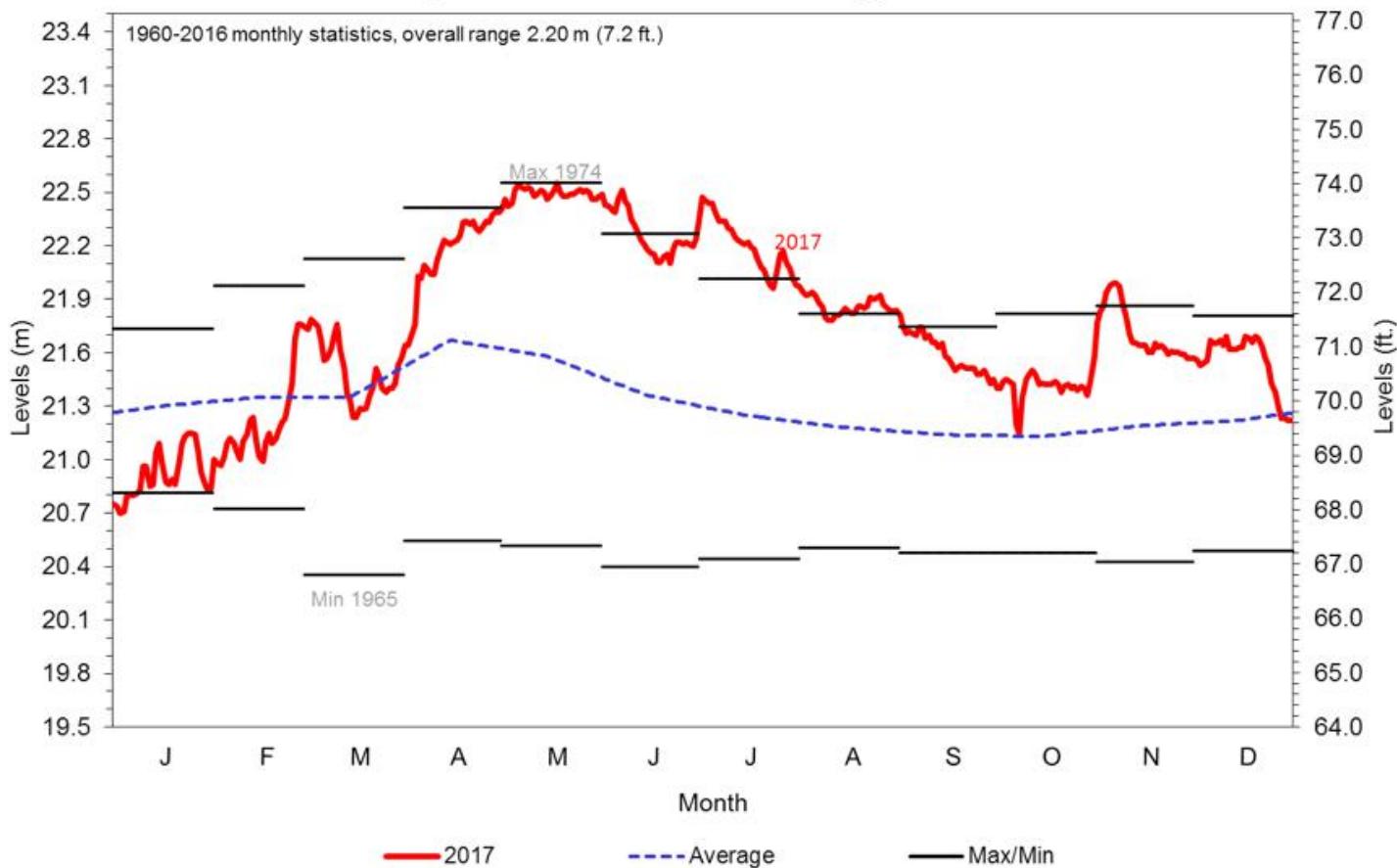
As Ottawa River flows subsided, the Lake Ontario outflow was increased from 6,200 m<sup>3</sup>/s (219,000 cfs) on May 7 to 10,200 m<sup>3</sup>/s (360,200 cfs) on May 24. In doing so, the Board continued to balance upstream and downstream levels according to the Plan 2014 “F-limit” rules. Beginning on May 24 the flow of 10,200 m<sup>3</sup>/s (360,200 cfs) exceeded the Plan 2014 flow and the Board initiated major deviations in accordance with criterion H14 to provide all possible relief to riparian areas upstream of the dam.

The flow of 10,200 m<sup>3</sup>/s (360,200 cfs) matched the record maximum weekly mean flow released by the Board in 1993 and 1998, when at the time the Board was operating under Plan 1958-D but deviating and releasing more than the plan-prescribed flow. The flow of 10,200 m<sup>3</sup>/s (360,200 cfs) was also equivalent to the maximum “L-limit” value during the navigation season (another rule within Plan 2014, see section 4.0). This limit defines the maximum outflow that can be released from Lake Ontario while still maintaining adequate levels and safe conditions for navigation in the International Section of the St. Lawrence River. This maximum flow limit varies according to water levels of Lake Ontario; when levels are high, as they were at the end of May, outflows can also be very high while still permitting safe navigation. The Plan 2014 L-limit defines the flow of

10,200 m<sup>3</sup>/s (360,200 cfs) as the maximum that can be released for a level of Lake Ontario from above 75.70 m to 76.00 m (248.36 ft to 249.34 ft). This high flow required the St. Lawrence Seaway Corporations to begin imposing several mitigation measures, including a notice advising mariners of critical areas for high flows (Galop Island, Toussaint Island, Ogden Island, Copeland Cut and Polly’s Gut) and no meet zones (American Narrows, Brockville Narrows and Wiley Dondero Canal).

Inflows to Lake Ontario throughout May remained well above normal seasonal values. Lake Ontario continued to rise throughout the month, and after starting the year slightly below average, it eventually peaked near the end of May at 75.88 m (248.95 ft), more than 80 cm (30 in.) above the seasonal average, setting a new record daily mean level (1918 to present). Downstream, after a rapid rise toward record values throughout the first third of May, St. Lawrence River levels around Lake St. Louis and Montreal generally declined slowly thereafter (Figure 5.11) as Ottawa River outflows decreased at a faster rate than Lake Ontario outflows were increased. In total, Lake Ontario outflows were adjusted 25 times in May as the Board constantly monitored conditions and adjusted outflows in response (see Appendix B).

## Daily Lake St. Louis Levels @ Pointe-Claire



**Figure 5.11**

Daily Lake St. Louis water levels in 2017 (red line) compared to the 1960-2016 long-term average (blue dashed line) and the monthly minimum and maximum levels (dark grey bars).

## 5.4 HEAVY RAINFALLS AND RECORD OUTFLOWS CONTINUE (JUNE, JULY, AND AUGUST)

By June 2, as Ottawa River flows had decreased and despite record high releases from Lake Ontario continuing, water levels on Lake St. Louis had started to decline. To provide further relief to shoreline areas around Lake Ontario, the Board discussed the potential for further increases in outflows as well as the effects such increases would have on all interests, including the additional rate of lowering that could be achieved on Lake Ontario, and the adverse impacts of increased flows on commercial navigation and recreational boaters in the St. Lawrence River.

The Board reached consensus to initiate additional major deviations from Plan 2014 flows by increasing the Lake Ontario outflow to 10,400 m<sup>3</sup>/s (367,300 cfs) on June 14. This was a new record maximum weekly flow, the highest ever released from Lake Ontario on a sustained basis, including both prior to regulation (1900-1959) and since regulation began in 1960 (Figure 5.12).

The 10,400 m<sup>3</sup>/s (367,300 cfs) outflows increased velocities and cross-currents in the St. Lawrence River and presented additional challenges to navigation in the St. Lawrence River. The St. Lawrence Seaway Corporations imposed additional mitigation measures including a revision to no-meet zones, tightened transit requirements, and the availability of a tug for assistance in the approach to the Iroquois Lock. The Seaway Corporations also undertook an assessment of this higher outflow for several days, consulting with mariners and technical experts, before concluding that it was safe to continue operations under the higher flows, but that 10,400 m<sup>3</sup>/s (367,300 cfs) would be the absolute maximum flow possible that would still maintain adequate levels and safe velocities for navigation to continue in the St. Lawrence River.

In response to the ongoing extreme and unprecedented conditions on Lake Ontario at the time, the Board considered other potential outflow strategies, including more extreme measures than the record release of 10,400 m<sup>3</sup>/s (367,300 cfs). Again, consideration was given to the effects that such flows would have on further lowering Lake Ontario levels, as well as the impacts that this would have on multiple interests throughout the system.

The strategies considered included potentially increasing outflows to as high as 11,500 m<sup>3</sup>/s (406,100 cfs). This extremely high flow has never occurred historically, but was identified during the development of Plan 2014 as the theoretical maximum flow (during the non-navigation season) that could be physically released given the current configuration of the St. Lawrence River. The Board considered that this flow would have increased the rate of lowering of Lake Ontario by approximately 10 percent over what was achieved at a flow of 10,400 m<sup>3</sup>/s (367,300 cfs), equivalent to an additional 3.4 cm (1.3 in.) per week lowering

at most if sustained, a significant amount for many Lake Ontario shoreline residents.

However, the Board also considered the adverse effects that higher flows would have had on other interests throughout the system. This included sustaining the high levels and flooding impacts in the lower St. Lawrence River from Montreal to Lake St. Peter for a longer period, while similar high levels and impacts on Lake Ontario were starting to slowly decline. The Board also noted that the flow of 10,400 m<sup>3</sup>/s (367,300 cfs) already exceeded the total capacity of both the Beauharnois and Moses-Saunders generating stations, requiring the excess water to be spilled at the adjacent Coteau and Long Sault Dams, respectively. Any additional increases in flow would have increased the spilled water, which would reduce the operating head and amount of hydropower generated at both stations, and in the case of Coteau, it could have potentially flooded properties along the St. Lawrence River immediately downstream. Furthermore, a flow of this magnitude might have been physically unsustainable given the significant decline in water levels that would have occurred upstream of Moses-Saunders on Lake St. Lawrence, and this may have resulted in a hydraulic control or restriction, preventing a discharge of this magnitude. The low levels on Lake St. Lawrence also would have potentially impacted recreational boaters and domestic water intakes in this area.

The Board also considered temporary increases in flow and interruptions to commercial navigation, such as those that occurred in 1993 (Figure 5.12). Such a strategy would have increased the rate of lowering of Lake Ontario by less than the 3.4 cm (1.3 in) per week that would have been achieved by increasing and sustaining flows at a rate of 11,500 m<sup>3</sup>/s (406,100 cfs), yet it would have had similar impacts as those outlined above. The 1993 flow increases that resulted in interruptions of Seaway operations that year were a short-term, experimental measure and removed just over an inch of water from Lake Ontario, whereas in 2017, Lake Ontario outflows were comparable to, or higher than, those released in 1993 on a weekly basis and were sustained over an extended period. These record releases in 2017 resulted in a faster lowering of Lake Ontario than that which was achieved in 1993 and with fewer impacts on other stakeholders in the system.

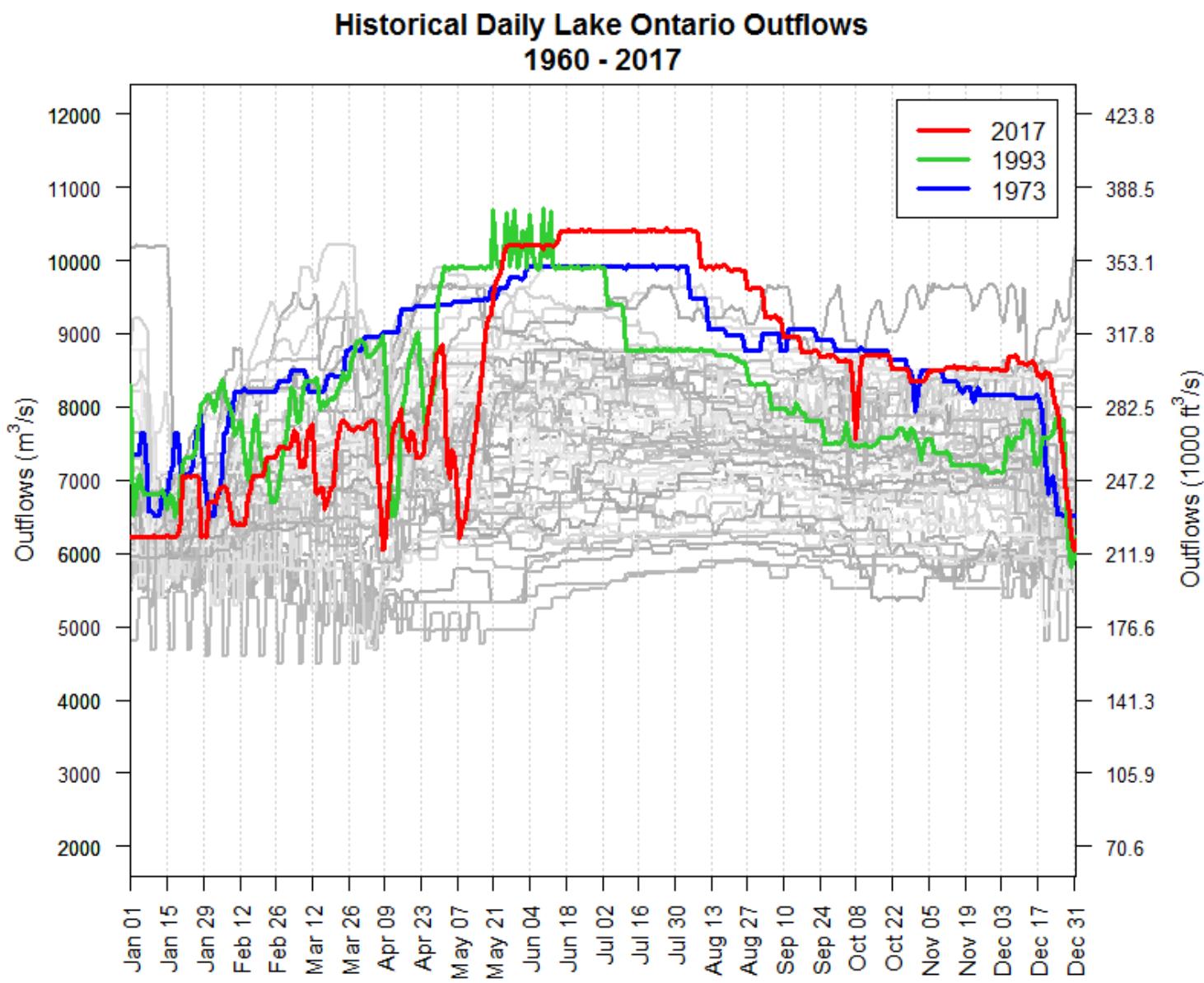
In consideration of lowering the level of Lake Ontario as quickly as possible while also maintaining safe navigation conditions and limiting other impacts in the St. Lawrence River, the Board maintained the outflow of 10,400 m<sup>3</sup>/s (367,300 cfs) through the remainder of June, July and into August (outflows during the period that major deviations occurred are highlighted by the dashed orange rectangle

in Figure 5.5). The monthly mean outflow from Lake Ontario in June averaged 10,310 m<sup>3</sup>/s (364,100 cfs), 38 percent above the June long-term average (1900-2016) and a new record high value for any month, exceeding the previous record monthly mean of 10,010 m<sup>3</sup>/s (353,500 cfs) set in May and June of 1993.

However, wet weather continued in June and, despite the record-high outflows, the Lake Ontario level remained above historical record highs for most of the month. A particularly noteworthy storm on June 22 and 23 (Figure 5.13) resulted in approximately 25 to 60 mm (1 to 2.4 in.) falling over a large area of Lake Ontario itself and the northern parts of the basin, and after gradually declining for most of the month,

Lake Ontario levels rose slightly as a result. The total inflow to Lake Ontario during the month was the second highest recorded in June since 1900.

As a result, June's monthly mean Lake Ontario level of 75.81 m (248.72 ft) was even higher than May's monthly level of 75.80 m (248.69 ft), setting a new record for any month previously recorded (1918 to present). Nonetheless, the record high outflows contributed to Lake Ontario levels falling from 75.87 m (248.92 ft) at the start of June to 75.78 m (248.62 ft) by the end of the month, a decline of 9 cm (3.5 in.) overall, which is the 11th highest June decline on record and, much more than the average June decline of 1 cm (0.4 in.). The end-of-June level was 10 cm (3.9 in) below the peak



**Figure 5.12**

Lake Ontario daily outflows since regulation began in 1960. Each line represents a calendar year, the high water years of 2017 (red), 1993 (green) and 1973 (blue) are highlighted for comparison. Outflows in 2017 generally increased during the first five months of the year, but were frequently reduced due to highly variable ice conditions (Jan-Mar) and extremely wet spring weather and record Ottawa River flows (Apr-May). Starting at the end of May, outflows were comparable or higher than the previous record outflows set in 1993 on a weekly basis and were sustained over a longer period.

level last recorded on May 29, and about 6.6 cm (2.6 in) of this decline was a direct result of the major deviations of Plan 2014 that had been undertaken since May 23. The remainder was due to high outflows prescribed by Plan 2014 itself and the fact that inflows, while still high, had begun to decline.

With levels declining, but still extremely high, the Board agreed to continue to release 10,400 m<sup>3</sup>/s (367,300 cfs) into July. Despite these efforts, continued wet conditions sustained the high levels and severe impacts to Lake Ontario and St. Lawrence River property owners, recreational boaters, businesses, and tourism. Lake Erie remained well above average as well, and combined with significant rainfall, the total inflow to Lake Ontario remained high.

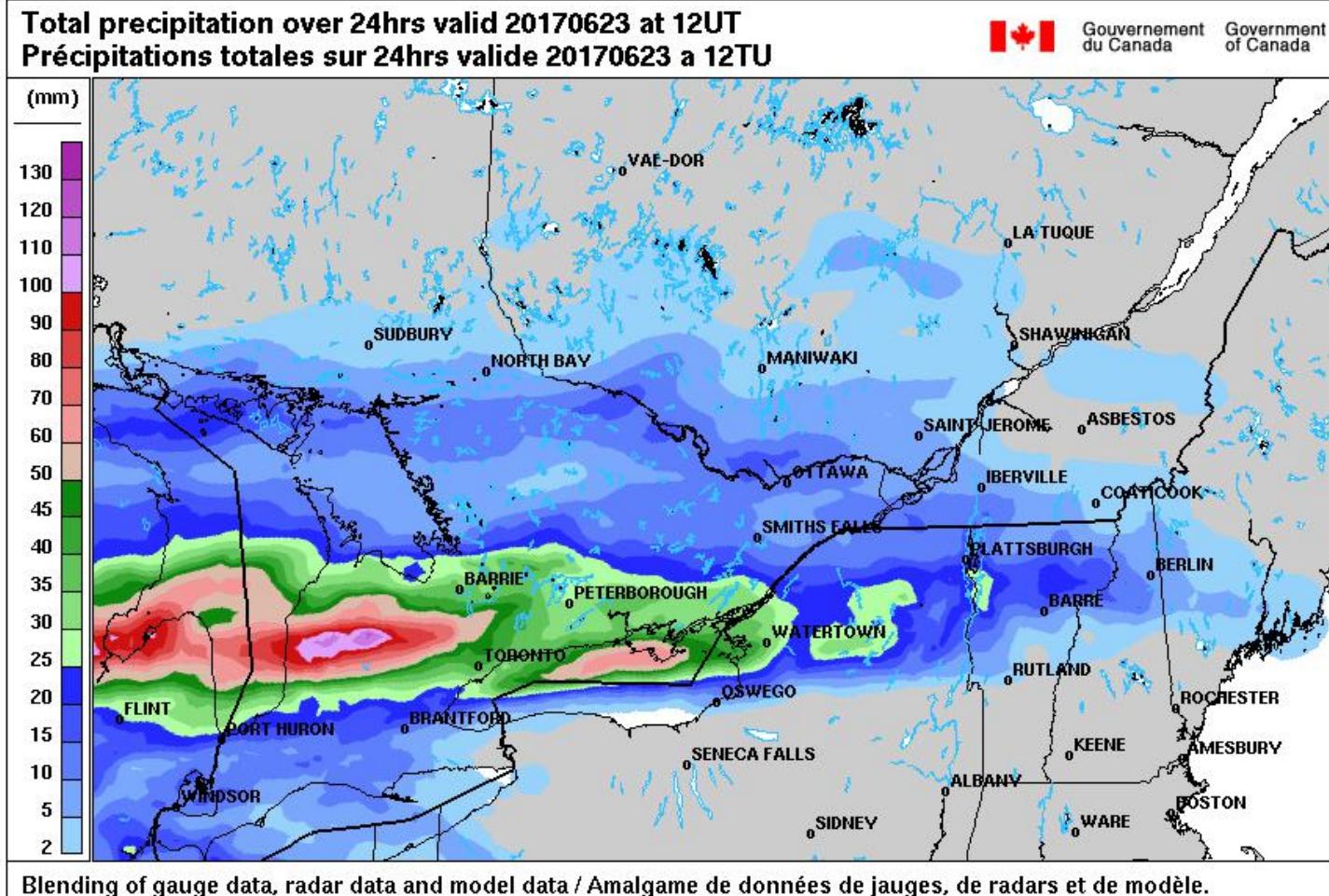
Montreal area levels, which had generally been declining since May as Ottawa River outflows continued to decrease, rose slightly at the end of June, and then rapidly following a major storm on July 1. The Board, while deviating from the rules of Plan 2014, continued to respect the Plan 2014 maximum F-limit during this event, and with Lake Ontario still above 75.60 m (248.03 ft), levels of Lake St. Louis again rose to the highest F-limit tier of 22.48 m (73.75 ft) (Figure 5.11).

Wet conditions continued on Lake Ontario as well through the start of July (Figure 5.14), and like May and June, the monthly mean water level of 75.69 m (248.33 ft) set a new monthly record in July. Drier conditions finally returned to the Lake Ontario basin near the end of July and into August,

and combined with continuing high outflows, Lake Ontario levels began to decline more rapidly during this period. Lake Ontario declined 20 cm (7.87 in.) during the month of July, the 5th highest decline on record for this month (tied with 1978 and 1989). At the start of August, the level of 75.58 m (247.97 ft) remained the highest since regulation began in 1960, but below the record highs recorded at the start of August 1947, prior to regulation.

As Lake Ontario levels declined, velocities and water level gradients in the upper St. Lawrence River gradually increased while the record high outflows of 10,400 m<sup>3</sup>/s (367,300 cfs) continued. Essentially, the same record amount of water was being released, but through a channel that was slowly getting smaller and smaller. Eventually, this high flow could no longer be sustained without impacting commercial navigation operations in various parts of the St. Lawrence River. As a result, starting August 8 the Board agreed to begin gradually reducing outflows according to Plan 2014 L-limit. This strategy continued to prescribe the maximum flow that could be released from Lake Ontario as its level declined, while still maintaining safe conditions for navigation in the St. Lawrence River.

The high outflows and declining inflows resulted in a record decline of Lake Ontario levels of 35 cm (13.8 in.) during the month of August, the largest decline seen in any month previously recorded (1918 to present). Even with the record

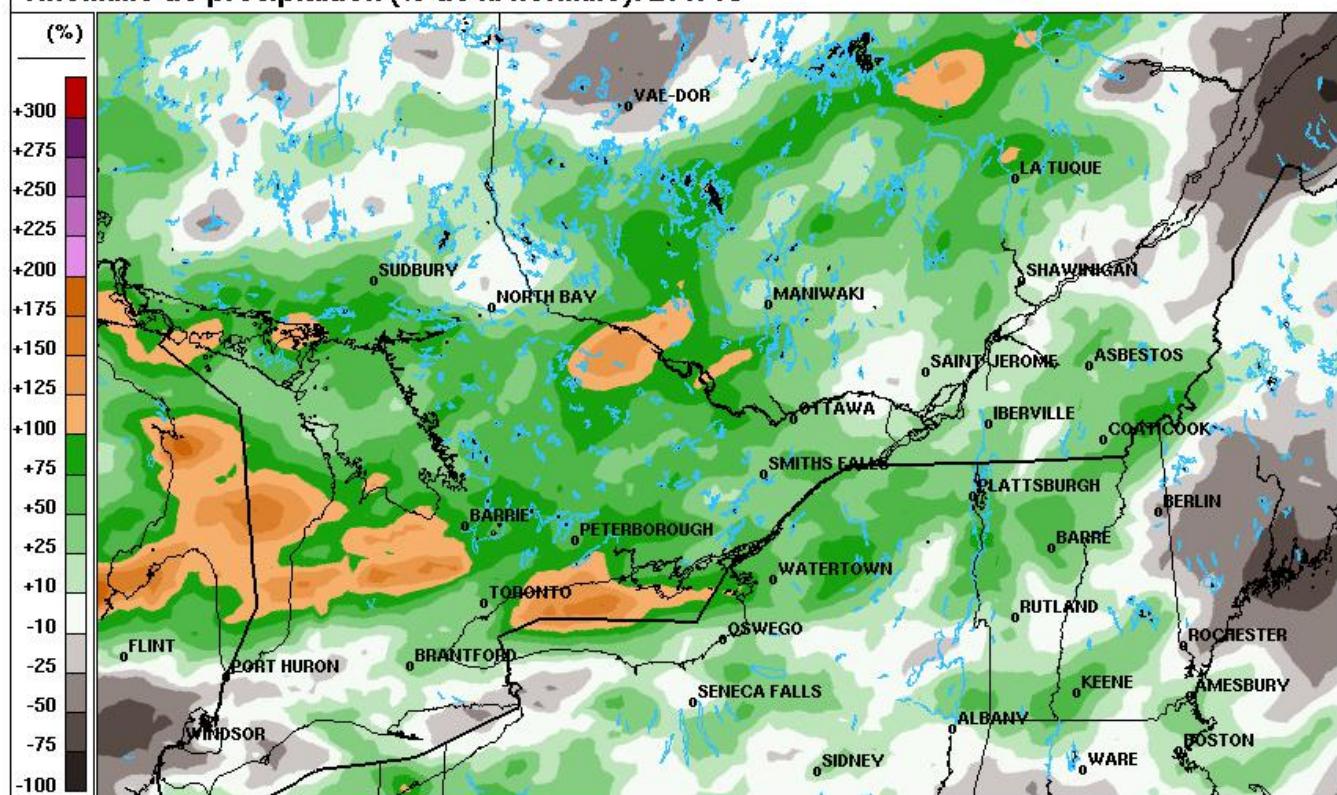


**Figure 5.13**

A total of 25 to 60 mm (1.0 to 2.4 in) of rain fell on Lake Ontario over June 22 and 23.

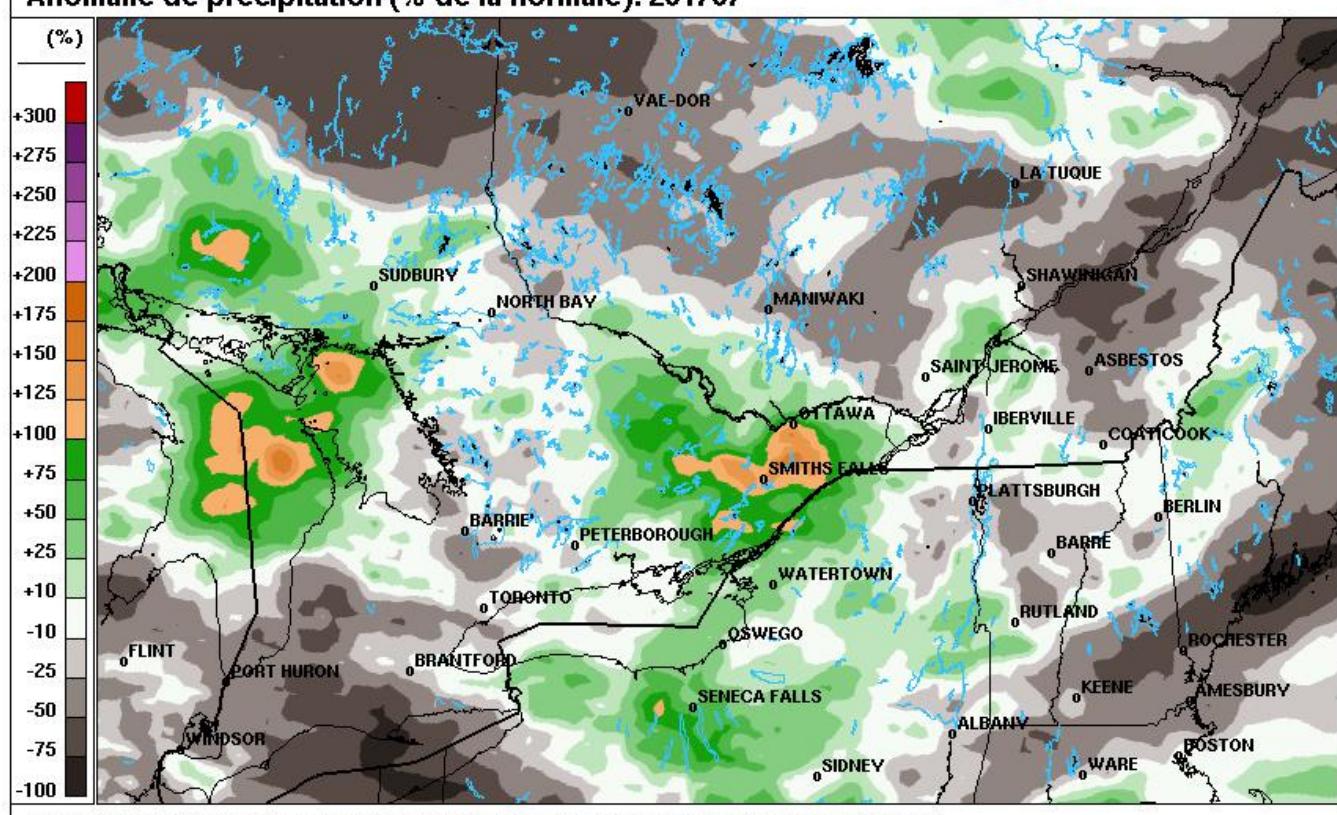
Precipitation Anomaly (% of normal): 201706  
Anomalie de précipitation (% de la normale): 201706

Gouvernement du Canada Government of Canada



Precipitation Anomaly (% of normal): 201707  
Anomalie de précipitation (% de la normale): 201707

Gouvernement du Canada Government of Canada

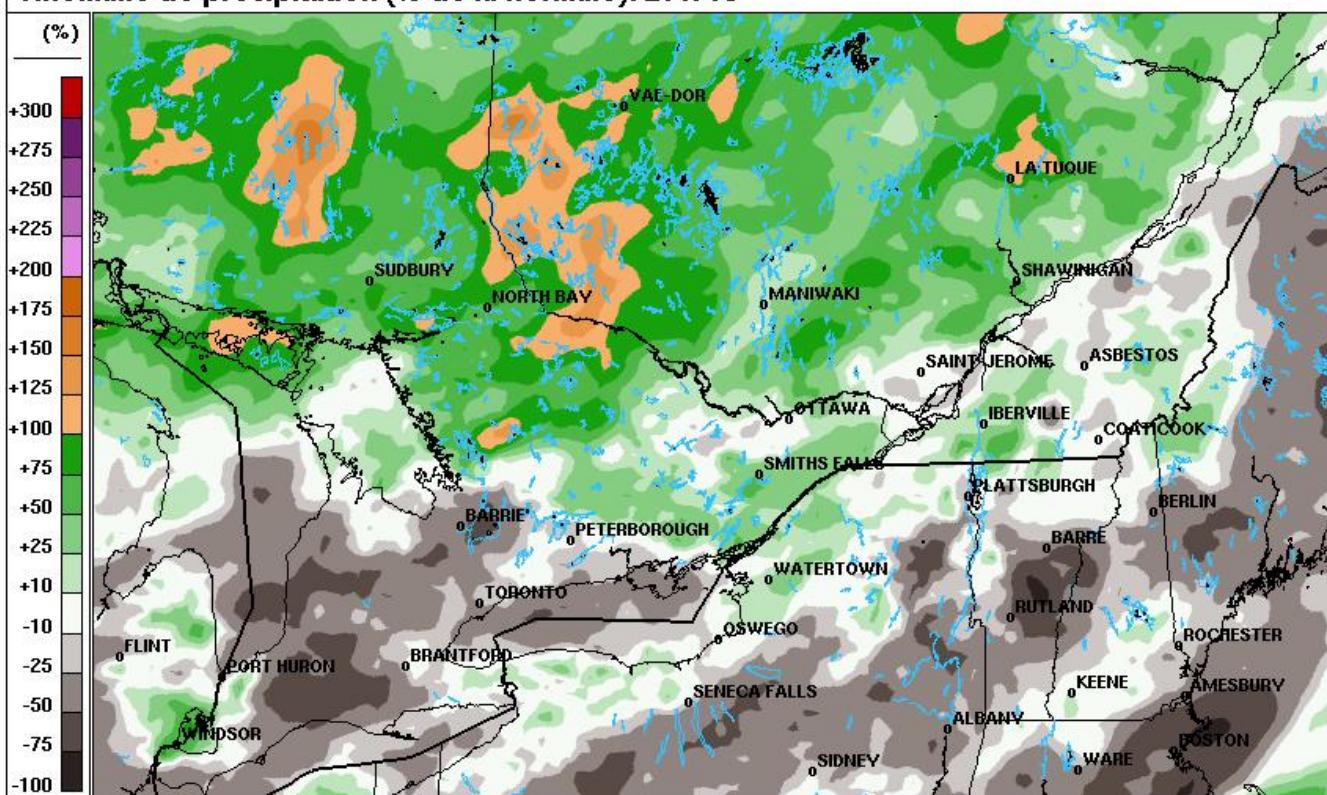


**Figure 5.14**

Precipitation anomalies indicate that wet weather continued in June (top) and into July 2017. Source: ECCC.

Precipitation Anomaly (% of normal): 201708  
Anomalie de précipitation (% de la normale): 201708

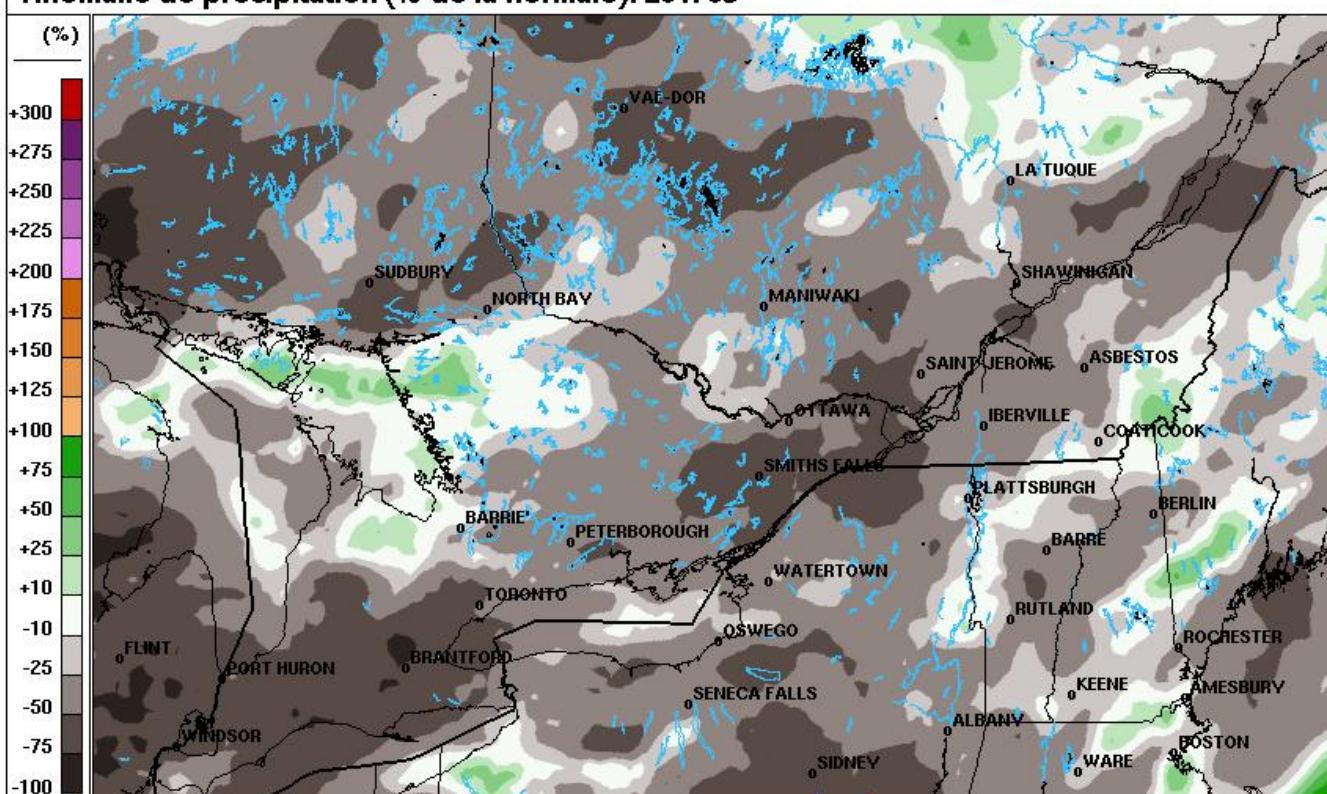
Gouvernement du Canada Government of Canada



ECCC NWP model gridded data / Données sur grille de modèle de PNT de ECCC. Normal: 2002-2016

Precipitation Anomaly (% of normal): 201709  
Anomalie de précipitation (% de la normale): 201709

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ECCC NWP model gridded data / Données sur grille de modèle de PNT de ECCC. Normal: 2002-2016

**Figure 5.15**

Precipitation anomalies indicate that weather conditions were drier in August (top) and September (bottom) 2017. Source: ECCC.

drop, levels remained above criterion H14 threshold levels throughout August, reaching a level of 75.23 m (246.82 ft) by the end of the month, the 6th highest recorded since 1918, and higher than any end of August level since regulation beginning in 1960 (Figure 4.16). By following the maximum L-limit rules during this period, the Board continued to deviate and release outflows above the prescribed Plan 2014 releases. The monthly mean outflow of 9,950 m<sup>3</sup>/s (351,381 cfs) set a new record for the month of August.

## 5.5 RETURN TO PLAN 2014, HIGH FLOWS CONTINUE (SEPTEMBER THROUGH DECEMBER)

During the last week of August, water levels of Lake Ontario finally fell below the criterion H14 high thresholds. In accordance with the Directive on Operational Adjustments, Deviations and Extreme Conditions, the Board reviewed options to manage outflows into the fall, including the potential effects of returning to Plan 2014 flows or continuing major deviations and releasing outflows above those expected to be prescribed by Plan 2014. It was determined that Plan 2014 would prescribe the maximum L-limit outflows (i.e., the maximum that could be released from Lake Ontario while still maintaining safe navigation conditions) through much of the fall under most potential water supply scenarios and unless very dry conditions occurred and Lake Ontario declined rapidly. Based on these findings, the Board recommended to the IJC that outflows return to following Plan 2014 on September 2. The Board also recommended that the 15.4 cm (6.1 in.) of extra water released from Lake Ontario through major deviations during the summer not be restored at a later date. The IJC agreed with both of these recommendations.

Throughout September, outflows were set according to the Plan 2014 maximum L-limit, and as the levels of Lake Ontario continued to decline, outflows were gradually reduced. Outflows nonetheless remained high, and combined with relatively dry conditions this allowed water levels to fall 29 cm (11.4 in) in September, a record decline for the month.

Maximum L-limit flows generally continued to be released in October. The high flows combined with the declining level of Lake Ontario resulted in extremely low levels of Lake St. Lawrence (Figure 5.16). From October 6 at 12:01 pm to October 8 at 1:01 pm, the Board reduced outflows to allow water levels to rise temporarily and facilitate boat haul-out in Lake St. Lawrence and immediately upstream on the St. Lawrence River. The temporary flow reduction, which was a minor deviation made in accordance with the Directive on Operational Adjustments, Deviations and Extreme Conditions, is clearly visible in the early October portion of Figure 5.5. The reduction in outflow amounted to less than a 1 cm (0.4 in.) increase in water levels on Lake Ontario relative to Plan 2014. This small amount of water stored was subsequently removed in the following weeks by releasing outflows slightly higher than the Plan 2014 flows until October 27. The Seaway Corporations were consulted before the Board passed outflows slightly in excess of those specified by the L-limit rules during this period.

The level of Lake Ontario was 75.23 m (246.82 ft) at the start of September, 41 cm (16.1 in) above long-term average for this time of year, but 65 cm (25.6 in.) below the peak level of 75.88 m (248.95 ft) that was last recorded on May 29. Most of the decline in Lake Ontario levels would have occurred with releases prescribed by Plan 2014 during this period; however, major deviations from Plan 2014 while operating under criterion H14 were responsible for 15.4 cm (6.1 in.) of the 65 cm (25.6 in) water level decline.

Coincident with this temporary minor deviation, a significant rainfall event associated with the remnants of Hurricane Nate made its way across both Lake Erie and Lake Ontario on October 8 through 10. The eastern end of Lake Ontario was hardest hit, as Watertown, New York, recorded an exceptional 106 mm (4.16 in.) of rainfall during this event. The heavy rains led to a significant rise in Lake Ontario levels following this storm.

By October 28, the level of Lake Ontario had declined to 74.79 m (245.37 ft). For the week of October 28 to November 3, the Plan 2014 flow was 8360 m<sup>3</sup>/s (295,200 cfs), set according to the adjusted rule curve flow, and slightly lower than the L-limit flow, which would have been 8460 m<sup>3</sup>/s (298,800 cfs) or less depending on levels of Lake St. Lawrence, which were approaching 72.6 m (238.19 ft).

Once again, the slightly reduced flows from October 28 to November 3 coincided with another significant precipitation event October 29 through 31, which once again was most notable in the eastern part of the Lake Ontario basin. During this event, Watertown, New York received more than 130 mm (5 in.) of rain during an approximately 48 hour period as shown in Figure 5.17. Overall, October was a very wet month across the basin, nowhere more so than Watertown, which recorded 312 mm (12.3 in.) of precipitation during the month of October, a new record (1893 to present) and well above the previous October record of 221 mm (8.7 in) set in 2010. Lake Erie levels remained high, total inflows to Lake Ontario in October remained well above average and near record highs, and in fact total inflows were the 7th highest recorded in October since 1900.

In part due to the late October storm, high inflows to Lake Ontario persisted into November. At the start of the month, the Lake Ontario level was 74.82 m (245.47 ft), the 11th highest beginning-of-November level on record since 1918, but below the highest levels recorded since regulation began, including the levels at the same time of year in 1967 and 1986.

While not as wet as October, well above average precipitation was again received across most of the basin in November, and combined with continuing high inflows from Lake Erie and local tributaries, net total water supplies to Lake Ontario in November were again well above average and the third highest on record. Levels of Lake Ontario rose 2 cm (0.8 in.) as a result, and despite the fact outflows from Lake Ontario (which after the storm and rise in water levels during the week ending November 3, resumed being set

according to the Plan 2014 maximum L-limit) were also well above average, in fact, the second highest monthly mean November outflow recorded since 1900.

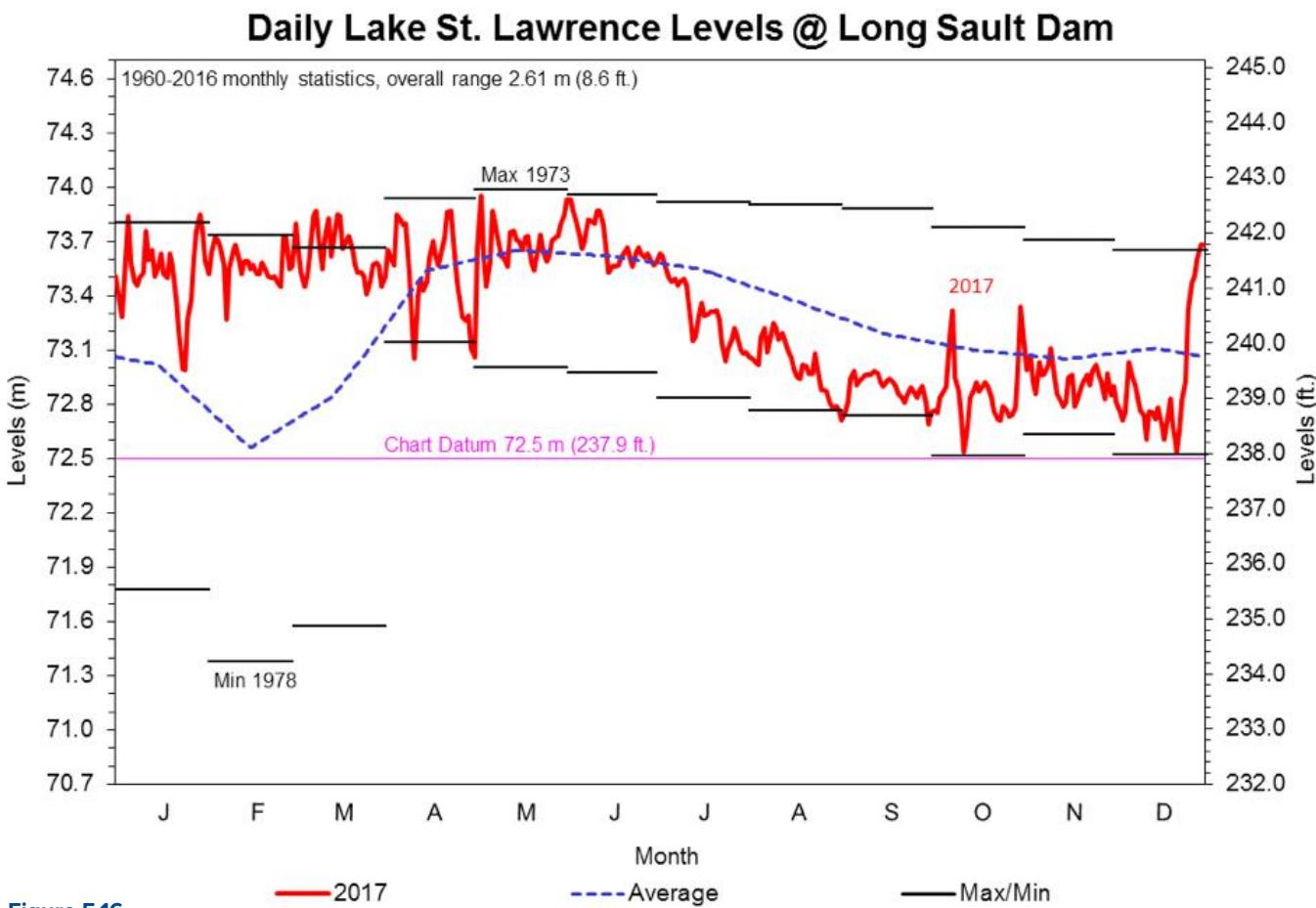
Beginning December 5, the Board agreed to increase outflows by up to 200 m<sup>3</sup>/s (7,100 cfs) above the maximum L-limit value. The increases were done in accordance with the intent of Plan 2014 and specifically the rule that attempts to lower the continued high levels of Lake Ontario and increase the likelihood of reaching 74.80 m (245.41 ft) by January 1, 2018. The increases were also done in consultation with commercial navigation authorities to ensure the increases remained consistent with the intent of Plan 2014's maximum L-limit rule, which prescribes maximum flows to maintain safe conditions for navigation in the St. Lawrence River. The Board notified the IJC and later received approval for the increased flows. The IJC deemed the increased flow to be deviations rather than operational adjustments from Plan 2014 rules. In accordance with "Condition J" of the December 8, 2016 Supplementary Orders of Approval, the increased flow was treated as a temporary, minor modification of the regulated outflow to test potential changes to the L-limit of the regulation plan.

The increased flows were only possible for a short period. By December 12, levels of Lake St. Lawrence dropped to 72.60 m (238.2 ft), a critical low level for ships navigating through this area. The Board returned to Plan 2014 flow at this time, and the temporary flow increases only amounted

to an additional lowering of 0.8 cm (0.3 in.) of the Lake Ontario water level beyond what would have occurred had the Plan 2014 maximum L-Limit been strictly followed. Levels on Lake St. Lawrence fell below the 72.60 m (238.2 ft) threshold again for about two days from December 22 to 23, so the Board temporarily reduced the flow accordingly. An equivalent of 0.3 cm (0.1 in.) of water remained removed from Lake Ontario (beyond strict adherence to Plan 2014) at the end of 2017.

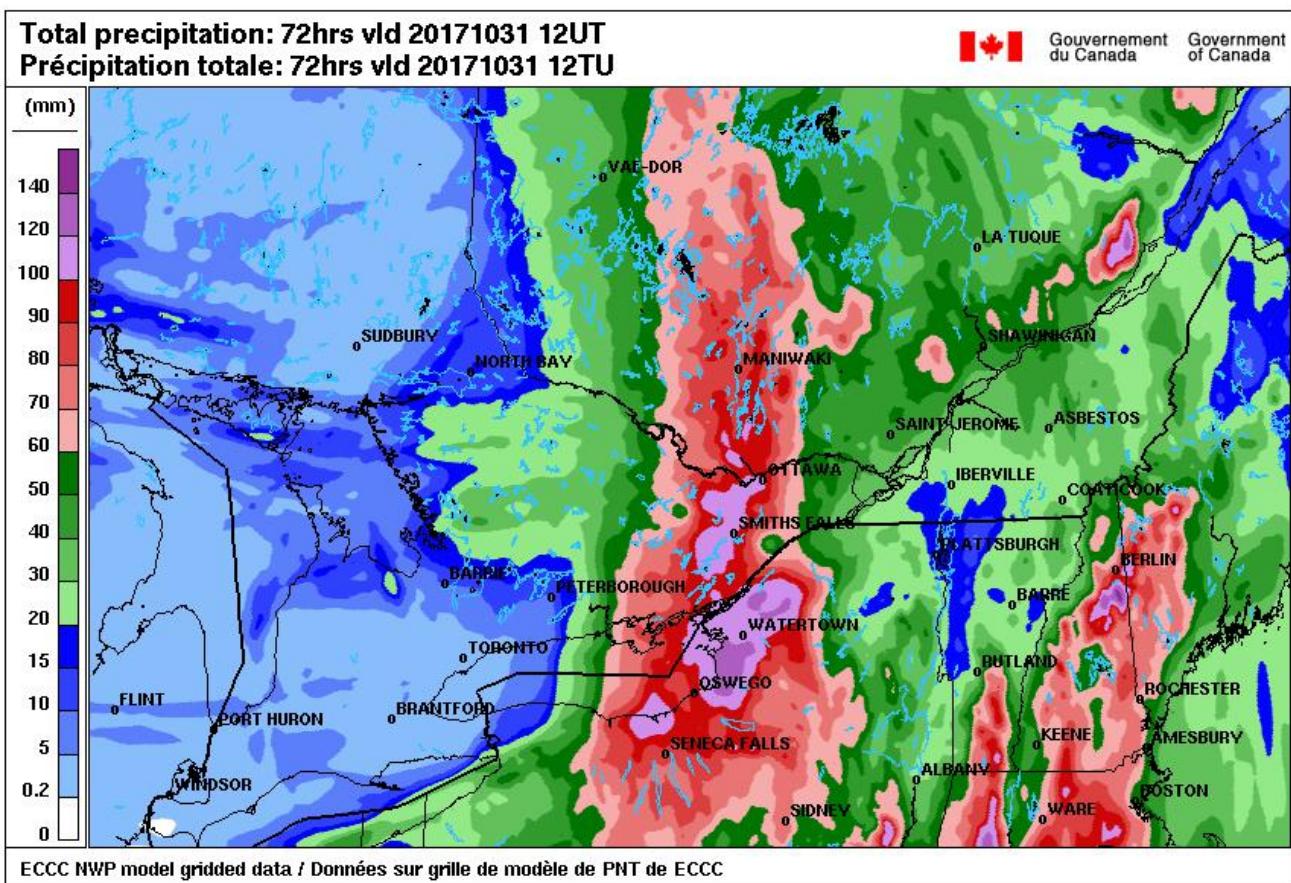
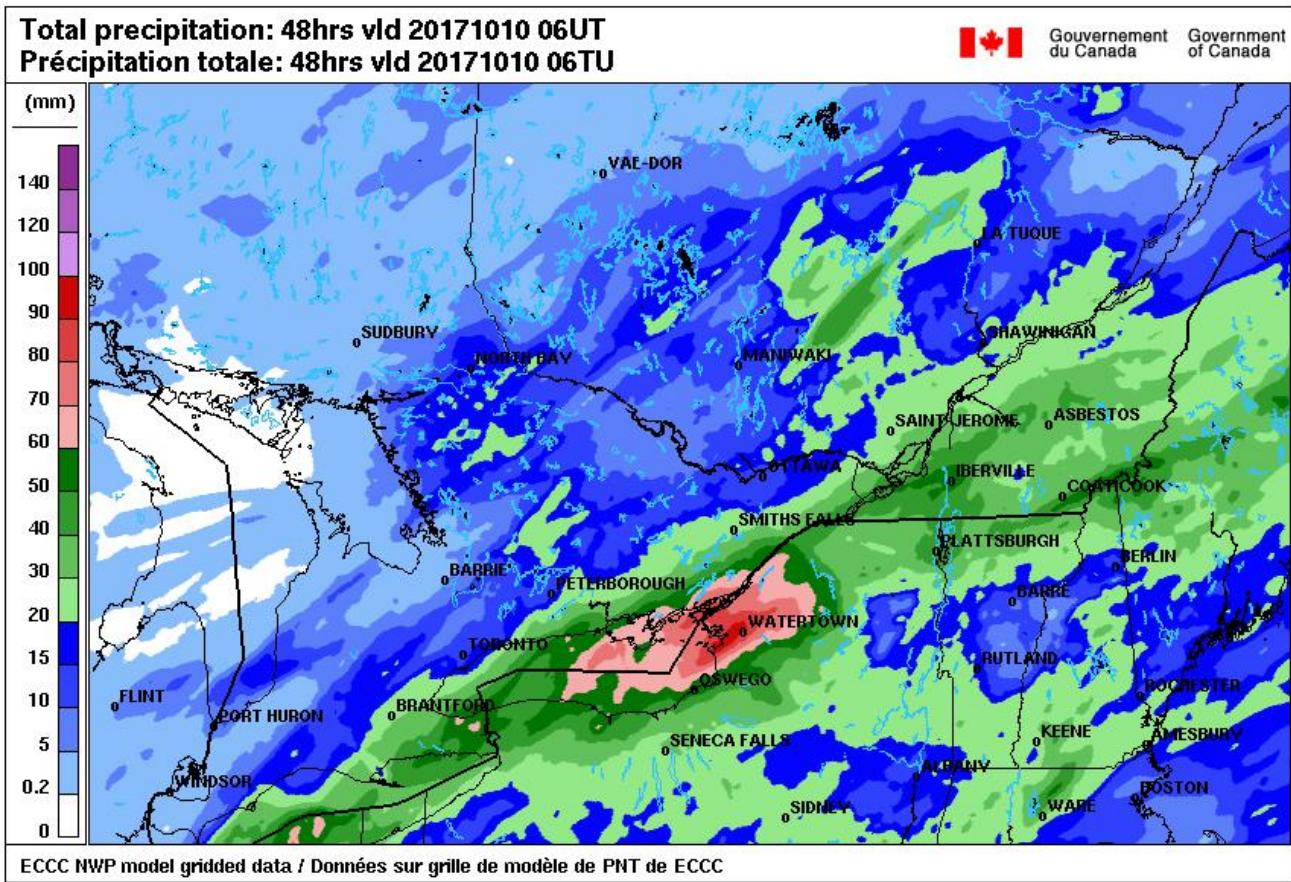
As of December 25, ice had started to form in critical sections of the St. Lawrence River and outflows were subsequently adjusted in accordance with the Plan 2014 L-limit, thus ending the year under the same flow limits as it began. Outflows were much higher at the onset of ice formation in 2017 than occurred at the end of 2016. As a result, the reduction in flows was much more significant than in the previous year: from approximately 8,000 m<sup>3</sup>/s (282,500 cfs) down to approximately 6,000 m<sup>3</sup>/s (211,900 cfs) to support operational ice management requirements.

After starting the year at a level of 74.49 m (244.39 ft) and increasing to a record peak of 75.88 m (248.95 ft) by late-May, Lake Ontario generally declined thereafter and ended 2017 at a level of 74.76 m (245.28 ft), 22 cm (8.7 in.) above average, the 20th highest end-of-December level on record but well below the historical record highs for this time of year (Figure 5.18).



**Figure 5.16**

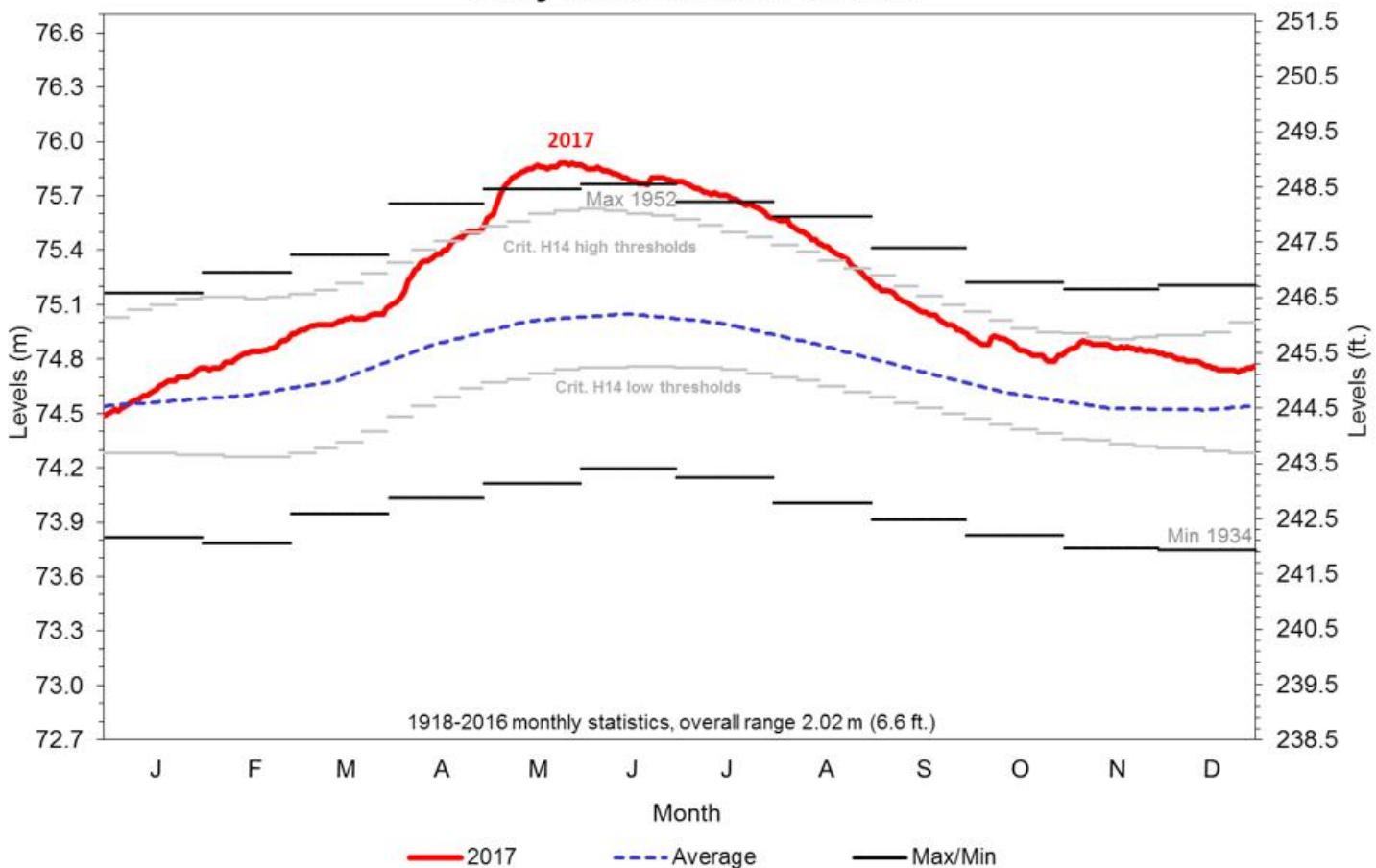
Daily Lake St. Lawrence water levels in 2017 (red line) compared to the 1960-2016 long-term average (blue dashed line) and the monthly minimum and maximum levels (dark grey bars).



**Figure 5.17**

Total precipitation (mm) during two significant storms events in October 2017. On October 9-10, 2017 (top), Lake Ontario received a minimum of 20 mm (0.8 in.) to almost 100 mm (4 in.) near Watertown, NY. Then on October 29-31, 2017 (bottom), the eastern part of the lake received an additional 20 to 130 mm (0.8 to 5 in.) Source: ECCC.

## Daily Lake Ontario Levels



**Figure 5.18**

Daily Lake Ontario water levels in 2017 (red line) compared to the 1918–2016 long-term average (blue dashed line), the monthly minimum and maximum levels (dark grey bars), and the criterion H14 high and low thresholds (light grey dashes).

## 6.0 SUMMARY

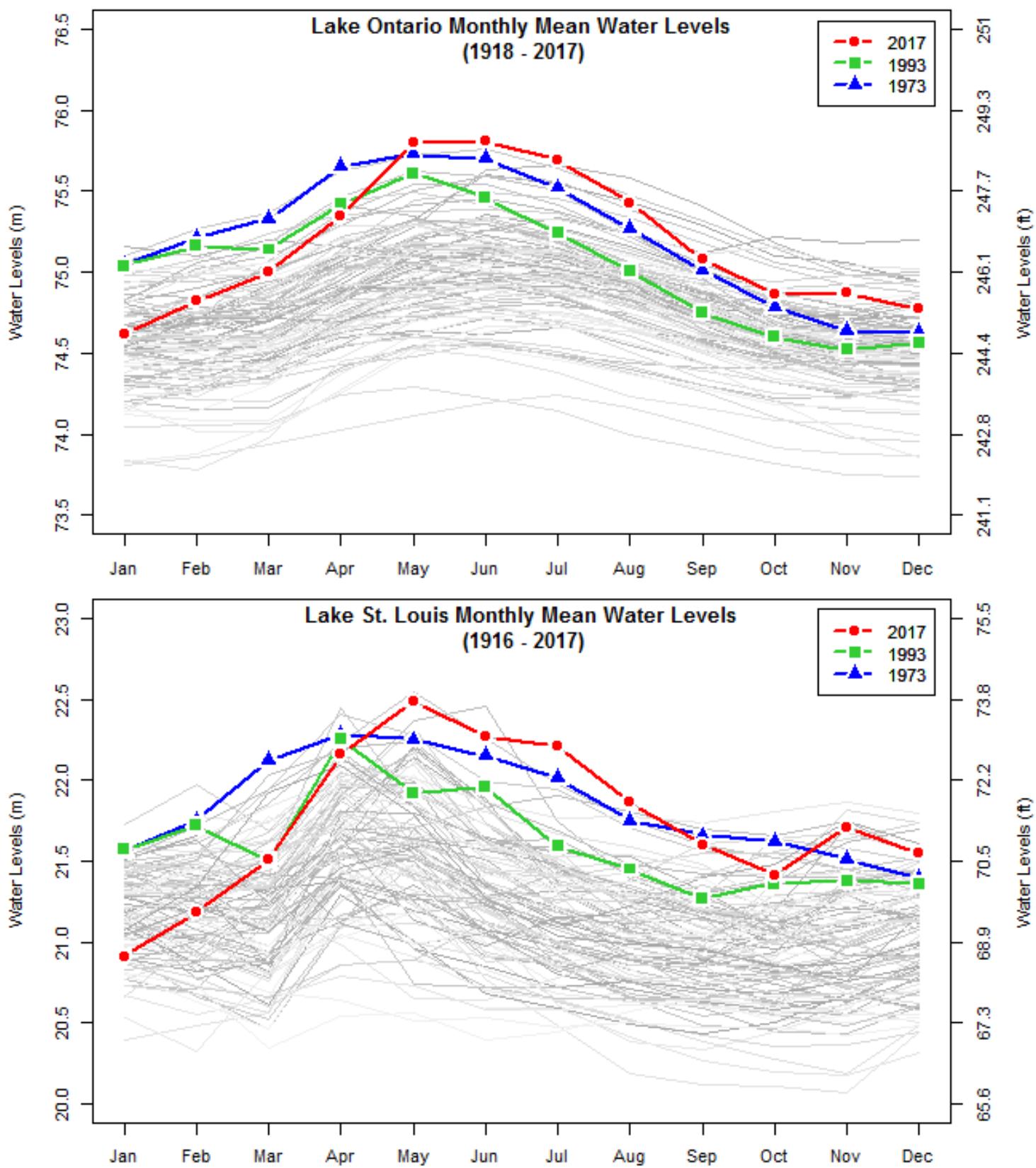
The high water event of 2017 is perhaps the most extraordinary to ever occur in the Lake Ontario – St. Lawrence River system (Figure 6.1). While similar high water conditions and associated impacts have occurred in the past, the events of 2017 were exceptional in a number of ways. Highly variable winter weather and unprecedented ice conditions were followed by an exceptionally wet spring. Extreme and in many cases record rainfall was recorded across widespread areas of the Lake Ontario – St. Lawrence River basin, as well as in the Ottawa River basin and upstream on Lake Erie. The total amount of water entering the system was overwhelming, setting records both at Lake Ontario and in the St. Lawrence River, causing a record rise in water levels leading to record high levels. The wet conditions generally persisted into the summer, and while not as extreme as the first part of 2017, the fall of 2017 was exceptionally wet as well, the net result being that 2017 was one of the wettest calendar years ever recorded in the Lake Ontario – St. Lawrence River system (Figure 6.2).

The unprecedented conditions demanded an equally exceptional response (Figure 6.2). Record outflows were released from Lake Ontario in an attempt to provide relief

to those shoreline communities, home owners, and local businesses that were so severely impacted, both upstream and downstream. These efforts caused Lake Ontario levels to decline at record rates from the summer and through the fall.

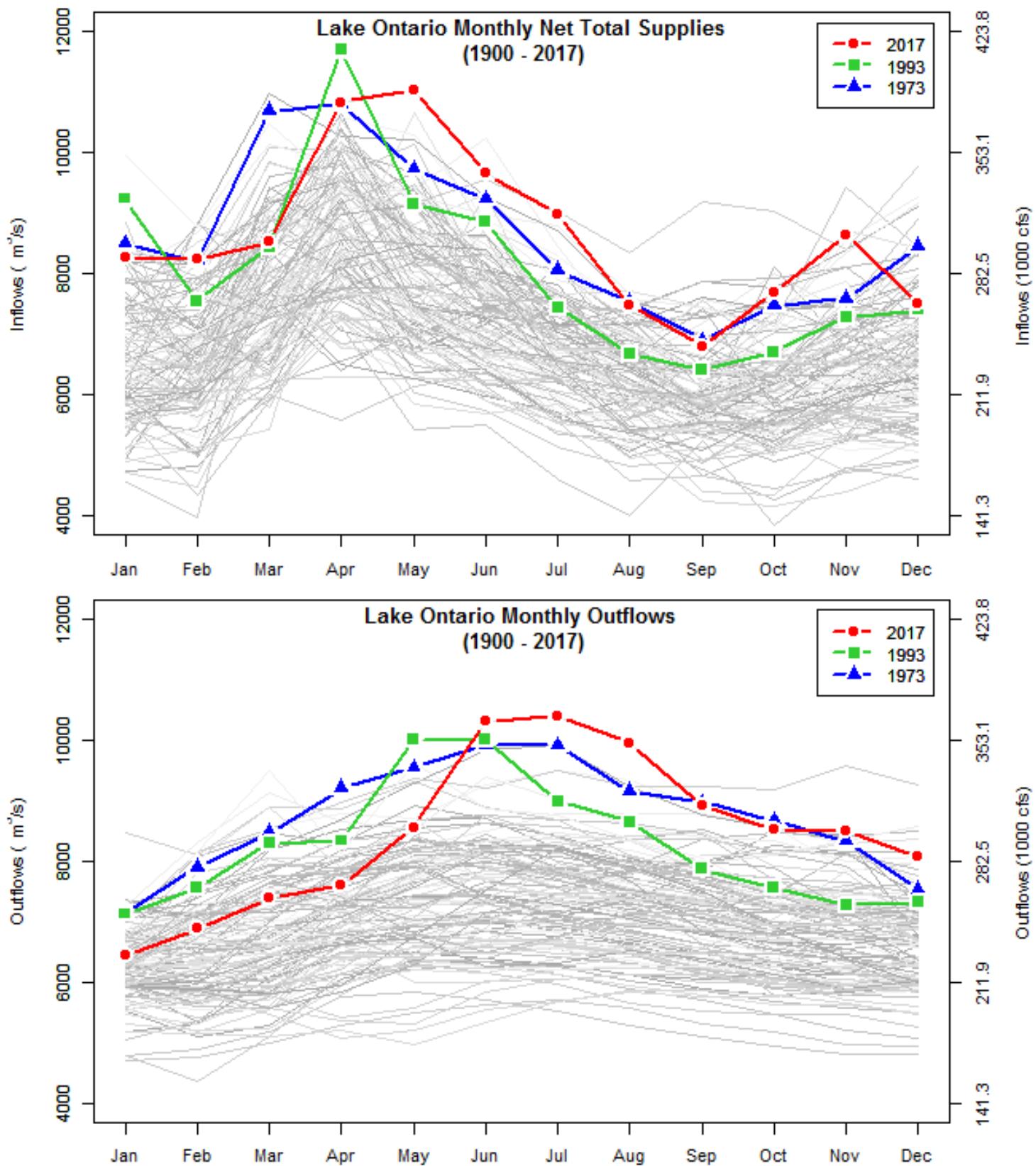
Plan 2014 did not cause the high water levels in 2017, or contribute to them in any significant way. Outflows throughout almost all of 2017 were dictated by rules within Plan 2014 designed to respond to extreme weather and water supply conditions in much the same way that the Board had responded in the past when operating under the old plan, or by Board decisions to deviate from these rules, it is highly likely that the outcome would have also been the same regardless of regulation plan.

In all but three weeks of 2017, actual outflows were determined by either maximum flow limits within Plan 2014 related to ice operations, balancing upstream and downstream flooding, erosion impacts, or maintenance of safe navigation, or they were determined by deviations agreed to and undertaken by the Board. The Board believes that decisions that would have been made by the Board when faced with the same conditions and circumstances



**Figure 6.1**

Lake Ontario (top) and Lake St. Louis (bottom) historical monthly mean water levels. Each line represents a calendar year. 2017 (red circles) is highlighted, along with previous high water years of 1993 (green squares) and 1973 (blue triangles) for comparison.



**Figure 6.2**

Lake Ontario historical monthly mean inflows (top) and outflows (bottom). Each line represents a calendar year. 2017 (red circles) is highlighted, along with previous high water years of 1993 (green squares) and 1973 (blue triangles) for comparison.

under Plan 1958-D with deviations would not have been significantly different. The Board cannot state this unequivocally because Board members were theoretically free under the old Plan to propose decisions that were inconsistent with past practices, but there is no reason to believe the Board would have made such decisions. The rules built into Plan 2014 that define the maximum flows are based primarily on Board operations during similar extreme conditions in the past under Plan 1958-D with deviations. These rules reflect the common practices and lessons learned by the Board over the years, often through deviations. This includes the rules governing flows released during periods of ice formation and flooding, and which were followed throughout most of January through May 2017. Following this, the Board deviated from the regulation plan rules from the end of May through August, releasing record high outflows, higher than have ever occurred under Plan 1958-D or prior to regulation, in an effort to accelerate the rate of lowering of Lake Ontario water levels and provide relief to shoreline interests, while also considering the impacts these actions would also have on multiple interests throughout the Lake Ontario – St. Lawrence River system, including the impacts on commercial navigation in the St. Lawrence River. The Board notes that it would have been faced with these same considerations and requirements when conducting deviations under the old regulation plan, and given this, it is unlikely that the Board would have deviated in some other way. Finally, starting

in September, the Board returned to following Plan 2014 which continued to set outflows at the maximum that could be released while maintaining commercial navigation operations in the St. Lawrence River throughout the fall and until ice formation began in late December. Had outflows been increased further, whether under any regulation plan or through deviations, it would have increased the risk to ships and may have suspended commercial navigation operations in the St. Lawrence River. Again, except for a one week experiment in 1993, this never happened under the previous regulation plan.

In summary, the extreme weather and water supply conditions were the primary factor in causing Lake Ontario water levels to rise a record breaking 1.38 m (~4.5 ft) from the beginning of January to the end of May. While 2017 was an exceptional year, extreme conditions have occurred in the past and are expected to occur again in the future. Though water regulation plans will continue to provide the extent of the relief possible to shoreline property owners; while balancing all other interests in the system, water regulation cannot prevent the occurrence of extreme high or low water levels in the future. With the unpredictability of when extreme weather conditions and water levels may occur again, and the limitations in water regulation to control such events, preventing similar impacts in the future will be a shared goal requiring a collaborative approach.

## 7.0 NEXT STEPS: THE GREAT LAKES – ST. LAWRENCE RIVER ADAPTIVE MANAGEMENT COMMITTEE REPORTS

This report was produced to summarize the extraordinary conditions that occurred in 2017 and the actions taken by the Board in accordance with the rules of Plan 2014. This report does not cover ongoing research on the severe and widespread damages that occurred. The Board's sub-committee, the GLAM Committee is a 16 member binational sub-committee to the IJC's Great Lakes Boards. The Committee was established by the IJC directive to ensure that the Boards, the IJC as well as the governments have the best available data, science and knowledge in a format needed to support decisions about regulation plans over time with the primary goal of assessing whether water level management can be improved. As part of their regular requirements, the GLAM Committee is producing an annual report to support the Committee's essential mission to coordinate the required monitoring, modeling, and assessment related to the ongoing evaluation of the impacts and effectiveness of the regulation plans on the Great Lakes and report that information back to the Great Lakes Boards and the IJC. The GLAM Committee is to undertake specific tasks to review and evaluate the regulation plans over time, focusing on mid-term to long-term assessments and not within-year decisions.

Over the long-term, the GLAM Committee will seek information from other government agencies and stakeholders that will be used to assess regulation plan performance. The GLAM Committee will ensure information on impacts of changing water levels is up-to-date, track

changes in hydrologic conditions that might influence regulation of outflows in the future, and implement a strategy for the long-term evaluation of the existing outflow regulation plans. The GLAM Committee is documenting what has been learned regarding water level impacts as well as some preliminary tests to further examine the effects and the limitations of outflow management under the extreme conditions of 2017. The data and information obtained in 2017 will be used to validate, update and improve the models and tools used to formulate and assess the current regulation plan, and particular aspects of its performance under a range of conditions. This effort is intended to evolve into a routine annual report to the Great Lakes Boards which will summarize the hydrologic conditions each year, describe monitoring efforts and outcomes of existing plan performance indicators, and highlight any impacts or emerging issues. Given the extraordinary conditions of 2017 in the Lake Ontario - St. Lawrence River system, the GLAM Committee has focused their attention on a detailed assessment for the annual report.

The GLAM Committee's annual report for 2017 is still under development and will be submitted to the Board and IJC in October 2018. The GLAM Annual Report for 2017 will focus on the impacts of 2017 water levels and the degree to which plan evaluation models used to design and evaluate regulation plans captured those impacts. This summary will serve as a template for future annual reports and support the long-term adaptive management effort.

## APPENDIX A CRITERION H14 HIGH AND LOW WATER LEVEL TRIGGERS

QUARTER-MONTH OF THE YEAR	LAKE ONTARIO LEVEL (METERS IGLD85)		LAKE ONTARIO LEVEL (FEET IGLD85)	
	HIGH TRIGGER	LOW TRIGGER	HIGH TRIGGER	LOW TRIGGER
1	1-Jan	75.03	74.28	246.16
2		75.07	74.28	246.29
3		75.10	74.28	246.39
4		75.13	74.27	246.49
5	1-Feb	75.14	74.27	246.52
6		75.14	74.26	246.52
7		75.13	74.26	246.49
8		75.14	74.26	246.52
9	1-Mar	75.16	74.28	246.59
10		75.18	74.31	246.65
11		75.22	74.34	246.78
12		75.27	74.40	246.95
13	1-Apr	75.33	74.48	247.15
14		75.40	74.54	247.38
15		75.45	74.59	247.54
16		75.50	74.64	247.70
17	1-May	75.53	74.67	247.80
18		75.56	74.69	247.90
19		75.60	74.72	248.03
20		75.62	74.74	248.10
21	1-Jun	75.63	74.75	248.13
22		75.62	74.75	248.10
23		75.60	74.76	248.03
24		75.59	74.76	248.00
25	1-Jul	75.57	74.75	247.93
26		75.54	74.75	247.83
27		75.50	74.74	247.70
28		75.47	74.72	247.60
29	1-Aug	75.43	74.70	247.47
30		75.39	74.68	247.34
31		75.34	74.65	247.18
32		75.30	74.62	247.05
33	1-Sep	75.26	74.59	246.92
34		75.20	74.56	246.72
35		75.15	74.53	246.56
36		75.10	74.50	246.39
37	1-Oct	75.06	74.47	246.26
38		75.01	74.44	246.10
39		74.97	74.41	245.96
40		74.95	74.39	245.90
41	1-Nov	74.94	74.36	245.87
42		74.92	74.35	245.80
43		74.91	74.33	245.77
44		74.92	74.32	245.80
45	1-Dec	74.93	74.31	245.83
46		74.93	74.31	245.83
47		74.95	74.29	245.90
48		75.00	74.28	246.06

## APPENDIX B SUMMARY OF OUTFLOW CHANGES FOR 2017 1/6

WEEK ENDING	FLOW CHANGES								DETAILS
	Day	Hr	(M3/S)		(TCFS)		Reason	App. Rule/ Limit	
			From	To	From	To			
06-JAN	--	--	--	--	--	--	--	--	Plan 1958-D
	--	--	--	--	--	--	OpA	I	Plan 2014 as of 07-Jan; Ice management at Beauharnois Canal as of 08-Jan
20-JAN	20-Jan	1201	6230	6640	220.0	234.5	OpA	I	Ice management at Beauharnois Canal
27-JAN	21-Jan	0001	6640	7050	234.5	249.0	Plan	RC	Ice formation stalled
03-FEB	28-Jan	0001	7050	6230	249.0	220.0	OpA	I	Ice management at Beauharnois Canal
	31-Jan	0001	6230	6700	220.0	236.6	OpA	I	Ice management at Beauharnois Canal
10-FEB	4-Feb	0001	6700	6900	236.6	243.7	OpA	I	Ice management at Beauharnois Canal
	8-Feb	1201	6900	6400	243.7	226.0	OpA	I	Ice management at Beauharnois Canal
17-FEB	15-Feb	0001	6400	6800	226.0	240.1	OpA	I	Ice management at Beauharnois Canal
	17-Feb	0001	6800	7050	240.1	249.0	OpA	I	Ice management at Beauharnois Canal
24-FEB	22-Feb	0001	7050	7300	249.0	257.8	OpA	I	Ice management at Beauharnois Canal
03-MAR	27-Feb	0001	7300	7450	257.8	263.1	OpA	I	Ice management at Beauharnois Canal
	4-Mar	0001	7450	7680	263.1	271.2	OpA	I	Ice management at Beauharnois Canal
10-MAR	5-Mar	2201	7680	7180	271.2	253.6	OpA	I	Ice management at Beauharnois Canal
	9-Mar	0001	7180	7680	253.6	271.2	OpA	I	Ice management at Beauharnois Canal
17-MAR	11-Mar	0001	7680	7760	271.2	274.0	OpA	I	Ice management at Beauharnois Canal
	12-Mar	0001	7760	6900	274.0	243.7	OpA	I	Ice management at Beauharnois Canal
24-MAR	13-Mar	0001	6900	6700	243.7	236.6	OpA	I	Ice management at Beauharnois Canal
	13-Mar	1301	6700	6900	236.6	243.7	OpA	I	Ice management at Beauharnois Canal
31-MAR	16-Mar	0001	6900	6600	243.7	233.1	OpA	I	Ice management at Beauharnois Canal
	17-Mar	1601	6600	6900	233.1	243.7	OpA	I	Ice management at Beauharnois Canal
07-APR	20-Mar	0001	6900	7300	243.7	257.8	OpA	I	Ice management at Beauharnois Canal
	21-Mar	0001	7300	7620	257.8	269.1	OpA	I	Ice management at Beauharnois Canal
	22-Mar	0001	7620	7800	269.1	275.5	OpA	I	Ice management at Beauharnois Canal
	25-Mar	0001	7800	7700	275.5	271.9	Plan	RC	No ice remaining
	1-Apr	0001	7700	7790	271.9	275.1	Plan	RC	
	5-Apr	1201	7790	7090	275.1	250.4	OpA	F	Maintain Lake St. Louis at 22.10 m, Lake Ont. < 75.30 m
	6-Apr	0001	7090	6800	250.4	240.1	OpA	F	Maintain Lake St. Louis at 22.10 m, Lake Ont. < 75.30 m
	7-Apr	0001	6800	6400	240.1	226.0	OpA	F	Maintain Lake St. Louis at 22.10 m, Lake Ont. < 75.30 m
	7-Apr	1401	6400	5700	226.0	201.3	OpA	F	Maintain Lake St. Louis at 22.10 m, Lake Ont. < 75.30 m

## APPENDIX B SUMMARY OF OUTFLOW CHANGES FOR 2017 2/6

WEEK ENDING	FLOW CHANGES								DETAILS	
	Day	Hr	(M3/S)		(TCFS)		Reason	App. Rule/ Limit		
			From	To	From	To				
14-APR	8-Apr	1201	5700	6300	201.3	222.5	OpA	F	Maintain Lake St. Louis at 22.10 m, Lake Ont. < 75.30 m	
	9-Apr	1301	6300	6900	222.5	243.7	OpA	F	Maintain Lake St. Louis at 22.10 m, Lake Ont. < 75.30 m	
	10-Apr	1301	6900	7300	243.7	257.8	OpA	F	Maintain Lake St. Louis at 22.10 m, Lake Ont. < 75.30 m	
	11-Apr	0001	7300	7600	257.8	268.4	OpA	F	Maintain Lake St. Louis at 22.20 m, Lake Ontario >= 75.30 m & < 75.37 m	
	12-Apr	1201	7600	7800	268.4	275.5	OpA	F	Maintain Lake St. Louis at 22.20 m, Lake Ontario >= 75.30 m & < 75.37 m	
	12-Apr	1801	7800	8000	275.5	282.5	OpA	F	Maintain Lake St. Louis at 22.20 m, Lake Ontario >= 75.30 m & < 75.37 m	
	13-Apr	0901	8000	7700	282.5	271.9	OpA	F	Maintain Lake St. Louis at 22.20 m, Lake Ontario >= 75.30 m & < 75.37 m	
	14-Apr	0001	7700	8000	271.9	282.5	OpA	F	Maintain Lake St. Louis at 22.20 m, Lake Ontario >= 75.30 m & < 75.37 m	
	15-Apr	0001	8000	7600	282.5	268.4	OpA	F	Maintain Lake St. Louis at 22.20 m, Lake Ontario >= 75.30 m & < 75.37 m	
	17-Apr	0001	7600	7400	268.4	261.3	OpA	F	Maintain Lake St. Louis at 22.20 m, Lake Ontario >= 75.30 m & < 75.37 m	
21-APR	18-Apr	0001	7400	7600	261.3	268.4	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	18-Apr	1601	7600	7750	268.4	273.7	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	19-Apr	1601	7750	7500	273.7	264.9	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	20-Apr	0001	7500	7300	264.9	257.8	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	15-Apr	0001	8000	7600	282.5	268.4	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	17-Apr	0001	7600	7400	268.4	261.3	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	18-Apr	0001	7400	7600	261.3	268.4	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	18-Apr	1601	7600	7750	268.4	273.7	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	19-Apr	1601	7750	7500	273.7	264.9	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	20-Apr	0001	7500	7300	264.9	257.8	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	

## APPENDIX B SUMMARY OF OUTFLOW CHANGES FOR 2017 3/6

WEEK ENDING	FLOW CHANGES								DETAILS	
	Day	Hr	(M3/S)		(TCFS)		Reason	App. Rule/ Limit		
			From	To	From	To				
28-APR	23-Apr	1201	7300	7500	257.8	264.9	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	24-Apr	1201	7500	7800	264.9	275.5	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	25-Apr	1201	7800	8100	275.5	286.0	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	26-Apr	1201	8100	8300	286.0	293.1	OpA	F	Maintain Lake St. Louis at 22.33 m; Lake Ontario >= 75.37 m & < 75.50 m	
	27-Apr	1401	8300	8700	293.1	307.2	OpA	F	Maintain Lake St. Louis at 22.40 m; Lake Ontario >= 75.50 m & < 75.60 m	
	29-Apr	1401	8700	8850	307.2	312.5	OpA	F	Maintain Lake St. Louis at 22.40 m; Lake Ontario >= 75.50 m & < 75.60 m	
05-MAY	1-May	1401	8850	8300	312.5	293.1	OpA	F	Maintain Lake St. Louis at 22.40 m; Lake Ontario >= 75.50 m & < 75.60 m	
	2-May	0001	8300	7900	293.1	279.0	OpA	F	Maintain Lake St. Louis at 22.40 m; Lake Ontario >= 75.50 m & < 75.60 m	
	2-May	0901	7900	7200	279.0	254.3	OpA	F	Maintain Lake St. Louis at 22.40 m; Lake Ontario >= 75.50 m & < 75.60 m	
	2-May	1401	7200	6800	254.3	240.1	OpA	F	Maintain Lake St. Louis at 22.40 m; Lake Ontario >= 75.50 m & < 75.60 m	
	3-May	0901	6800	7100	240.1	250.7	OpA	F	Maintain Lake St. Louis at 22.40 m; Lake Ontario >= 75.50 m & < 75.60 m	
	4-May	0001	7100	7400	250.7	261.3	OpA	F	Maintain Lake St. Louis at 22.40 m; Lake Ontario >= 75.50 m & < 75.60 m	
12-MAY	5-May	1801	7400	7100	261.3	250.7	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
	6-May	0901	7100	6800	250.7	240.1	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
	6-May	1701	6800	6500	240.1	229.5	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
	6-May	2201	6500	6200	229.5	219.0	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
	8-May	0001	6200	6400	219.0	226.0	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
	9-May	1601	6400	6600	226.0	233.1	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
19-MAY	10-May	0901	6600	7000	233.1	247.2	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
	11-May	1501	7000	7400	247.2	261.3	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
	13-May	0001	7400	7700	261.3	271.9	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
	14-May	0001	7700	7900	271.9	279.0	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	
	15-May	0001	7900	8100	279.0	286.0	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m	

## APPENDIX B SUMMARY OF OUTFLOW CHANGES FOR 2017 4/6

WEEK ENDING	FLOW CHANGES								DETAILS
	Day	Hr	(M3/S)		(TCFS)		Reason	App. Rule/ Limit	
			From	To	From	To			
19-MAY	15-May	1201	8100	8500	286.0	300.2	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m
	16-May	1201	8500	8900	300.2	314.3	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m
	17-May	1501	8900	9200	314.3	324.9	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m
	19-May	1401	9200	9350	324.9	330.2	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m
26-MAY	20-May	1001	9350	9600	330.2	339.0	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m
	21-May	1201	9600	9800	339.0	346.1	OpA	F	Maintain Lake St. Louis at 22.48 m; Lake Ontario >= 75.60 m
	23-May	1401	9800	10000	346.1	353.1	Dev	Major (H14)	Flows greater than Plan 2014 begin
	24-May	1601	10000	10200	353.1	360.2	Dev	Major (H14)	Flows increased; Lake St. Louis declining
02-JUN	--	--	--	--	--	--	Dev	Major (H14)	
09-JUN	--	--	--	--	--	--	Dev	Major (H14)	
16-JUN	14-Jun	1201	10200	10400	360.2	367.3	Dev	Major (H14)	Flows increased; Lake St. Louis declining, Seaway mitigation measures deployed
23-JUN	--	--	--	--	--	--	Dev	Major (H14)	
30-JUN	--	--	--	--	--	--	Dev	Major (H14)	
07-JUL	--	--	--	--	--	--	Dev	Major (H14)	
14-JUL	--	--	--	--	--	--	Dev	Major (H14)	
21-JUL	--	--	--	--	--	--	Dev	Major (H14)	
28-JUL	--	--	--	--	--	--	Dev	Major (H14)	
04-AUG	--	--	--	--	--	--	Dev	Major (H14)	
11-AUG	8-Aug	0001	10400	9910	367.3	350.0	Dev	Major (H14)	Flow set to maximum L limit to maintain safe conditions in upper St. Lawrence River, further lower Lake Ontario
18-AUG	--	--	--	--	--	--	Dev	Major (H14)	
25-AUG	19-Aug	0001	9910	9870	350.0	348.6	Dev	Major (H14)	Flow set to maximum L limit to maintain safe conditions in upper St. Lawrence River, further lower Lake Ontario
01-SEP	26-Aug	0001	9870	9620	348.6	339.7	Dev	Major (H14)	Flow set to maximum L limit to maintain safe conditions in upper St. Lawrence River, further lower Lake Ontario
08-SEP	2-Sep	0001	9620	9220	339.7	325.6	Plan	L+	Plan (maximum L limit)

## APPENDIX B SUMMARY OF OUTFLOW CHANGES FOR 2017 5/6

WEEK ENDING	FLOW CHANGES								DETAILS
	Day	Hr	(M3/S)		(TCFS)		Reason	App. Rule/ Limit	
			From	To	From	To			
15-SEP	9-Sep	0002	9220	8960	325.6	316.4	Plan	L+	Plan (maximum L limit)
22-SEP	16-Sep	0003	8960	8750	316.4	309.0	Plan	L+	Plan (maximum L limit)
29-SEP	23-Sep	0004	8750	8690	309.0	306.9	Plan	L+	Plan (maximum L limit)
06-OCT	30-Sep	0005	8690	8630	306.9	304.8	Plan	L+	Plan (maximum L limit)
	6-Oct	1201	8630	7550	304.8	266.6	Dev	Minor (Op)	Boat haul-out on Lake St. Lawrence
	8-Oct	1201	7550	8120	266.6	286.8	Dev	Minor (Op)	Boat haul-out on Lake St. Lawrence
13-OCT	8-Oct	1301	8120	8700	286.8	307.2	Dev	Minor (Op)	Boat haul-out on Lake St. Lawrence
20-OCT	--	--	--	--	--	--	Dev	Minor (Op)	Boat haul-out on Lake St. Lawrence
27-OCT	21-Oct	0001	8700	8530	307.2	301.2	Dev	Minor (Op)	Remove water stored previously on Lake Ontario due to Lake St. Lawrence boat haul-out
03-NOV	28-Oct	0001	8530	8360	301.2	295.2	Plan	R+	Plan (Adjusted Rule Curve)
10-NOV	4-Nov	0001	8360	8490	295.2	299.8	Plan	L+	Plan (maximum L limit)
17-NOV	11-Nov	0001	8490	8540	299.8	301.6	Plan	L+	Plan (maximum L limit)
24-NOV	18-Nov	0001	8540	8530	301.6	301.2	Plan	L+	Plan (maximum L limit)
01-DEC	25-Nov	0001	8530	8510	301.2	300.5	Plan	L+	Plan (maximum L limit)
08-DEC	2-Dec	0001	8510	8490	300.5	299.8	Plan	L+	Plan (maximum L limit)
	5-Dec	0001	8490	8690	299.8	306.9	Dev	Minor (Op)	Condition J test (+200 m3/s above Plan flow of 8490 m3/s)
	9-Dec	0001	8690	8610	306.9	304.1	Dev	Minor (Op)	Condition J test (+160 m3/s above Plan flow of 8450 m3/s)
15-DEC	12-Dec	1301	8610	8450	304.1	298.4	Dev	Minor (Op)	Low Lake St. Lawrence Level
	12-Dec	2001	8450	8610	298.4	304.1	Dev	Minor (Op)	Condition J test (+160 m3/s above Plan flow of 8450 m3/s)
22-DEC	16-Dec	0001	8610	8440	304.1	298.1	Dev	Minor (Op)	Maximum L limit computed using actual end of week level of 74.79 m (L limit 8440 m3/s), rather than computed EOW level of 74.80 m (Plan L limit 8450 m3/s)
	22-Dec	1001	8440	8000	298.1	282.5	Dev	Minor (Op)	Minor deviation (paybacks) and low Lake St. Lawrence Level

## APPENDIX B SUMMARY OF OUTFLOW CHANGES FOR 2017 6/6

WEEK ENDING	FLOW CHANGES								DETAILS	
	Day	Hr	(M3/S)		(TCFS)		Reason	App. Rule/ Limit		
			From	To	From	To				
29-DEC	--	--	--	--	--	--	Dev	Minor (Op)	Minor deviation (paybacks) and low Lake St. Lawrence Level	
	25-Dec	0001	8000	7600	282.5	268.4	OpA	I	Ice management at Beauharnois Canal	
	26-Dec	1601	7600	6700	268.4	236.6	OpA	I	Ice management at Beauharnois Canal	
	27-Dec	1801	6700	6900	236.6	243.7	OpA	I	Ice management at Beauharnois Canal	
	28-Dec	1601	6900	6400	243.7	226.0	OpA	I	Ice management at Beauharnois Canal	
	29-Dec	1201	6400	6230	226.0	220.0	OpA	I	Ice management at Beauharnois Canal	
	29-Dec	1801	6230	5900	220.0	208.4	OpA	I	Ice management at Beauharnois Canal	
05-JAN	30-Dec	1201	5900	6230	208.4	220.0	OpA	I	Ice management at Beauharnois Canal	
	30-Dec	1801	6230	6100	220.0	215.4	OpA	I	Ice management at Beauharnois Canal	
	31-Dec	1001	6100	6230	215.4	220.0	OpA	I	Ice management at Beauharnois Canal	



## Observed Conditions and Regulated Outflows in 2017

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*May 25, 2018*