Monitoring the State of the
ST. LAWRENCE RIVER

# Changes in the levels and flows of the St. Lawrence River

## Background

Using a single indicator to characterize water conditions in the St. Lawrence River is not a simple matter, as specific local features and short-term fluctuations must be disregarded. The flow at Sorel has several advantages as an indicator: it incorporates inputs from the two main hydrologic sources, the Great Lakes and the Ottawa River; and Sorel is located at approximately the midpoint of the fluvial section of the Great Lakes–St. Lawrence system, upstream of Lake St. Pierre (Figure 1). In addition, because the flow is calculated from the hydrologic inputs, interference effects from wind, tides, growth of aquatic plants and ice cover are not incorporated in the indicator.

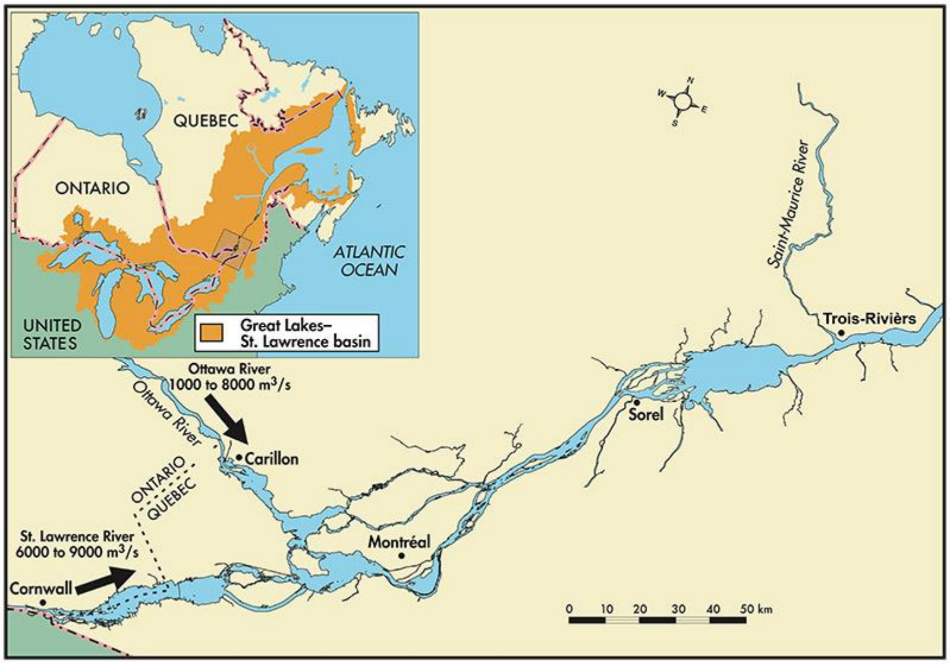


*Figure 1Fluvial section of the Great Lakes–St. Lawrence system between Cornwall and Trois-Rivières*

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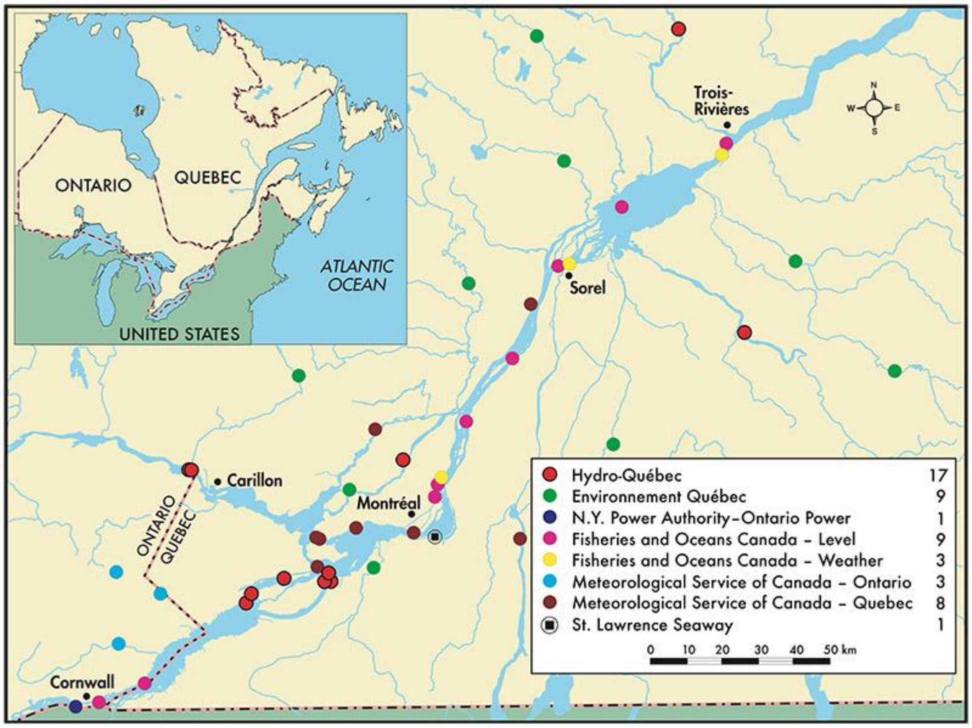



*Figure 2. Location of the main hydrometric measuring stations of the river section and its main tributaries.*

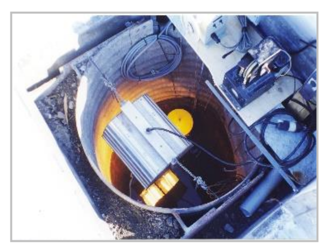
## History of the hydrometric network

In Quebec, the current distribution of level and flow stations is the result of the installation of the first stations of the hydrometric network at the end of the 19th century. Those located on the St. Lawrence River have historically been dedicated to measuring water levels, firstly because this facilitates navigation and secondly because the physical characteristics of the flow downstream of the Lachine Rapids make it difficult to estimate flows. The latter must therefore be calculated by adding the flows from tributary rivers and ungauged areas, while taking into account the time it takes for the water to travel from upstream to downstream. As for the river's tributaries, stations dedicated to flow calculations are also installed.

Over the decades, the density of the hydrometric network has increased to include 51 stations on the St. Lawrence River and its tributaries (Figure 2). The distribution of stations has been modified to improve efficiency and reliability, particularly with respect to flow stations located on the tributaries. This hydrometric network allows a complete assessment of the hydrology in the fluvial section of the Great Lakes–St. Lawrence watershed, both for water level measurements and flow calculations.

In the past, the network was characterized by an essentially manual mode of operation. Today, hydrometric stations are mostly automated, so that data are accessible in real time using the Internet.

Hydrometric station in Lanoraie



Water level measuring instruments

# Overview of the situation

The river's current flow regime reflects the impacts of the regulation of hydrologic inputs as well as other human interventions. Data produced by the hydrometric network shed light on the cyclical nature of flows in the St. Lawrence.

## Hydrological cycle

Figure 3 illustrates the temporal evolution of the calculated flow at Sorel from 1932 to 2020. Examined as a whole, this series of data makes it possible to appreciate the extent of the fluctuations in the flow rate, which is of the order of 14,000 $m^3/s$ between the minimum of 6,000 $m^3/s$ and the maximum of approximately 20,000 $m^3/s$. Very low flows were observed in the mid-1930s (6,601 $m^3/s$), followed by high flows reaching 19,655 $m^3/s$ in 1943. Very low flows were again observed in the mid-1960s (6,093 $m^3/s$), followed by high flows (20,343 $m^3/s$) in 1976 and, more recently, since the end of the 1990s, low flows have been observed on several occasions (7,014 $m^3/s$ in 2001, 6,940 $m^3/s$ in 2007, 7,160 $m^{3/}s$ in 2010 and 7,020 $m^3/s$ in 2012). In general, the river's hydraulicity since the end of the 1990s has been lower without reaching the minimum values observed during the 1930s and 1960s. Since 2015, however, the average flow of the river shows an increasing trend with peaks in 2017 (17,801 $m^3/s$) and 2019 (17,270 $m^3/s$) that are comparable to the levels of the early 1970s.

Figure 4 compares average annual flows at Sorel for each hydrologic year (October to September) with water inputs to Lake Ontario. Mean annual flows rather than mean monthly flows are used in order to filter out some of the effects of regulation, which can be seen in the monthly values. The series of flow values at Sorel is shorter than the series of inputs to Lake Ontario because flow data are not available for the main tributaries of the St. Lawrence before 1930.

Flows in the St. Lawrence at Sorel vary greatly from year to year, and they depend on interannual variations in water inputs to Lake Ontario, which in turn depend on climatic conditions. After the first decade of the 2000s, which saw relatively low outflows and associated Lake Ontario levels, there has been an increase in water supplies and hence in St. Lawrence River outflows. The values reached are at the level of the lake's historical records, both in terms of flow and level.

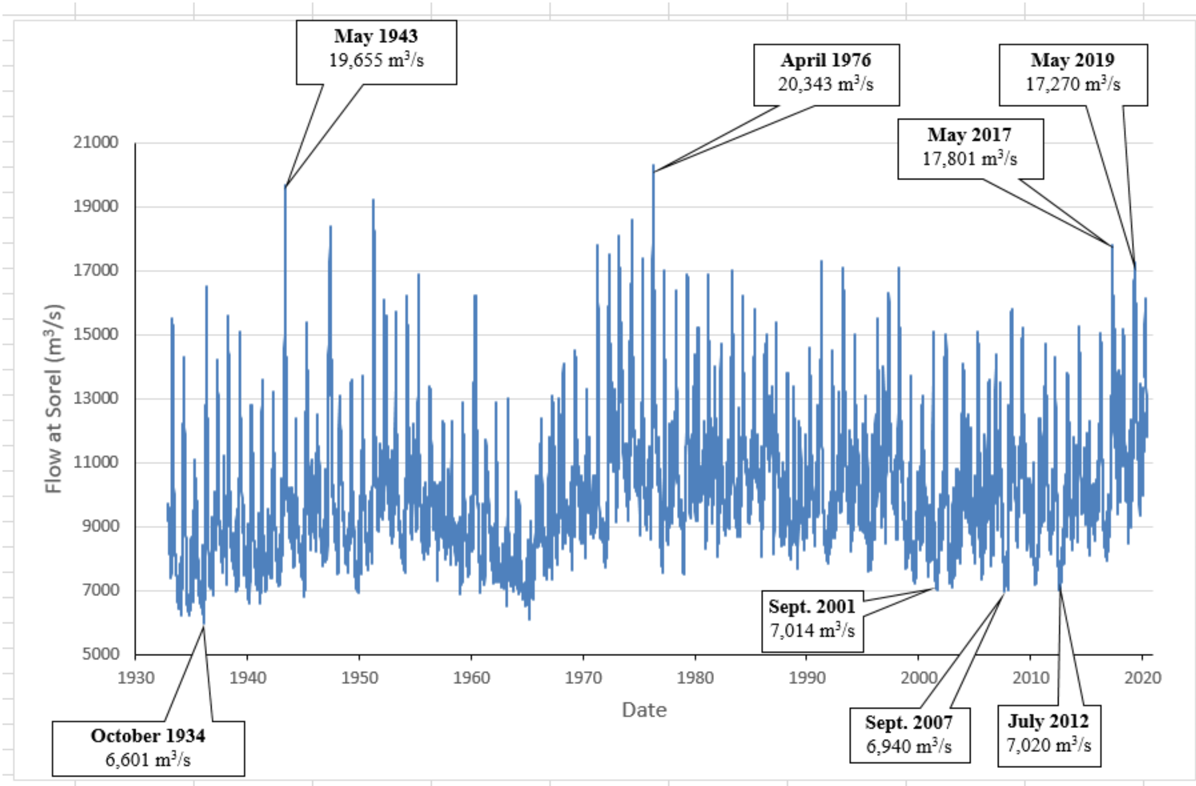



*Figure 3. Flow of the St. Lawrence River calculated at Sorel from December 1932 to June 2020.*

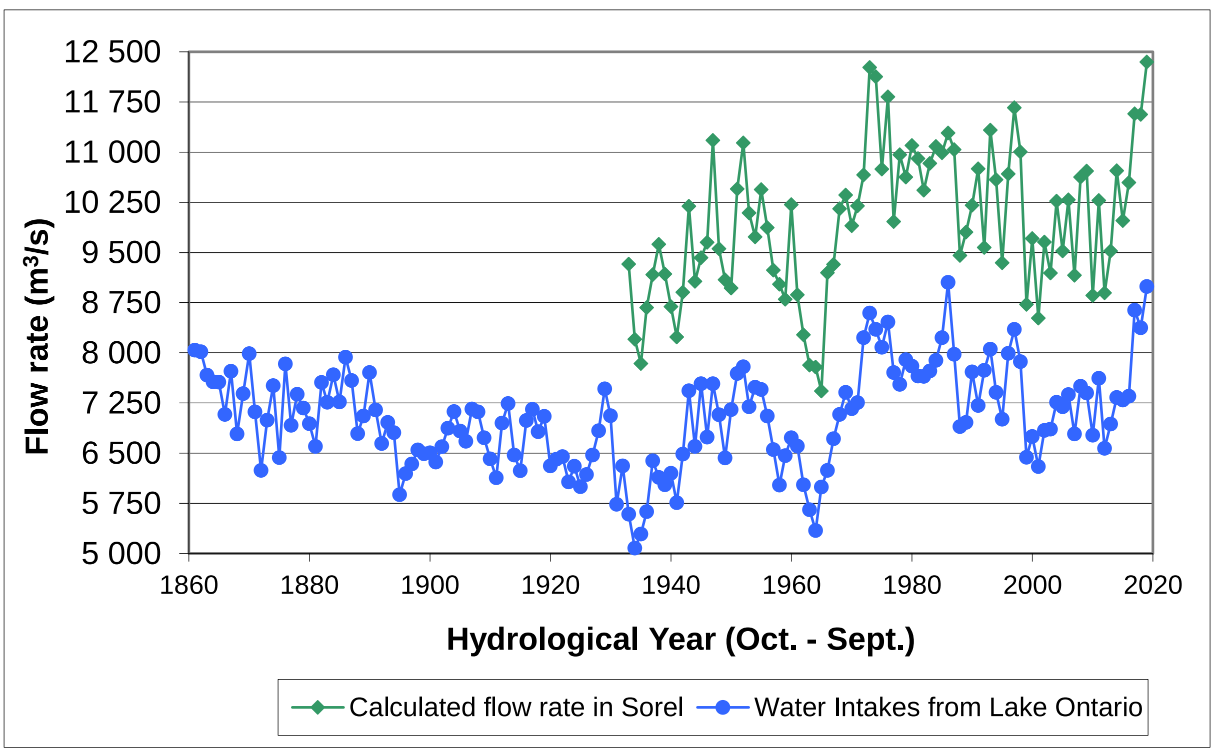



*Figure 4: Annual averages (hydrological year from October to September) of the St. Lawrence River flow calculated at Sorel from 1932 to 2019, and of the water supply to Lake Ontario from 1861 to 2019*

In recent decades, the pattern of flow in the St. Lawrence has changed drastically as a result of numerous human interventions whose impacts, whether local or more widespread, are directly reflected in water levels. The changes are so significant that it has become extremely difficult to make historical comparisons of flow before and after such interventions. For that reason, water level is still useful as an indicator of water quantity in the St. Lawrence, but to a limited extent.

A means of mitigating the problem would be to use another indicator: streamflow. This indicator offers some advantages for the purpose of describing changes in the flow regime in the St. Lawrence. Even though its temporal distribution is affected by human interventions (regulation, engineering structures), flow is a good indicator of water conditions in the river and can be compared with time series measured or generated by numerical modelling.

## Engineering works

Flows in the river are also affected by engineering structures. In addition to the construction of the Moses-Saunders, Beauharnois, Des Cèdres and Carillon dams and other control structures farther upstream in the watershed, a number of major projects were carried out in the fluvial section in the 20th century. Dredging of the shipping channel, deposition of the dredged materials, construction of spillways, bridges and tunnels, and the creation of Notre Dame Island opposite Montréal have altered the configuration of the river bottom and, as a result, the spatial distribution of water levels.

Winter maintenance of the shipping channel, including installation of booms to maintain navigability, has also changed the natural distribution of levels and flows—for example, by minimizing the frequency and extent of ice jams. In addition, water levels are affected by the growth of aquatic plants in summer and ice cover in winter, and by winds and tides.

## Regulation of flow

The St. Lawrence River is fed by two main regulated watersheds: the Great Lakes (Cornwall station) and the Ottawa River (Carillon station) (Figure 1). At Cornwall, the flow generally varies between 6,000 $m^3$/s and 9,000 $m^3$/s throughout the year (mean annual flow: 7,060 $m^3$/s), while at Carillon it varies between 1,000 $m^3$/s and 8,000 $m^3$/s (mean annual flow: 1,910 $m^3$/s).

Figure 5 illustrates the average effect of regulation of the Great Lakes and the Ottawa River on the river's flow at Sorel, calculated for the period of 1960–1997.

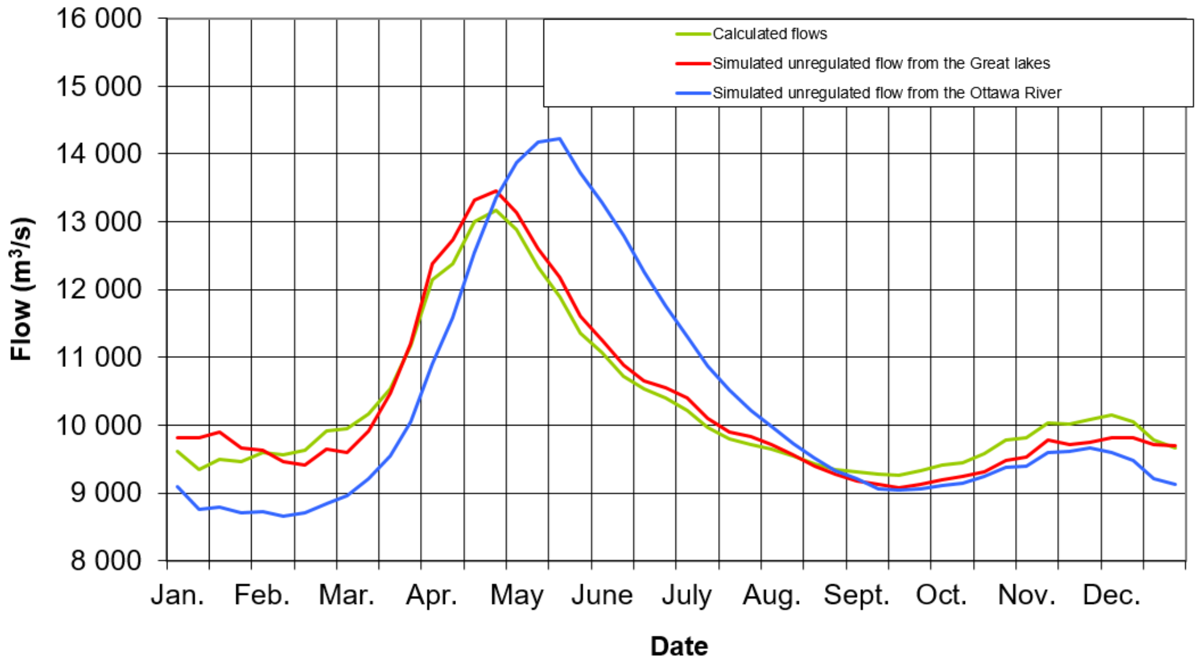



*Figure 5: Interannual average flow at Sorel (1960–1997): calculated and simulated flows without the effect of Great Lakes and Ottawa River regulation (Morin and Bouchard 2000)*

Regulation of flow has a stabilizing effect, minimizing extreme values, and typically results in flow reduction in spring and an increase in the fall and winter. In general, flow is reduced in spring by as much as 2,000 $m^3$/s or more and increases between September and March by 300 $m^3$/s to 900 $m^3$/s. However, flow is reduced in January to allow for the formation of the ice cover upstream of the Beauharnois and Moses-Saunders hydroelectric dams.

Figure 5 also shows the comparative effect on flow at Sorel caused by regulating the Great Lakes and the Ottawa River. Regulation has had a greater impact on the Ottawa River than on the Great Lakes, primarily by reducing flood flows, causing high spring flows to occur earlier in the year, and by increasing flow in winter.

Although the typical impact of flow regulation seems considerable, the Great Lakes–St. Lawrence Regulation Office actually has little room to manoeuvre when trying to prevent extreme events. For example, during extended periods of low flow, the level of the Great Lakes drops significantly, making it very difficult to compensate for a downstream shortage of water without aggravating an already difficult situation upstream. The same is true when trying to prevent flooding during high flow events in the system, such as during the events of 2017 and 2019, when the lake level was already very high and therefore did not allow for much water storage in Lake Ontario.

Even so, regulation mitigates the impact of extreme flow conditions. For example, during a dry spell in 2012, when there was no significant precipitation in the basin for an extended period, the Lake Ontario outflow was regulated to keep water levels in the St. Lawrence just high enough to ensure the continuity of shipping operations.

Currently, the regulation plan used for Lake Ontario dates back to 2014, following an update of the previous plan dating back to the late 1950s.

## Key variables

Two indicators—water level and flow—are used to monitor flow conditions in the St. Lawrence.

Water level is measured at each hydrometric station. The associated flow must be calculated from the water level using a mathematical equation calibrated specifically for each site. For this purpose, certain physical conditions, including a control section, must exist in order to establish a relationship between water level and flow. In the St. Lawrence, the last control section is located at LaSalle, near Montréal. Downstream of this point, flow must be estimated by adding the flow from tributaries and ungauged areas, a calculation that must also take into account upstream-to-downstream transit time.

There are some limitations associated with the use of water level as an indicator. For example, human-made modifications to river systems, including dredging, construction of islands, etc., have resulted in local changes in annual patterns of variations, which in turn complicate the use of the water-level measurements. Another factor limiting this indicator's usefulness is that natural interference effects from wind, tides, growth of aquatic plants and ice cover are considered in its interpretation.

Conversely, use of the flow of the St. Lawrence River at Sorel as an indicator offers a number of advantages: it incorporates the input from the river's main tributaries, the Great Lakes and the Ottawa River; it gives a calculation from the midpoint of the fluvial portion of the system; and it does not incorporate the above-mentioned natural interference factors. The thresholds used to qualify flow values and associated water levels are calculated from historical data and can take the form of quartiles in the statistical distribution or flow values/levels for flood and low-water recurrence intervals (for example, every 20 or 100 years). Therefore, this indicator can be used to obtain a comprehensive evaluation of the situation.

## Outlook

The variations shown in Figures 3 and 4, with periods of low flow regularly followed by periods of high flow, would lead one to expect flow and associated water levels in the St. Lawrence to rise again in the coming decade.

However, according to an international group of experts, the climate has warmed by 0.7°C over the past century, and precipitation has risen over all. Numerical climate-change models suggest that, over the next century, North America will experience warming of between 1°C and 7.5°C, depending on the scenario, and there is a high margin of error associated with the precipitation predictions.

With this in mind, numerical models simulating the effect of higher temperatures on the Great Lakes, the main source of the St. Lawrence River, predict an increase in both evaporation and precipitation. Although the projections tend to show a slight increase in lake levels, the most significant result of these models is that they project an increase in the range between extreme low and high levels, i.e. higher high levels and lower low levels. It is reasonable to expect that the variations in river flow will follow the same trend.

As a result, it is extremely difficult to predict the river's hydraulicity in a few decades. The temporal variation in flows—and associated levels—suggests an upward trend in flows, as observed in the late 2010s, but climate change scenarios indicate that greater variations in the outflow of the Great Lakes compared with historical measurements are to be expected over the next century.

Seasonal fluctuations can be seen in the time series of flow values for the St. Lawrence. The river's flow is the product of a number of factors, the most important of which is the amount of precipitation received by the Great Lakes–St. Lawrence system. Given that changes in water level and flow over the course of a given year are also subject to other factors, including evaporation, soil saturation, snow cover and regulation of the Great Lakes and the St. Lawrence, it remains difficult to forecast the river's flow for a time horizon of a few months.

The interannual, seasonal or monthly variations are easily illustrated by the analysis of the river's flow over the last few years. Figure 6 shows, for example, that in recent years, 2017 and 2019 are very similar (years of high runoff), while the years 2013, 2015 and 2016 show lower flows. Among other things, the flood observed in 2015 was very low, with a virtually non-existent peak flood and subsequent very low flows until mid-summer. In 2017 and 2019, the flood was relatively early and flows remained quite high thereafter with values above 9,500 $m^3/s$ throughout the year.

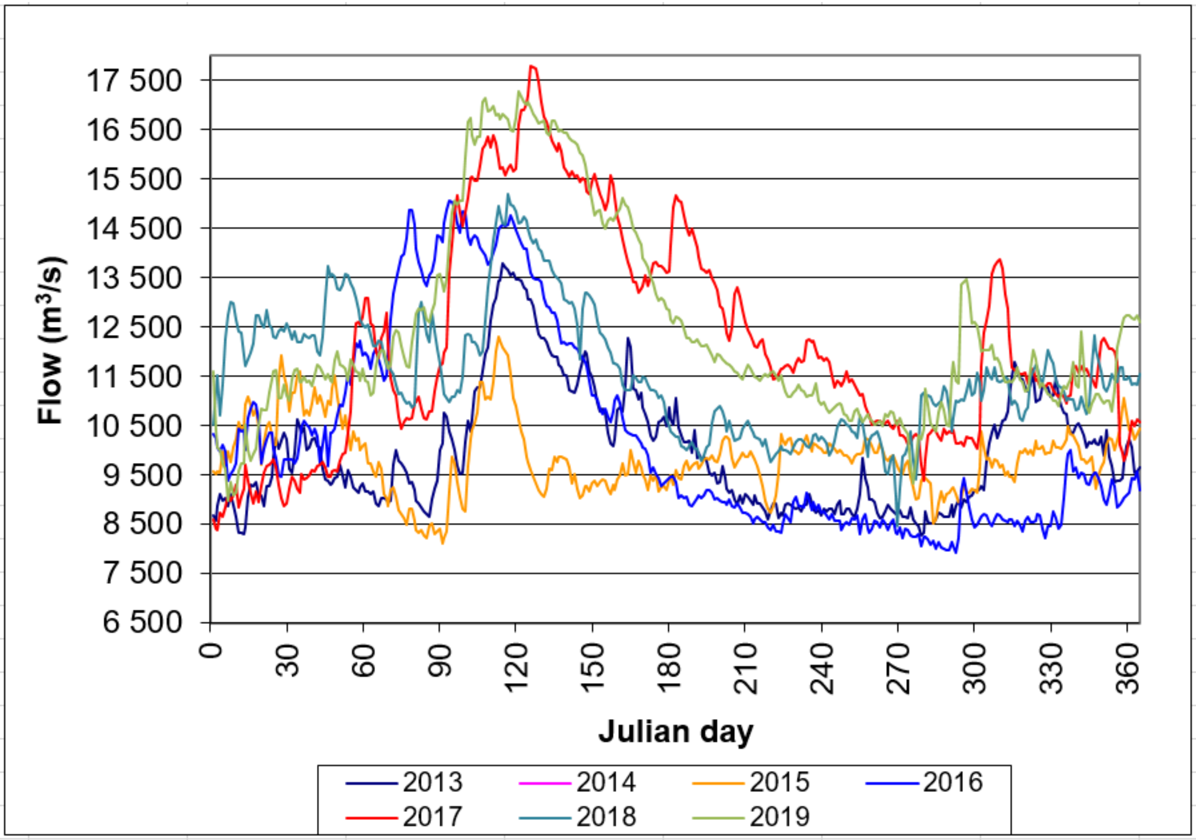



*Figure 6. Annual flow pattern of the St. Lawrence River calculated at Sorel from 2013 to 2019.*

# For more information

BOUCHARD, A. and J. MORIN. 2000. *Reconstruction of St. Lawrence River flows between 1932 and 1998*. Environment Canada, Meteorological Service of Canada, Hydrology Section. Technical Report RT-101.

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MORIN, J. and A. BOUCHARD. 2000. *Les bases de la modélisation du tronçon Montréal–Trois-Rivières.* Environment Canada, Meteorological Service of Canada, Hydrology Section, Sainte-Foy. Scientific Report RS-102, ISBN 0-662-85363-6, 55 p.

See https://ijc.org/en/ijc-moves-ahead-plan-2014 for more information on the International Joint Commission's Lake Ontario–St. Lawrence River Study Plan (LOSLR).

Info-Levels (Environment Canada):

https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/great-lakes-levels-related-data/levelnews-great-lakes-st-lawrence.html

Centre d'expertise hydrique du Québec: http://www.cehq.gouv.qc.ca/suivihydro/default.asp

International St. Lawrence River Board of Control: https://ijc.org/en/loslrb

Ottawa River Regulation Board:

http://ottawariver.ca/

Department of Fisheries and Oceans: http://www.meds-sdmm.dfo-mpo.gc.ca/

United States Geological Survey: http://water.usgs.gov/

Hydro-Québec: http://www.hydroquebec.com/

New York Power Authority: http://www.nypa.gov/

St. Lawrence Seaway: http://www.greatlakes-seaway.com/fr/

Real-time and historical data (Hydat): http://www.eau.ec.gc.ca/index_f.html

Seasonal forecasts: https://weather.gc.ca/saisons/index_e.html

**State of the St. Lawrence Monitoring Program**

Five government partners—Environment and Climate Change Canada; Fisheries and Oceans Canada; Parks Canada; the Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques du Québec; and the Ministère des Forêts, de la Faune et des Parcs du Québec—and Stratégies Saint-Laurent, a non-governmental organization that works actively with riverside communities, are pooling their expertise and efforts to provide Canadians with information on the state of the St. Lawrence and the long-term trends affecting it.

For more information about the State of the St. Lawrence Monitoring Program, please consult our website: http://planstlaurent.qc.ca/en/state_monitoring.html.

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