Monitoring the State of the ST. LAWRENCE RIVER

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Changes in water levels and flows in 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 portion of the Great Lakes–St. Lawrence system, upstream of Lake Saint 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.

History of the hydrometric network

In Quebec, the current distribution of the stations that measure water level and flow dates back to the installation of the first stations in the hydrometric network in the late 19th century. Historically, the function of stations located on the St. Lawrence has been to measure water levels, partly to facilitate navigation and partly because the physical characteristics of the river downstream of the Lachine Rapids make it difficult to estimate flow. Flow must therefore be calculated by adding inputs from tributaries and ungauged areas and taking into account upstream-to-downstream transit time. Stations on tributaries of the St. Lawrence have traditionally focused on calculating flow.

Over the decades, the hydrometric network grew to include 51 stations along the St. Lawrence and its tributaries (Figure 2). Distribution was changed to improve the efficiency and reliability of stations, particularly those located along tributaries. The network produces both water-level measurements and streamflow calculations, providing a comprehensive evaluation of the fluvial portion of the Great Lakes–St. Lawrence basin.

Hydrometric station at Lanoraie
Photo: © Environment Canada

In the past, the network consisted mainly of manually operated sites. Now, most hydrometric stations are automated, disseminating data in real time by various methods, including the Internet.

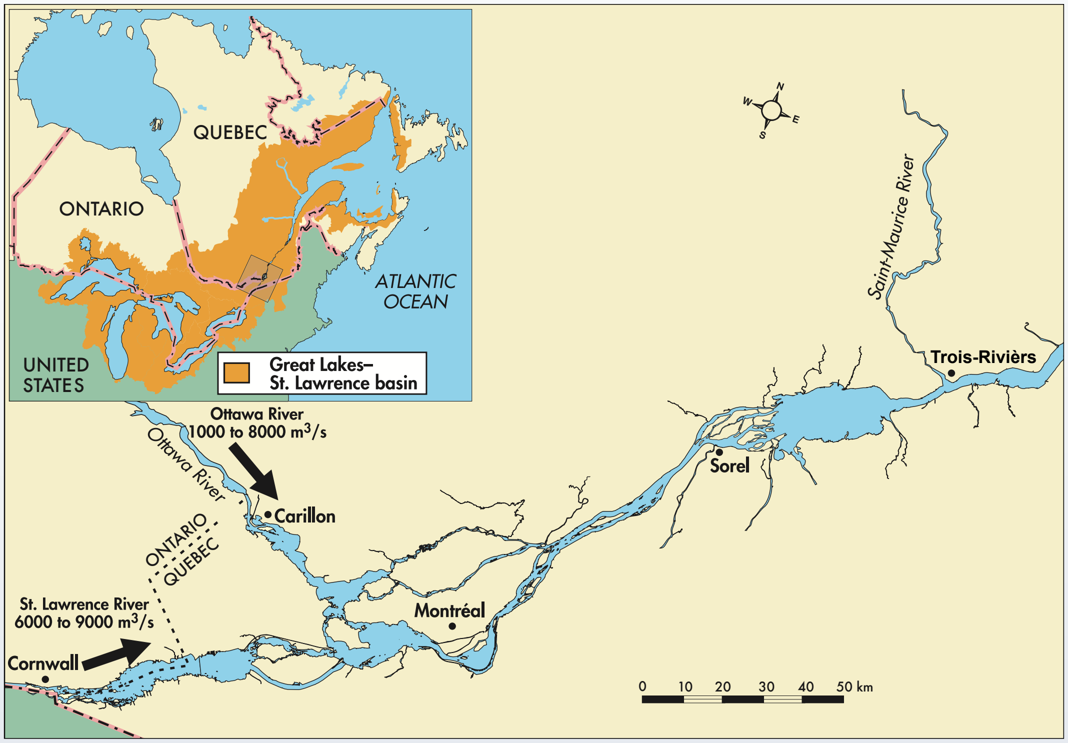

Figure 1. Fluvial portion of the Great Lakes–St. Lawrence system, between Cornwall and Trois-Rivières

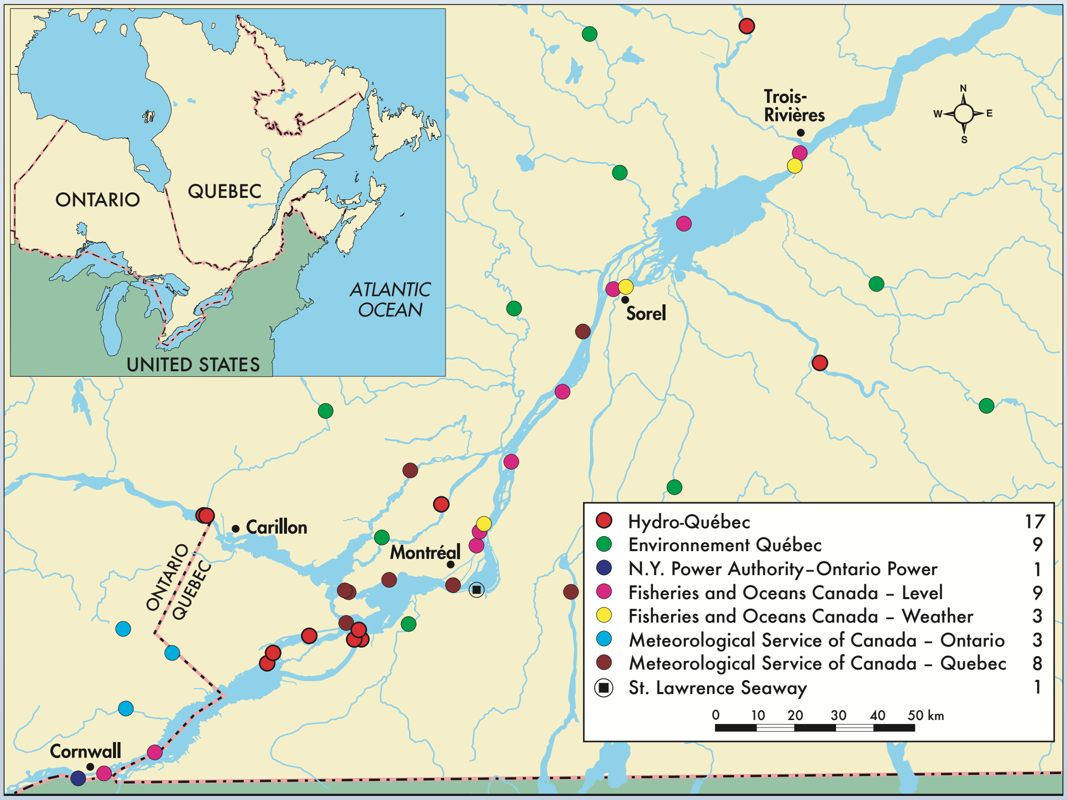

Figure 2. Locations of the main hydrometric stations along the fluvial portion of the system and its main tributaries

Instruments used to measure water level
Photo: © Environment Canada

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.

Hydrologic cycle

Figure 3 illustrates the temporal variations in the flow at Sorel for the period 1932–2012. Viewed as a whole, this data series shows the range of fluctuation, which is about 14 000 m^3/s (ranging from a minimum of 6 000 m^3/s to a maximum of about 20 000 m^3/s). Very low flows were observed (6 601 m^3/s) in the mid-1930s, followed in the 1940s by high flows, which reached 19 655 m^3/s in 1943. In the mid-1960s, very low flows were recorded again (6 093 m^3/s), followed by high flows (20 343 m^3/s) in 1976. More recently, since the late 1990s, several periods of low flows have been observed (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 flow since the late 1990s has been lower, but without dropping to the lows seen in the 1930s and 1960s.

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. Flows—and associated levels—recorded during past periods of very low water include extreme values that have not been seen in low-water events since the early 2000s. The Great Lakes–St. Lawrence system is therefore not currently setting records for low flows. Values measured in recent years, although very low, are within the range recorded over the last century.

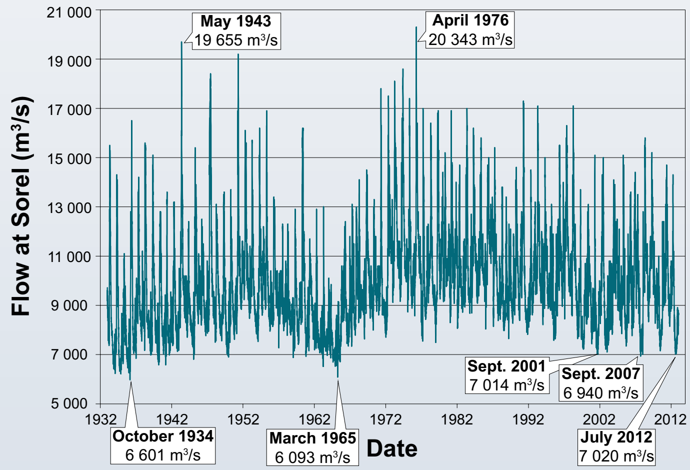

Figure 3. St. Lawrence River flow at Sorel from December 1932 to December 2012

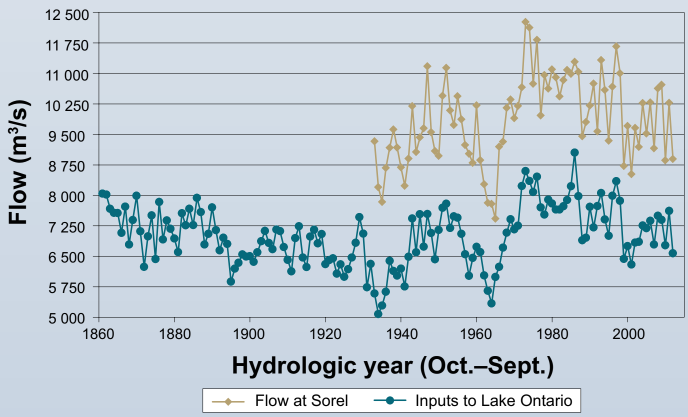

Figure 4. Average annual St. Lawrence River flow (October-to-September hydrologic year) at Sorel from 1932 to 2012 and water inputs to Lake Ontario from 1861 to 2012

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.

For example, the International St. Lawrence River Board of Control's use of the hydrometric station in Montréal harbour to measure water levels in the river has been controversial. Work carried out in this part of the channel to extend the shipping season and construct Notre Dame Island for Expo 67 has had a critical impact and radically changed the flow pattern. Because of this work, statisticians now compile historical data only from 1967 onward. The low levels recorded in the early 1930s and in 1964 and 1965 are not included in the statistical database, and their absence biases the results obtained when comparing modern water-level observations with historical values.

In concrete terms, this situation led to incorrect readings of water levels in the St. Lawrence during several years of low flow, with the statistics seeming to show that the Great Lakes would fall below their long-term average and that Montréal harbour would see record minimums. Therefore, in any report on flow conditions in the Great Lakes–St. Lawrence system, it is important to indicate what period has been used to calculate water-level statistics for Montréal harbour and to explain why that period differs from the one used for statistical calculations of water levels in the Great Lakes and why the two data sets are difficult to compare. Including information on water levels at other locations along the St. Lawrence River that are less affected by human activities would produce a more realistic picture of flow conditions in the river.

Another 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 structures

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 portion 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 6000 m^3/s and 9000 m^3/s throughout the year (mean annual flow: 7060 m^3/s), while at Carillon it varies between 1000 m^3/s and 8000 m^3/s (mean annual flow: 1910 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 1960–1997.

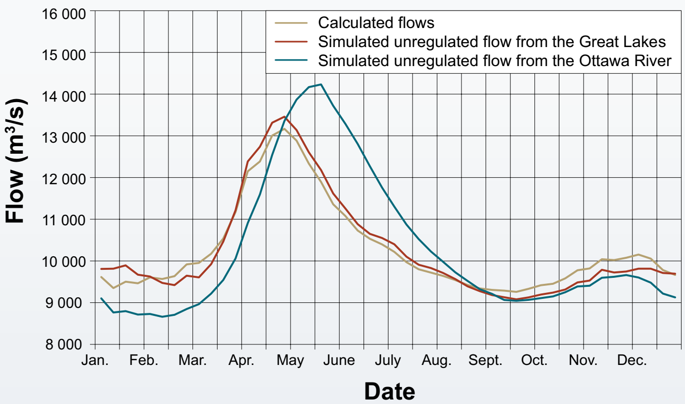

Figure 5. Mean interannual flow at Sorel (1960–1997): calculated flow, simulated unregulated flow from the Great Lakes and the Ottawa River

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 2000 m^3/s or more and increased 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 much less 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. 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.

The regulation plan currently used for Lake Ontario (plan 1958 D) was developed in the late 1950s. Based on a study conducted by the International Joint Commission in the early 2000s, a new regulation plan was drawn up and has been revised several times. It was designed to take into account not only the needs targeted in the original plan (navigation, hydro-electric production, etc.) but also issues such as erosion and the environment. The new plan is expected to be approved and implemented within the next few years.

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 overall. 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.

Numerical models that simulate the effect of higher temperatures on evaporation in the Great Lakes—the main source of water for the St. Lawrence—forecast declining water levels and flow for almost all the climate-change scenarios considered. Such a decline would be magnified or diminished as a function of precipitation, but it seems reasonable to expect a decrease in water supply to the river.

Consequently, it is very difficult to predict water conditions in the river in a few decades' time. The temporal variation in flow and associated water levels suggests an increase in flow, but in almost all cases the climate-change scenarios point to a decrease in outflow from the Great Lakes 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.

Year-to-year, seasonal and monthly variations can be readily identified by analyzing the flow in the river in recent years. Figure 6 shows, for example, that the years 2008, 2009 and 2011 were very similar (years of high flow), but in 2010 and 2012 there was lesser flow. The freshet in 2010 was weak, showing almost no peak, and subsequent flows were very low until midsummer. In 2012, the freshet was early and flows diminished quickly afterwards, with values below 7500 m^3/s for an extended period beginning in midsummer.

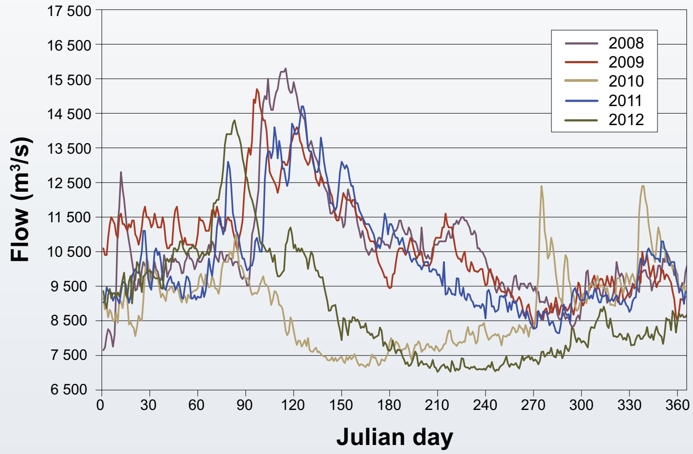

Figure 6. Annual flow pattern in the St. Lawrence River at Sorel from 2008 to 2012

Photo: © Thinkstock.com, 2015

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.

Further reading

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INTERNATIONAL ST. LAWRENCE RIVER BOARD OF CONTROL. 1958. *Regulation of Lake Ontario: Plan 1958-A*. Report to the International Joint Commission. Volume 2, Appendix A.

McCARTHY, JAMES J. 2001. *Climate Change 2001 Impacts, Adaptation, and Vulnerability*. Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press. ISBN 0-521-80768-9.

MORIN, J., and A. BOUCHARD. 2000. *Background information for the modeling of the Montréal / Trois-Rivières river reach*. Scientific Report RS-102. Environment Canada, Meteorological Service of Canada, Hydrological Section, Sainte-Foy. ISBN 0-662-85363-6, 55 pp.

See www.ijc.org/loslr/en/index.php for more about the International Joint Commission's new approach to regulation of the Lake Ontario–St. Lawrence River system.

LEVELnews (Environment Canada):
www.ec.gc.ca/eau-water/default.asp?lang=En&n=F6F3D96B-1

Centre d'Expertise Hydrique du Québec:
www.cehq.gouv.qc.ca/suivihydro/default.asp

International St. Lawrence River Board of Control:
www.islrbc.org

Ottawa River Regulation Planning Board:
http://ottawariver.ca/index-ottawa-river.php

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

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

Hydro-Québec:
www.hydroquebec.com

New York Power Authority:
www.nypa.gov

St. Lawrence Seaway:
www.greatlakes-seaway.com/en/index.html

Real-time and historical data (Hydat):
http://wateroffice.ec.gc.ca/index_e.html

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

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State of the St. Lawrence Monitoring Program

Five government partners—Environment Canada, Fisheries and Oceans Canada, Parks Canada, Quebec's Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques and the Ministère des Forêts, de la Faune et des Parcs—in collaboration with 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 its long-term changes.

To this end, environmental indicators have been developed on the basis of data collected as part of each organization's ongoing environmental monitoring activities over the years. These activities cover the main components of the environment, namely water, sediments, biological resources, uses and shorelines.

For more information on the State of the St. Lawrence Monitoring Program, please visit our website at **www.planstlaurent.qc.ca**.

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