Changes in Water Level and Flow in the St. Lawrence River

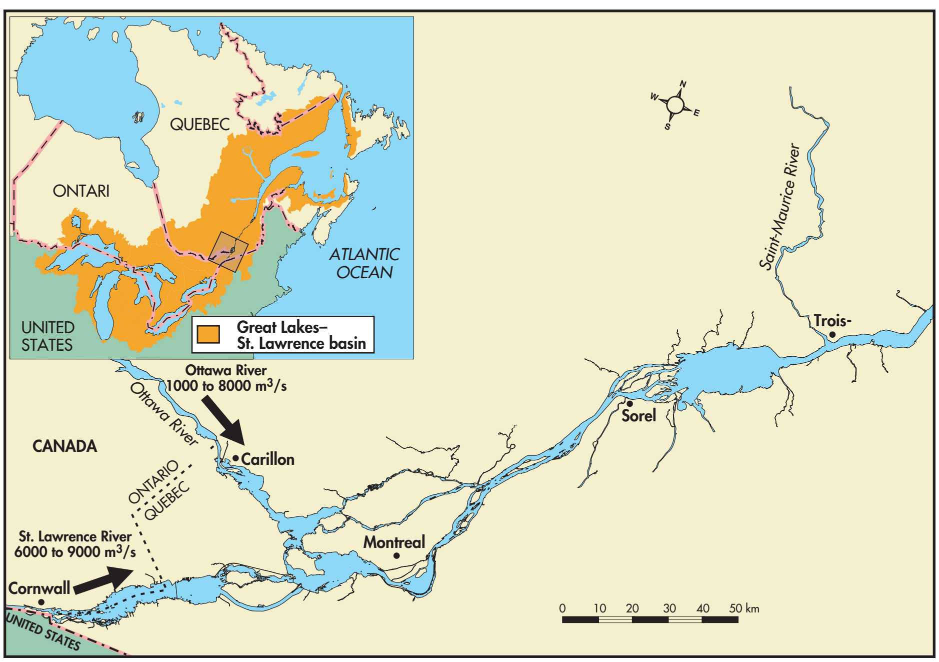
Photo: Meteorological Service of Canada

Example of a hydrometric station: Station No. 020B011 in Lanoraie

Background

Using a single indicator to characterize the St. Lawrence River's status in terms of hydraulicity is not a simple matter because specific local features and short-term fluctuations must be disregarded. In this respect, the flow at Sorel offers several advantages: it incorporates input from the two main hydrologic sources, the Great Lakes and the Ottawa River, and it is located approximately at the mid-point of the fluvial portion of the Great Lakes–St. Lawrence system and upstream of Lake Saint-Pierre (Figure 1). In addition, because the flow is calculated from the hydrologic inputs, interference effects resulting from wind, tidal signal, growth of aquatic plants and ice cover are not incorporated in the indicator.

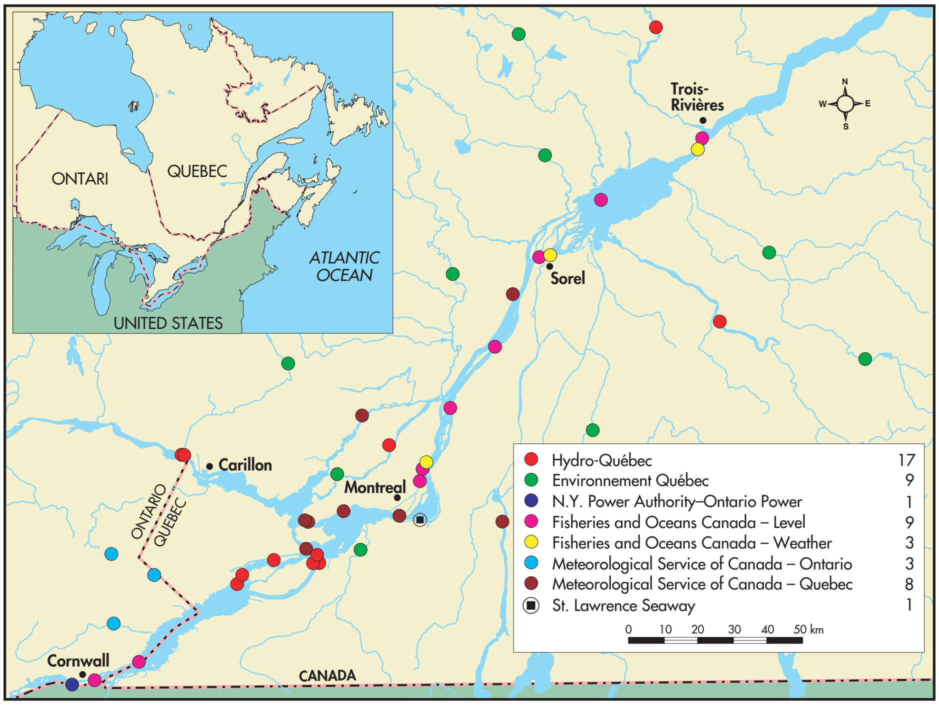
Figure 1. Fluvial portion of the Great Lakes–St. Lawrence basin, between Cornwall and Trois-Rivières



History of the hydrometric network

In Quebec, the present distribution of stations that provide data on water level and flow dates back to the end of the 19th century and the installation of the first stations in the hydrometric network. The historical function of those

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



located on the St. Lawrence has been to measure water levels, partly in order 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 input from tributaries and ungauged areas and taking into account upstream-to-downstream transit time. Stations on the tributaries of the river have traditionally focused on calculating flow.

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

In the past, operation of the network was essentially a manual process. Today, most hydrometric stations are automated, disseminating data in real time by various methods, including the Internet.

Overview of the Situation

The current status of the flow regime of the river reflects the impact 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 the hydraulicity of the St. Lawrence River.

Hydrologic cycle

Figure 3 illustrates the temporal variations in the flow at Sorel as calculated for the period from 1932 to 2001. Viewed as a whole, this series of data shows that flow ranged from a minimum of 6000 m^3/s to a maximum of approximately 20 000 m^3/s, for a total range in fluctuation on the order of 14 000 m^3/s. Very low flows were observed in the mid-1930s (6601 m^3/s) and mid-1960s (6093 m^3/s), while high flows were observed in the 1940s (19 655 m^3/s) and again in 1976 (20 343 m^3/s). Low flows were recorded again at the end of the 1990s and in early 2000 (7014 m^3/s).

Figure 3. St. Lawrence River flow at Sorel for December 1932 to December 2001

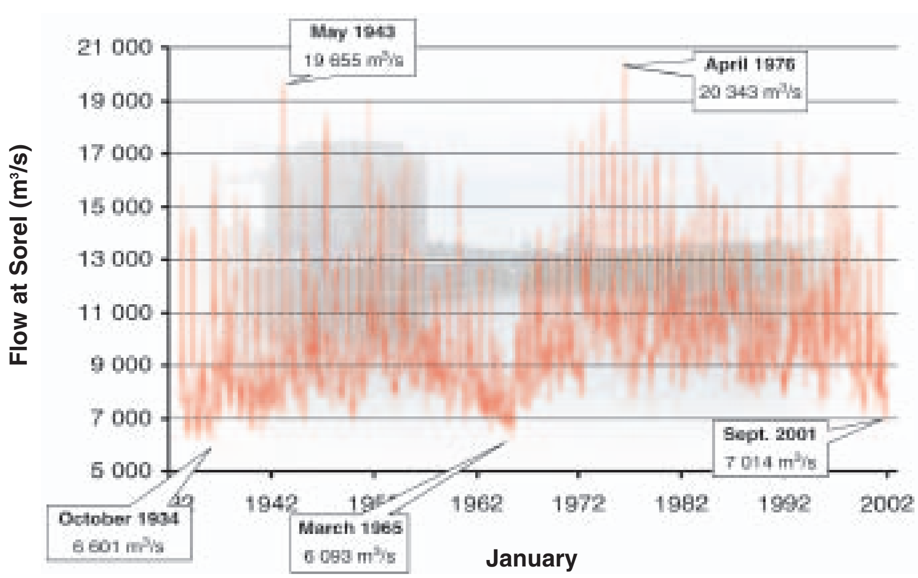
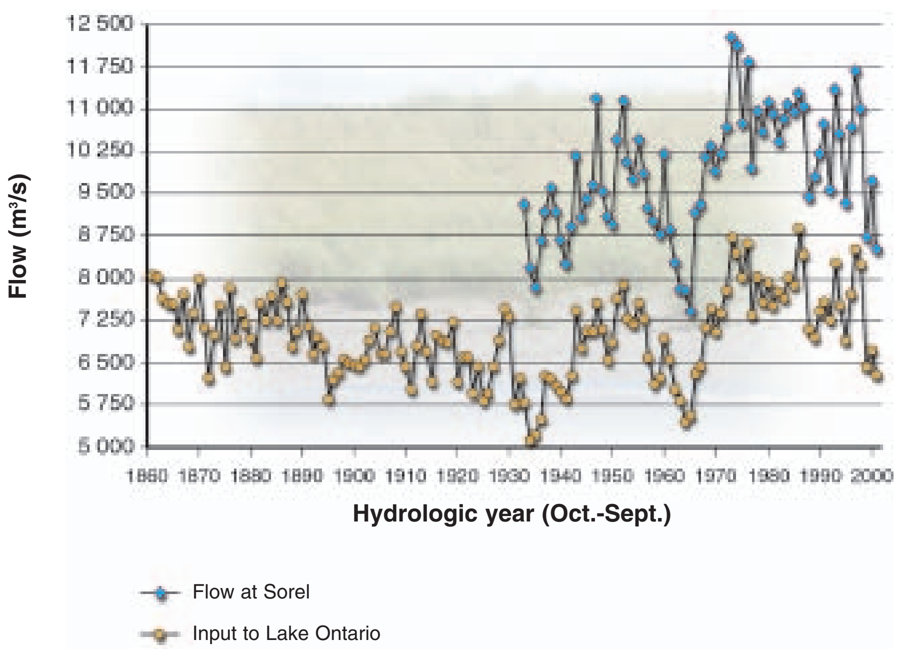


Figure 4 compares the series of annual average flows at Sorel for each hydrologic year (October to September) against the series of water-supply values to Lake Ontario. Annual rather than monthly flow values are used in order to filter out some of the effect of regulation, which becomes apparent if the latter are used. The series of flow values at Sorel is shorter than the series of water supplies for Lake Ontario because historical flow data are not available for the main tributaries of the river before 1930.

Flow values for the St. Lawrence at Sorel vary greatly from year to year and depend on year-to-year variations in water supplies to Lake Ontario, which in turn depend on climatic conditions. It is also noted that flow values — and associated levels — recorded during past periods of extremely low water levels reached values that were not seen during the recent low-water event of the summer of 2001. The Great Lakes–St. Lawrence system is therefore not currently setting records in terms of low hydraulicity. Although they are very low, values measured during the summer of 2001 are within the range seen within the last hundred years.

In recent decades, the pattern of flow in the St. Lawrence has changed drastically as a result of numerous human interventions, the impacts of which, whether local or more widespread, are directly reflected in water levels. The changes brought about are so significant that it becomes extremely difficult to make historical comparisons of flow before and after such interventions.

Figure 4. Average annual St. Lawrence River flow (October-to-December hydrologic year) at Sorel for 1932 to 2001, and water inputs to Lake Ontario from 1861 to 2001



Therefore, as an indicator of water quantity in the St. Lawrence, water level is still useful, but to a limited extent.

For example, use of the hydrometric station located in Montreal harbour by the International St. Lawrence River Board of Control for purposes of measuring the water level of the river is controversial. Work carried out in this portion of the channel to extend the shipping season and construct Notre-Dame Island for Expo 67 has had a critical impact, resulting in a radical change in the flow pattern. Because of this work, statisticians now compile historical data as of 1967, and the low levels recorded in the early 1930s and in 1964 and 1965 are not included in the statistical base. Their absence biases the results obtained when qualifying modern water-level observations by comparing them with historical values.

In concrete terms, this situation led to an incorrect reading of water level conditions in 2001: statistics announcing that the Great Lakes would fall

Photo: Meteorological Service of Canada

Examples of instruments used to measure water levels and calculate flow below their long-term average and that Montreal harbour would see record minimums. Therefore, in any document that deals with the state of flow in the Great Lakes–St. Lawrence system, it is important to indicate what period has been used to calculate water-level statistics for Montreal harbour and to explain why that period differs from the one used for statistical calculations of water levels in the Great Lakes and why two such sets of information are difficult to compare. By including information on water levels at other locations along the St. Lawrence River that are less affected by anthropogenic activities, a more realistic description could be provided of the flow conditions in the river.

Another means of mitigating the problem would be to use another indicator, i.e. streamflow. This indicator offers certain advantages in terms of describing the evolution of the flow regime in the St. Lawrence. Although its temporal distribution is affected by human interventions (regulation, engineering structures), flow constitutes a good indicator of water availability in the river and can be compared against chronological series that have been measured or generated by numerical modelling.

Engineering structures

Flow in the river is also affected by engineering structures. In addition to the construction of the Moses-Saunders, Beauharnois, Des Cèdres and Carillon dams as well as other regulating structures higher up in the watershed, a number of major projects were carried out in the fluvial portion during the 20th century. Dredging of the shipping channel, deposition of dredged materials, construction of weirs, bridges and tunnels, and the creation of Notre Dame Island opposite Montreal have altered the configuration of the river bottom and, as a result, the spatial distribution of water levels.

Moreover, winter maintenance of the waterway, including installation of booms to maintain navigability, has also changed the natural distribution of levels and flow, for example, by minimiz-

Photo: Environment Canada

Scirpus *sp. aquatic plant community in* Lake Saint-Pierre ing the frequency and extent of ice jams. Finally, water levels throughout the entire length of the river are affected by the growth of aquatic plants in summer and ice cover in winter, and by winds and the tidal signal.

Regulation of flow

The St. Lawrence is fed by two main regulated watersheds: the Great Lakes (Cornwall station) and the Ottawa River (Carillon station) (Figure 1). As a result, the flow at Cornwall varies generally between 6000 and 9000 m^3/s throughout the year (mean annual flow: 7060 m^3/s), whereas that of Carillon varies from 1000 to 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 flow for the river at Sorel calculated for the period from 1960 to 1997.

Regulation of flow has a stabilizing effect, minimizing extreme values, and typically results in a flow reduction in spring and an increase in the fall and winter. In general, flow is reduced in spring by as much as over 2000 m^3/s and increased between September and March by 300 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 power dams.

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

Although the typical impact of the regulation of flow seems considerable, in actual fact, the Great Lakes–St. Lawrence Regulation Office is much more limited in terms of its manoeuvring room in order to avoid the occurrence of extreme events. For example, during extended periods of low water availability, the level of the Great Lakes drops significantly, making it very difficult to make up for a downstream shortage of water without aggravating an already difficult situation upstream. The same is also true in the case of preventing flooding during high flow events in the system.

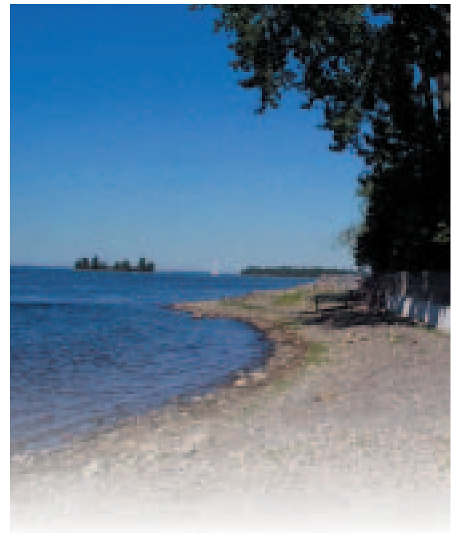
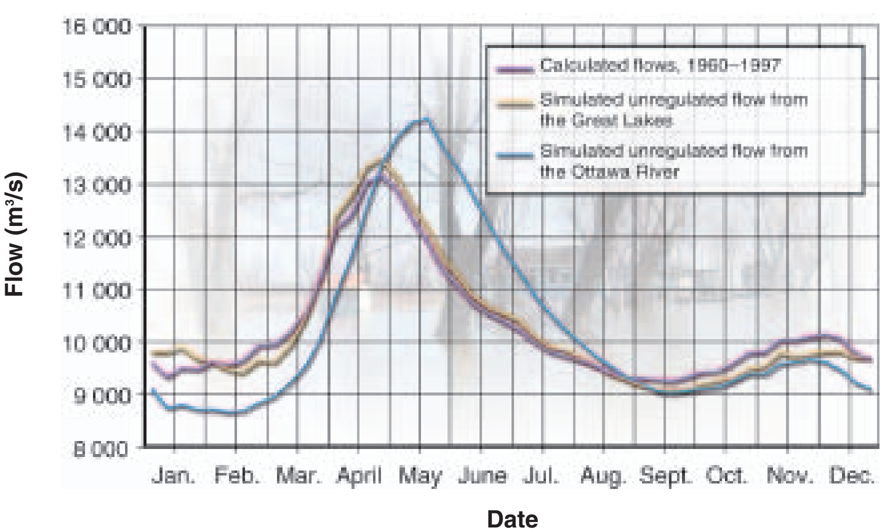


Photo: J.-F. Bibeault, St. Lawrence Centre

Protective structure on the banks of the Lachine riverside park (north shore of Lake Saint-Louis)

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



Outlook

In terms of a long-term prediction of the flow regime for the St. Lawrence River, based on the variations depicted in figures 3 and 4, flow — and associated water levels — can be expected to rise again in the coming decade. In fact, low-flow periods commonly alternate with periods of high flow.

Examples of instruments used to measure water levels and calculate flow

KEY VARIABLES

Two indicators, water level and flow, are used to monitor flow conditions in the river.

Water level is measured at each hydrometric station, whereas 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 the presence of a control section, are required in order to establish an unequivocal link between water level and flow. In the St. Lawrence, the last control section is located at LaSalle, near Montreal. Downstream of this point, the flow in the river must be estimated by adding the flow from tributaries and ungauged zones, a calculation which must also take into account upstream-to-downstream transit time.

There are certain limitations associated with the use of water level as an indicator. For example, anthropogenic modifications to river systems, including dredging, construction of islands, etc., have resulted in local changes in annual patterns of variations, which in turn complicates the use of the water level measurements. In addition, the usefulness of this indicator is limited by the fact that natural interference effects resulting from the wind, tidal signal, growth of aquatic plants and ice cover, are considered in its interpretation.

Conversely, use of the flow of the St. Lawrence at Sorel as an indicator offers a number of advantages because it incorporates the input from the main tributaries of the river, namely the Great Lakes and the Ottawa River, it is calculated at the mid-point of the fluvial portion of the system, and it does not incorporate the natural interference factors listed above. 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). As a result, this indicator can be used to obtain a comprehensive evaluation of the situation.

However, according to an international group of experts, the climate has warmed by 0.7°C in the past century, and precipitation has increased globally. Numerical models of climate change suggest that, in the next century, the North American continent will experience a warming of between 1°C and 7.5°C, depending on the scenario considered, and anticipated changes in precipitation are associated with very high margins of error.

In this regard, numerical models that simulate the impact of higher temperatures on evaporation of the Great Lakes — the main source of water for the St. Lawrence River — forecast declining water levels and flow for almost all 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.

Accordingly, it is extremely difficult to predict the hydraulic characteristics of 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, climate change scenarios call for a decrease in outflow from the Great Lakes in the coming century.

The Captain Neil Marina in Contrecoeur, in the fluvial section

Seasonal fluctuations are apparent in the time series of flow values for the St. Lawrence. The flow in the river is the product of a number of factors, the most significant being the quantity 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 hydraulicity for a time horizon of a few months.

Year-to-year, seasonal and monthly variations can be readily identified by analysing the flow in the river over recent years. Figure 6 shows, for example, that the years 1999 and 2001 were very similar (years of low hydraulicity), while the years 1997 and 1998 were marked by greater flow. The year 2000 was unique in that the freshet was not very pronounced and was followed by a second, late peak, and the remainder of the season resembled that of 1998.

Figure 6. Annual flow pattern in the St. Lawrence River at Sorel for 1997 to 2001

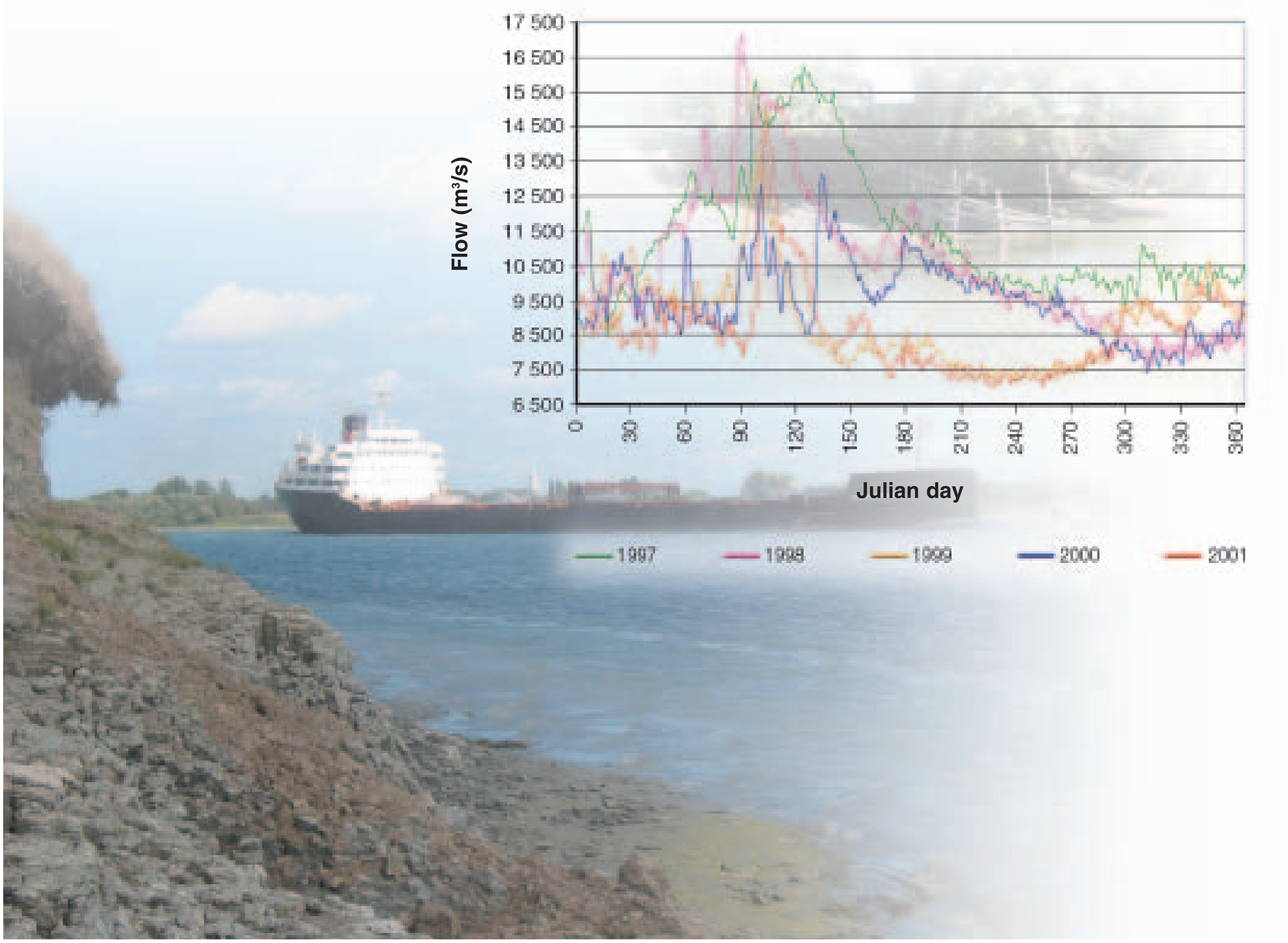


Photo: Environment Canada

Natural, exposed shoreline of Ile aux Boeufs in the shipping channel, Vercheres archipelago

To Know More

BOUCHARD, A. and J. MORIN. 2000. *Reconstitution des débits du fleuve Saint-Laurent entre 1932 et 1998*. Technical Report RT-101. Environment Canada, Meteorological Service of Canada, Hydrology Section.

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, J. J. 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Intergovermental Panel on Climate Change. Cambridge University Press, Cambridge, U.K.

MORIN, J. and A. BOUCHARD. 2000. *Background Information for the Modeling of the Montreal–Trois-Rivières River Reach*. Scientific Report SR-102. Environment Canada, Meteorological Service of Canada, Hydrology Section, Sainte-Foy. 55 pp.

Level News (Environment Canada):
http://www.on.ec.gc.ca/water/level-news/

Quebec Environment Ministry:
http://www.menv.gouv.qc.ca/indexA.htm

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

Ottawa River Regulation Planning Board:
http://www.ottawariver.ca/

Fisheries and Oceans Canada:
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/

Great Lakes–St. Lawrence Seaway System:
http://www.greatlakes-seaway.com/en/sitemap.html

Historical data (HYDAT):
http://www.msc-smc.ec.gc.ca/climate/hydat/index_e.cfm

Seasonal forecasts:
http://meteo.ec.gc.ca/saisons/index_e.html
http://www.meto.govt.uk/index.html
http://iri.ldeo.columbia.edu/

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Photo: Environment Canada

State of the St. Lawrence Monitoring Program

Four government partners — Environment Canada, the ministère de l'Environnement du Québec, the Société de la faune et des parcs du Québec, and Fisheries and Oceans Canada — are pooling their expertise and efforts to provide Canadians with information on the state of the St. Lawrence and long-term trends affecting it. To this end, environmental indicators have been developed on the basis of data collected as part of each organization's ongoing environmental monitoring activities. These activities cover the main components of the environment, namely water (quality and quantity), sediments, biological resources (species diversity and condition), uses and, eventually, shorelines.

For additional copies or the complete collection of fact sheets, contact the St. Lawrence Vision 2000 Coordination Office:

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P.O. Box 10 100
Sainte-Foy, Quebec G1V 4H5
Tel.: (418) 648-3444

The fact sheets and additional information about the program are also available on the Web site: **www.slv2000.qc.ca** .

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