Shoreline Erosion in Freshwater Areas

Photo: Germain Brault, Environment Canada

Monitoring erosion of St. Lawrence riverbanks

Background

Erosion is caused by natural and anthropogenic processes whereby soils are removed from streambanks, transported by currents in the form of fine particles and deposited further downstream. This sedimentary process is a fundamental aspect of the fluvial dynamics of the St. Lawrence River and all other major rivers in the world where shore recession is observed.

Photo: Louis-Filip Richard, Environment Canada

Shoreline erosion

The dynamics of sedimentary processes are the result of the action of a large number of physical, chemical and biological phenomena. Shoreline erosion along the freshwater reach of the St. Lawrence River is a natural phenomenon, but is exacerbated by human action. It occurs when the forces affecting shorelines (waves, freeze-thaw action, etc.) are stronger than the natural protection mechanisms (cohesion of clays, boulder size, presence of vegetation, slope type, etc.). According to recent studies, several mechanisms are simultaneously at play in the process of shoreline erosion.

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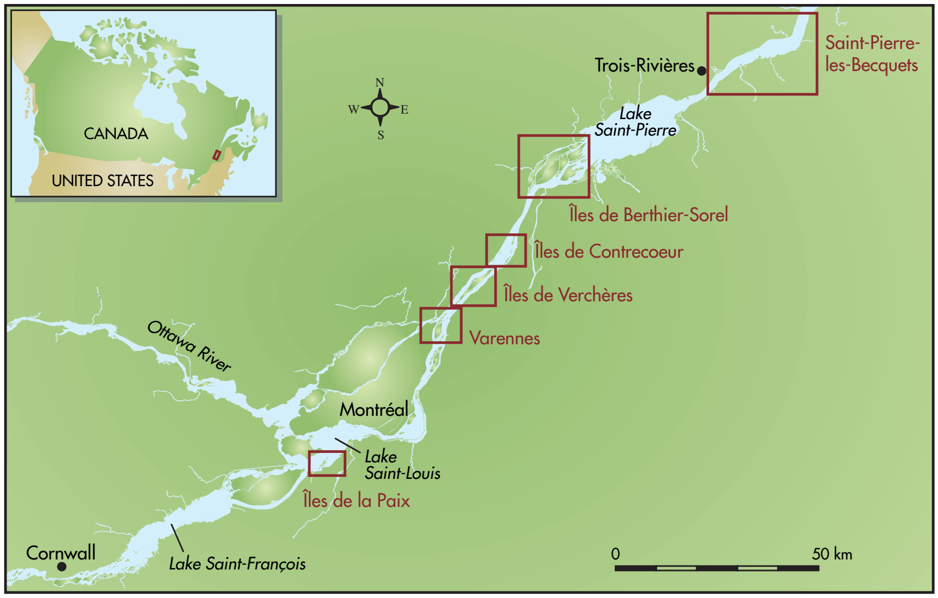
It is estimated that 440 km of the total of 1 600 km of freshwater shoreline of the St. Lawrence River between Cornwall and Montmagny are affected by erosion. In addition, 680 km of shoreline have been altered or developed over the last century by various projects.

During dredging operations in the St. Lawrence River, sediments have been deposited on islands or on the riverbed, enlarging existing shoals and islands and sometimes even creating new ones. These changes began in 1847 and continue today. Clays, which form most of the St. Lawrence shoreline, generally erode more easily and more quickly when disturbed by dredging because their cohesive forces are significantly reduced. One major project was the relocation of the section of the St. Lawrence Seaway shipping channel in the Berthier–Sorel islands between Île de Grâce and Île Saint-Ignace. It was relocated between Île des Barques and Île à la Pierre, resulting in the reconfiguration of this sector of the river.

Monitoring shoreline erosion is essential to assessing the state of the St. Lawrence and accurately determining the extent of shoreline recession, the mechanisms governing erosion, the sectors in which it occurs and the periods during which these phenomena are most likely to occur. Erosion monitoring is also important in that it provides decision-makers and local residents with useful information that guides efforts aimed at improving shoreline protection and the conservation of sensitive or significant sites.

Area covered by shoreline erosion monitoring



Shoreline erosion monitoring has been carried out since 1998 using a network of reference stakes. A network is comprised of more than 120 stations throughout the upstream section of the St. Lawrence River, between Lake Saint-Louis and Saint-Pierre-les-Becquets. Most of the stations are located in the Berthier–Sorel Islands sector, at the mouth of Lake Saint-Pierre, where there are a large number of recreational navigation channels. In addition, the islands bordering the shipping channel are subject to extensive shoreline erosion.

Communities along the river are actively involved in the monitoring effort. They are responsible for gathering part of the data recorded in the field. The stations are visited three times a year: in April after the ice has melted, in August and in November. This makes it possible to identify the phenomena that are more active than others, depending on water level, climate, etc.

Overview of the Situation

The results obtained to date suggest that navigation and water level fluctuations are determining factors in the rate of shoreline erosion. In the fall of 2000, the shipping industry implemented a voluntary speed reduction in three sensitive sections of the river. The rate of compliance with this measure is over 85%. However, the hydrological regime of the river cannot be controlled or predicted. From 1998 to 2002, average water levels were relatively constant, but in the last three years of monitoring, the regime has not been as constant, shedding light on the various mechanisms involved in shoreline erosion.

For example, in both the fall of 2006 and 2007, water levels were low, but the rise in water levels differed in the two years.

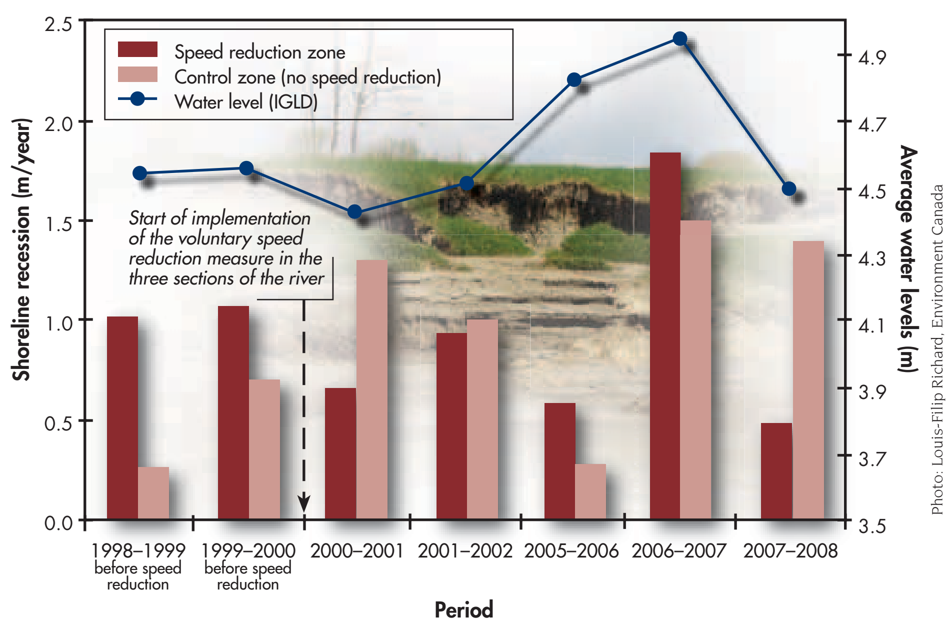
Analysis by Period

Shoreline erosion is not constant from year to year or from season to season. For example, for the period 2006–2007, average annual recession was 1.85 m and over 67% of the erosion occurred in winter (November to April). By comparison, in 2005–2006, average shoreline recession was only 0.59 m/year and the rate of erosion was constant throughout the period. In 2007–2008, average recession was even lower, at 0.49 m/year (Figure 1).

The very low water levels have had a major effect on shoreline recession. For example, from April 2007 to November 2007, water levels in the river were on average 35 cm lower than in the two previous years. Shoreline erosion was virtually non-existent, since the water did not reach the banks. In 2007–2008, the rate of recession was the lowest to date, at 0.49 m/year, 70% of which occurred in winter.

On the basis of the field observations, it is possible to confirm that during low water level episodes, terrestrial vegetation grows on the face of the bank, which is normally free of vegetation due to its exposure to wave action, which strips these portions of the shore. However, in 2006, vegetation was unable to grow or protect the shoreline because the low water level episode was not long enough and occurred in the fall. The clays had time to dry out before the water levels rose in November 2006, thus becoming more friable through erosion phenomena.

Figure 1 Variation in shoreline recession according to voluntary speed reduction zone and average water level



IGLD: International Great Lakes Datum.

Analyses for Sectors of Interest

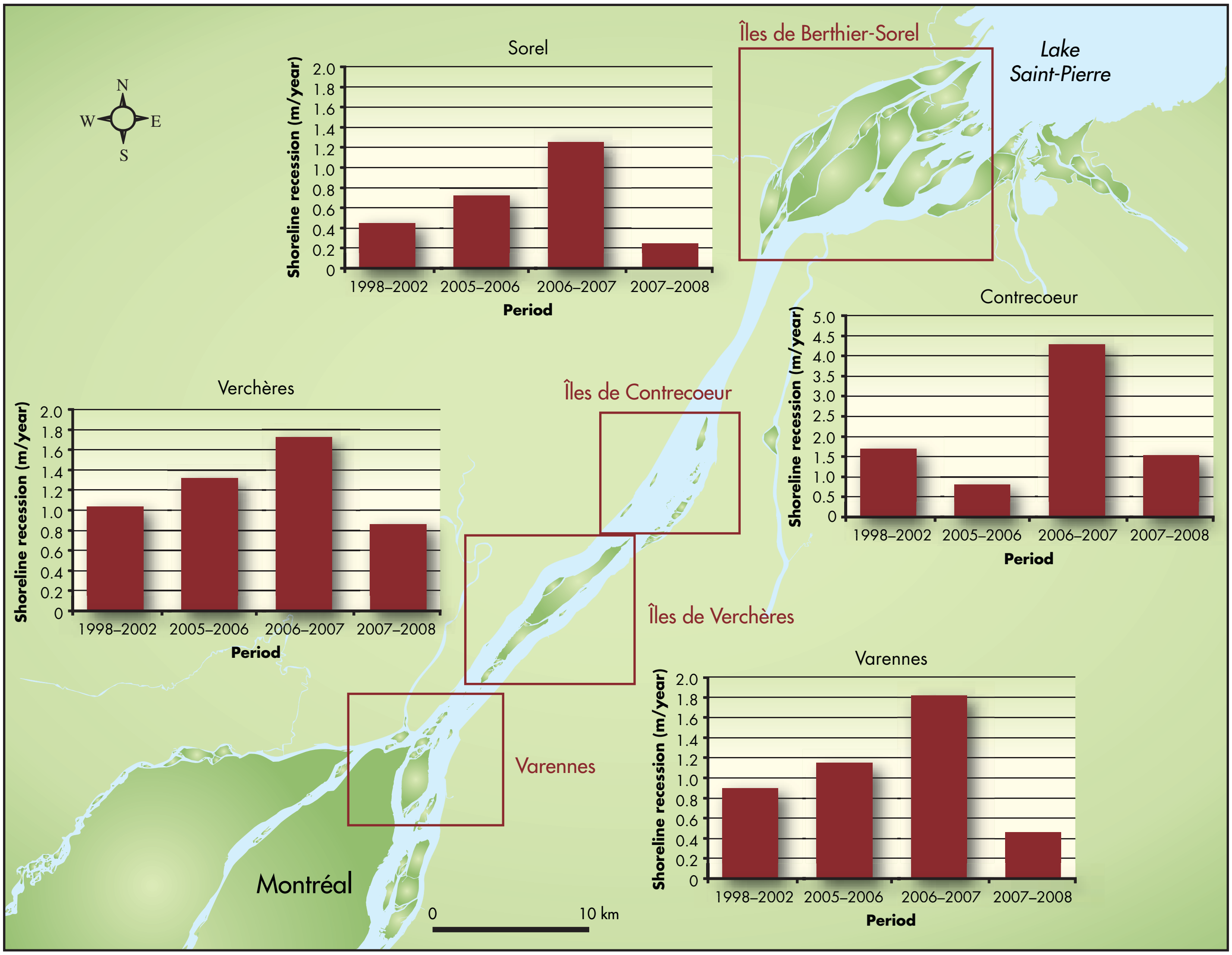
Of all the sectors undergoing significant shoreline recession, the Berthier–Sorel islands sector is a notable example. The islands, which are located in both sides of the shipping channel, are the most affected of all the sections studied.

Between 2005 and 2007, the rate of erosion in the northeast part of Île des Barques averaged 15 m/year. This significant rate of shoreline recession is largely due to the waves produced by winds sweeping across Lake Saint-Pierre, which have a larger fetch[1] at the downstream end than for the rest of the islands. A second possible explanation for the rate of erosion in this sector is the proximity of the shipping channel to the islands. This area is located 280 m from the shipping channel, and the configuration of the river at this location (shallow depth between the island and channel, shape of the island) is such that ship-generated waves are stronger at the downstream end of the island than at its centre.

In 2006–2007, all stations showed an increase in shoreline recession due to the rise in the river's water level except for the Île des Barques station, which recorded a slight decline (from 16.4 m/year to 13.5 m/year). This shows that for this sector, the winds on Lake Saint-Pierre are a greater determinant than water level fluctuations. In 2007–2008, erosion was only 3.84 m. This significant difference is the direct

1. **Fetch** is the distance a wind blows without interruption (ashore) over the ocean or other body of water, from where it begins on the water or from the shoreline from which it comes.

Figure 2 Shoreline recession by sector



result of the very low water levels. The decline in shoreline recession is even larger at the other Île des Barques stations, where the rate of erosion fell from over 6.0 m/year to less than 0.7 m/year.

Factors Affecting Erosion

There are several natural and anthropogenic causes of erosion (Table 1).

The main cause of shoreline erosion is water level fluctuations. They determine current velocities and dessication phenomena (drying of clays), and influence clay freeze-thaw cycles.

Water level fluctuations and effect on water quality

During long periods of low water levels, marine clays exposed to air dry out completely at the surface. When the water level rises, dispersion (deflocculation) of the clays occurs, which causes a significant increase in turbidity and in the concentration of suspended solids in the water.

At the Bécancour station, a very large increase in suspended solids was measured in the fall of 2006, during a rise in water levels that had been preceded by a long period of low water levels. The maximum suspended solids concentration was 275 mg/l,

Table 1 Main factors causing shoreline erosion in the fluvial sector

Natural factors	
Natural variations in water levels	
Currents	
Large waves generated by storms	
Runoff due to heavy rain or snow melt	
Nature of soil and slope of shoreline	
Dessiccation and deflocculation of clays	
Spring ice movements	
Freeze/thaw cycle	
Factors associated with human activities	
Variations in water levels caused by water control structures (dams, dikes, canals, etc.)	
Shoreline clearing	
Effect of waves generated by ships and pleasure craft	
Agriculture, grazing and tilling near shores	

Photo: Louis-Filip Richard, Environment Canada

measured when the water reached 5.5 m (IGLD). In the weeks that followed, the water level continued to increase, but the suspended solids concentrations did not increase in the same proportion as initially. The first increase in suspended solids concentrations was the result of the combined effect of deflocculation of clays and the increase in the current velocities near the shore. The subsequent increases in suspended solids concentrations reflected only the increase in velocity, since massive deflocculation did not reoccur. This likely explains why suspended solids concentrations increase to a lesser extent during subsequent rises in water level.

During the 2007 spring freshet, the maximum water level was 6.25 m and suspended solids concentrations measured at that time were 175 mg/l. However, shortly before the peak freshet, when the water level first peaked at 5.5 m, suspended solids concentrations totalled 200 mg/l.

These observations can be explained by the fact that clays are deflocculated as soon as the water level rises, resulting in a disproportionate increase in suspended solids concentrations. After the initial episode of deflocculation, the variations in concentrations are more closely tied to water level fluctuations.

Figure 3 illustrates the phenomenon of clay dispersion after a long drying period. It also more accurately identifies the periods during which water levels have an influence on the deflocculation episodes.

Ship-generated waves

Waves generated by commercial ships are often considered one of the main causes of shoreline erosion. Studies show that the velocity of currents near the shore increases from 20 cm/s to close to 100 cm/s following

Figure 3 Empirical model of the relationship between water level fluctuations and variations in suspended solids concentrations for 2006-2007

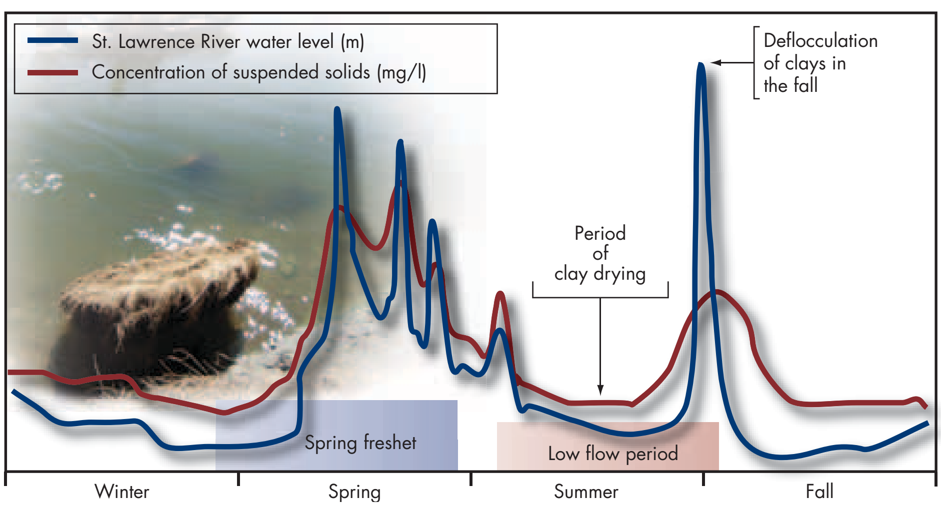
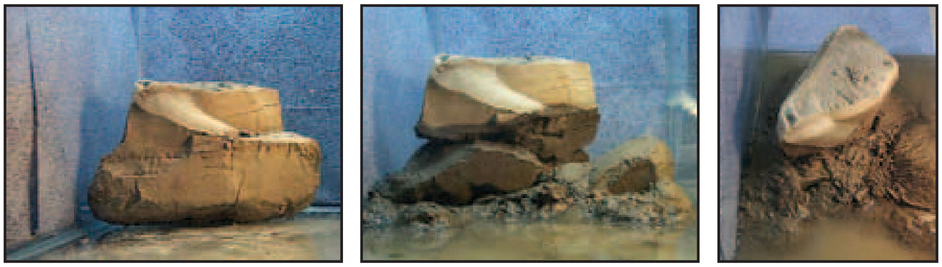


Photo: Louis-Filip Richard, Environment Canada

Deflocculation of a clay boulder in the presence of freshwater in the St. Lawrence



Time = 0 minutes Time = 60 minutes Time = 90 minutes

the passage of ships. In some cases, in addition to the increase in currents, breaking waves pound the shoreline. The results of tank trials show that Champlain clays are relatively resistant to increased wave velocity, but are much less resistant to breaking waves. When water levels are very low, waves do not reach the shore. The results show that the rate of erosion was lower in the areas targetted by the voluntary speed reduction program (in place since the fall of 2000), except in 2006–2007, when water levels were particularly high.

Cryogenic processes

Cryogenic processes, i.e., frost action and freeze-thaw action, create many disturbances in clay soils. At the time of the first fall frosts, fragments of clay soils fall to the base of the slope. In the spring, when daytime temperatures start to rise due to increased sunlight, water flows into cracks in the face of the clay riverbank. When the night temperature drops below 0°C, ice forms in the cracks. As the water freezes and expands, part of the face detaches and falls to the base of the slope. This phenomenon erodes the clay face, forming overhangs, where the roots retain surface soils. The clay face thus becomes smooth and vertical.

Bank covered with protective vegetation in the fall of 2007

Photo: Louis-Filip Richard, Environment Canada

Outlook

Since the fall of 2000, the shipping industry, in cooperation with the Navigation Coordination Committee, has implemented voluntary speed reductions in three sections of the river. Ship speed is monitored by Fisheries and Oceans Canada. Over 85% of the ships comply with this voluntary measure.

Recent years have shown that certain natural phenomena, such as water level fluctuations, can significantly increase shoreline recession. It is difficult to accurately predict such changes. With climate change, major variations in water levels can be expected, resulting in alternating periods of high and low erosion rates and pronounced effects on the entire St. Lawrence.

Through the expansion of the monitoring network, which was made possible by the collaboration of local partners, the processes that cause erosion will be better defined and monitored, specifically in locations such as Lac des Deux-Montagnes, and the sections of the St. Lawrence River between Portneuf and Quebec City and between Charny and Sainte-Croix de Lotbinière.

Photo: Germain Brault, Environment Canada

KEY MEASURES

Annual Shoreline Recession

Several techniques are available for measuring shoreline erosion. The technique used since 1998 by Environment Canada consists in installing reference stakes and simply measuring the distance between the stakes and the shoreline to obtain the total erosion for a given period.

Through the production of figures and maps for the various sectors and periods of the year, it is possible to differentiate between natural and anthropogenic causes of shoreline erosion and to identify critical periods.

By comparing seasonal observations of shoreline recessions, it is possible to guide actions, and through research, the various factors that affect shoreline erosion can be identified. By taking measurements in November immediately prior to freeze-up, during the spring freshet and at the end of August, the various factors involved in shoreline erosion can be more accurately identified. This technique has already shed light on the effect of cryogenic phenomena and deflocculation of clays.

To Know More

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Prepared by: Louis-Filip Richard
Science and Technology Branch
Environment Canada

Photo: Louis-Filip Richard, Environment Canada

State of the St. Lawrence Monitoring Program

Under the current Canada–Quebec agreement, the St. Lawrence Plan for a Sustainable Development, six government partners—Environment Canada, the Ministère du Développement durable, de l'Environnement et des Parcs du Québec, Fisheries and Oceans Canada, the Ministère des Ressources naturelles et de la Faune du Québec, the Canadian Space Agency, and the Parks Canada Agency—together with Stratégies Saint-Laurent, a non-governmental organization that works actively with riverside communities, are pooling their expertise to provide Canadians with information on the state of the St. Lawrence River at regular intervals.

To obtain the fact sheets and additional information about the State of the St. Lawrence Monitoring Program, please visit our website at:

www.planstlaurent.qc.ca

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