



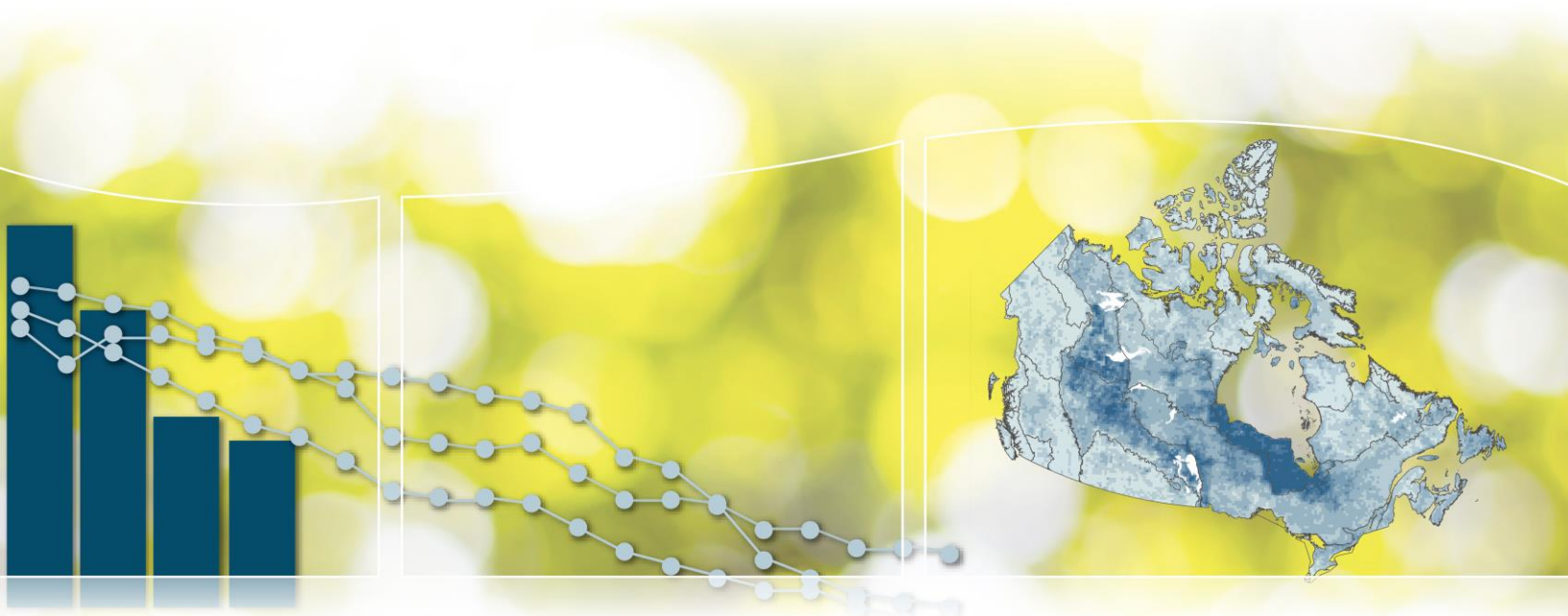
Environment and  
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# Canadian Environmental Sustainability Indicators

## Nutrients in the St. Lawrence River



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# Canadian Environmental Sustainability Indicators

## Nutrients in the St. Lawrence River

September 2016

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## **Part 1. Nutrients in the St. Lawrence River Indicator**

Phosphorus and nitrogen levels at the majority of water quality monitoring stations along the St. Lawrence River were above water quality guidelines more than 50% of the time during the 2012–2014 period. Higher phosphorus and nitrogen levels were found at stations next to agricultural areas along the south shore of the river between Richelieu and Bécancour.

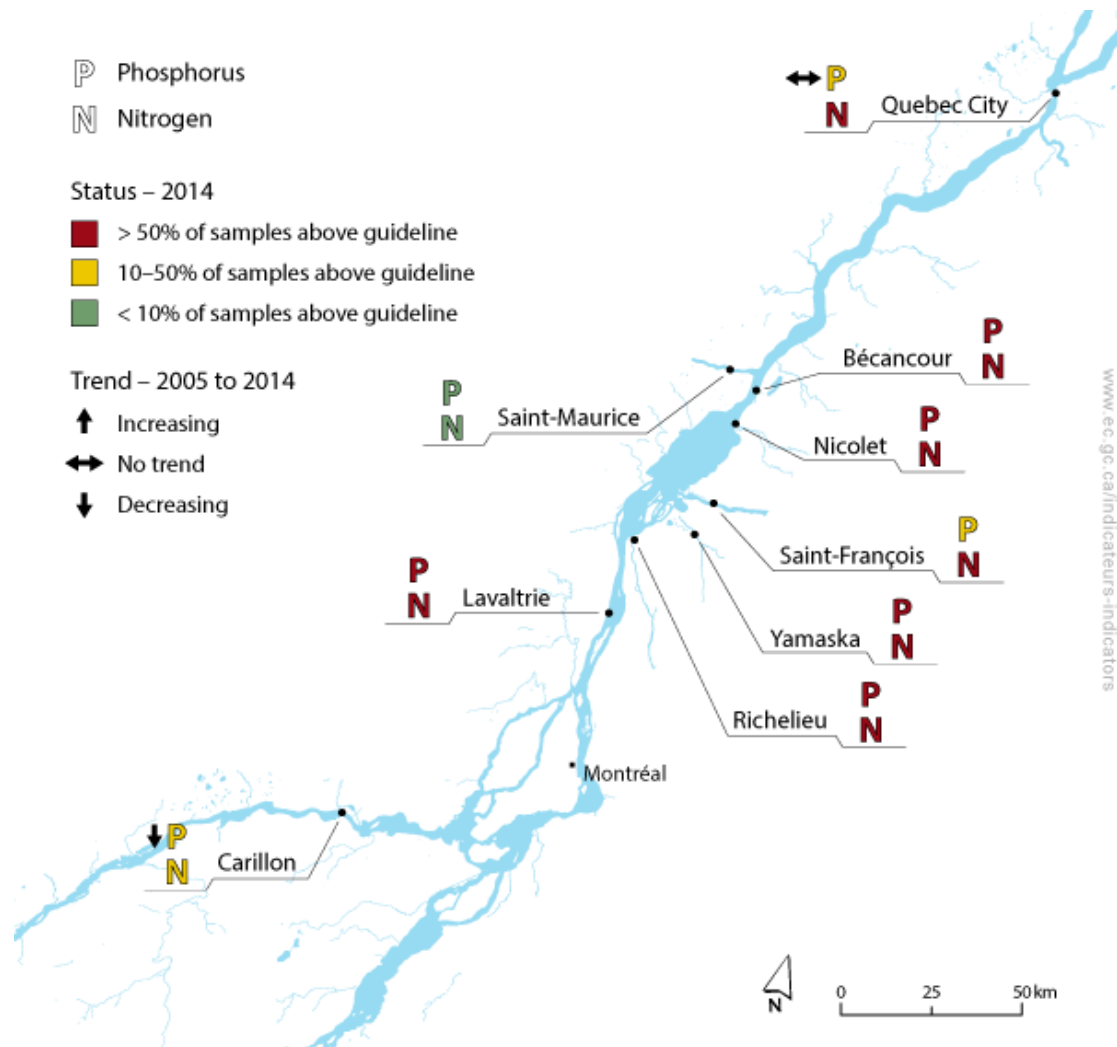
Compared with the 2010–2012 period, two monitoring stations saw their status in terms of phosphorus levels change:

- The status at Saint-François improved from > 50% of samples above the guideline to 10–50% above
- The status at Carillon deteriorated from < 10% of samples above the guideline to 10–50% above

For nitrogen, a more precise guideline of 0.63 milligrams per litre was established specifically for the St. Lawrence River in 2016. As a result, the water quality at seven stations appears to have changed, even though there were no changes in nitrogen levels over the same period. The change in the guideline value did not impact the nitrogen status at the Saint-Maurice or Yamaska stations.

Only the stations at Carillon and Quebec City have data for phosphorus starting in 2005, which allows for an assessment of trends. Phosphorus levels in water entering the St. Lawrence River at Carillon decreased between 2005 and 2014 and showed no trend at Quebec City over the same period.

**Figure 1. Status of total phosphorus and total nitrogen levels in the St. Lawrence River, Canada, 2012 to 2014, and total phosphorus level trends at Carillon and Quebec City, 2005 to 2014**



[Data for Figure 1](#)

**Note:** Water quality at a monitoring station is considered green when ambient water quality exceeds the guideline less than 10% of the time. A yellow status is applied when the guideline is exceeded 10–50% of the time. Red status is applied when exceedances occur in over 50% of samples. The status of total phosphorus and total nitrogen at water quality monitoring stations was determined by comparing water quality monitoring data to Quebec's total phosphorus water quality guideline of 0.03 milligrams of phosphorus per litre (mg P/L)<sup>1</sup> and total nitrogen water quality guideline of 0.63 milligrams of nitrogen per litre (mg N/L). The nitrogen guideline was changed from 1 mg N/L to 0.63 mg N/L for this update; for more details about the water quality guidelines, please refer to [Part 2](#) of this report.

**Source:** St. Lawrence River Water Quality Monitoring and Surveillance Division (2015) Environment and Climate Change Canada.

<sup>1</sup> Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (2009) [Critères de qualité de l'eau de surface: phosphore total \(en P\)](#) (available in French only). Retrieved on April 28, 2016.

The St. Lawrence River links the Great Lakes with the Atlantic Ocean and is among the world's most important commercial waterways. It is a complex ecosystem that includes freshwater lakes and river reaches, a long estuary, and a salt-water gulf. Its many different habitats are home to a diverse range of plants, fish and animals.

Phosphorus and nitrogen levels in the St. Lawrence River are affected by a variety of human activities along the river. Just downstream of Montreal, at Lavaltrie, phosphorus and nitrogen levels exceeded the water quality guidelines because of the release of municipal wastewater into the river. Further along, tributary rivers draining agricultural regions bring more phosphorus and nitrogen with them from the chemical fertilizers and manure used to grow crops. Just upstream of Quebec City, water from tributary rivers draining the north shore have lower phosphorus and nitrogen levels because they run through a more forested area than the land on the south shore of the river. The cleaner water allows phosphorus and nitrogen levels in the water to decline to levels closer to the guidelines. Past Quebec City, the St. Lawrence River flows into the Gulf of the St. Lawrence, where the nitrogen and phosphorus levels contribute to harmful algal blooms.

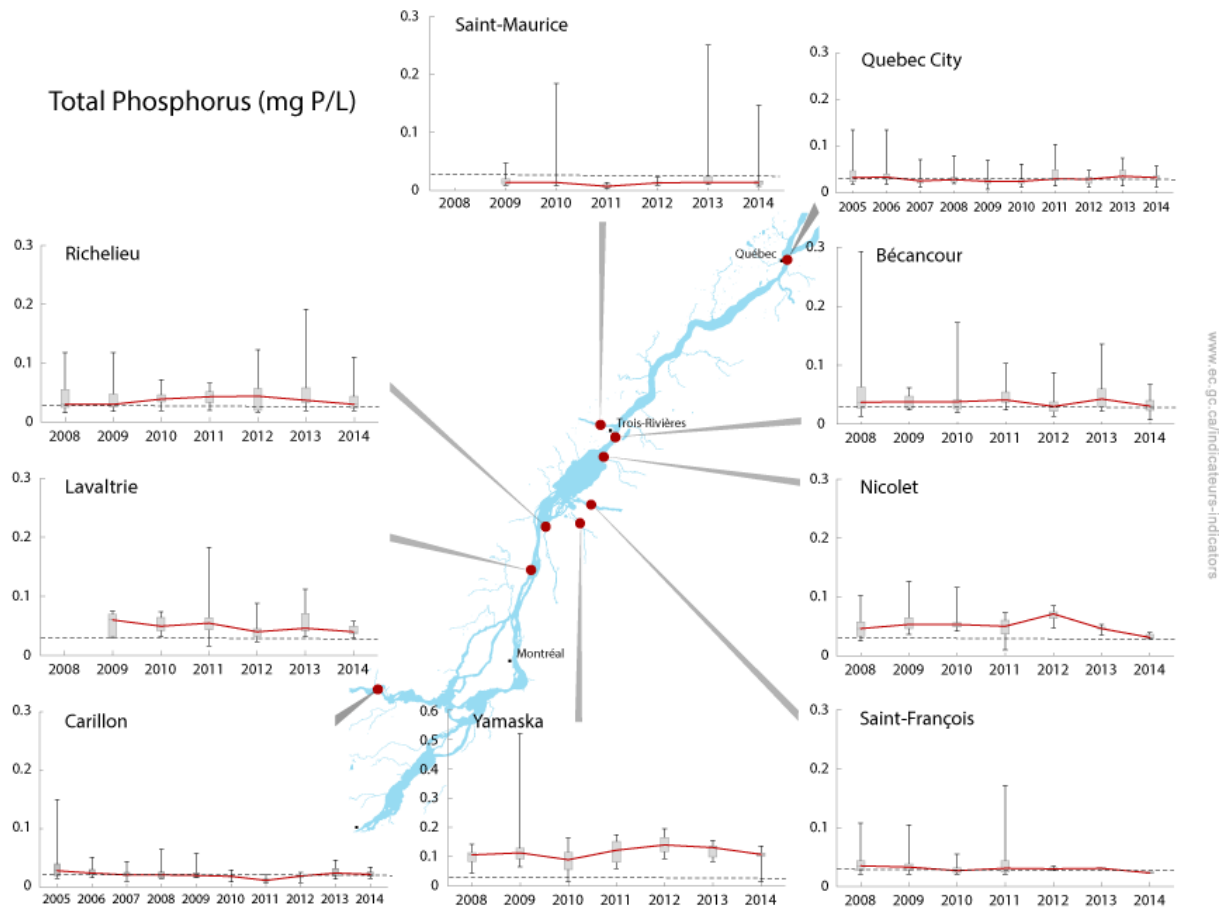
Phosphorus and nitrogen are key nutrients for plant growth in lakes and rivers. They are both naturally occurring and manufactured by human activity. Natural sources of phosphorus include weathering of rocks and decomposition of plants and animals. Nitrogen is added to the environment by bacteria that convert nitrogen gas in the air into forms plants can use for growth. Phosphorus and nitrogen from human activity enters the St. Lawrence River through municipal and industrial wastewaters, agricultural runoff, and air pollution. Problems arise when too much, or too little, nitrogen and phosphorus enters the environment. When phosphorus and nitrogen levels in water become too high, aquatic plant growth thrives and can cause excessive blooms. The decay of excess plant material can reduce the amount of oxygen available for fish and other aquatic animals. Further, high nutrient levels can also lead to harmful algal blooms, which can kill animals that use the water and affect human health.

## **Phosphorus levels by water quality monitoring stations**

Plotting phosphorus data for each station for each year provides a general view of how phosphorus levels are changing along the St. Lawrence River. Each boxplot summarizes annual phosphorus levels at a monitoring station and shows the range of values measured. The boxes are joined by a solid line (red) to give a sense of the direction of change in phosphorus levels over time.

Trend analysis can be performed for Carillon and Quebec City, where data are available from 2005. The analysis indicates a decreasing trend at Carillon, and no change at Quebec City. While this analysis cannot be performed for other stations, the available data suggest that phosphorus levels are slowly falling at the Saint-François station and are not changing at any of the other stations along the river.

**Figure 2. Annual total phosphorus boxplots for nine water quality monitoring stations along the St. Lawrence River**



[Data for Figure 2](#)

**Note:** The dotted line shows the guideline value of 0.03 mg P/L. The solid (red) line is drawn through the median to give a sense of the changes in concentrations over time. Only the Carillon and Quebec City stations have enough data for a seasonal Mann-Kendall trend analysis for phosphorus. Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May until the end of September only.

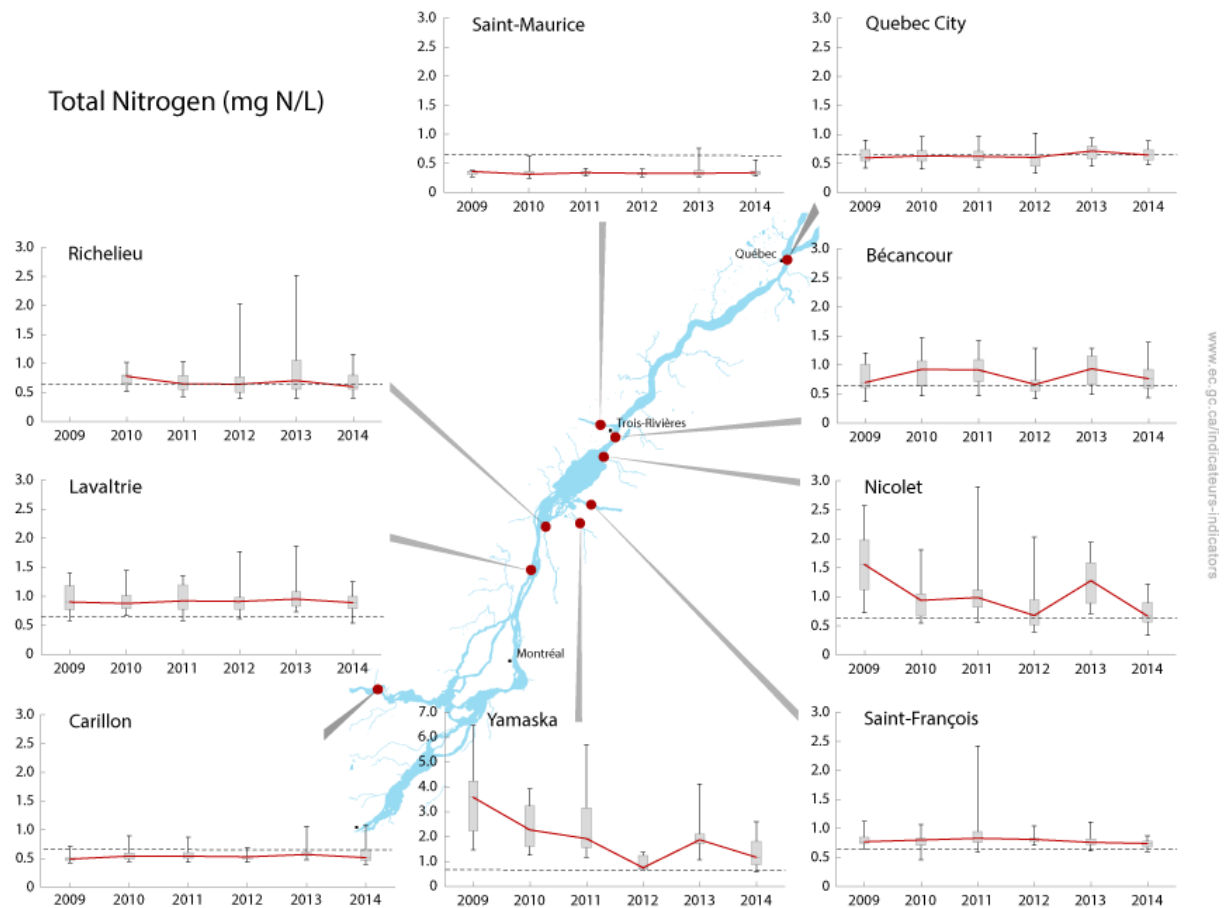
**Source:** St. Lawrence River Water Quality Monitoring and Surveillance Division (2015) Environment and Climate Change Canada.

## Nitrogen levels by water quality monitoring stations

Plotting nitrogen data for each station for each year provides a general view of how nitrogen levels are changing over time along the St. Lawrence River. Each boxplot below summarizes annual nitrogen levels for a monitoring station and shows the range of values measured. The boxes are joined by a solid line (red) to give a sense of the direction of change in nitrogen levels over time.

None of the stations have enough data to perform a trend analysis. However, the information available suggest nitrogen levels have declined at the Richelieu, Yamaska and Nicolet stations and are not changing at any of the other stations along the river.

**Figure 3. Annual total nitrogen boxplots for nine water quality monitoring stations along the St. Lawrence River**



[Data for Figure 3](#)

**Note:** The dotted line shows the guideline value of 0.63 mg N/L. The solid line (red) is drawn through the median to give a sense of trends in concentration. Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May until the end of September only.

**Source:** St. Lawrence River Water Quality Monitoring and Surveillance Division (2015) Environment and Climate Change Canada.



This indicator is used to measure progress towards [Target 3.5: St. Lawrence River – Take federal actions to reduce pollutants in order to improve water quality, conserve biodiversity and ensure beneficial uses in the St. Lawrence River by 2016](#) of the [Federal Sustainable Development Strategy 2013–2016](#).

## Part 2. Data Sources and Methods for the Nutrients in the St. Lawrence River Indicator

### Introduction

The [Nutrients in the St. Lawrence River](#) indicator is part of the [Canadian Environmental Sustainability Indicators](#) (CESI) program, which provides data and information to track Canada's performance on key environmental sustainability issues. This indicator is also used to measure progress towards the goals and targets of the [Federal Sustainable Development Strategy 2013–2016](#).

### Description and rationale of the Nutrients in the St. Lawrence River indicator

#### Description

The Nutrients in the St. Lawrence River indicator reports on the status of total phosphorus and total nitrogen concentrations along the St. Lawrence River. It rates total nitrogen and total phosphorus status based on whether total phosphorus and total nitrogen concentrations exceed Quebec's total phosphorus water quality guideline for the protection of aquatic life and a total nitrogen water quality guideline for the protection of aquatic life specific to the St. Lawrence River (see [Data source](#)). Exceeding a water quality guideline suggests a greater risk to the health of the St. Lawrence River ecosystem posed by phosphorus and/or nitrogen.

For the St. Lawrence River, water quality at a monitoring station is considered to be minimally impacted by nutrients from human activities when fewer than 10% of samples exceed the water quality guidelines for total phosphorus or total nitrogen, as indicated by a green symbol. When 10% to 50% of the samples exceed the guidelines, the waterways are considered more impaired with nutrients from human activity. This situation is denoted by a yellow symbol on the indicator map. If more than 50% of the samples exceed the guidelines, water quality is considered to be impacted by excessive nutrients and is represented by a red symbol.

Trends are also presented to illustrate how total phosphorus concentrations have changed since 2005 upstream of Montreal at the Carillon station and at the outlet of the river at Quebec City.

#### Rationale

Phosphorus and nitrogen are essential plant nutrients, but when concentrations in the environment are too high, or too low, they can cause harmful impacts on the river. Used in chemical fertilizers, phosphorus and nitrogen reach the river through erosion and leaching from urban areas, farmland runoff, municipal and industrial wastewaters, and air pollution. Over time, excess phosphorus and nitrogen in the river can alter its food web.

The Nutrients in the St. Lawrence River indicator assumes that water in the St. Lawrence River would rarely exceed water quality guidelines for phosphorus and nitrogen in the absence of human development. Thus, the indicator provides information about how human activity contributes to phosphorus and nitrogen concentrations in the river. The more often the water quality guidelines are exceeded, the greater the risk phosphorus and nitrogen pose to the health of the St. Lawrence River. Adding phosphorus trend analysis to the indicator provides information about how concentrations are changing over time. Ongoing tracking of phosphorus and nitrogen concentrations allows governments and citizens to remain aware of an important aspect of the environmental condition of the river.

In rivers, total phosphorus and total nitrogen concentrations will often exceed the guidelines when water levels are high, a situation that occurs most commonly when the snow melts in the spring. The 10% cut-off limit allows for one sample per year to exceed the guideline. Thus, a green designation means total phosphorus and nitrogen concentrations are minimally impacted by human development. In contrast, if more than 50% of the samples exceed the water quality guidelines, median total phosphorus and nitrogen concentrations are more consistently above the guidelines and water quality is being impaired by human activity.

### Recent changes to the indicator

The methodology for this indicator has been reviewed and updated since it was last published in 2014. Changes to the indicator include:

- A total nitrogen guideline for the protection of aquatic life for the St. Lawrence River was derived using a lines-of-evidence approach to replace the generic international value used in the previous report. The guideline was changed from 1 milligram of nitrogen per litre (mg N/L) to 0.63 mg N/L. Annex A provides information on the guideline selection. This change in the guideline resulted in what appears to be a large change in water quality along the St. Lawrence River. A comparison of the current data with the 1 mg N/L guideline used in the previous release shows no change in water quality due to nitrogen pollution at any of the stations, except the Saint-François station, where water quality improved.
- Total phosphorus trends are reported for the Carillon and Quebec City stations that met the trend data requirements (see [Trend Analysis](#)).

## Data

### Data source

Total phosphorus and total nitrogen data were provided by Environment and Climate Change Canada's Fresh Water Quality Monitoring and Surveillance program. The data can be found on Environment and Climate Change Canada's [Fresh Water Quality Monitoring and Surveillance Online data](#) website.

Quebec's provincial water quality guideline for total phosphorus is 0.03 milligrams of phosphorus per litre (mg P/L).<sup>2</sup>

Neither Quebec nor the Canadian Council of Ministers of the Environment (CCME) has a water quality guideline for total nitrogen. Accordingly, a total nitrogen guideline for the St. Lawrence River was derived following the CCME's [lines-of-evidence approach](#) (PDF; 1.9 MB). A total nitrogen guideline of 0.63 milligrams of nitrogen per litre (mg N/L) was selected based on the following evidence:

- The United States Environmental Protection Agency's (U.S. EPA) [ecoregional nutrient criteria](#) are empirically derived standards designed to represent surface waters conditions that are minimally impacted by human activities and protective of aquatic life and recreational uses. To derive these criteria, the U.S. EPA recommends using the 75th percentile of 10 years of monitoring data from reference, or low-impact, sites. In the absence of adequate reference data, the 25th percentile of all monitoring sites can be used. For the St. Lawrence River, these values are 0.60 mg N/L based on the 75th percentile of total nitrogen concentrations at Carillon station, the low-impact site. The 25th percentile of seasonal medians for total nitrogen for the four stations

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<sup>2</sup> Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (2009) [Critères de qualité de l'eau de surface : phosphore total \(en P\)](#) (available in French only). Retrieved on May 6, 2016.

on the St. Lawrence River (Carillon, Lavaltrie, Bécancour and Quebec City) is 0.65 mg N/L.

- An ideal performance standard<sup>3</sup> of 0.63 mg N/L for large rivers in the Mixedwood Plains ecozone was recommended during Environment Canada's National Agri-Environmental Standards Initiative; it was based on two lines of data analysis.<sup>4</sup> The first was to apply the U.S. EPA ecoregional nutrient criteria methodology to total nitrogen data from large rivers (drainage basin area  $\leq 10\,000\text{ km}^2$ ) across the ecozone. The second method was to explore relationships between total nitrogen and either benthic or sestonic algal biomass, expressed as chlorophyll *a*, using stepwise multiple linear regression on  $\log_{10}$ -transformed data.
- The U.S. EPA's recommended [criteria for total nitrogen for rivers and streams in Nutrient Ecoregion VII](#) (PDF; 331 KB) is 0.54 mg N/L, with a range of 0.46 to 1.88 mg N/L for Level III subregions. Nutrient Ecoregion VII includes the St. Lawrence Lowlands ecozone from Lake Ontario to just east of the Quebec–Ontario border. Similarly, the U.S. EPA [nutrient criteria for streams in Nutrient Ecoregion VIII](#) (PDF; 2.53 MB), which extends from just east of the Quebec–Ontario border to New Brunswick, is 0.38 mg N/L, with a range of 0.32–0.63 mg N/L.

See [Annex A](#) for more detail about how the total nitrogen guideline was derived.

### Spatial coverage

Data were obtained from nine water quality monitoring stations along the St. Lawrence River from the Quebec–Ontario border in the west to Quebec City in the east (Table 1). The stations are located so as to monitor the principal water sources entering the St. Lawrence River and are sometimes installed at the mouths of tributary rivers.

**Table 1. Water quality monitoring stations used for this indicator**

Monitoring Station	Station Code	Station Name	Longitude	Latitude
Carillon	QU02LB9001	Rivière des Outaouais, en aval du barrage de Carillon	-74.37987	45.56757
Lavaltrie	QU02OB9004	Fleuve Saint-Laurent, prise d'eau de l'usine de filtration de Lavaltrie	-73.280645	45.874418
Richelieu	QU02OJ0052	Rivière Richelieu, prise d'eau de l'usine de filtration de Sorel	-73.117582	46.033974
Yamaska	QU02OG3007	Rivière Yamaska, pont de la route 132	-72.910075	46.005059
Saint-François	QU02OF3004	Rivière Saint-François à Pierreville	-72.81218	46.066375

<sup>3</sup> An ideal performance standard is a long-term goal describing the desired level of environmental quality, which makes it comparable to a water quality guideline. It contrasts with an achievable performance standard, which describes environmental quality attainable using current technology.

<sup>4</sup> Chambers PA, Guy M, Dixit SS, Benoy GA, Brua RB, Culp JM, McGoldrick D, Upsdell BL, Vis C (2009) Nitrogen and Phosphorus Standards to Protect the Ecological Condition of Canadian Streams, Rivers and Coastal Waters. National Agri-Environmental Standards Initiative Synthesis Report No. 11. Environment Canada. Gatineau, Quebec. 79 p.

Monitoring Station	Station Code	Station Name	Longitude	Latitude
Nicolet	QU02OD3004	Rivière Nicolet à Nicolet	-72.651229	46.245373
Bécancour	QU02OD9009	Fleuve Saint-Laurent, prise d'eau de l'usine de filtration de Bécancour	-72.546012	46.311578
Saint-Maurice	QU02NG3013	Rivière Saint-Maurice, prise d'eau de l'usine de filtration de Trois-Rivières	-72.6105	46.382
Quebec City	QU02PH9024	Fleuve Saint-Laurent, prise d'eau de l'usine de filtration de Lévis	-71.190009	46.807123

### Temporal coverage

The total phosphorus and total nitrogen ratings reported in the indicator are based on measurements recorded between January 2012 and December 2014.

Total phosphorus data from January 2005 to December 2014 at the Carillon and Quebec City stations were used for trend analysis.

### Data completeness

The sampling frequency at the water quality monitoring stations included in this indicator is not uniform. Sampling at the Carillon, Lavaltrie, Richelieu, Bécancour, Saint-Maurice and Quebec City stations is conducted on a monthly basis. Samples at monitoring stations at the mouths of the Nicolet, Saint-François and Yamaska rivers are collected biweekly from May until the end of September. Gaps exist in the data due to program changes, weather and mechanical issues with the equipment used to collect the data.

### Data timeliness

The indicator was calculated using the most recent data available.

## Methods

### Calculation of phosphorus and nitrogen status for the St. Lawrence River

The phosphorus status at each of the nine water quality monitoring stations was computed by comparing total phosphorus concentrations with Quebec's total phosphorus water quality guideline for the protection of aquatic life of 0.03 milligrams of phosphorus per litre (mg P/L).<sup>5</sup> Similarly, the nitrogen status at each water quality monitoring station was determined by comparing the total nitrogen concentrations at each station to the St. Lawrence-specific total nitrogen water quality guideline for the protection of aquatic life of 0.63 milligrams of nitrogen per litre (mg N/L) (see [Annex A](#)).

The number of times total phosphorus and total nitrogen concentrations exceeded the guidelines were summed from 2012 to 2014, and the results were divided by the total number of samples collected over the same time period. The status of each station was determined by calculating the percentage of samples exceeding the guidelines. Stations with

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<sup>5</sup> Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (2009) [Critères de qualité de l'eau de surface : phosphore total \(en P\)](#) (available in French only). Retrieved on May 6, 2016.

fewer than 10% of samples exceeding the guidelines were given a green water quality status. Stations with 10 to 50% exceedances were given a yellow water quality status because phosphorus or nitrogen may be becoming a problem in these areas. Stations with more than 50% of samples exceeding the guidelines were given a red water quality status.

### Trend Analysis

The Seasonal Kendall test with Seasonal Kendall slope was used to test for the presence of a statistically significant increasing or decreasing trend in total phosphorus.<sup>6</sup> For this analysis, each month was designated as a season. To correct sampling frequency variation in the data, and to minimize analytical issues associated with serial correlation in the data, total phosphorus concentrations at approximately 30-day intervals were selected from the complete dataset. The analysis was run using the Kendall package within the R software environment.

With environmental trend analysis, the more data available, the more statistical power in the test. For a station to be included for trend analysis reporting, at least 10 years of monthly data were required. Total phosphorus concentrations are strongly correlated with the river's flow because high flows bring with them more suspended sediment with bound phosphorus.

Only two stations in the dataset, Carillon and Quebec City, meet the data requirements (Table 2).

**Table 2. Seasonal Kendall analysis output for Carillon and Quebec City for total phosphorus, 2005 to 2014**

Station	Parameter	Tau	Score	2-sided p-value	Seasonal Kendall slope
Carillon	Total phosphorus	-0.288	-148	0.000077	-0.00067
Quebec City	Total phosphorus	-0.047	-24	0.54	-0.00025

### Caveats and limitations

The Nutrients in the St. Lawrence River indicator reflects the state of water quality in the St. Lawrence River based on total phosphorus and total nitrogen concentrations. These concentrations do not show the effect of spills or other transient events unless they are frequent or long-lasting.

Caution must be exercised when comparing this indicator with similar indicators for lakes. In rivers, total phosphorus concentrations are influenced by suspended particles in the water that increase during high-flow events. Elevated total nitrogen concentrations result from high runoff due to precipitation, which washes nitrogen out of soils. This situation differs in lake ecosystems, as suspended particles generally settle out. However, it is still reasonable to compare lake and river systems as long as the methods used to determine the water quality classifications are clear.

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<sup>6</sup> Helsel DR and Hirsch RM (2002) Chapter 12 Trend Analysis in in [Statistical Methods in Water Resources Techniques of Water Resources Investigations](#). Book 4, chapter A3. US Geological Survey. 522 p. Retrieved on May 6, 2016.

## Part 3. Annexes

### Annex A. A total nitrogen guideline to protect the ecological condition of the St. Lawrence River

Neither the Quebec government nor the Canadian Council of Ministers of the Environment (CCME) has a water quality guideline for total nitrogen. In the previous version of this indicator, a water quality guideline for total nitrogen of 1 milligram of nitrogen per litre (mg N/L) was used. This value was chosen because it was consistent with the United States Environmental Protection Agency's (U.S. EPA) total nitrogen criteria for rivers and streams in Nutrient Ecoregion VII<sup>7</sup> and because it is an internationally accepted water quality guideline that has been adopted to prevent eutrophication.

Further research and analysis was performed following the lines-of-evidence approach outlined in the CCME [Guidance manual for developing nutrient guidelines for rivers and streams](#) (PDF; 1.95 MB). This approach recommends a number of consecutive steps to formulate a final guideline. A summary of the key steps followed to develop the guideline of 0.63 milligrams of nitrogen per litre (mg N/L) used for the calculation of the Nutrients in the St. Lawrence River indicator are set-out below.

It is important to note that this guideline has been designed for use in this indicator and may not include all possible data. Should an official total nitrogen guideline be developed for the St. Lawrence River, it will replace the guideline derived here.

#### Step 1. Definition of the area of interest

For the purpose of the indicator and the analysis performed, the St. Lawrence River is defined as extending from the Ontario–Quebec border in the west to Quebec City in the east.

##### Site Description

The St. Lawrence River is a very large river with a catchment area of 1 610 000 km<sup>2</sup>. It is situated in the St. Lawrence Lowlands ecoregion of the Mixedwood Plains ecozone. Most of the region is intensively cultivated farmland (60%) with dairy and mixed farming systems prevailing. Urban development is extensive. Intensive land use is increasing, with a trend toward rising nutrient loads to streams and rivers. The St. Lawrence Lowlands ecoregion has a humid, continental climate with very cold winters and very hot summers. Rivers in humid regions tend to have more water throughout the year.

The river was formed around the end of the Ice Age when the faults lead to the sinking of the area around the river (a rift valley), which was flooded with water from the Atlantic Ocean. It forms much of the southwestern outline of the Canadian Shield in Quebec.

#### Step 2. Establishment of the desired outcomes and selection of the guideline variables

The desired outcome of this guideline is to prevent eutrophication in the St. Lawrence River and the Gulf of St. Lawrence caused by total nitrogen.

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<sup>7</sup> United States Environmental Protection Agency (2000b) [Ecoregional Nutrient Criteria Documents for Rivers and Streams: Nutrient Ecoregion VII: Mostly Glaciated Dairy Region](#) (PDF; 331 KB). Report No. EPA-822-B-00-018. Retrieved on May 6, 2016.

### **Step 3. Classification of streams**

The St. Lawrence River is a very large river ecosystem. In such systems, the relationships between aquatic communities and nutrients may be confounded by physical factors that exert their influence temporally and spatially at the local scale, as well as along a continuum of river size from small streams to large rivers. Water quality in streams is more subject to sudden changes in hydrology than rivers, and plant and animal community abundance and composition varies with river size. For these reasons, separate standards to protect the ecological condition of rivers are necessary.

The river was not subdivided into separate subregions for this guideline derivation because of the need for a single value that would apply along the whole river to allow comparability among stations.

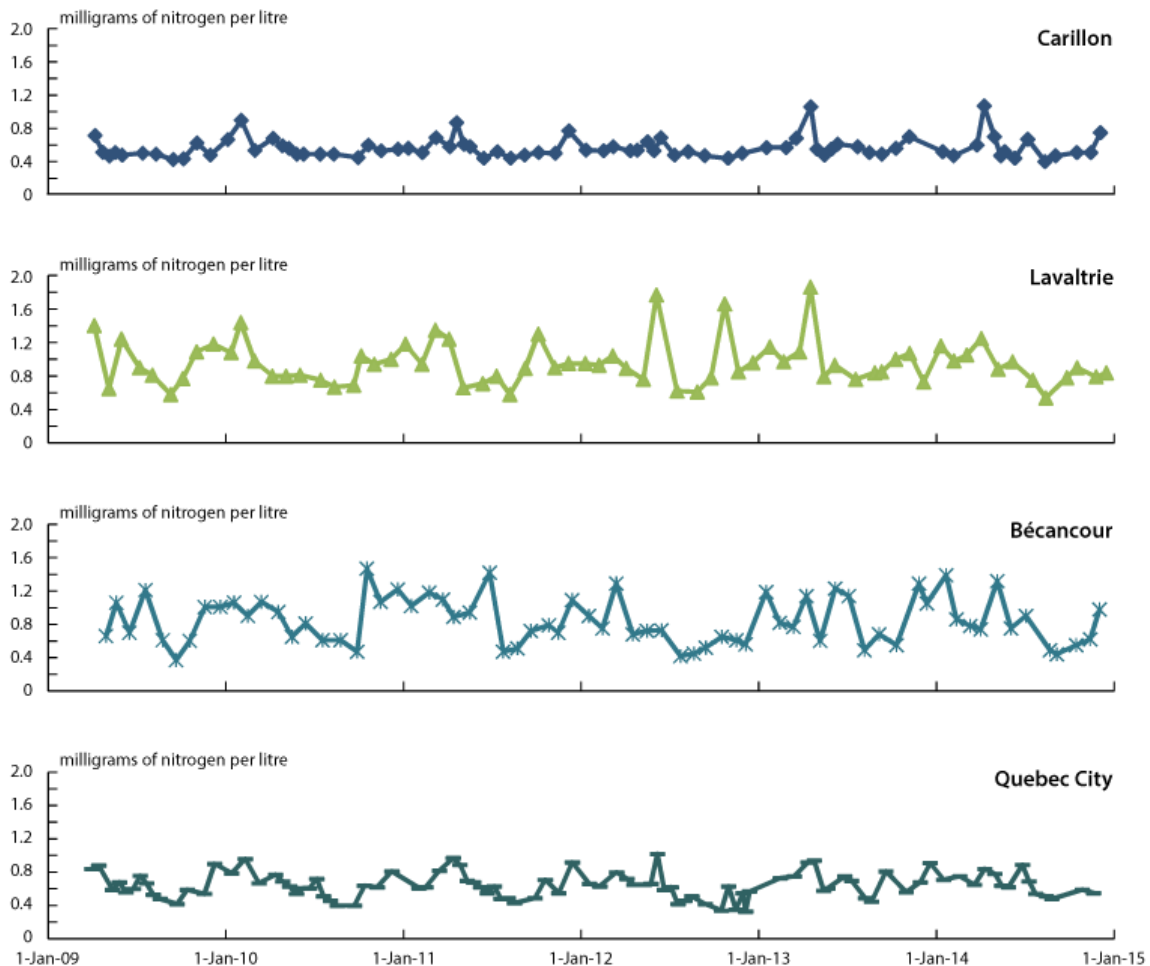
### **Step 4. Collection and analysis of data**

Total phosphorus and total nitrogen data were provided by Environment and Climate Change Canada's Fresh Water Quality Monitoring and Surveillance program. The data can be found on Environment and Climate Change Canada's [Fresh Water Quality Monitoring and Surveillance Online data](#) website.

Observed spatial patterns in the data:

- Total nitrogen concentrations in the river tend to be lowest in summer and highest in winter (Figure A.1; Table A.3).
- Total nitrogen concentrations increase from Carillon to Lavaltrie and then decrease to Bécancour and Quebec City (Figure A.1; Table A.3).
- Total nitrogen concentrations at Lavaltrie are influenced by the Region of Montreal's sewage outfall. At Bécancour, the influence of nitrogen inflow from tributaries draining the agricultural regions on the south shore of Lake Saint-Pierre can be seen (Figure A.1; Table A.3).

**Figure A.1. Total nitrogen data for four water quality monitoring stations on the St. Lawrence River (stations are ordered from Carillon in the west to Quebec City in the east)**



www.ec.gc.ca/indicateurs-indicators

### Step 5: Literature review

Existing suggested guidelines for the St. Lawrence River were found in the primary and grey literature. The following examples were the most applicable.

Chambers *et al.* 2009

Ideal performance standards for medium and large rivers draining agricultural regions in Canada were developed following two lines of data analysis. The first was to approximate background nutrient concentrations by calculating 25th percentiles for total phosphorus and total nitrogen following the U.S. EPA's nutrient criteria methodology (U.S. EPA 2000a). The second method was to explore relationships between total nitrogen and total phosphorus and either benthic or sestonic algal biomass expressed as chlorophyll *a* using stepwise multiple linear regression on  $\log_{10}$ -transformed data.

The results of the analysis produced a suggested total nitrogen guideline for large rivers in the Mixedwood Plains of 0.63 mg N/L. Chambers *et al.* also recommended ideal performance standards for total nitrogen for Prince Edward Island coastal waters of 0.100 mg N/L. This value is six times lower than the concentrations currently seen at Quebec City.

Caveats:

- Rivers with drainage basins larger than 10 000 km<sup>2</sup> were considered too large to be included in Chambers *et al.* (2009)'s analysis.
- The methods deviated from the U.S. EPA method by only using 25th percentiles for two reasons. First, given the amount of data in the freshwater database and the number of disparate sources of the data, they were not able to determine if a site could be considered reference or low-impact. Second, the data came from rivers draining agricultural areas, signifying that they are, by definition, impacted. They also deviated from the U.S. EPA method by analyzing data for large rivers collected for a 20-year period between 1985 and 2005 rather than the recommended 10-year period.

U.S. EPA 2000b

The U.S. EPA's ecoregional nutrient criteria are intended to address cultural eutrophication. The criteria, or guidelines, are empirically derived to represent surface waters conditions that are minimally impacted by human activities and protective of aquatic life and recreational uses.

This document contains the U.S. EPA's recommended criteria for total nitrogen for rivers and streams in Nutrient Ecoregion VII (Mostly Glaciated Dairy Region) derived following procedures described in U.S. EPA 2000a. Reference condition criteria are based on 25th percentiles of all nutrient data including a comparison of reference conditions for the aggregate ecoregion and the sub-ecoregions.

The results of the analysis produced suggested total nitrogen guidelines for the whole ecoregion, as well as the sub-ecoregions closest to the St. Lawrence River (Table A.1).

**Table A.1. Suggested total nitrogen guidelines for the United States Nutrient Ecoregion VII: Mostly Glaciated Dairy Region**

Name	Suggested total nitrogen guideline (milligrams of nitrogen per litre)
Aggregate ecoregion VII	0.54 (reported)
Aggregate ecoregion VII	0.54 (calculated)
Sub-ecoregion 83 – Eastern Great Lakes and Hudson Lowlands	0.48 (reported)
Sub-ecoregion 83 – Eastern Great Lakes and Hudson Lowlands	0.50 (calculated)

Caveats:

- Nutrient criteria are derived for wadeable streams in the U.S. only, which generally have basins much less than 10 000 km<sup>2</sup>.

U.S. EPA 2001

The analysis in U.S. EPA 2001 is the same as that in U.S. EPA 2000b, except that it encompasses Nutrient Ecoregion VIII (Nutrient Poor Largely Glaciated Upper Midwest and Northeast) (Table A.2).

**Table A.2. Suggested total nitrogen guidelines for the United States Nutrient Ecoregion VIII (Nutrient Poor Largely Glaciated Upper Midwest and Northeast)**

<b>Name</b>	<b>Suggested total nitrogen guideline (milligrams of nitrogen per litre)</b>
Aggregate ecoregion VIII	0.38 (reported)
Sub-ecoregion 58 – Northeastern Highlands	0.42 (reported)
Sub-ecoregion 58 – Northeastern Highlands	0.26 (calculated)

#### **Step 6. Collection and analysis of data**

The following guideline calculation techniques were applied to the data for the four St. Lawrence River water quality monitoring stations. The U.S. EPA recommends 10 years of data for its analysis; however, there are only 6 years of data available for the St. Lawrence River.

U.S. EPA 2000a

To derive nutrient criteria, the U.S. EPA recommends using the 75th percentile of 10 years of monitoring data from reference or low-impact sites. In the absence of adequate reference data, the 25th percentile of all monitoring sites can be used (Table A.3).

For the 25th percentile analysis for the St. Lawrence River, all total nitrogen data for each station were combined into a single median value for each season. The 25th percentile of all station medians was then calculated for each season (Table A.3). The median value from the four seasonal 25th percentile values is considered the standard. The output of this analysis produces a guideline of 0.65 mg N/L (Table A.4).

**Table A.3. Total nitrogen data summary for the St. Lawrence River**

<b>Season</b>	<b>Number of records for total nitrogen</b>	<b>Minimum (milligrams of nitrogen per litre)</b>	<b>25th percentile (milligrams of nitrogen per litre)</b>	<b>Median (milligrams of nitrogen per litre)</b>	<b>75th Percentile (milligrams of nitrogen per litre)</b>	<b>Maximum (milligrams of nitrogen per litre)</b>
<b>Carillon</b>						
Whole year	79	0.400	0.490	0.530	0.600	1.070
Spring	31	0.440	0.499	0.550	0.625	1.070
Summer	17	0.400	0.470	0.490	0.510	0.670
Fall	16	0.434	0.494	0.510	0.607	0.770
Winter	15	0.470	0.533	0.560	0.624	0.897

Season	Number of records for total nitrogen	Minimum (milligrams of nitrogen per litre)	25th percentile (milligrams of nitrogen per litre)	Median (milligrams of nitrogen per litre)	75th Percentile (milligrams of nitrogen per litre)	Maximum (milligrams of nitrogen per litre)
<b>Lavaltrie</b>						
Whole year	69	0.540	0.780	0.900	1.070	1.860
Spring	19	0.650	0.795	0.890	1.240	1.860
Summer	15	0.540	0.615	0.750	0.825	0.900
Fall	21	0.690	0.790	0.940	1.040	1.660
Winter	14	0.930	0.973	1.045	1.158	1.440
<b>Bécancour</b>						
Whole year	69	0.370	0.610	0.780	1.060	1.470
Spring	18	0.600	0.705	0.780	1.033	1.320
Summer	17	0.420	0.490	0.610	0.720	1.420
Fall	19	0.370	0.580	0.700	1.060	1.470
Winter	15	0.750	0.840	1.010	1.125	1.390
<b>Quebec City</b>						
Whole year	96	0.330	0.540	0.630	0.735	1.020
Spring	29	0.540	0.620	0.680	0.840	1.020
Summer	30	0.400	0.480	0.520	0.660	0.890
Fall	23	0.330	0.515	0.570	0.660	0.920
Winter	14	0.610	0.653	0.720	0.780	0.960
<b>Whole river</b>						
Whole year	313	0.330	0.540	0.670	0.890	1.860
Spring	97	0.440	0.590	0.690	0.890	1.860
Summer	79	0.400	0.480	0.540	0.695	1.420
Fall	79	0.330	0.550	0.680	0.915	1.660
Winter	58	0.470	0.653	0.810	1.018	1.440

**Table A.4. Twenty-fifth percentiles of seasonal means for each station along the St. Lawrence River as well as the all stations combined (whole river)**

Station Name	25th percentile of seasonal medians (milligrams of nitrogen per litre)
Carillon	0.505
Lavaltrie	0.855
Bécancour	0.678
Québec City	0.558
Whole river	0.645

The U.S. EPA also suggests using reference reaches to establish criteria. For this approach, it recommends using the 75th percentile of the nutrient frequency distribution for reference sites. As Carillon is the most upstream station, it can be considered the reference site for the dataset, even though it is technically not undisturbed water quality as it is situated at the mouth of the Ottawa River. Total nitrogen is at its lowest here until the water reaches Quebec City. The 75th percentile of Carillon's total nitrogen concentrations is 0.60 mg N/L (Table A.3).

#### Step 7. Establishment of guidelines

In the absence of more detailed analyses to assess the relationship between nitrogen and aquatic plant growth in the St. Lawrence River, the analysis presented here helps point toward a total nitrogen guideline. Assessing the values in the summary table, the values calculated using Canadian data for the area result in a total nitrogen guideline in the 0.60 to 0.65 mg N/L range (Table A.5). The mid-point of the range, 0.63 mg N/L, is the value used for calculation of the Nutrients in the St. Lawrence River indicator.

**Table A.5. Comparison of possible total nitrogen standards**

Guideline analysis reference	Recommended total nitrogen guideline (milligrams of nitrogen per litre)	Notes/Comments
<b>Calculated values</b>		
U.S. EPA 2000a	0.65	25th percentile of seasonal medians for all sites in an ecoregion
U.S. EPA 2000a	0.60	75th percentile of reference site (Carillon)
<b>Literature values</b>		
Chambers <i>et al.</i> 2009	0.63	For large rivers in the Mixedwood Plains Ecozone

<b>Guideline analysis reference</b>	<b>Recommended total nitrogen guideline (milligrams of nitrogen per litre)</b>	<b>Notes/Comments</b>
U.S. EPA 2000b	0.54	Streams in Aggregate ecoregion VII – Mostly Glaciated Dairy Region
U.S. EPA 2001	0.38	Streams in Aggregate ecoregion VIII – Nutrient Poor Largely Glaciated Upper Midwest and Northeast

## Annex B. Data tables for the figures presented in this document

**Table B.1. Data for Figure 1. Status of total phosphorus and total nitrogen levels in the St. Lawrence River, Canada, 2012 to 2014, and total phosphorus level trends at Carillon and Quebec City, 2005 to 2014**

Monitoring station	2012–2014 Total phosphorus guideline exceedance (percent)	Total phosphorus status	2012–2014 Total nitrogen guideline exceedance (percent)	Total nitrogen status	Trend 1995 to 2014
Carillon	20	Yellow	22	Yellow	Phosphorus levels are decreasing
Lavaltrie	89	Red	89	Red	n/a
Richelieu	65	Red	51	Red	n/a
Yamaska	96	Red	96	Red	n/a
Saint-François	44	Yellow	92	Red	n/a
Nicolet	84	Red	71	Red	n/a
Saint-Maurice	8	Green	3	Green	n/a
Bécancour	56	Red	65	Red	n/a
Quebec City	36	Yellow	52	Red	Phosphorus levels show no trend

**Note:** n/a = not available. Water quality at a monitoring station is considered green when ambient water quality exceeds the guideline less than 10% of the time. A yellow status is applied when the guideline is exceeded 10–50% of the time. Red status is applied when exceedances occur in over 50% of samples. The status of total phosphorus and total nitrogen at water quality monitoring stations was determined by comparing water quality monitoring data to Quebec's total phosphorus water quality guideline of 0.03 milligrams of phosphorus per litre (mg P/L)<sup>8</sup> and total nitrogen water quality guideline of 0.63 milligrams of nitrogen per litre (mg N/L). The nitrogen guideline was changed from 1 mg N/L to 0.63 mg N/L for this update; for more details about the water quality guidelines, please refer to [Part 2](#) of this report.

**Source:** St. Lawrence River Water Quality Monitoring and Surveillance Division (2015) Environment and Climate Change Canada.

<sup>8</sup> Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (2009) [Critères de qualité de l'eau de surface: phosphore total \(en P\)](#) (available in French only). Retrieved on April 28, 2016.

**Table B.2. Data for Figure 2. Annual total phosphorus boxplots for nine water quality monitoring stations along the St. Lawrence River**

<b>Monitoring station</b>	<b>Year</b>	<b>Median phosphorus level (milligrams of phosphorus per litre)</b>	<b>Minimum phosphorus level (milligrams of phosphorus per litre)</b>	<b>Maximum phosphorus level (milligrams of phosphorus per litre)</b>	<b>Number of samples</b>
Carillon	2005	0.028	0.018	0.150	23
Carillon	2006	0.024	0.016	0.051	20
Carillon	2007	0.021	0.010	0.044	20
Carillon	2008	0.021	0.015	0.065	14
Carillon	2009	0.020	0.016	0.058	17
Carillon	2010	0.019	0.009	0.030	14
Carillon	2011	0.012	0.008	0.021	14
Carillon	2012	0.019	0.008	0.025	14
Carillon	2013	0.024	0.014	0.046	13
Carillon	2014	0.022	0.015	0.034	14
Lavaltrie	2009	0.060	0.030	0.075	9
Lavaltrie	2010	0.050	0.032	0.074	12
Lavaltrie	2011	0.055	0.016	0.183	12
Lavaltrie	2012	0.040	0.023	0.088	12
Lavaltrie	2013	0.046	0.032	0.112	13
Lavaltrie	2014	0.040	0.030	0.058	12
Richelieu	2008	0.030	0.016	0.118	12
Richelieu	2009	0.030	0.018	0.118	10
Richelieu	2010	0.039	0.019	0.072	12
Richelieu	2011	0.043	0.020	0.066	12
Richelieu	2012	0.044	0.017	0.123	12
Richelieu	2013	0.037	0.019	0.192	13
Richelieu	2014	0.030	0.019	0.110	12

<b>Monitoring station</b>	<b>Year</b>	<b>Median phosphorus level (milligrams of phosphorus per litre)</b>	<b>Minimum phosphorus level (milligrams of phosphorus per litre)</b>	<b>Maximum phosphorus level (milligrams of phosphorus per litre)</b>	<b>Number of samples</b>
Yamaska	2008	0.106	0.044	0.143	19
Yamaska	2009	0.113	0.066	0.520	17
Yamaska	2010	0.090	0.015	0.164	18
Yamaska	2011	0.122	0.060	0.175	14
Yamaska	2012	0.140	0.093	0.195	7
Yamaska	2013	0.131	0.084	0.156	9
Yamaska	2014	0.108	0.015	0.136	9
Saint-François	2008	0.035	0.021	0.108	15
Saint-François	2009	0.033	0.021	0.105	15
Saint-François	2010	0.027	0.021	0.055	15
Saint-François	2011	0.031	0.021	0.172	14
Saint-François	2012	0.030	0.027	0.035	7
Saint-François	2013	0.031	0.025	0.064	9
Saint-François	2014	0.023	0.019	0.028	9
Nicolet	2008	0.046	0.025	0.102	15
Nicolet	2009	0.053	0.036	0.126	15
Nicolet	2010	0.053	0.042	0.116	15
Nicolet	2011	0.050	0.010	0.073	14
Nicolet	2012	0.071	0.047	0.085	7
Nicolet	2013	0.046	0.035	0.053	9
Nicolet	2014	0.031	0.029	0.039	9
Bécancour	2008	0.037	0.013	0.293	12
Bécancour	2009	0.038	0.024	0.062	12
Bécancour	2010	0.038	0.020	0.172	12
Bécancour	2011	0.041	0.024	0.103	12

Monitoring station	Year	Median phosphorus level (milligrams of phosphorus per litre)	Minimum phosphorus level (milligrams of phosphorus per litre)	Maximum phosphorus level (milligrams of phosphorus per litre)	Number of samples
Bécancour	2012	0.030	0.013	0.087	12
Bécancour	2013	0.043	0.022	0.136	12
Bécancour	2014	0.031	0.007	0.067	12
Saint-Maurice	2009	0.015	0.010	0.048	10
Saint-Maurice	2010	0.015	0.009	0.184	12
Saint-Maurice	2011	0.008	0.005	0.015	13
Saint-Maurice	2012	0.014	0.010	0.024	12
Saint-Maurice	2013	0.015	0.012	0.250	13
Saint-Maurice	2014	0.015	0.008	0.147	12
Quebec City	2005	0.033	0.019	0.135	16
Quebec City	2006	0.034	0.019	0.135	16
Quebec City	2007	0.026	0.013	0.072	18
Quebec City	2008	0.029	0.020	0.080	18
Quebec City	2009	0.025	0.008	0.070	17
Quebec City	2010	0.025	0.013	0.062	17
Quebec City	2011	0.030	0.015	0.104	17
Quebec City	2012	0.030	0.013	0.049	20
Quebec City	2013	0.036	0.015	0.075	15
Quebec City	2014	0.033	0.013	0.058	15

**Note:** Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May until the end of September only.

**Source:** St. Lawrence River Water Quality Monitoring and Surveillance Division (2015) Environment and Climate Change Canada.

**Table B.3. Data for Figure 3. Annual total nitrogen boxplots for nine water quality monitoring stations along the St. Lawrence River**

<b>Monitoring station</b>	<b>Year</b>	<b>Median nitrogen level (milligrams of nitrogen per litre)</b>	<b>Minimum nitrogen level (milligrams of nitrogen per litre)</b>	<b>Maximum nitrogen level (milligrams of nitrogen per litre)</b>	<b>Number of samples</b>
Carillon	2009	0.492	0.426	0.713	11
Carillon	2010	0.543	0.450	0.897	14
Carillon	2011	0.540	0.440	0.870	14
Carillon	2012	0.530	0.440	0.690	13
Carillon	2013	0.570	0.480	1.06	13
Carillon	2014	0.515	0.400	1.07	14
Lavaltrie	2009	0.900	0.580	1.40	9
Lavaltrie	2010	0.875	0.670	1.44	12
Lavaltrie	2011	0.920	0.580	1.35	12
Lavaltrie	2012	0.910	0.610	1.77	12
Lavaltrie	2013	0.950	0.730	1.86	12
Lavaltrie	2014	0.890	0.540	1.25	12
Richelieu	2010	0.780	0.520	1.02	9
Richelieu	2011	0.650	0.430	1.03	12
Richelieu	2012	0.645	0.400	2.03	12
Richelieu	2013	0.705	0.400	2.52	12
Richelieu	2014	0.600	0.410	1.16	12
Yamaska	2009	3.58	1.46	6.48	15
Yamaska	2010	2.27	1.25	3.91	15
Yamaska	2011	1.92	1.17	5.70	14
Yamaska	2012	0.750	0.660	1.37	7
Yamaska	2013	1.87	1.07	4.12	9
Yamaska	2014	1.17	0.570	2.60	9
Saint-François	2009	0.770	0.650	1.12	15

<b>Monitoring station</b>	<b>Year</b>	<b>Median nitrogen level (milligrams of nitrogen per litre)</b>	<b>Minimum nitrogen level (milligrams of nitrogen per litre)</b>	<b>Maximum nitrogen level (milligrams of nitrogen per litre)</b>	<b>Number of samples</b>
Saint-François	2010	0.800	0.460	1.07	15
Saint-François	2011	0.830	0.590	2.42	14
Saint-François	2012	0.810	0.710	1.04	7
Saint-François	2013	0.760	0.610	1.11	9
Saint-François	2014	0.740	0.600	0.87	9
Nicolet	2009	1.56	0.730	2.57	15
Nicolet	2010	0.940	0.550	1.81	15
Nicolet	2011	0.990	0.570	2.90	14
Nicolet	2012	0.680	0.400	2.03	16
Nicolet	2013	1.28	0.710	1.94	9
Nicolet	2014	0.670	0.340	1.22	9
Bécancour	2009	0.855	0.370	1.21	10
Bécancour	2010	0.925	0.470	1.47	12
Bécancour	2011	0.915	0.470	1.42	12
Bécancour	2012	0.665	0.420	1.29	12
Bécancour	2013	0.935	0.490	1.29	12
Bécancour	2014	0.765	0.440	1.39	12
Saint-Maurice	2009	0.360	0.270	0.380	9
Saint-Maurice	2010	0.315	0.243	0.630	12
Saint-Maurice	2011	0.340	0.290	0.417	13
Saint-Maurice	2012	0.330	0.270	0.400	12
Saint-Maurice	2013	0.330	0.270	0.760	13
Saint-Maurice	2014	0.340	0.280	0.560	12
Quebec City	2009	0.595	0.420	0.900	14
Quebec City	2010	0.630	0.400	0.960	17

Monitoring station	Year	Median nitrogen level (milligrams of nitrogen per litre)	Minimum nitrogen level (milligrams of nitrogen per litre)	Maximum nitrogen level (milligrams of nitrogen per litre)	Number of samples
Quebec City	2011	0.620	0.430	0.970	17
Quebec City	2012	0.605	0.330	1.02	20
Quebec City	2013	0.715	0.450	0.940	14
Quebec City	2014	0.645	0.480	0.890	14

**Note:** Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May until the end of September only.

**Source:** St. Lawrence River Water Quality Monitoring and Surveillance Division (2015) Environment and Climate Change Canada.

## Annex C. References and additional information

### References and further reading

Canadian Council of Ministers of the Environment (2016) [Guidance manual for developing nutrient guidelines for rivers and streams](#) (PDF; 1.95 MB). Retrieved on May 6, 2016.

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United States Environmental Protection Agency (2001) [Ecoregional Nutrient Criteria Documents for Rivers and Streams: Nutrient Ecoregion VIII: Nutrient-poor, Largely Glaciated Upper Midwest and Northeast](#) (PDF; 2.53 MB). Report No. EPA-822-B-01-015. Retrieved on May 6, 2016.

### Related information

[Local Freshwater Quality in Canada](#)

More information about [water quality on the St. Lawrence River](#) can be found in the Canadian Environmental Sustainability Indicators mapping application.

[Nutrients in Lake Winnipeg](#)

[Phosphorus Levels in the Great Lakes](#)

[Regional Freshwater Quality in Canadian Rivers](#)

**[www.ec.gc.ca](http://www.ec.gc.ca)**

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