Environment and Climate Change Canada
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PHOSPHORUS LOADING TO LAKE ERIE

CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

Canada

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Environment and Climate Change Canada
Public Inquiries Centre
12th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 819-938-3860
Toll Free: 1-800-668-6767 (in Canada only)
Email: ec.enviroinfo.ec@ec.gc.ca

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PHOSPHORUS LOADING TO LAKE ERIE

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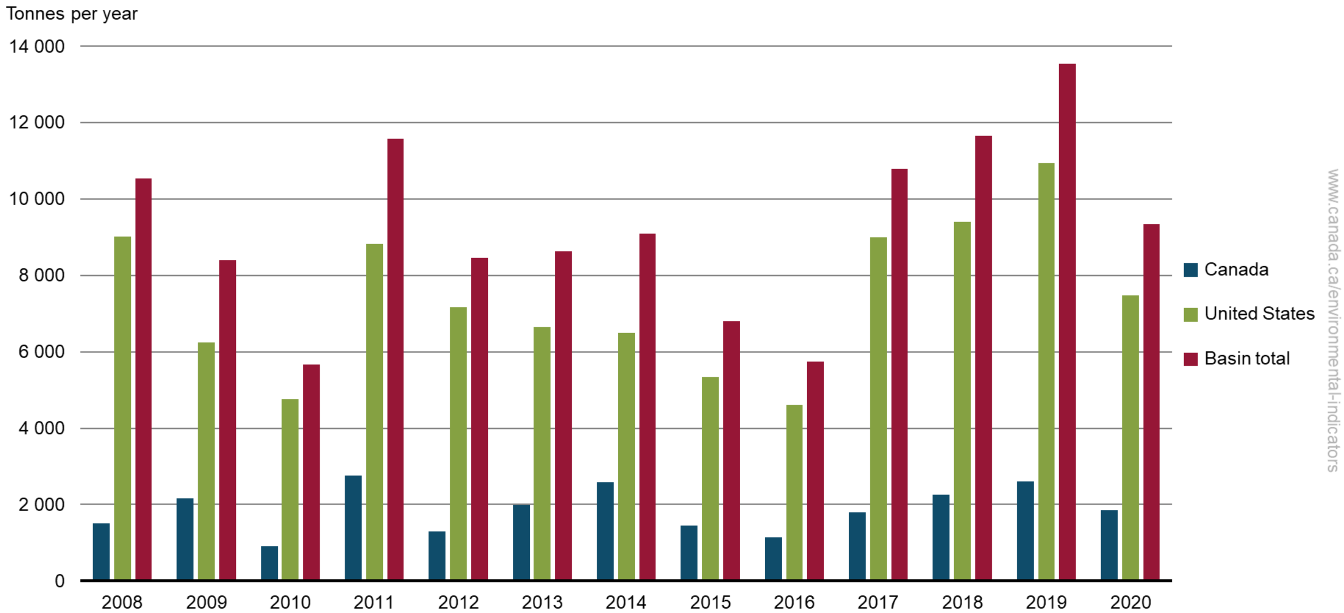
Phosphorus loading to Lake Erie

Phosphorus is an essential plant nutrient. However, when phosphorus levels are too high, they can have harmful impacts on the health of a lake. High phosphorus levels in Lake Erie are leading to degraded water quality, algal blooms and zones of low oxygen which harm aquatic life. These indicators report on the amount of phosphorus reaching Lake Erie, known as phosphorus loading.

Key results

- In 2020, total estimated phosphorus loading to Lake Erie was 9 336 tonnes, with 20% (1 849 tonnes) of the total load estimated to be from Canada
- Phosphorus loading varies between years mostly due to precipitation and snowmelt levels, which drive the amount of runoff from surrounding lands

Figure 1. Total estimated phosphorus loading to Lake Erie, 2008 to 2020



Data for Figure 1

Note: Basin total values include loadings from runoff and tributaries in Canada and the United States, flows from Lake Huron and atmospheric sources of phosphorus. Half of the total phosphorus loadings from atmospheric sources and half of those from Lake Huron were allocated to each country.
Source: Environment and Climate Change Canada (2021).

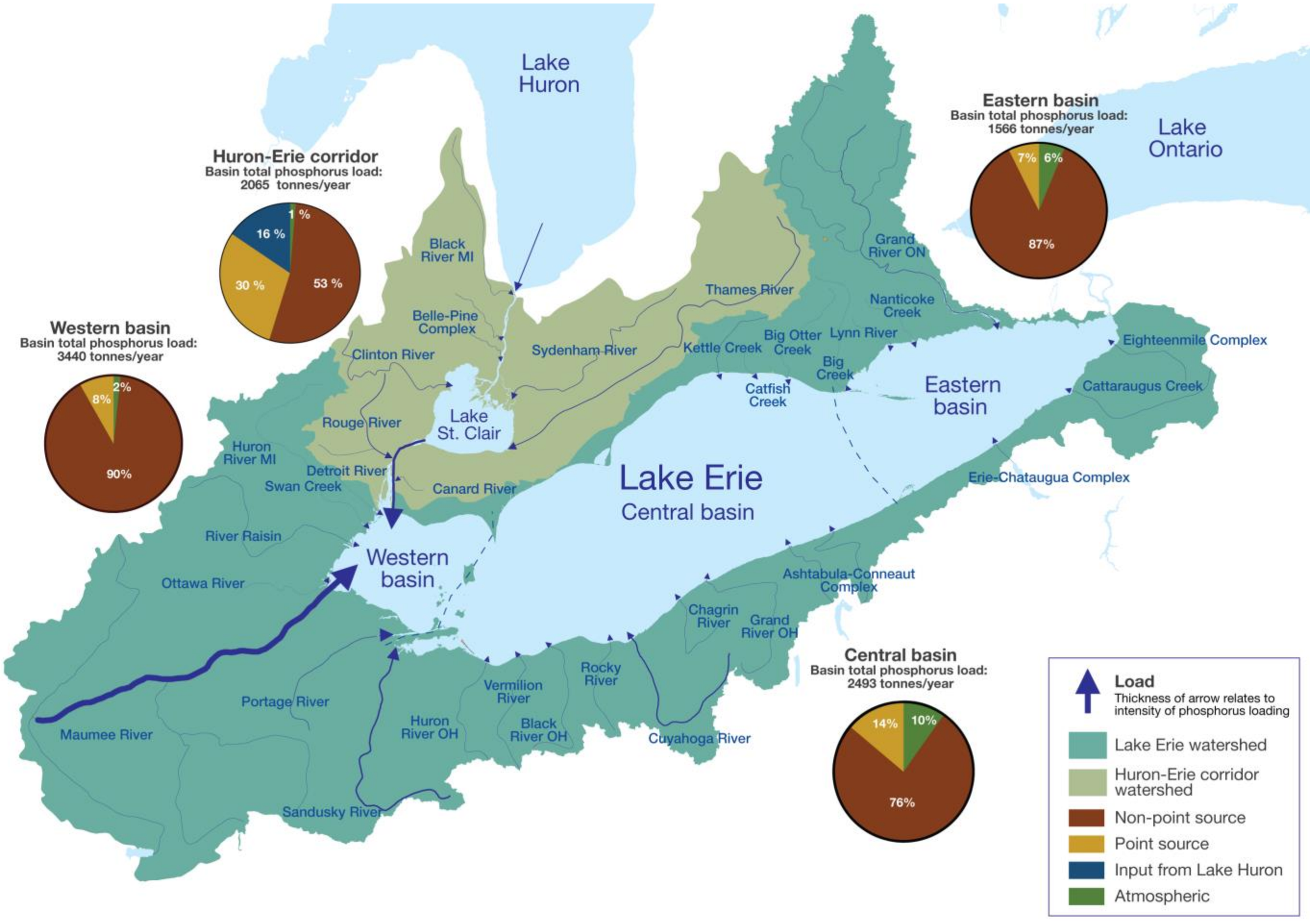
Phosphorus loading varies year to year due mainly to climatic factors. Dry years in the region will lead to low levels of runoff from surrounding lands and less phosphorus being washed into the lake and tributaries feeding the lake.

In 2020, phosphorous loading to Lake Erie from all sources within Canada and the United States (9 336 tonnes) was relatively average compared to the last 12 years, and similar to loads in 2014 (9 092 tonnes) and 2013 (8 634 tonnes). Canada's contribution fluctuated over the period from a low of 903 tonnes in 2010 to a high of 2 758 tonnes in 2011. The year 2011 was marked by record high precipitation in the Lake Erie basin[1], leading to increased phosphorus loading through runoff from surrounding lands.

[1] Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (2019) Coordinating Committee Products and datasets. Great Lakes Coordinated Precipitation 1900-2017. Retrieved on September 15, 2021.

Lake Erie is the shallowest, warmest and most productive of the 5 Great Lakes. The lake is divided into 3 sub-basins: western (the shallowest), central (the largest) and eastern (the deepest). More than 50% of phosphorus enters the lake from either the Detroit River or the western basin tributaries. Figure 2 shows that non-point sources, such as agriculture and, to a much lesser extent, urban storm water runoff, are the largest contributors of phosphorus loads to Lake Erie, particularly in the western basin of the lake, where algae impacts are greatest.

Figure 2. Annual 10 year average phosphorus loading estimated in tonnes to Lake Erie, 2011 to 2020



Data for Figure 2

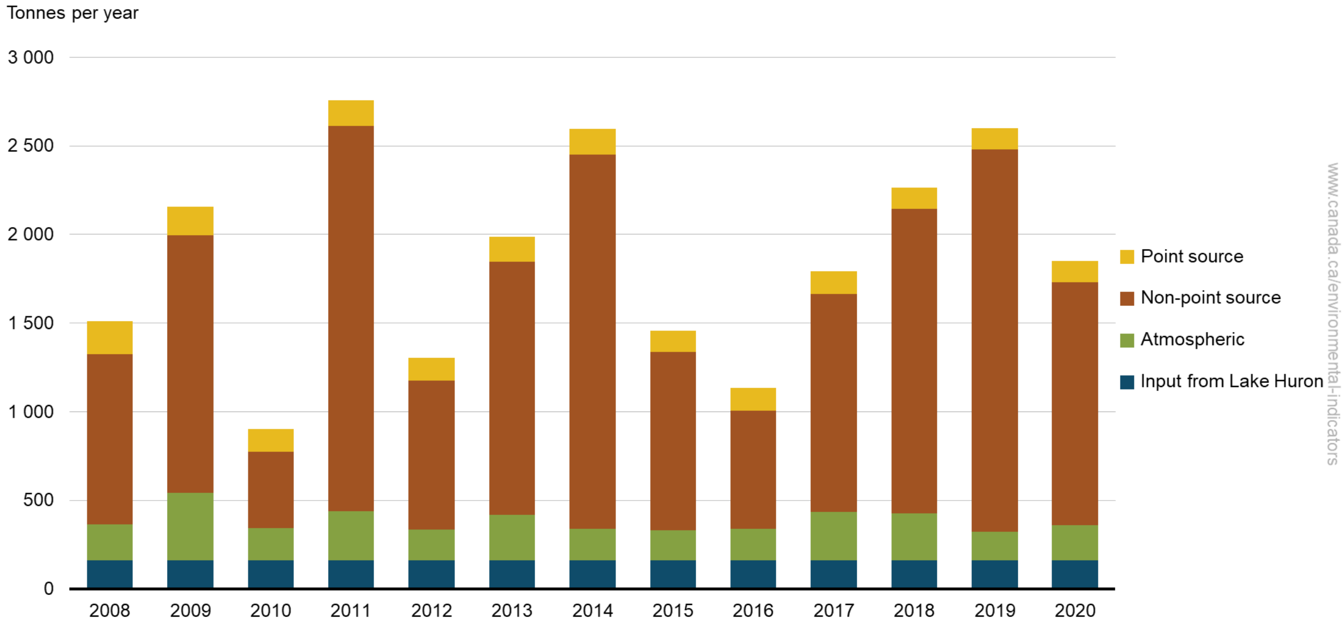
Note: Point source includes municipal sewage treatment plant effluent and industrial effluent. Non-point source includes agriculture and urban storm water runoff. Atmospheric deposition refers to phosphorus being deposited directly to the lake from the air. The Huron-Erie corridor watershed includes input from Lake Huron, point and non-point sources and atmospheric deposition within the watershed.
Source: Environment and Climate Change Canada (2021).

Phosphorus loading to Lake Erie from Canadian sources

Key results

- Phosphorus loading to Lake Erie comes mainly from non-point sources such as agriculture and urban storm water runoff
- Non-point sources accounted for 74% of the phosphorus loading in 2020 compared to the high of 83% in 2019 and the low of 47% in 2010[2]
- Phosphorus loading from non-point sources is highly variable from year to year and is greater during wetter years than in drier years

Figure 3. Phosphorus loading estimates to Lake Erie by source, Canada, 2008 to 2020



Data for Figure 3

Note: The total phosphorous loadings from atmospheric sources and from Lake Huron were halved to roughly estimate the Canadian contributions. Loadings from Lake Huron are estimates generated through models. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2021).

Point sources include municipal sewage treatment plant effluent and industrial effluent. These are sources of phosphorus that can be identified as a single source such as an effluent pipe going into a water body.

Non-point sources are diffuse sources of pollution and include agriculture and urban storm water runoff. Non-point sources of phosphorus are mostly in the form of excess fertilizer and manure spread on the ground. Runoff from rainfall or snowmelt picks up and carries these pollutants, and deposits them into lakes and rivers.

Phosphorus loading from non-point sources was lowest in 2010, 2012 and 2016 which coincides with low precipitation years in the Lake Erie basin.[3]

[2] Lake Huron is excluded from these percentages as an estimate of point sources versus non-point sources is not available for that watershed.

[3] Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (2019) Coordinating Committee Products and datasets. Great Lakes Coordinated Precipitation 1900-2017. Retrieved on September 15, 2021.

About the indicators

What the indicators measure

The Phosphorus loading to Lake Erie indicators report on the total phosphorus loadings flowing directly into Lake Erie or from its tributary rivers and includes loads from:

- atmospheric deposition
- point sources (for example, wastewater treatment plants)
- non-point sources (primarily from agriculture runoff)
- Lake Huron

In the absence of human development, natural background levels of phosphorus loading are relatively low. The indicators provide information about the amount of phosphorus flowing into Lake Erie mainly due to human activity.

Why these indicators are important

Clean freshwater is an essential resource. It protects aquatic plant and animal biodiversity. We use it for manufacturing, energy production, irrigation, swimming, boating, fishing and for domestic use (for example, drinking, washing). Degraded water quality damages the health of all freshwater ecosystems, such as rivers, lakes, reservoirs and wetlands. It can also disrupt fisheries, tourism and agriculture, and makes it more expensive to treat to meet drinking water standards. When phosphorus levels in water become too high, algal growth and certain types of bacteria associated with them, called cyanobacteria, can become excessive and harmful. Cyanobacteria can release substances that can harm, and in some cases kill animals that depend on the water. The decay of the excess algae and bacteria can also reduce the amount of oxygen available for fish and other aquatic animals. They can also affect human health, if humans are exposed to them.

Although this is not the case in Lake Erie, some lake ecosystems can have the opposite problem: too little phosphorus can result in not enough plant or algal growth to support a lake's food web, which could reduce fish populations and impact local fisheries.

Through the Canada–US Great Lakes Water Quality Agreement, Canada and the United States have agreed to reduce phosphorus loads entering the western and central basin of Lake Erie by 40% from 2008 levels in order to reduce the extent of harmful and nuisance algal blooms and zones of depleted oxygen (hypoxia), to protect water quality and ecosystem health. For Canada, this means a reduction in phosphorus loads by 212 tonnes per year. Studies are under way to support the development of a target for the eastern basin of Lake Erie.

These indicators are used to provide information about the state of the Lake Erie basin and the Canadian environment.

Pristine lakes and rivers

These indicators track progress on the 2019 to 2022 Federal Sustainable Development Strategy, supporting the target: Achieve and maintain a 40% reduction in annual phosphorus loading into Lake Erie from a 2008 baseline to meet the binational (Canada-US) phosphorus targets.

Several more years of data are necessary to detect a definite overall trend in phosphorus loading that accommodates for variations in climate from year to year.

Related indicators

The Phosphorus levels in the offshore waters of the Canadian Great Lakes, the Nutrients in Lake Winnipeg and the Nutrients in the St. Lawrence River indicators report the status of total phosphorus and total nitrogen levels.

The Water quality in Canadian rivers indicators provide a measure of the ability of river water across Canada to support plants and animals.

The Household use of chemical pesticides and fertilizers indicator reports on how many people in Canada use pesticides and fertilizers on their lawns and gardens.

Data sources and methods

Data sources

The data used in these indicators are from both Canadian and American sources, at the provincial/state and federal levels.

More information

Data on phosphorus loading are derived from a number of Canadian and American sources:

- Canadian sources
  - Environment and Climate Change Canada
  - Ontario Ministry of Environment, Conservation and Parks
- American sources
  - United States Geological Survey
  - Heidelberg University
  - Michigan Department of Environmental Quality
  - Ohio Environmental Protection Agency
  - United States Environmental Protection Agency

The data are of various types, including point source discharges (for example, municipal sewage treatment plant effluent or industrial effluent), hydrologic flow, tributary water quality and atmospheric deposition. Tributary water quality includes data from sampling sites at 10 Canadian tributaries (the Thames, Sydenham, Grand, Turkey, Big, Big Otter, Lynn, Kettle, Canard, and Nanticoke). Data are associated with Lake Erie's 3 basins: western, central and eastern. The data allow for the specification of the general geographic origin of point source and non-point sources. The geographic origin is not specified for atmospheric deposition and input from Lake Huron and, for these sources, an equal allocation to the United States and Canada was used as an approximation.

Detailed data files are available through the Government of Canada's Open Data Portal.

Methods

Data on point source discharges, atmospheric deposition and non-point sources (calculated using water flows and water quality data) are used to estimate phosphorus loading to Lake Erie.

More information

Phosphorus loading is calculated on a water year basis. A water year differs from a calendar year, in that it spans from October 1 of a given year to September 30 of the following year. Water years are commonly used for calculations, to account for precipitation falling as snow in late autumn and winter and draining in the following spring or summer's snowmelt.

Point source discharge data, in the form of monthly average total phosphorous effluent concentration and associated flows, were retrieved from effluent compliance data maintained by the Ontario Ministry of the Environment, Conservation and Parks and the United States' Environmental Protection Agency. Tributary phosphorous concentrations are based on water quality monitoring data from the Ontario Ministry of the Environment, Conservation and Parks, Environment and Climate Change Canada, United States Geological Survey, US state agencies and Heidelberg University. Atmospheric deposition data were retrieved as monthly values of precipitation depth and total phosphorous concentrations from Environment and Climate Change Canada. Flow data were obtained as daily mean discharge data retrieved from the National Water Inventory System in the United States' Geological Survey and from the Water Survey Canada hydrometric data, maintained by Environment and Climate Change Canada.

For all sources, phosphorus loading is estimated by multiplying the concentration (for example, kilograms of phosphorus per litre of water) by the flow rate (for example, cubic metres of water per day). Total loading to the lake is the sum of atmospheric deposition, loads entering from Lake Huron, as well as point source and non-point source contributions that flow into the lake directly or from tributaries.

Phosphorus loadings from 2008 to 2019 are estimated by using the Erie Loading Tool version 1.4.0, which is based on the process and methods used by Maccoux et al. 2016. Loading for the water year

2020 was calculated using a regression analysis approach, rather than the the Beale approach described in Maccoux et al. 2016. This approach was determined to be the most appropriate because a lot of data was missing for most of the tributaries due to restrictions related to the COVID-19 pandemic.[4] Unmonitored watershed areas were estimated using the Unit Area Load (UAL) approach, where the loading per square kilometre is calculated using data from an adjacent monitored watershed. The unmonitored areas typically consist of the area downstream of a monitored tributary that flows directly into the lake.

Phosphorus loadings from Lake Huron are estimates that are generated from models with the assumption that the phosphorus loads from Lake Huron are relatively stable from year to year.

For more details on the methods and calculations used, please see Maccoux et al. 2016.

Recent changes

Watershed areas were recalculated in 2021 using updated Canadian geographic information system (GIS) mapping, resulting in minor changes to some watersheds. Values for past years were recalculated based on these updated watershed areas.

Caveats and limitations

The indicator is based on total phosphorus concentrations only. Concentrations of total phosphorus may include differing proportions of the more bioavailable soluble reactive phosphorus which is the most impactful in terms of algae blooms and eutrophication. The indicator and data included in this report are not suitable for assessing soluble reactive phosphorus loads.

Phosphorus loadings from Lake Huron are estimates that are generated from models and then applied to all years. This approach to estimating the Lake Huron load is based on the assumption that the phosphorus loads from Lake Huron are relatively stable from year to year. Recently, studies on the Huron-Erie corridor have suggested that loadings from Lake Huron are more variable than previously assumed. The methods are under review.

Climate factors, such as precipitation or drought, greatly influence the amount of phosphorus entering a water body. Given this year-to-year variability, a longer time period is required to determine a statistically significant trend of phosphorus loading. As such, much caution is needed in making comparisons across years and estimating trends.

The 2020 data were calculated using a regression analysis approach, rather than the usual Beale approach. This was done because most tributaries were missing data in 2020, due to the COVID-19 pandemic related restrictions.

Resources

References

Environment and Climate Change Canada and the U.S. Environmental Protection Agency (2021) State of the Great Lakes 2019 Technical Report. Cat No. En161-3/1E-PDF. EPA 905-R-20-044. Retrieved on September 15, 2021.

Environment and Climate Change Canada and the U.S. National Oceanic and Atmospheric Administration (2020) 2019 Annual Climate Trends and Impacts Summary for the Great Lakes Basin. Retrieved on October 14, 2021.

Maccoux MJ, Dove A, Backus SM and Dolan DM (2016) Total and soluble reactive phosphorus loadings to Lake Erie: A detailed accounting by year, basin, country, and tributary. Journal of Great Lakes Research 42(6):1151 to 1165. Retrieved on September 9, 2021.

[4] Greenberg T (2021) Environment and Climate Change Canada, personal communication.

Related information

Canada–Ontario Agreement on Great Lakes Water Quality and Ecosystem Health

Canada–US Great Lakes Water Quality Agreement

Great Lakes protection

Annex

Annex A. Data tables for the figures presented in this document

Table A.1 Data for Figure 1. Total estimated phosphorus loading to Lake Erie, 2008 to 2020

Year	Total phosphorus loading United States portion (tonnes per year)	Total phosphorus loading Canada portion (tonnes per year)	Total phosphorus loading Basin total (tonnes per year)
2008	9 026	1 509	10 535
2009	6 242	2 156	8 398
2010	4 768	903	5 672
2011	8 817	2 758	11 575
2012	7 161	1 305	8 466
2013	6 648	1 987	8 634
2014	6 497	2 594	9 092
2015	5 342	1 458	6 800
2016	4 613	1 133	5 747
2017	8 998	1 792	10 789
2018	9 395	2 266	11 661
2019	10 944	2 599	13 544
2020	7 486	1 849	9 336

Note: Values are rounded to the nearest whole number. Totals may not add up due to rounding. Basin total values include loadings from runoff and tributaries in Canada and the United States, flows from Lake Huron and atmospheric sources of phosphorus. Half of the total phosphorus loadings from atmospheric sources and half of those from Lake Huron were allocated to each country.
Source: Environment and Climate Change Canada (2021).

Table A.2 Data for Figure 2. Annual 10 year average phosphorus loading estimated in tonnes to Lake Erie, 2011 to 2020

Watershed	Source	Annual 10 year average from 2011 to 2020 of phosphorus loading (tonnes per year)
Huron-Erie corridor	Lake Huron	321
Huron-Erie corridor	Atmospheric	27
Huron-Erie corridor	Point source	613
Huron-Erie corridor	Non-point source	1 104
Huron-Erie corridor	Total	2 065
Western basin	Atmospheric	58
Western basin	Point source	282
Western basin	Non-point source	3 099
Western basin	Total	3 440
Central basin	Atmospheric	244
Central basin	Point source	344
Central basin	Non-point source	1 904
Central basin	Total	2 493

Watershed	Source	Annual 10 year average from 2011 to 2020 of phosphorus loading (tonnes per year)
Eastern basin	Atmospheric	98
Eastern basin	Point source	114
Eastern basin	Non-point source	1 354
Eastern basin	Total	1 566

Note: Values are rounded to the nearest whole number. Totals may not add up due to rounding. Point source includes municipal sewage treatment plant effluent and industrial effluent. Non-point source includes agriculture and urban storm water runoff. Atmospheric deposition refers to phosphorus being deposited directly to the lake. The Huron-Erie corridor watershed includes input from Lake Huron, non-point sources and atmospheric deposition within the watershed.
Source: Environment and Climate Change Canada (2021).

Table A.3 Data for Figure 3. Phosphorus loading estimates to Lake Erie by source, Canada, 2008 to 2020

Year	Total phosphorus loading point sources (tonnes per year)	Total phosphorus loading non-point sources (tonnes per year)	Total phosphorus loading atmospheric (tonnes per year)	Total phosphorus loading from Lake Huron (tonnes per year)	Total phosphorus loading from all sources (tonnes per year)
2008	186	958	204	161	1 509
2009	161	1 452	382	161	2 156
2010	132	427	184	161	903
2011	147	2 173	277	161	2 758
2012	131	838	175	161	1 305
2013	141	1 427	258	161	1 987
2014	143	2 114	177	161	2 594
2015	120	1 009	169	161	1 458
2016	127	667	179	161	1 133
2017	129	1 229	273	161	1 792
2018	120	1 718	267	161	2 266
2019	120	2 157	162	161	2 599
2020	120	1 370	199	161	1 849

Note: Values are rounded to the nearest whole number. Totals may not add up due to rounding. The total phosphorous loadings from atmospheric sources and from Lake Huron were halved to roughly estimate the Canadian contributions. Loadings from Lake Huron are estimates generated through models. For more information, please see the data sources and methods section.
Source: Environment and Climate Change Canada (2021).

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