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PHOSPHORUS LOADING TO LAKE ERIE

CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

Canada

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CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

PHOSPHORUS LOADING TO LAKE ERIE

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Phosphorus loading to Lake Erie

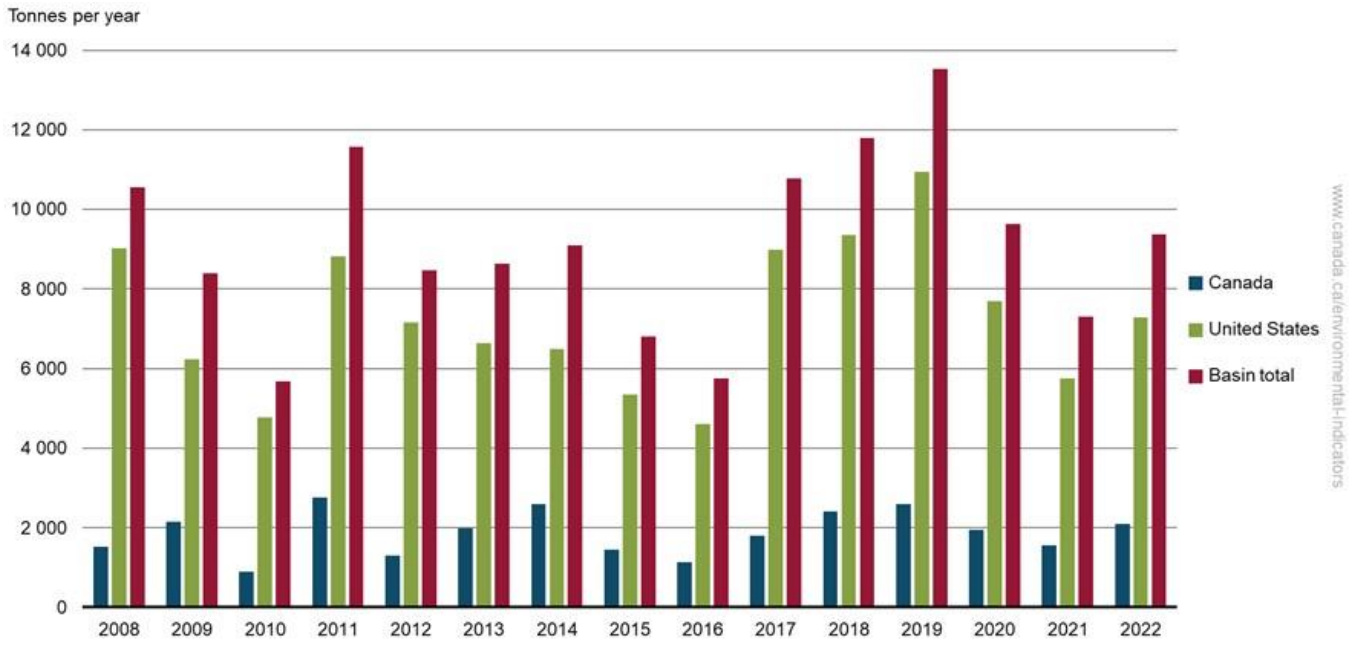
Phosphorus is a plant nutrient that is essential in freshwater systems. However, when phosphorus levels are too high, or too low, they can have harmful impacts on the health of a lake. High phosphorus levels in Lake Erie are leading to degraded water quality, algal blooms and zones of low oxygen which negatively impact aquatic life. In the absence of human development, natural background levels of phosphorus are relatively low. This indicator provides information about the amount of phosphorus reaching Lake Erie, known as phosphorus loading, mainly due to human activity.

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 to protect water quality and ecosystem health.

Key results

- In 2022, total estimated phosphorus loading to Lake Erie was 9 379 tonnes, with 22% (2 091 tonnes) of the total load estimated to be from Canada
- The highest total estimated phosphorus loading to Lake Erie was 13 533 tonnes in 2019 with 19% (2 588 tonnes) of the total load estimated to be from Canada
- The lowest total estimated phosphorus loading to Lake Erie was 5 672 tonnes in 2010 with 16% (903 tonnes) of the total load estimated to be from Canada
- There has not been a clear upward or downward trend over time; the 2022 results were in line with the average of the 2008 to 2022 period

Figure 1. Total estimated phosphorus loading to Lake Erie, 2008 to 2022



Data for Figure 1

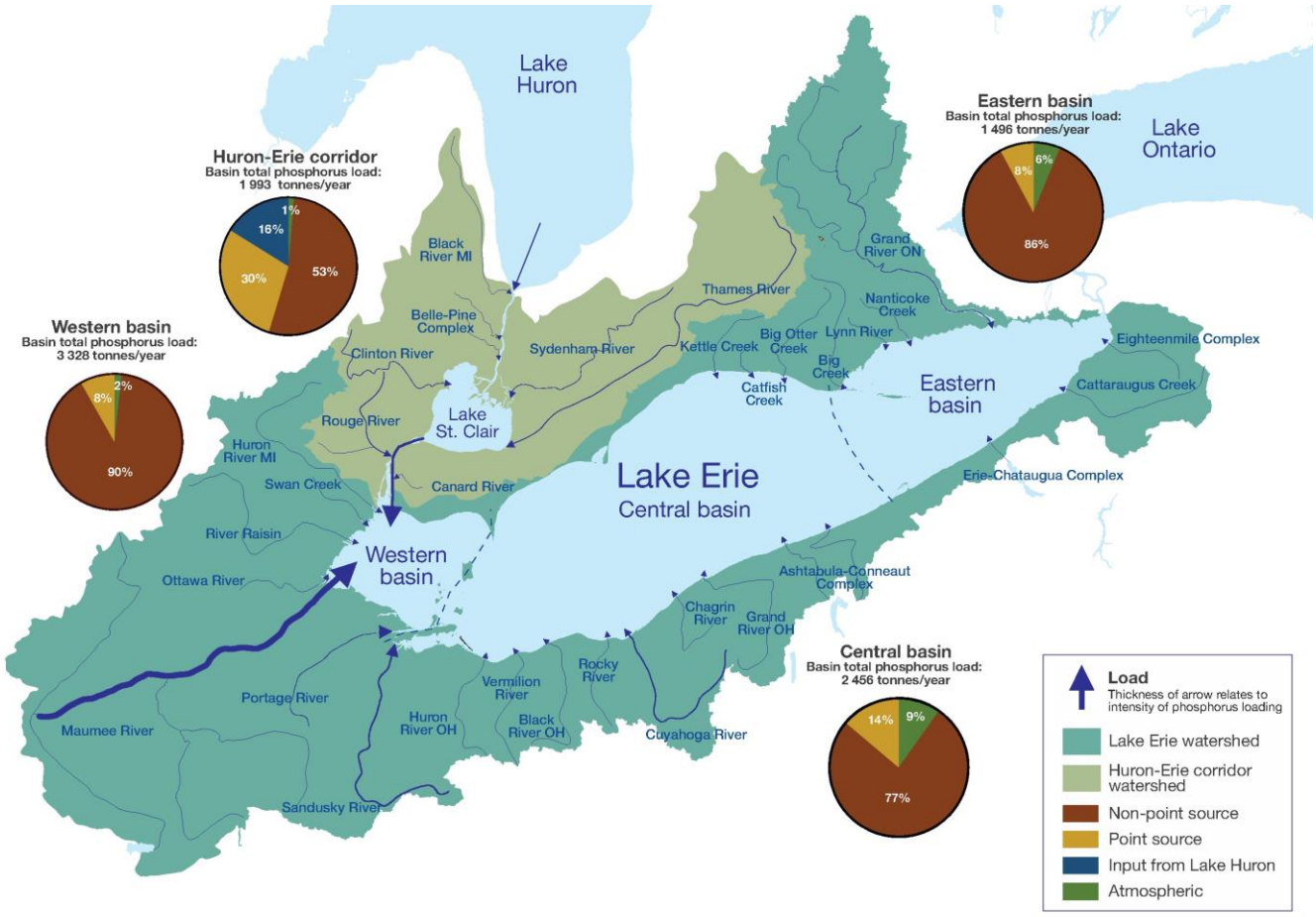
Note: Basin total values include loadings from runoff and tributaries in Canada and the United States, flows from Lake Huron and atmospheric sources of phosphorus. Half of the total phosphorus loadings from atmospheric sources and half of those from Lake Huron were allocated to each country.
Source: Environment and Climate Change Canada (2023).

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 2022, phosphorous loading to Lake Erie from all sources within Canada and the United States (9 379 tonnes) was relatively average compared to the last 14 years, and similar to loads in 2013 (8 634 tonnes), 2014 (9 091 tonnes) and 2020 (9 640 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.

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, 2013 to 2022



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 (2023).

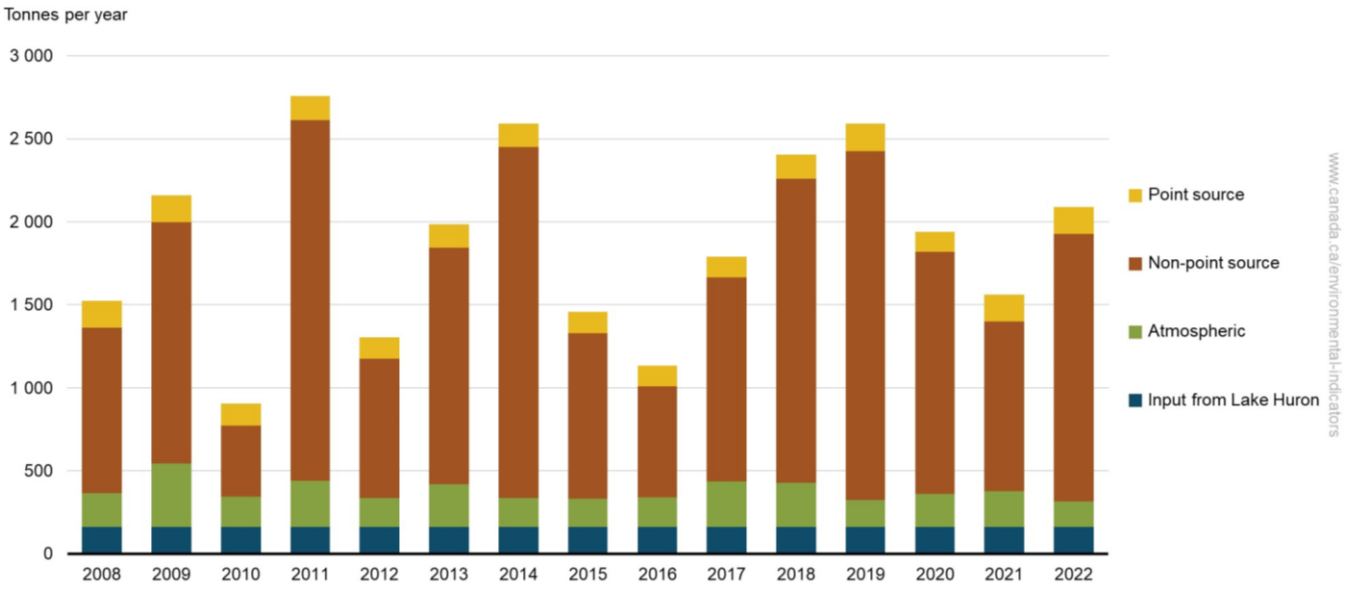
[1] Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (2022) Coordinating Committee Products and datasets. Great Lakes Coordinated Precipitation 1900-2020. Retrieved on August 30, 2023.

Phosphorus loading to Lake Erie from Canadian sources

Key results

- Phosphorus loading to Lake Erie from Canada comes mainly from non-point sources such as agriculture and urban storm water runoff
- Non-point sources accounted for 77% of the phosphorus loading from Canada in 2022 compared to a high of 81% in 2014 and 2019, and a low of 47% in 2010[2]

Figure 3. Phosphorus loading estimates to Lake Erie by source, Canada, 2008 to 2022



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 (2023).

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.[1]

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

About the indicator

What the indicator measures

The Phosphorus loading to Lake Erie indicator reports on the total phosphorus loads 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 indicator provides information about the amount of phosphorus flowing into Lake Erie mainly due to human activity.

Why this indicator is 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. 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.

To calculate phosphorus loads, it is important to know the volume of water and phosphorus levels in the water. Phosphorus level is the concentration of phosphorus in a given volume of water. Phosphorus loading is the total quantity of phosphorus that is being released into a water body within a certain time period such as per day, month, or year and/or by certain sources (e.g. agriculture, runoff, etc.). Increased loads from various sources can lead to increased concentrations in a water body.

This indicator is used to provide information relevant to the state of the Lake Erie basin and the Canadian environment.

Related initiatives

The indicator contributes to the Sustainable Development Goals of the 2030 Agenda for Sustainable Development. It is linked to the 2030 Agenda's Goal 6: Clean water and sanitation and Target 6.6: "By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes" and Target 6.5 "By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate."

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 indicator reports the status of total phosphorus and total nitrogen levels.

The Water quality in Canadian rivers indicator provides 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 this indicator 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 13 Canadian tributaries (the Thames, Sydenham, Grand River, Turkey, Big Creek, Big Otter, Lynn, Kettle, Leamington tributaries (3 tributaries; included in 2018-2022 loading estimates), Canard,[3] 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.

[3] Prior to 2017, Canard River was used as a placeholder in the Western basin to account for the missing Leamington tributary data. The Leamington tributuary only started being monitored in 2017 and data for the years 2008 to 2016 is not available.

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 and 2022 were 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. For the 2020 year, loadings were calculated using a regression analysis approach, rather than the Beale approach described in Maccoux et al. 2016 due to low sample counts at all sites. For the 2021 year, loadings were calculated using a regression analysis for sites with low sample counts and the Beale approach for sites with sufficient sample counts. These approaches were determined to be the most appropriate because a lot of data were 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.

For the 2020 data and the 2021 data, where there were sites with low sample counts, a regression analysis approach was applied because sampling frequency at most tributaries was reduced or not completed due to the COVID-19 pandemic related restrictions.

Resources

References

Environment and Climate Change Canada and the U.S. Environmental Protection Agency (2022) State of the Great Lakes 2019 Technical Report (PDF; 19.9 MB). Retrieved on August 8, 2023.

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

Environment and Climate Change Canada and the U.S. National Oceanic and Atmospheric Administration (2022) 2021 Annual Climate Trends and Impacts Summary for the Great Lakes Basin. Retrieved on August 8, 2023.

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 August 8, 2023.

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 2022

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	1 525	10 551
2009	6 242	2 158	8 400
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	9 091
2015	5 342	1 456	6 798
2016	4 613	1 133	5 747
2017	8 993	1 792	10 785
2018	9 395	2 405	11 800
2019	10 944	2 588	13 533
2020	7 701	1 939	9 640
2021	5 746	1 562	7 308
2022	7 288	2 091	9 379

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 (2023).

Table A.2 Data for Figure 2. Annual 10 year average phosphorus loading estimated in tonnes to Lake Erie, 2013 to 2022

Watershed	Source	Annual 10 year average from 2013 to 2022 of phosphorus loading (tonnes per year)
Huron-Erie corridor	Lake Huron	321
Huron-Erie corridor	Atmospheric	26
Huron-Erie corridor	Point source	589
Huron-Erie corridor	Non-point source	1 058
Huron-Erie corridor	Total	1 993
Western basin	Atmospheric	56
Western basin	Point source	275
Western basin	Non-point source	2997
Western basin	Total	3 328
Central basin	Atmospheric	235
Central basin	Point source	335
Central basin	Non-point source	1 886

Watershed	Source	Annual 10 year average from 2013 to 2022 of phosphorus loading (tonnes per year)
Central basin	Total	2 456
Eastern basin	Atmospheric	94
Eastern basin	Point source	116
Eastern basin	Non-point source	1 286
Eastern basin	Total	1 496

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 (2023).

Table A.3 Data for Figure 3. Phosphorus loading estimates to Lake Erie by source, Canada, 2008 to 2022

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	162	999	204	161	1 525
2009	160	1 456	382	161	2 158
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	2 113	177	161	2 594
2015	129	997	169	161	1 456
2016	125	669	179	161	1 133
2017	127	1 231	273	161	1 792
2018	146	1 831	267	161	2 405
2019	164	2 103	162	161	2 588
2020	120	1 460	199	161	1 939
2021	164	1 021	216	161	1 562
2022	164	1 612	154	161	2 091

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 (2023).

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