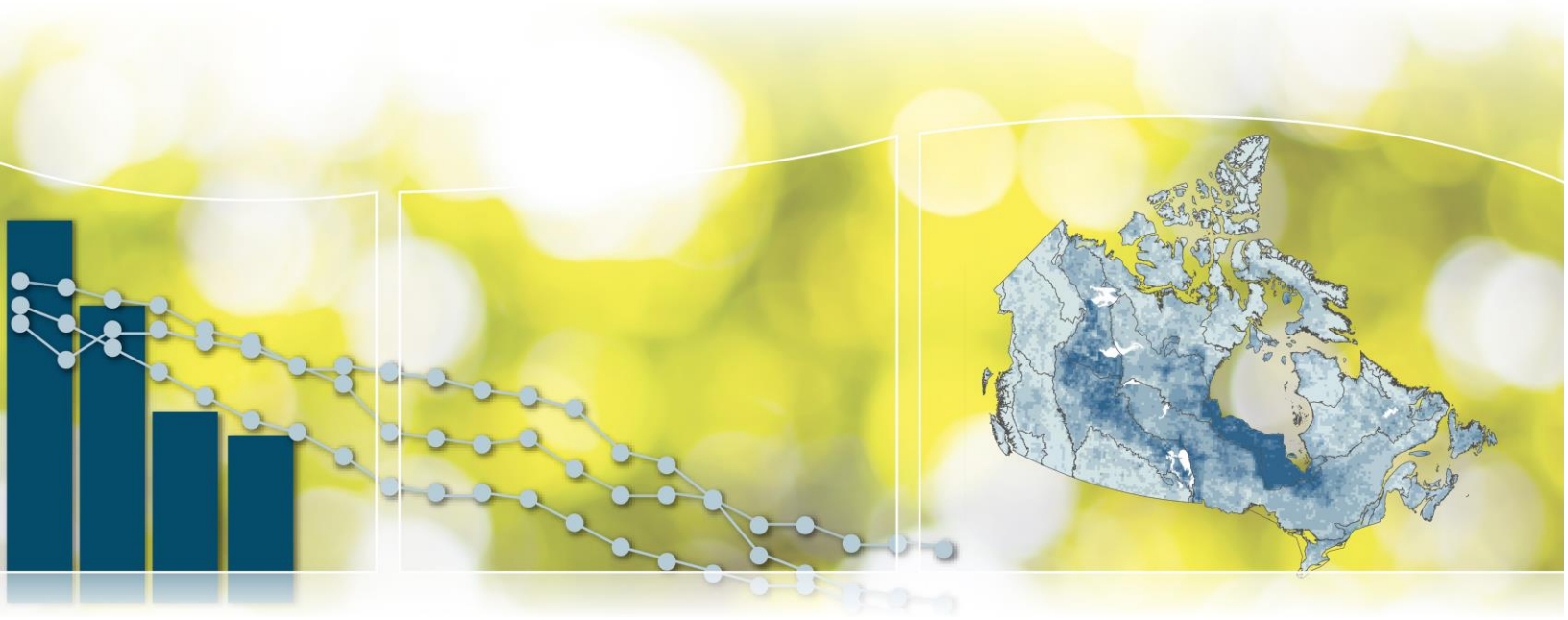
Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canadian Environmental Sustainability Indicators

Nutrients in Lake Winnipeg



Canada

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Canadian Environmental Sustainability Indicators

Nutrients in Lake Winnipeg

January 2018

Table of Contents

List of Figures

List of Tables

Nutrients in Lake Winnipeg indicators

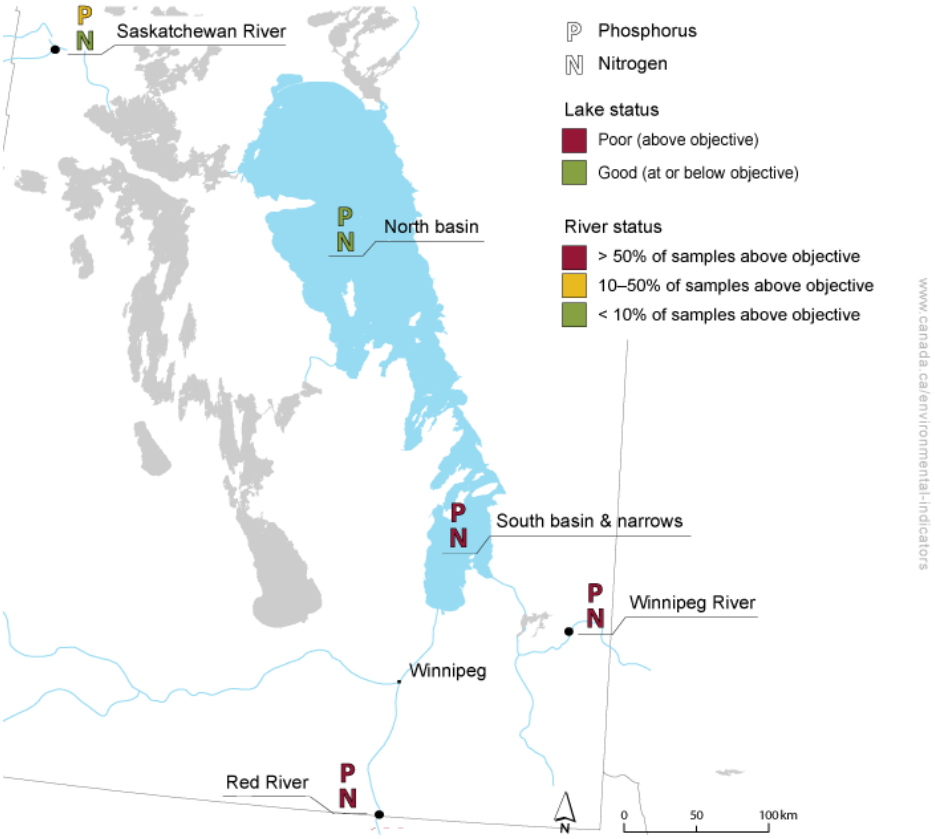
Phosphorus and nitrogen are essential plant nutrients. When phosphorus or nitrogen levels are too high or too low, they can have harmful impacts on the food web of a lake or river. They are a measure of the health of Lake Winnipeg and its surrounding watershed. These indicators provide the status of phosphorus and nitrogen levels in Lake Winnipeg and 3 of its tributary rivers.

Phosphorus and nitrogen levels in Lake Winnipeg

Key results

- In Lake Winnipeg, the highest levels of phosphorus and nitrogen in 2016 are found in the south basin near the inflow from the Red River. Levels decline as the water flows north.
- In the 3 largest tributary rivers, for the 2014 to 2016 period,
    - High phosphorus levels were detected frequently in the Red and Winnipeg rivers and intermittently in the Saskatchewan River.
    - High nitrogen levels were detected frequently in the Red River and in the Winnipeg River, but rarely in the Saskatchewan River.

Figure 1. Status of phosphorus and nitrogen levels in Lake Winnipeg, 2016, and its 3 largest tributary rivers, Canada, 2014 to 2016



Data for Figure 1

Note: For Lake Winnipeg, an objective for total nitrogen of 0.75 milligrams per litre (mg N/L) and an objective for total phosphorus of 0.05 milligrams per litre (mg P/L) were used. For the Red, Winnipeg and Saskatchewan rivers, water quality is considered good when water quality measurements exceed the river's nutrient criteria or objective less than 10% of the time

(see Data sources and methods). A fair status is applied when the nutrient criteria or objective is exceeded 10% to 50% of the time. Poor status is applied when measurements are above the nutrient criteria or objective in over 50% of samples.
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Lake Winnipeg is Canada's sixth-largest freshwater lake and the world's third-largest reservoir, generating hydro-electric power for all of Manitoba.[1] The Lake Winnipeg area is home to over 30 communities and supports a large commercial fishery, as well as numerous recreational activities.

At between 9 to 13 metres in depth, the lake is shallow compared to the Laurentian Great Lakes. However, the lake's drainage basin is the largest in Canada, having an area of some 953 240 square kilometres and covering 4 Canadian provinces and 4 American states. The shallow nature of the lake and large volume of inflows from the rivers draining into the lake are major influences on its water quality.

Water quality in Lake Winnipeg has been deteriorating for many years. Phosphorus and nitrogen from human activity enters Lake Winnipeg through municipal and industrial wastewaters, agricultural runoff, and air pollution. Losses of wetlands and other land developments can also result in increased flows of these nutrients. The excess amount of phosphorus and nitrogen flowing into Lake Winnipeg contributes to increasingly large, frequent, and potentially toxic, algal blooms. These blooms harm the lake's ecosystem, threaten the fishery, and reduce enjoyment of the lake.

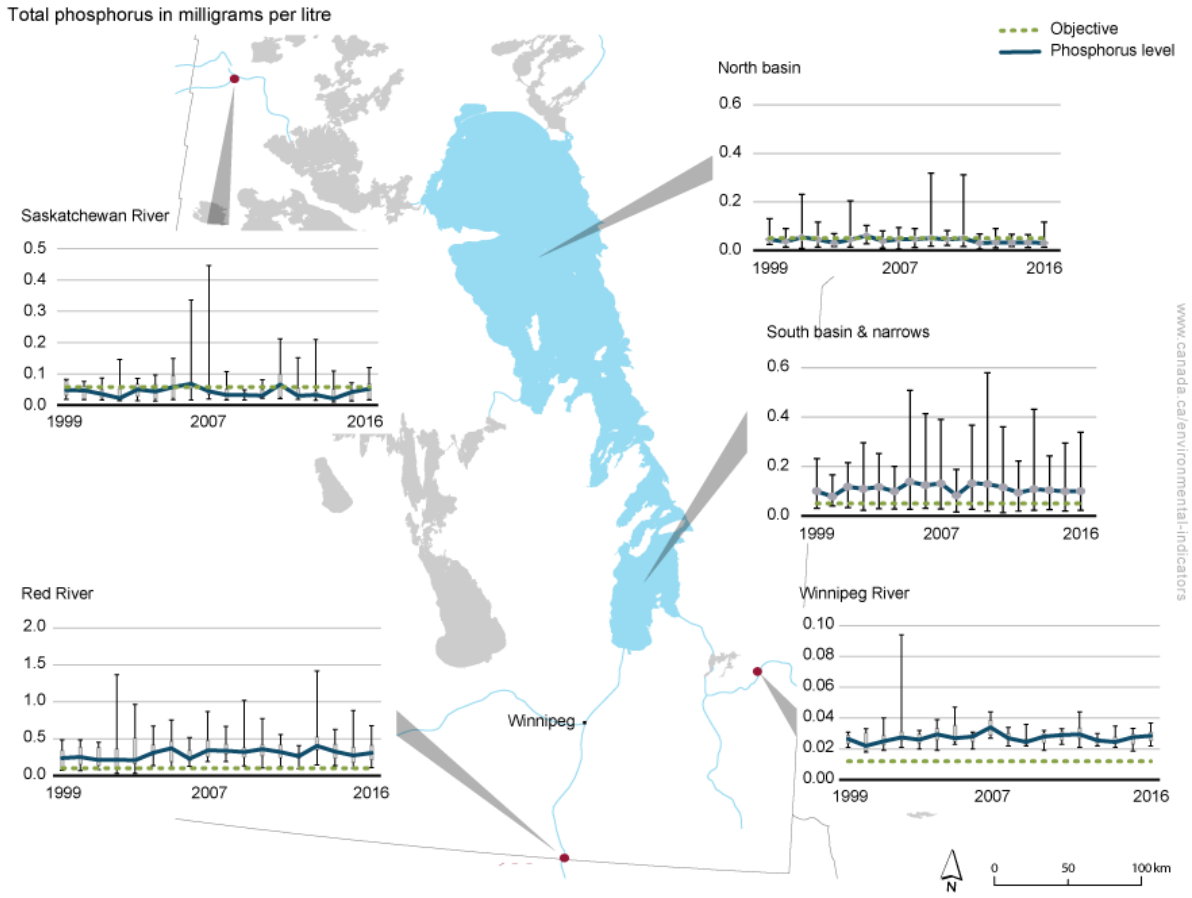
[1] Environment Canada and Manitoba Conservation and Water Stewardship (2011) State of Lake Winnipeg Report: 1999 to 2007. Retrieved on May 30, 2017

Phosphorus levels by water quality monitoring site

Key results

- Phosphorus levels are fluctuating but no trends between 1999 and 2016 can be detected at any of the sites.

Figure 2. Annual total phosphorus concentrations in Lake Winnipeg and its 3 largest tributary rivers, Canada, 1999 to 2016



Data for Figure 2

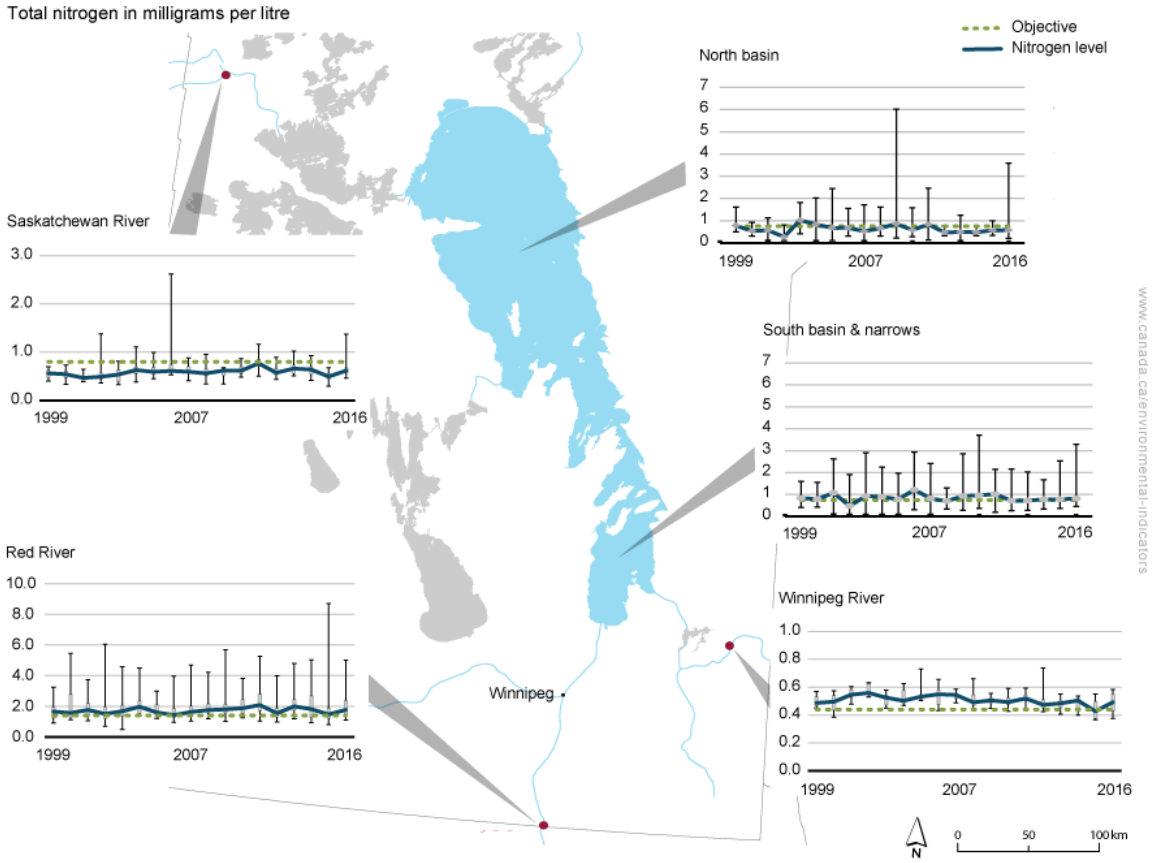
Note: The dotted line shows the objective or criteria value of 0.05 mg P/L for Lake Winnipeg, 0.058 mg P/L (an average of the seasonal objectives) for the Saskatchewan River, 0.102 mg P/L for the Red River, and 0.012 mg P/L for the Winnipeg River. The solid (blue) line links the symbols to show the tendency in the average values. For the north basin and south basin and narrows, data are seasonally-weighted averages and vertical bars show annual minimum and maximum concentrations. For the Saskatchewan, Red and Winnipeg rivers, each boxplot summarizes annual phosphorus levels at a monitoring site and shows the range of values measured.
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Nitrogen levels by water quality monitoring site

Key results

- Nitrogen levels are not changing at any of the sites.

Figure 3. Annual total nitrogen concentrations in Lake Winnipeg and its 3 largest tributary rivers, Canada, 1999 to 2016



Data for Figure 3

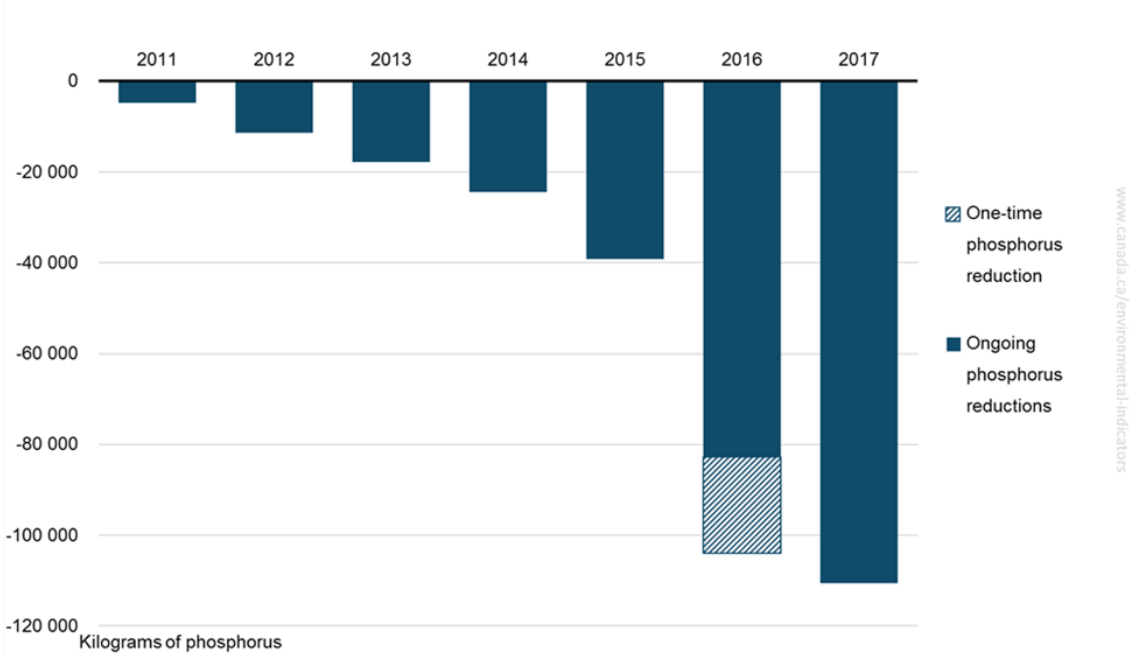
Note: The dotted line shows the objective or criteria value of 0.75 mg N/L for Lake Winnipeg, 0.80 mg N/L (an average of the seasonal objectives) for the Saskatchewan River, 1.4 mg N/L for the Red River, and 0.44 mg N/L for the Winnipeg River. The solid (blue) line links the symbols to show the tendency in the average values. For the north basin and south basin and narrows, data are seasonally-weighted averages and vertical bars show annual minimum and maximum concentrations. For the Saskatchewan, Red and Winnipeg rivers, each boxplot summarizes annual nitrogen levels at a monitoring site and shows the range of values measured.
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Reducing phosphorus loads to Lake Winnipeg

Key results

- Lake Winnipeg Basin Stewardship Fund projects completed between 2010 and 2017 have prevented an estimated 110 700 kilograms of phosphorus from reaching Lake Winnipeg.
- The bioremediation of a retired municipal wastewater lagoon in 2015 prevented 21 300 kilograms of phosphorus from ever reaching Lake Winnipeg.

Figure 4. Estimated cumulative reduction in the amount of phosphorus reaching Lake Winnipeg because of completed stewardship projects, Canada, April 2010 to March 2017



Data for Figure 4

Note: The estimated reduction in phosphorus load is based on the results of projects completed between April 2010 and March 2017. Estimated phosphorus loads for each project type are rounded and then summed to calculate the total. Year refers to fiscal year, which runs from April to March. The year 2017 therefore refers to April 1, 2016 to March 31, 2017.
Source: Environment and Climate Change Canada (2017) Lake Winnipeg Basin Initiative.

The amount of phosphorus pollution reaching Lake Winnipeg is reduced every time

- retention ponds are built to intercept water flow across the landscape and to capture nutrients
- river banks and lake shorelines are stabilized
- wetlands are restored
- native shrubs, plants and trees are planted in the watershed, and
- a fence is built to prevent livestock from entering lakes and rivers

Environment and Climate Change Canada, Manitoba Sustainable Development and other partners are engaging people in nutrient reducing activities and supporting innovative nutrient reduction demonstration projects and research through the Lake Winnipeg Basin Program. Supporting these projects will help Manitoba achieve its long-term goal of reducing phosphorus concentrations in the lake to pre-1990 levels of approximately 0.05 milligrams per litre.

About the indicators

What the indicators measure

The Phosphorus and nitrogen levels in Lake Winnipeg indicator reports on the status of total phosphorus and total nitrogen levels in Lake Winnipeg and its 3 largest tributaries: the Red, Saskatchewan and Winnipeg rivers.

The indicator assumes that water in the region would never be above phosphorus and nitrogen water quality criteria or objectives in the absence of human development. It provides information about how human activity contributes to phosphorus and nitrogen levels in lakes and rivers.

The phosphorus and nitrogen status in Lake Winnipeg is established by comparing phosphorus and nitrogen levels to water quality objectives. Failure to meet a water quality objective suggests a greater risk to the health of the lake ecosystem. In rivers, phosphorus and nitrogen status is determined by the frequency with which a water quality objective is exceeded. The more often the criteria or objective is exceeded, the greater the risk to the health of the river ecosystems.

The Reducing phosphorus loads to Lake Winnipeg indicator shows the extent to which Lake Winnipeg Basin Stewardship Fund projects have reduced the amount of phosphorus reaching the lake from its watershed. By changing how land is managed, the amount of phosphorus reaching Lake Winnipeg is lowered, and restoration of the lake can begin.

Why these indicators are important

Clean freshwater is an essential resource. It protects the biodiversity of aquatic plants and animals. We use it for drinking, manufacturing, energy production, irrigation, swimming, boating and fishing. Degraded water quality damages the health of freshwater ecosystems and can disrupt economic activities, such as fisheries, tourism and agriculture. When phosphorus and nitrogen levels in water become too high, aquatic plant growth can become excessive and harmful. The decay of excess plant material can reduce the amount of oxygen available for fish and other aquatic animals. High nutrient levels can also lead to harmful algal blooms, which can kill animals that use the water and affect human health. Conversely, too little phosphorus or nitrogen can result in not enough plant growth to support a lake's food web, which can result in a collapse of the fishery.

These indicators are used to provide information about the state of the Lake Winnipeg Basin and Canadian environment. They are also used to assess progress towards the goals of the 2016–2019 Federal Sustainable Development Strategy.

Related indicators

The Phosphorus levels in the offshore waters of the Canadian Great Lakes and the Nutrients in the St. Lawrence River indicators report the status of total phosphorus and total nitrogen levels in those 2 ecosystems.

The Water quality in Canadian rivers indicator ranks water quality at monitoring sites across Canada where human activity is likely to harm a river's ecosystem.

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.

The Reducing phosphorus loads to Lake Simcoe and South-eastern Georgian Bay indicator reports the amount of phosphorus no longer reaching Lake Simcoe and South-eastern Georgian Bay because of completed stewardship projects.

Pristine lakes and rivers

These indicators support the measurement of progress towards the following 2016–2019 Federal Sustainable Development Strategy long-term goal: Clean and healthy lakes and rivers support economic prosperity and the well-being of Canadians.

Data sources and methods

Data sources

Manitoba Sustainable Development's Water Quality Management Section collects and provides the average phosphorus and nitrogen concentration data for Lake Winnipeg.

Data for the Red, Winnipeg and Saskatchewan rivers are collected by the Freshwater Quality Monitoring and Surveillance Division of Environment and Climate Change Canada. The indicator is calculated using the most recent data available for the lake and each of the 3 rivers.

The amount of phosphorus diverted from Lake Winnipeg was estimated by Environment and Climate Change Canada's Lake Winnipeg Basin Stewardship Fund using data from the final reports of funded stewardship projects.

More information

Phosphorus and nitrogen levels in Lake Winnipeg indicator

Total phosphorus and nitrogen status ratings for Lake Winnipeg are based on phosphorus and nitrogen concentration data collected from May to October 2016 in the north and south basins of Lake Winnipeg and in the narrows connecting the 2 basins.

Total phosphorus and nitrogen status ratings for 3 of Environment and Climate Change Canada's water quality monitoring sites on the Red, Winnipeg and Saskatchewan rivers are calculated using data collected year-round from 2014 to 2016 (Table 1).

Table 1. Tributary water quality monitoring sites

Site code	Site name	Longitude	Latitude
MA05OC0001	Red River at Emerson, Manitoba	-97.21083	49.00806
MA05PF0022	Winnipeg River at Pointe du Bois	-95.5566116	50.30083
MA05KH0001	Saskatchewan River above Carrot River	-101.34194	53.84167

Reducing phosphorus loads to Lake Winnipeg indicator

The estimated phosphorus load reductions are calculated using the results of beneficial management projects completed in the Lake Winnipeg watershed between April 2010 and March 2017. The indicator includes data for all projects with final reports submitted by March 31, 2017.

From 2008 to 2017, the Lake Winnipeg Basin Stewardship Fund supported 89 projects. Of the projects funded, 48% are having a direct impact on phosphorus loading and 52% are having an indirect impact. The indicator reports on projects resulting in reductions in direct phosphorus loadings to Lake Winnipeg.

Methods

For the status of phosphorus and nitrogen levels in Lake Winnipeg, seasonally-weighted, average phosphorus and nitrogen concentrations for 2016 were compared to water quality objectives. The status of phosphorus and nitrogen levels was categorized as good (at or near the guideline) or poor (above the guideline).

For the status in the Red, Saskatchewan and Winnipeg rivers, the number of times total phosphorus and total nitrogen samples are above water quality guidelines is counted and divided by the total number of samples taken between 2014 and 2016. The status of phosphorus and nitrogen levels was categorized on the basis of how frequently levels are above their guidelines.

Estimates of how new land management projects reduced the amount of phosphorus loading to Lake Winnipeg are calculated using generic land use models collected from the scientific literature. The results for each year were added to estimate the total loading reduction.

More information

Phosphorus and nitrogen levels in Lake Winnipeg

For the lake, seasonally-weighted, average phosphorus and nitrogen concentrations are used to capture year-to-year variability in sample collection. These average values for 1999 to 2016 for Lake Winnipeg, along with the maximum and minimum concentrations, are provided to supplement information about nutrients in the lake through time.

For the Saskatchewan, Red and Winnipeg rivers, total nutrient concentrations often exceed the guidelines during high flows, which most commonly occur when snow melts in the spring. Stations with fewer than 10% of samples exceeding the guidelines were given a good water quality status. Stations with 10% to 50% exceedances were given a fair 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 poor water quality status. Data collected between 1999 and 2016 were summarized in box plots to provide information about nutrient levels in the rivers over time.

Phosphorus guidelines

For Lake Winnipeg, a total phosphorus objective of 0.05 milligrams of phosphorus per litre (mg P/L) was used.[2]

For the Saskatchewan River, the Prairie Provinces Water Board's interprovincial water objectives for phosphorus of 0.088 mg P/L for open-water periods and 0.028 mg P/L for ice-covered months were used.[3]

For the Red River, the United States Environmental Protection Agency's phosphorus criteria of 0.102 mg P/L for nutrient ecoregion 46 was used.[4]

For the Winnipeg River, the United States Environmental Protection Agency's phosphorus criteria of 0.012 mg P/L for nutrient ecoregion 50 was used.[5]

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[2] Bunting L, PR Leavitt, B Wissel, KR Laird, BF Cumming, A St. Amand, BJ Hann and DR Engstrom (2011) Sudden ecosystem state change in Lake Winnipeg, Canada, caused by eutrophication arising from crop and livestock production during the 20th century. 132 p.

[3] Prairie Provinces Water Board (2015) 2015 Interprovincial Water Quality Objectives. Retrieved on August 22, 2017. Note that for the chart the average of the 2 seasonal objectives was drawn in as a single-line reference. The months of November through March were assumed to be ice-covered for the purposes of applying the objectives and referring to the date of the sampling.

[4] United States Environmental Protection Agency (2000) Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion VI: Corn Belt and Northern Great Plains. Report No. EPA-822-B-00-017. United States Environmental Protection Agency. Washington, D.C. (PDF; 326 kB). Retrieved on August 22, 2017.

Nitrogen guidelines

Neither Manitoba nor the Canadian Council of Ministers of the Environment has a water quality guideline for total nitrogen.

For Lake Winnipeg, a total nitrogen objective of 0.75 milligrams of nitrogen per litre (mg N/L)[6] was used. The value has been derived using Lake Winnipeg's total phosphorus objective of 0.05 mg P/L and preserving the appropriate nitrogen-to-phosphorus ratio for the lake.

For the Red River, the United States Environmental Protection Agency's nitrogen criteria of 1.4 mg N/L for nutrient ecoregion 46 was used.[7]

For the Winnipeg River, the United States Environmental Protection Agency's nitrogen criteria of 0.44 mg N/L for nutrient ecoregion 50 was used.[8]

For the Saskatchewan River, the Prairie Provinces Water Board's 2015 interprovincial water quality objectives for nitrogen (PDF; 422 kB) of 0.838 mg N/L for open-water periods and 0.761 mg N/L for ice-covered months were used.[9]

Reducing phosphorus loads to Lake Winnipeg indicator

Estimates of reductions in phosphorus loading to Lake Winnipeg resulting from the implementation of beneficial management projects were calculated using equations from the Lake Simcoe Clean-Up Fund: Phosphorus Reduction Calculation Report.[10] The report is applicable to projects in the Lake Winnipeg basin because it uses generic land use models collected from scientific literature.

In general, the concentration of phosphorus reaching a watercourse is determined by the form and chemical nature of the phosphorus compounds and the degree of contact with the soil, soil pH, soil texture, soil type and aerobic conditions. Beneficial management practices to reduce phosphorus inputs from agriculture include practices such as limiting livestock access to streams through fencing and installing alternate watering sources. Rural projects include those that protect or stabilize stream banks or lake shores by installing erosion-control structures and planting trees and shrubs.

Once a stewardship project has been initiated, its impact on the removal of phosphorus in water running off the landscape is accounted for on a yearly basis. Loading reductions achieved each year over the life of the project are added to projects completed in 2010. In this way, the reduction of phosphorus runoff due to stewardship projects aggregates on the landscape.

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[5] United States Environmental Protection Agency (2001) Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion VIII: Nutrient-Poor, Largely Glaciated Upper Midwest and Northeast. Report No. EPA-822-B-01-015. Washington, D.C. (PDF; 2.53 MB). Retrieved on August 22, 2017.

[6] Page E (2007) Manitoba Sustainable Development, personal communication.

[7] United States Environmental Protection Agency (2000) Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion VI: Corn Belt and Northern Great Plains. Report No. EPA-822-B-00-017. Washington, D.C. (PDF; 326 kB). Retrieved on August 22, 2017.

[8] United States Environmental Protection Agency (2001) Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion VIII: Nutrient-Poor, Largely Glaciated Upper Midwest and Northeast. Report No. EPA-822-B-01-015. Washington, D.C. (PDF; 2.53 MB). Retrieved on August 22, 2017.

[9] For the chart, the average of the 2 seasonal objectives was drawn in as a single-line reference. The months of November through March were assumed to be ice-covered for the purposes of applying the objectives and referring to the date of the sampling.

[10] Sealock L (2011) Lake Simcoe Clean-Up Fund: Phosphorus Reduction Calculation Report. Great Lakes Management and Reporting Section, Environment Canada.

Given that the results are estimates, the figures for the total of each project type were rounded, and these rounded figures were summed to produce the final number.

Recent changes

The Phosphorus and nitrogen levels in Lake Winnipeg indicator now includes data for 2014, 2015 and 2016.

The water quality guideline for total nitrogen at all sites was changed from 1 milligram of nitrogen per litre (mg N/L) to a more appropriate site-specific target for each site.

Phosphorus guidelines were changed for the rivers to match the nitrogen guidelines:

- for Lake Winnipeg, a total nitrogen objective of 0.75 mg N/L was used for the north basin and south basin and narrows
- for the Red River, the United States Environmental Protection Agency's nutrient criteria for nutrient ecoregion 46 of 0.102 mg P/L and 1.4 mg N/L were used
- for the Saskatchewan River, the Prairie Provinces Water Board's 2015 interprovincial nutrient objectives of 0.088 mg P/L and 0.838 mg N/L for open-water periods and 0.028 mg P/L and 0.761 mg N/L for ice-covered months were used
- for the Winnipeg River, the United States Environmental Protection Agency's nutrient criteria for nutrient ecoregion 50 of 0.012 mg P/L and 0.44 mg N/L were used

These changes had affected nitrogen level status for all sites. The changes in status do not reflect a change in water quality at these sites due to increased nitrogen pollution; it reflects the changes in the guidelines.

The Reducing phosphorus loads to Lake Winnipeg indicator has been updated to include data from stewardship projects that were completed by March 31, 2017. Phosphorus loading reductions have been calculated as cumulative totals from the year the project was initiated, rather than the year the final project report was submitted.

Caveats and limitations

Phosphorus and nitrogen levels in Lake Winnipeg

The Phosphorus and nitrogen levels in Lake Winnipeg indicator reflects the overall state of phosphorus and nitrogen levels in the Lake Winnipeg basin. It does not show the effect of spills or other transient events, unless these are frequent or long-lasting.

Even where the average levels are generally below the guideline, the maximum recorded values may still be above.

The calculation used for the indicator for the tributaries is different from that used for the lake. This difference exists because total phosphorus concentrations in rivers are influenced by suspended particles in the water, which may increase during high-flow events. Allowing for some natural exceedances associated with high-flow events is important. The ratings for Lake Winnipeg and its tributaries are, however, comparable, with the poor status showing the highest level of impairment by phosphorus or nitrogen in both cases.

Reducing phosphorus loads to Lake Winnipeg

The Reducing phosphorus loads to Lake Winnipeg indicator assumes that each management project completed through the Lake Winnipeg Basin Stewardship Fund resulted in a permanent reduction in phosphorus loads to Lake Winnipeg.

The indicator does not compare results to data measuring annual phosphorus loads or the overall land use and activity changes in the basin that might affect phosphorus loading.

The indicator relies on the most appropriate equations to predict phosphorus loading reductions from the implementation of the beneficial management projects. Despite the rigour behind them, uncertainty exists when using these equations.

Resources

References

Bunting L, PR Leavitt, B Wissel, KR Laird, BF Cumming, A St. Amand, BJ Hann and DR Engstrom (2011) Sudden ecosystem state change in Lake Winnipeg, Canada, caused by eutrophication arising from crop and livestock production during the 20th century. 132 p.

Prairie Provinces Water Board (2015) 2015 Interprovincial Water Quality Objectives. Retrieved on August 22, 2017.

Sealock L (2011) Lake Simcoe Clean-Up Fund: Phosphorus Reduction Calculation Report. Great Lakes Management and Reporting Section, Environment Canada.

United States Environmental Protection Agency (2000) Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion VI: Corn Belt and Northern Great Plains. Report No. EPA-822-B-00-017. United States Environmental Protection Agency. Washington, D.C. (PDF; 326 kB). Retrieved on August 22, 2017.

United States Environmental Protection Agency (2001) Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion VIII: Nutrient-Poor, Largely Glaciated Upper Midwest and Northeast. Report No. EPA-822-B-01-015. United States Environmental Protection Agency. Washington, D.C. (PDF; 2.53 MB). Retrieved on August 22, 2017.

Related information

Cleaning Up Lake Winnipeg

Lake Winnipeg Basin Initiative

Manitoba Sustainable Development – Lake Winnipeg

Manitoba Sustainable Development – State of Lake Winnipeg Report

Annex

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

Table A.1. Data for Figure 1. Status of phosphorus and nitrogen levels in Lake Winnipeg, Canada, 2016

Lake Winnipeg	Phosphorus water quality objective (milligrams of phosphorus per litre)	Phosphorus level (milligrams of phosphorus per litre)	Phosphorus level status	Nitrogen water quality objective (milligrams of nitrogen per litre)	Nitrogen level (milligrams of nitrogen per litre)	Nitrogen level status
North basin	0.05	0.03	Good	0.75	0.58	Good
South basin and narrows	0.05	0.10	Poor	0.75	0.81	Poor

Note: For Lake Winnipeg, an objective for total nitrogen of 0.75 milligrams per litre (mg N/L) and an objective for total phosphorus of 0.05 milligrams per litre (mg P/L) were used.
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.2. Data for Figure 1. Status of phosphorus and nitrogen levels in Lake Winnipeg's 3 largest tributary rivers, Canada, 2014 to 2016

River	2014 to 2016 total phosphorus criteria exceedance (percentage)	Phosphorus level status	2014 to 2016 total nitrogen criteria exceedance (percentage)	Nitrogen level status
Saskatchewan River	14	Fair	8	Good
Red River	100	Poor	71	Poor
Winnipeg River	100	Poor	65	Poor

Note: For the Saskatchewan, Red and Winnipeg rivers, water quality is considered good when water quality measurements exceed the river's nutrient criteria or objective less than 10% of the time. A fair status is applied when the nutrient criteria or objective is exceeded 10% to 50% of the time. Poor status is applied when measurements are above the nutrient criteria or objective in over 50% of samples.
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.3. Data for Figure 2. Seasonally-weighted annual average total phosphorus levels in the north basin, Lake Winnipeg, Canada, 1999 to 2016

Year	Seasonally-weighted average (milligrams per litre)	Minimum (milligrams per litre)	Maximum (milligrams per litre)	Number of samples
1999	0.045	0.024	0.130	21
2000	0.036	0.013	0.091	29
2001	0.054	0.008	0.231	23
2002	0.045	0.014	0.116	85
2003	0.031	0.017	0.069	13
2004	0.044	0.014	0.204	30
2005	0.061	0.028	0.103	35
2006	0.038	0.009	0.080	60
2007	0.046	0.005	0.095	59
2008	0.046	0.012	0.090	63
2009	0.051	0.018	0.318	53
2010	0.045	0.020	0.082	62
2011	0.05	0.016	0.311	76
2012	0.03	0.005	0.068	78
2013	0.033	0.011	0.09	77
2014	0.032	0.016	0.067	25
2015	0.033	0.012	0.065	39
2016	0.031	0.014	0.117	43

Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.4. Data for Figure 2. Seasonally-weighted annual average total phosphorus levels in the south basin and narrows, Lake Winnipeg, Canada, 1999 to 2016

Year	Seasonally-weighted average (milligrams per litre)	Minimum (milligrams per litre)	Maximum (milligrams per litre)	Number of samples
1999	0.100	0.030	0.232	32
2000	0.078	0.040	0.166	24
2001	0.118	0.033	0.215	15
2002	0.109	0.023	0.296	87
2003	0.117	0.029	0.252	14
2004	0.099	0.028	0.200	14
2005	0.138	0.026	0.508	51
2006	0.124	0.030	0.414	82
2007	0.131	0.028	0.390	98
2008	0.083	0.016	0.188	103
2009	0.132	0.026	0.367	119
2010	0.129	0.019	0.579	105
2011	0.116	0.013	0.36	108
2012	0.094	0.019	0.222	113
2013	0.108	0.022	0.431	109
2014	0.104	0.025	0.242	56
2015	0.099	0.020	0.294	57
2016	0.100	0.023	0.338	57

Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.5. Data for Figure 2. Annual total phosphorus concentration data for the Saskatchewan River, Canada, 1999 to 2016

Year	Maximum (milligrams per litre)	Third quartile (milligrams per litre)	Median (milligrams per litre)	First quartile (milligrams per litre)	Minimum (milligrams per litre)
1999	0.082	0.076	0.048	0.032	0.019
2000	0.076	0.061	0.047	0.020	0.018
2001	0.087	0.049	0.036	0.023	0.016
2002	0.146	0.052	0.023	0.020	0.014
2003	0.086	0.067	0.050	0.028	0.014
2004	0.097	0.065	0.044	0.020	0.013
2005	0.149	0.094	0.058	0.023	0.018
2006	0.336	0.073	0.068	0.054	0.016
2007	0.446	0.061	0.045	0.035	0.020
2008	0.107	0.052	0.033	0.020	0.016
2009	0.049	0.039	0.033	0.026	0.016
2010	0.081	0.049	0.031	0.025	0.022
2011	0.212	0.099	0.066	0.026	0.021
2012	0.152	0.054	0.030	0.027	0.019
2013	0.210	0.044	0.033	0.024	0.015
2014	0.109	0.051	0.021	0.016	0.010
2015	0.072	0.046	0.042	0.017	0.013
2016	0.120	0.068	0.052	0.021	0.016

Note: Data are for Environment and Climate Change Canada's monitoring site: Saskatchewan River above Carrot River (MA05KH0001).
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.6. Data for Figure 2. Annual total phosphorus concentration data for the Red River, Canada, 1999 to 2016

Year	Maximum (milligrams per litre)	Third quartile (milligrams per litre)	Median (milligrams per litre)	First quartile (milligrams per litre)	Minimum (milligrams per litre)
1999	0.485	0.339	0.240	0.115	0.075
2000	0.486	0.386	0.254	0.159	0.068
2001	0.452	0.38	0.213	0.141	0.085
2002	1.37	0.361	0.218	0.109	0.032
2003	0.967	0.507	0.210	0.166	0.032
2004	0.673	0.414	0.312	0.288	0.137
2005	0.758	0.467	0.373	0.193	0.107
2006	0.520	0.339	0.230	0.206	0.129
2007	0.870	0.478	0.344	0.259	0.193
2008	0.670	0.428	0.339	0.299	0.194
2009	1.02	0.377	0.321	0.251	0.135
2010	0.773	0.418	0.361	0.272	0.104
2011	0.560	0.418	0.321	0.247	0.125
2012	0.409	0.302	0.265	0.241	0.096
2013	1.42	0.524	0.405	0.354	0.149
2014	0.626	0.426	0.327	0.239	0.136
2015	0.883	0.386	0.275	0.183	0.103
2016	0.676	0.411	0.309	0.218	0.108

Note: Data are for Environment and Climate Change Canada's monitoring site: Red River at Emerson, Manitoba (MA05OC0001).
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.7. Data for Figure 2. Annual total phosphorus concentration data for the Winnipeg River, Canada, 1999 to 2016

Year	Maximum (milligrams per litre)	Third quartile (milligrams per litre)	Median (milligrams per litre)	First quartile (milligrams per litre)	Minimum (milligrams per litre)
1999	0.031	0.029	0.027	0.024	0.021
2000	0.033	0.030	0.022	0.019	0.018
2001	0.040	0.029	0.025	0.023	0.019
2002	0.094	0.031	0.028	0.026	0.021
2003	0.032	0.030	0.026	0.024	0.020
2004	0.039	0.033	0.030	0.026	0.019
2005	0.047	0.035	0.027	0.025	0.023
2006	0.031	0.030	0.028	0.025	0.020
2007	0.044	0.039	0.034	0.029	0.027
2008	0.034	0.030	0.027	0.026	0.022
2009	0.036	0.026	0.025	0.023	0.022
2010	0.032	0.030	0.028	0.024	0.019
2011	0.033	0.031	0.029	0.026	0.023
2012	0.044	0.034	0.030	0.027	0.021
2013	0.030	0.027	0.026	0.023	0.022
2014	0.035	0.028	0.025	0.024	0.021
2015	0.033	0.030	0.028	0.023	0.019
2016	0.037	0.031	0.029	0.025	0.022

Note: Data are for Environment and Climate Change Canada's monitoring site: Winnipeg River at Pointe du Bois (MA05PF0022).
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.8. Data for Figure 3. Seasonally-weighted annual average total nitrogen levels in the north basin, Lake Winnipeg, Canada, 1999 to 2016

Year	Seasonally-weighted average (milligrams per litre)	Minimum (milligrams per litre)	Maximum (milligrams per litre)	Number of samples
1999	0.778	0.505	1.61	21
2000	0.535	0.305	0.920	29
2001	0.571	0.120	1.130	22
2002	0.267	0.105	0.810	85
2003	1.023	0.405	1.810	13
2004	0.830	0.105	2.030	30
2005	0.673	0.11	2.440	35
2006	0.677	0.305	1.550	59
2007	0.525	0.105	1.710	59
2008	0.662	0.305	1.605	62
2009	0.860	0.228	6.025	53
2010	0.577	0.283	1.583	62
2011	0.834	0.125	2.46	76
2012	0.476	0.325	0.755	78
2013	0.491	0.105	1.24	77
2014	0.482	0.320	0.750	26
2015	0.565	0.340	1.00	39
2016	0.575	0.210	3.59	44

Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.9. Data for Figure 3. Seasonally-weighted annual average total nitrogen levels in the south basin and narrows, Lake Winnipeg, Canada, 1999 to 2016

Year	Seasonally-weighted average (milligrams per litre)	Minimum (milligrams per litre)	Maximum (milligrams per litre)	Number of samples
1999	0.838	0.405	1.600	32
2000	0.788	0.430	1.560	24
2001	1.077	0.12	2.620	15
2002	0.480	0.105	1.910	87
2003	0.929	0.105	2.900	14
2004	0.896	0.105	2.250	14
2005	0.782	0.105	1.970	51
2006	1.214	0.305	2.930	82
2007	0.819	0.105	2.420	98
2008	0.700	0.34	1.300	100
2009	0.927	0.283	2.860	119
2010	0.967	0.372	3.710	104
2011	1.013	0.185	2.140	106
2012	0.717	0.255	2.154	113
2013	0.723	0.285	2.03	109
2014	0.779	0.335	1.67	56
2015	0.783	0.370	2.53	57
2016	0.813	0.450	3.29	57

Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.10. Data for Figure 3. Annual total nitrogen concentration data for the Saskatchewan River, Canada, 1999 to 2016

Year	Maximum (milligrams per litre)	Third quartile (milligrams per litre)	Median (milligrams per litre)	First quartile (milligrams per litre)	Minimum (milligrams per litre)
1999	0.699	0.621	0.563	0.474	0.403
2000	0.733	0.603	0.544	0.479	0.332
2001	0.641	0.498	0.466	0.402	0.390
2002	1.38	0.553	0.471	0.442	0.365
2003	0.814	0.628	0.537	0.393	0.328
2004	1.11	0.688	0.630	0.561	0.384
2005	0.997	0.681	0.593	0.540	0.447
2006	2.62	0.745	0.613	0.590	0.531
2007	0.882	0.702	0.594	0.572	0.411
2008	0.957	0.652	0.561	0.519	0.341
2009	0.680	0.658	0.619	0.516	0.339
2010	0.870	0.693	0.616	0.559	0.480
2011	1.16	0.845	0.770	0.710	0.505
2012	0.897	0.662	0.573	0.533	0.432
2013	1.02	0.726	0.660	0.560	0.508
2014	0.931	0.695	0.640	0.542	0.416
2015	0.682	0.558	0.495	0.441	0.293
2016	1.37	0.670	0.618	0.569	0.462

Note: Data are for Environment and Climate Change Canada's monitoring site: Saskatchewan River above Carrot River (MA05KH0001).
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.11. Data for Figure 3. Annual total nitrogen concentration data for the Red River, Canada, 1999 to 2016

Year	Maximum (milligrams per litre)	Third quartile (milligrams per litre)	Median (milligrams per litre)	First quartile (milligrams per litre)	Minimum (milligrams per litre)
1999	3.24	1.94	1.66	1.25	0.913
2000	5.46	2.77	1.56	1.27	1.12
2001	3.74	2.18	1.76	1.38	1.06
2002	6.05	1.96	1.50	1.19	0.687
2003	4.59	2.05	1.85	1.37	0.485
2004	4.50	2.34	1.97	1.55	1.40
2005	2.99	2.10	1.60	1.36	1.20
2006	3.96	1.87	1.43	1.28	0.951
2007	4.68	2.01	1.63	1.37	1.04
2008	4.23	2.16	1.75	1.57	1.18
2009	5.68	2.12	1.80	1.58	1.02
2010	3.81	2.42	1.88	1.56	1.24
2011	5.27	2.79	2.08	1.70	1.05
2012	3.98	1.88	1.54	1.31	0.977
2013	4.79	2.43	2.00	1.75	1.18
2014	5.02	2.68	1.81	1.29	0.934
2015	8.70	1.89	1.47	1.23	0.798
2016	5.00	2.40	1.77	1.49	1.11

Note: Data are for Environment and Climate Change Canada's monitoring site: Red River at Emerson, Manitoba (MA05OC0001).
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.12. Data for Figure 3. Annual total nitrogen concentration data for the Winnipeg River, Canada, 1999 to 2016

Year	Maximum (milligrams per litre)	Third quartile (milligrams per litre)	Median (milligrams per litre)	First quartile (milligrams per litre)	Minimum (milligrams per litre)
1999	0.570	0.530	0.487	0.469	0.450
2000	0.575	0.541	0.496	0.435	0.386
2001	0.605	0.582	0.547	0.530	0.479
2002	0.633	0.624	0.559	0.549	0.529
2003	0.580	0.539	0.525	0.473	0.450
2004	0.625	0.577	0.503	0.483	0.469
2005	0.732	0.544	0.533	0.513	0.505
2006	0.657	0.580	0.549	0.477	0.431
2007	0.585	0.556	0.545	0.521	0.488
2008	0.661	0.545	0.491	0.472	0.447
2009	0.556	0.525	0.506	0.484	0.448
2010	0.590	0.523	0.493	0.476	0.427
2011	0.594	0.543	0.519	0.503	0.448
2012	0.737	0.510	0.474	0.451	0.424
2013	0.551	0.505	0.484	0.455	0.406
2014	0.537	0.521	0.505	0.451	0.399
2015	0.550	0.498	0.427	0.377	0.367
2016	0.583	0.549	0.492	0.431	0.377

Note: Data are for Environment and Climate Change Canada's monitoring site: Winnipeg River at Pointe du Bois (MA05PF0022).
Source: Manitoba Sustainable Development and Environment and Climate Change Canada.

Table A.13. Data for Figure 4. Estimated cumulative reduction in the amount of phosphorus reaching Lake Winnipeg because of completed stewardship projects, Canada, April 2010 to March 2017

Year	Estimated phosphorus removal (kilograms of phosphorus/year)	Estimated one-time phosphorus removal (kilograms of phosphorus)	Total estimated phosphorus removal over all years (kilograms of phosphorus)
2010 to 2011	4 906	n/a	4 906
2011 to 2012	1 586	n/a	11 398
2012 to 2013	0[A]	n/a	17 890
2013 to 2014	122	n/a	24 504
2014 to 2015	8 194	n/a	39 312
2015 to 2016	7 388	21 345	82 853
2016 to 2017	5 635	n/a	110 734

Note: [A] The second phase of the Lake Winnipeg Basin Initiative began in 2012-2013. No new phosphorus reduction projects were funded that year. The estimated reduction in phosphorus load is based on the results of projects completed between April 2010 and March 2017. Estimated phosphorus loads for each project type are rounded and then summed to calculate the total. Year refers to fiscal year, which runs from April to March. The year 2017 therefore refers to April 1, 2016 to March 31, 2017.
n/a = not applicable.
Source: Environment and Climate Change Canada (2017) Lake Winnipeg Basin Initiative.

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