Provincial Water Quality Monitoring of Lake Winnipeg: Program Update

Lake Winnipeg Research Consortium Science Workshop
February 4-5, 2020

Andrew Burton, Senior Water Quality Specialist
Agriculture and Resource Development
Email: Andrew.Burton@gov.mb.ca

Manitoba

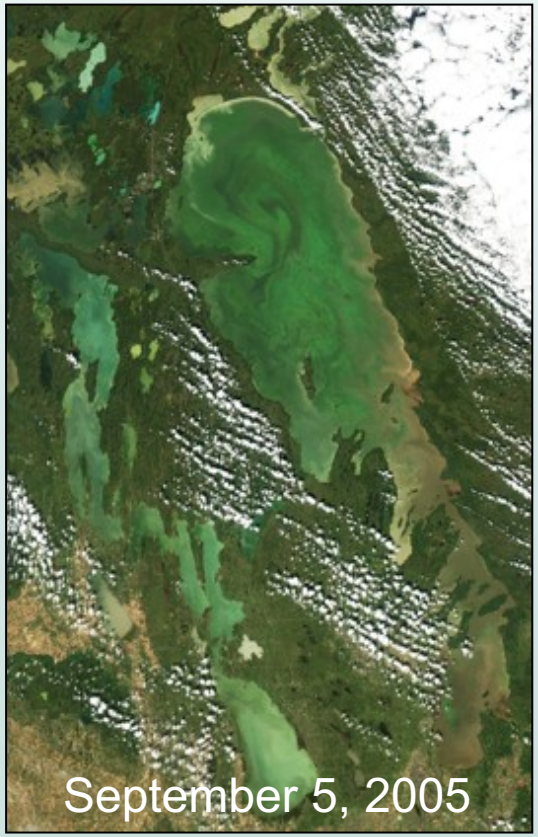
Outline

- Water Quality Concerns in Lake Winnipeg
- Provincial Monitoring Program on Lake Winnipeg
- Summary of Water Quality Data:
  - Nutrient loads (1994 – 2016)
  - Long-term changes in nutrients (1999 – 2018)
  - Algal blooms and microcystin (2018 – 2019)
  - Dissolved organic carbon (2018 – 2019)
  - Mercury (2018 – 2019)
- Plans for 2020

Water Quality Concerns

Major Concern: Eutrophication (symptom of excessive nutrients)

- Changes in water quality in Lake Winnipeg has occurred in recent decades.
- Increased nutrient loads to Lake Winnipeg and concentrations of nutrients in Lake Winnipeg has led to an increase in the frequency and magnitude of algal blooms.
- Eutrophication is not only a problem in Lake Winnipeg.



Current and Emerging Water Quality Concerns

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Trace Elements (e.g., metals)

Science of The Total Environment
Volumes 497–498, 1 November 2014, Pages 239-249

Defining fish community structure in Lake Winnipeg using stable isotopes ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$): Implications for monitoring ecological responses and trophodynamics of mercury & other trace elements

Amy F.A. Ofukany [a, 1], Leonard I. Wassenaar [b, 2], Alexander L. Bond [b], Keith A. Hobson [b]

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https://doi.org/10.1016/j.scitotenv.2014.07.125

Pesticides

Science of The Total Environment
Volume 635, 1 September 2018, Pages 803-816

Inputs, source apportionment, and transboundary transport of pesticides and other polar organic contaminants along the lower Red River, Manitoba, Canada

Jonathan K. Challis [a], Leah D. Cuscito [b], Shira Joudan [c], Kim H. Luong [b], Charles W. Knapp [d], Mark L. Hanson [e], Charles S. Wong [a, b, e]

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https://doi.org/10.1016/j.scitotenv.2018.04.128

Pharmaceuticals, Personal Care Products, Estrogenic Compounds

Emerging Contaminants 3 (2017) 1–16

Contents lists available at ScienceDirect

Emerging Contaminants

journal homepage: http://www.keaipublishing.com/en/journals/emerging-contaminants/

Pharmaceuticals and personal care products (PPCPs) in the freshwater aquatic environment

Anekwe Jennifer Ebele [a], Mohamed Abou-Elwafa Abdallah [a, b, *], Stuart Harrad [a]

[a] School of Geography, Earth, and Environmental Sciences, University of Birmingham, Birmingham, B15 2TT, United Kingdom
[b] Department of Analytical Chemistry, Faculty of Pharmacy, Assiut University, 71526 Assiut, Egypt

Algal Toxins

IS LAKE WINNIPEG THE NEXT LAKE ERIE? RECENT DREISSENID MUSSEL COLONIZATION MAY LEAD TO MORE TOXIC CYANOBACTERIAL BLOOMS

McKindles, Katelyn M; Bullerjahn, George; Zimba, Paul V; Chiu, Alexander S; Watson, Sue B; et al.

The Ohio Journal of Science; Columbus Vol. 118, Iss. 1, (Apr 2018): A29.

Microplastics

Microplastic contamination in Lake Winnipeg, Canada☆

Philip J. Anderson [a, 1], Sarah Warrack [b], Victoria Langen [c], Jonathan K. Challis [d], Mark L. Hanson [e], Michael D. Rennie [a, b, c, *]

Invasive Species (e.g., zebra mussels, spiny water flea, and others)

REABIC

Management of Biological Invasions (2017) Volume 8, Issue 3: 287–300
DOI: https://doi.org/10.3391/mbi.2017.8.3.03

Special Issue: Management of Invasive Species in Inland Waters

Research Article

Environmental DNA as a detection tool for zebra mussels *Dreissena polymorpha* (Pallas, 1771) at the forefront of an invasion event in Lake Winnipeg, Manitoba, Canada

Climate Change

ELSEVIER

Journal of Great Lakes Research
Volume 38, Supplement 3, 2012, Pages 83-94

Modelling of climate-induced hydrologic changes in the Lake Winnipeg watershed

Rajesh R. Shrestha [a, 1], Yonas B. Dibike [a], Terry D. Prowse [a, b]

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https://doi.org/10.1016/j.jglr.2011.02.004

Provincial Lake Winnipeg Water Quality Monitoring Program

- Monitoring in partnership with the Lake Winnipeg Research Consortium since 1999.
- Lake monitored intensively:
  - 65 stations (nearshore, offshore, river mouths, outflows)
  - Surveys during the spring, summer, fall
  - Reduced number of sites sampled during the winter (n = 13)
  - Measure physical, chemical, and biological parameters

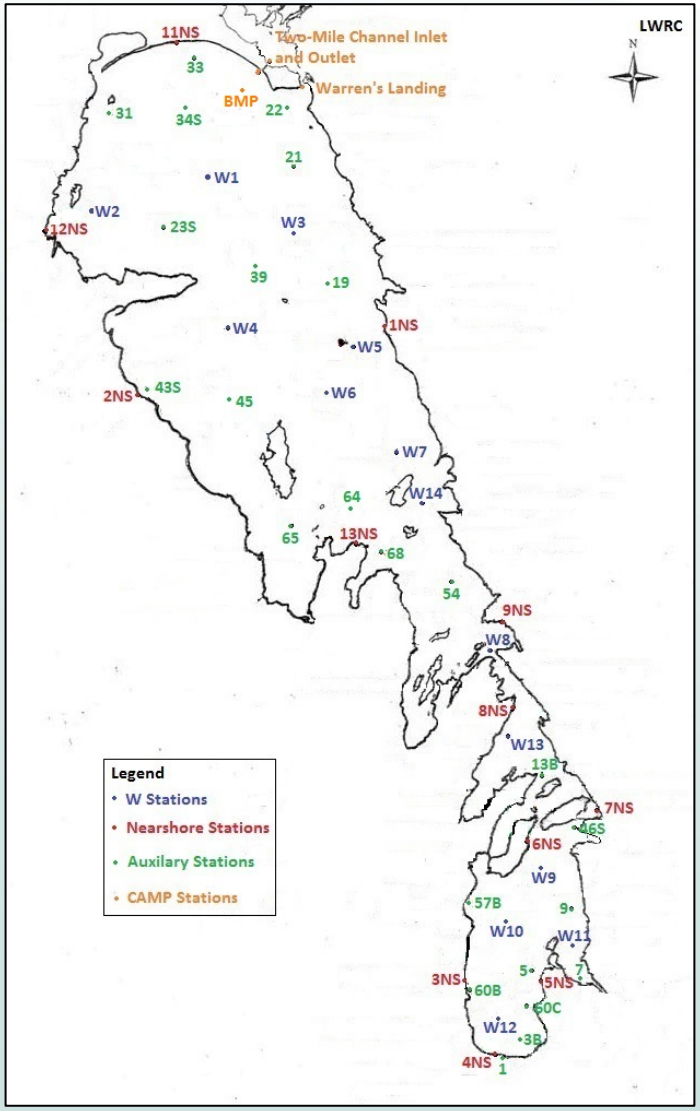


Figure 1. Sampling locations as part of the provincial Lake Winnipeg Water Quality Monitoring Program (2019)

W Stations

- 14 long-term stations monitored (1999 to present)
- Water Sampling (e.g., general chemistry, ions, nutrients, trace elements, mercury, pesticides x 3)
- Sediment Sampling (e.g., particle size, pH, nutrients, ions, carbon content, trace elements)
- Biological Sampling (e.g., benthic invertebrates, algae identification and biovolume, phytoplankton, algal toxins, chlorophyll a)
- Microbiology (e.g., e. coli if can be analyzed within 48 hours; cyanobacterial cell count if an algae bloom is present.

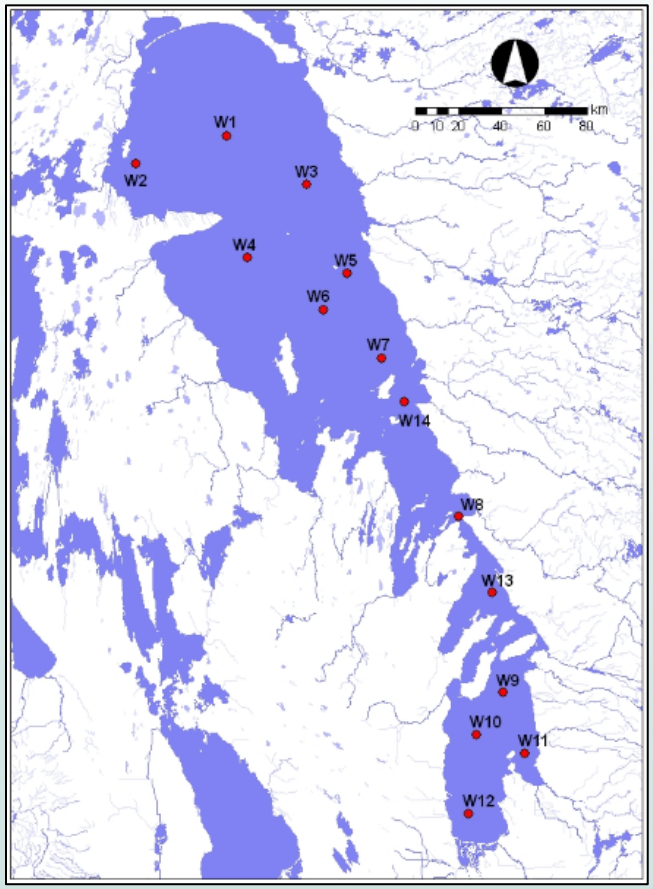


Figure 2. Fourteen long-term stations sampled as part of the Lake Winnipeg Water Quality Monitoring Program

Auxiliary Stations

- Provide additional information about geospatial characteristics.
- Reduced suite of water parameters measured (e.g., general chemistry, nutrients, chlorophyll a, TSS, e. coli if the samples can be analyzed within 48 hours; cyanobacterial cell count if there is an algae bloom).

Non-Routine Sampling

- Algal bloom sampling (e.g., microcystin and cyanobacterial cell count if observed).
- Partnerships with others (e.g., Environment and Climate Change Canada, Manitoba Hydro, University of Manitoba, etc.)

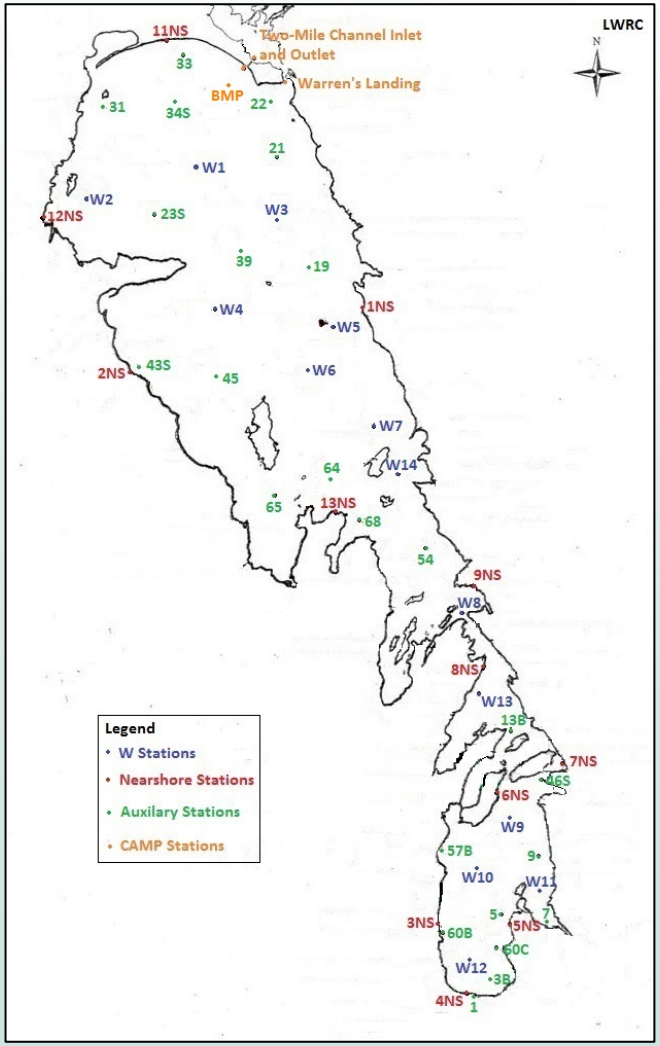


Figure 3. All stations sampled as part of the provincial Lake Winnipeg Water Quality Monitoring Program (2019)

Nearshore Stations

- 12 nearshore stations (added in 2014).
- Bridge knowledge gap and capture changes in the littoral zone.
- Water chemistry:
  - Transect with sites at 3m, 2m, 1m total depth.
  - General chemistry, total particulate and dissolved N & P, chlorophyll a, TSS, turbidity, PAR, calcium.

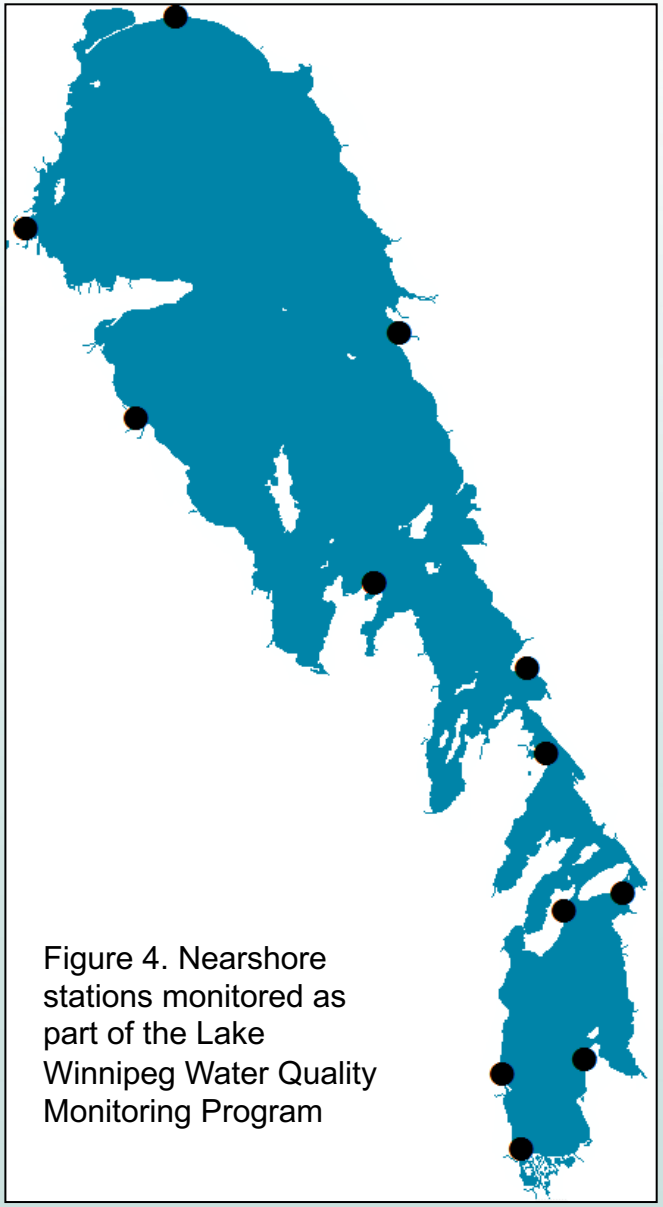
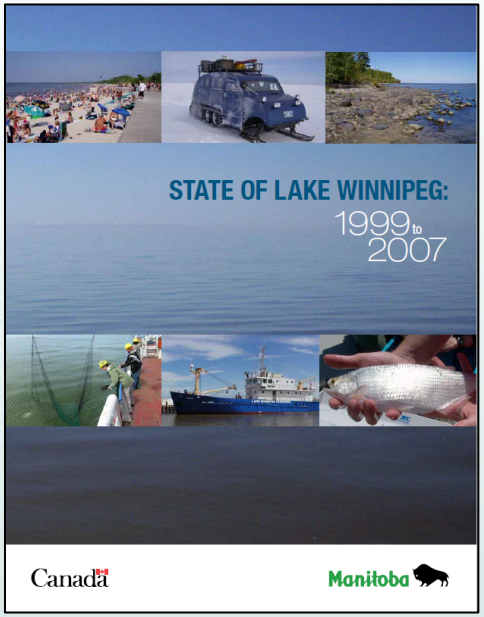


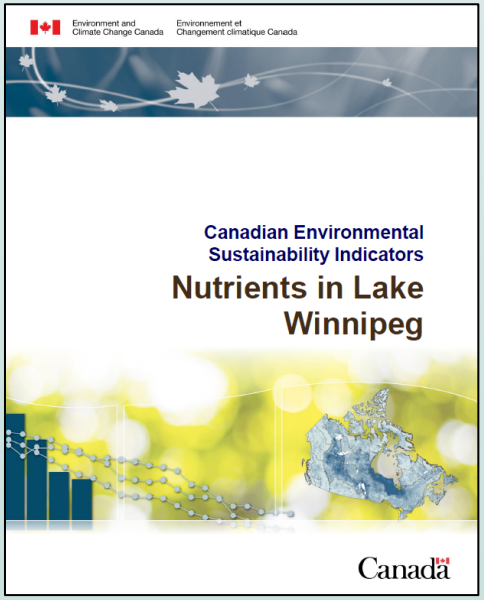
Figure 4. Nearshore stations monitored as part of the Lake Winnipeg Water Quality Monitoring Program

‘State of the Lake’ & Indicator Reporting

- In 2010, Canada and Manitoba committed to State of the Lake and Indicators reporting under the Science Subsidiary Agreement.

- First report released in 2011:
  - Physical, chemical, and biological characteristics of the lake
  - Described major seasonal, spatial and temporal patterns described.
  - Highlights current and emerging issues and recent research.





Nutrient Status Report

- New Status Report (February 2019) summarizing the most recent nutrient conditions in Lake Winnipeg and nutrient loads from major tributaries flowing into the lake.

- New website: https://www.gov.mb.ca/sd/water/lakes-beaches-rivers/lake-winnipeg.html

Results

Phosphorus Loads (1994-2016)

- Wet cycle observed over the past decade.
- Residence time reduced in recent years (~ 3 years).
- Hydrology plays a significant role influencing water quality in Lake Winnipeg.
- In general, phosphorus loading followed patterns in streamflow with the highest loads transported in wet years and the lowest loads in dry years.

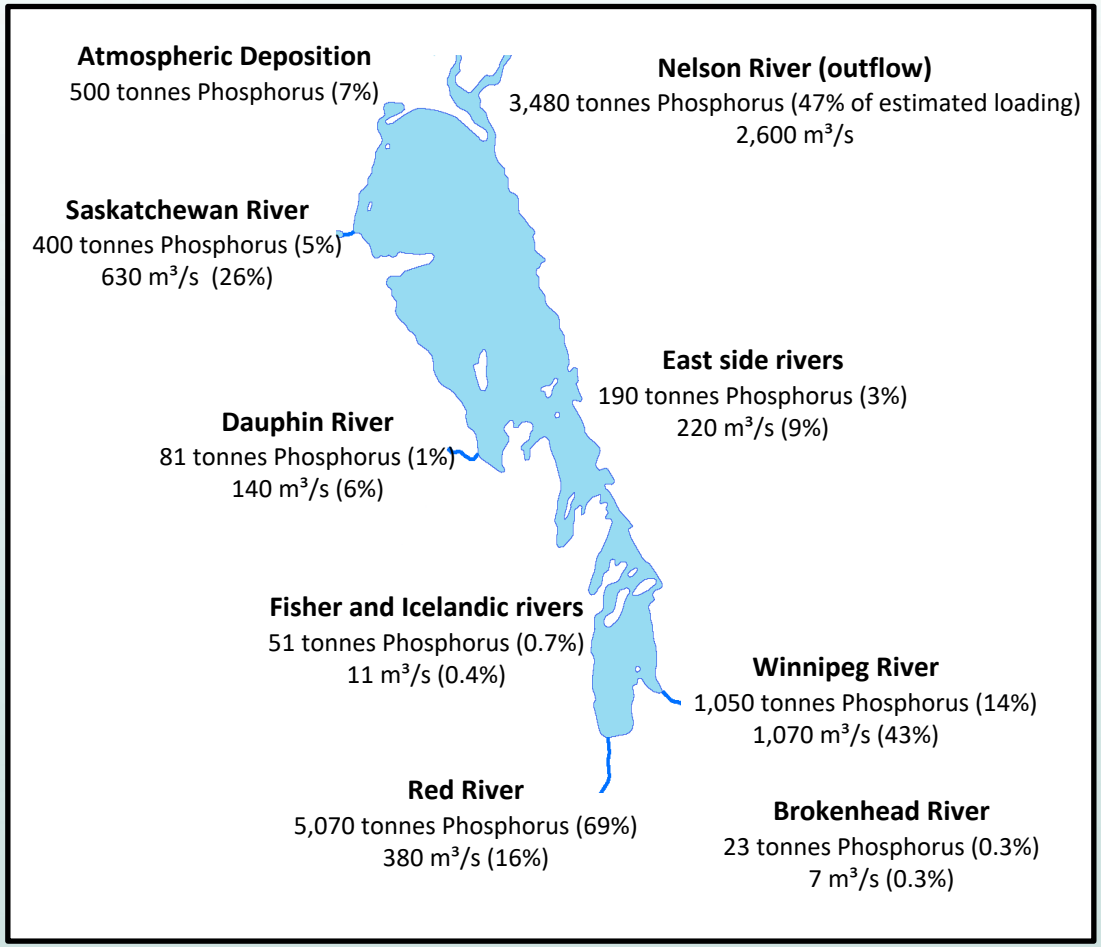


Figure 5. Estimated annual average loading (t/yr) and percent phosphorus contribution to Lake Winnipeg from 1994 to 2016 (Agriculture and Resource Development 2020).

Nitrogen Loads (1994-2016)

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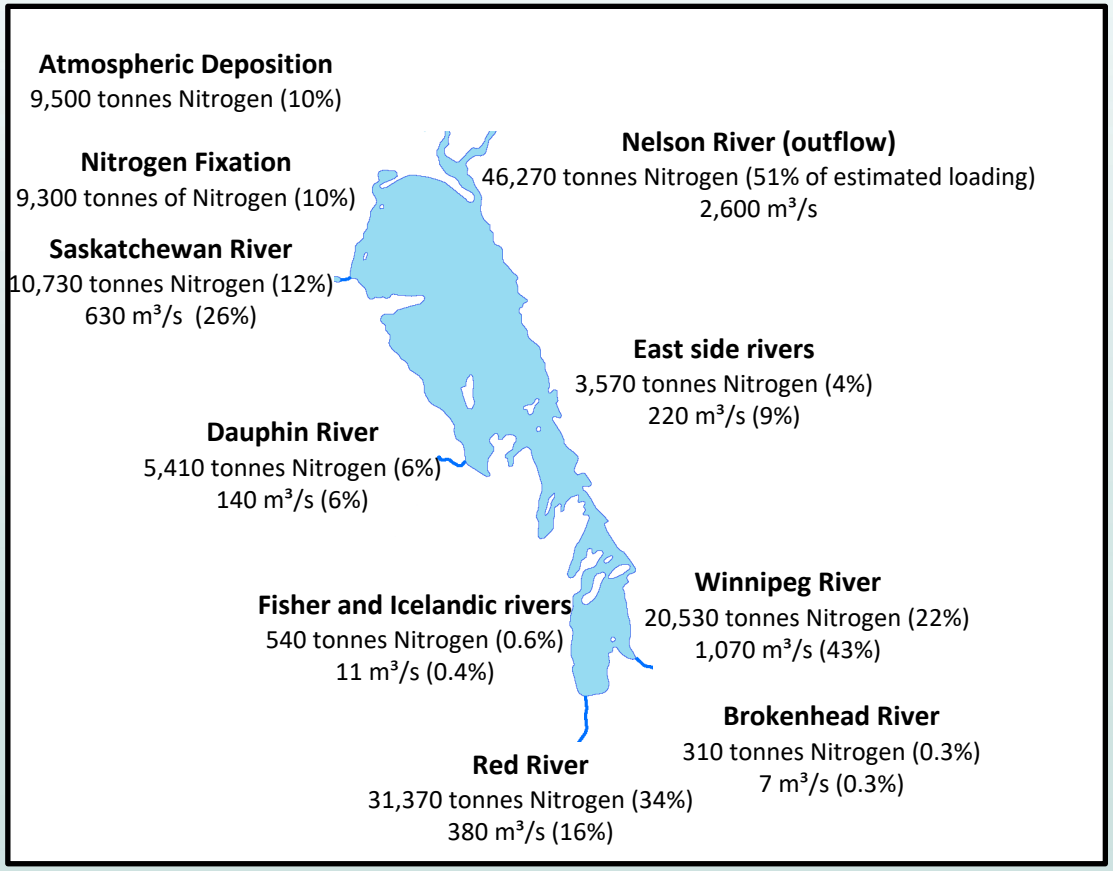

Figure 6. Estimated annual average loading (t/yr) and percent nitrogen contribution to Lake Winnipeg from 1994 to 2016 (Agriculture and Resource Development 2020).

Offshore Chemistry

Changes in Phosphorus Concentration in Lake Winnipeg (Offshore)

- Lake Winnipeg is rich in phosphorus and is considered hypereutrophic.
- Concentration measured below the long-term average in recent years.
- South basin and narrows up to 3 times higher than the north basin.

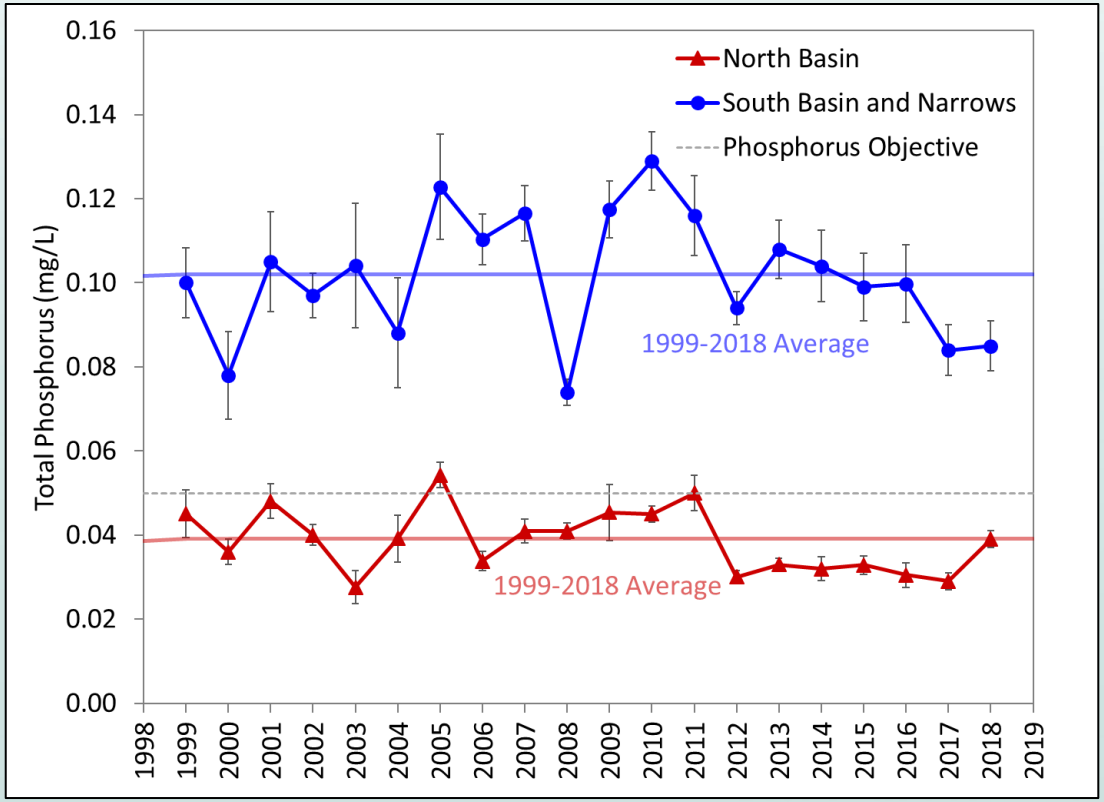

Figure 7. Total phosphorus concentrations in the north and south basins of Lake Winnipeg, 1999 to 2018 (Agriculture and Resource Development 2020).

Changes in Nitrogen Concentration in Lake Winnipeg (Offshore)

- Large between year variability in total nitrogen may be driven by a number of factors including nitrogen fixation, denitrification processes, nitrogen loading from tributary rivers, internal loading and wind-induced resuspension.

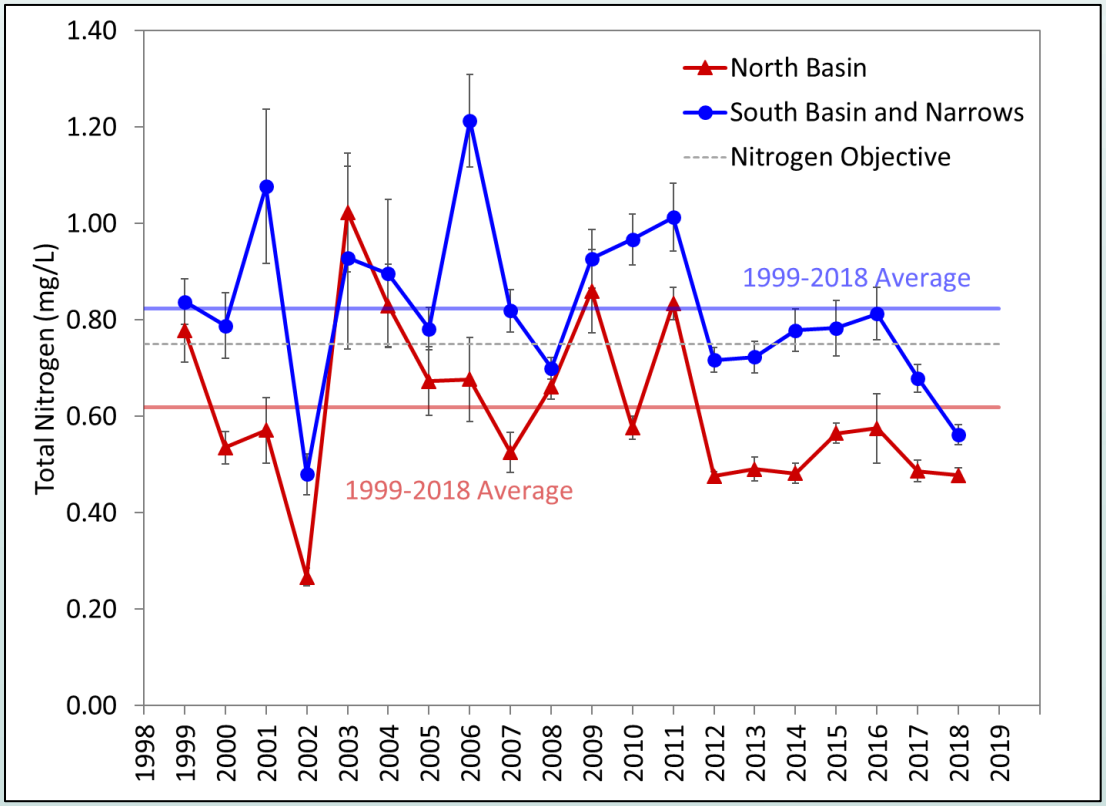

Figure 8. Total nitrogen concentrations in the north and south basins of Lake Winnipeg, 1999 to 2016 (Agriculture and Resource Development 2020).

Algal Blooms – Offshore (2018 and 2019)

- Microcystin concentrations always below detection limit of <0.2 µg/L (exception of two out of 87 samples).
- Maximum microcystin concentration measured was 0.44 µg/L.
- No microcystin samples exceeded the recreational water quality objective of 20 µg/L.
- Cyanobacteria only collected when a bloom was observed. Species dominated by Aphanizomenon with smaller amounts of Planktothrix and Anabaena.

Algal Blooms - Beaches (2018 and 2019)

- 19 beaches monitored as part of the Clean Beaches Program on Lake Winnipeg.
- Water samples are collected and analyzed for cyanobacteria and microcystin when algal blooms are observed.
- All samples collected and analyzed for cyanobacteria and microcystin from beaches along the east side of Lake Winnipeg.
- No microcystin samples exceeded the recreational water quality objective of 20 µg/L. Concentrations usually below detection of < 0.2 µg/L (80% BDL),
- However, microcystin concentration ranged up to 5.6 µg/L.

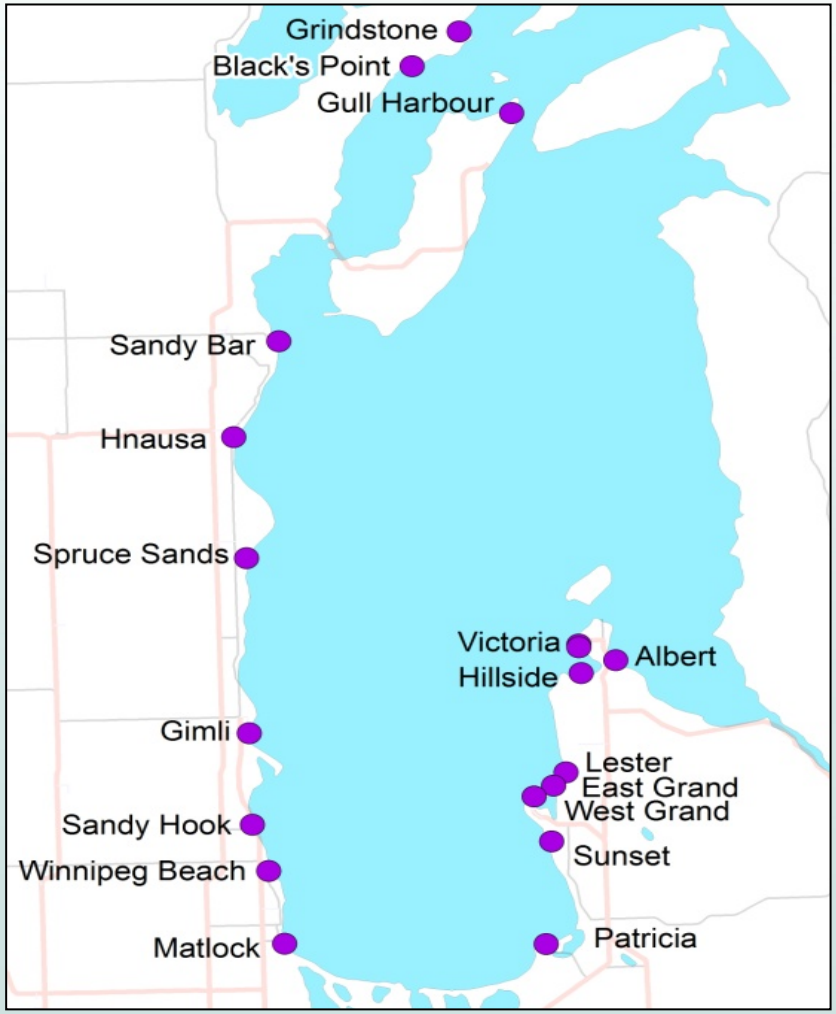

Figure 9. Beach monitoring locations on Lake Winnipeg (Clean Beaches Program, Manitoba Agriculture and Resource Development).

Algal Blooms - Beaches (2018 and 2019)

- Five beaches posted each year with an algal advisory sign (>100,000 cyanobacteria cells/mL); all on the east side of Lake Winnipeg (e.g., East and West Grand, Victoria, Hillside, Albert).

Algae and Foam at Victoria Beach on August 20, 2019

- Cyanobacteria species dominated by Aphanocapsa and/or Pseudoanabaena with smaller amounts of Planktothrix and Aphanizomenon.

Dissolved Organic Carbon – Offshore (2018 and 2019)

- Dissolved organic carbon (DOC) is often not included in surface water quality monitoring studies.

- DOC is an important water quality parameter as it can influence the speciation, bioavailability, mobility, and toxicity of many trace elements (e.g., metals) in surface waters.

- Natural lakes typically range from 2 to 10 mg/L. Lake Winnipeg median concentration was 8.6 mg/L in 2018/2019.

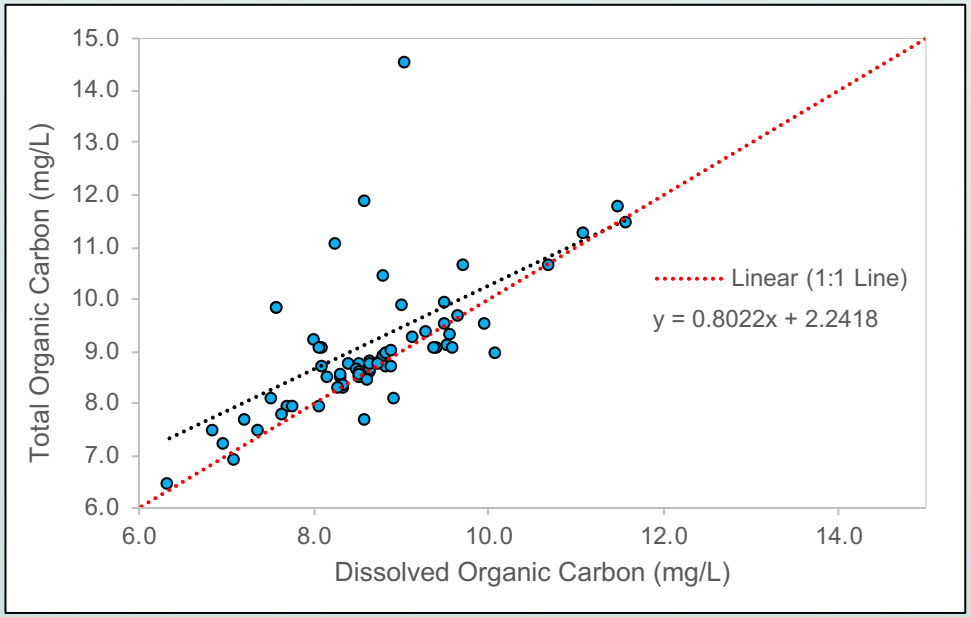

Figure 10. Comparison between dissolved organic carbon (DOC) and total organic carbon (TOC) in Lake Winnipeg surface waters in 2018 and 2019.

Mercury – Offshore (2018 and 2019)

- Surface waters measured for total mercury following the ultra trace method (DL = 0.5 ng/L) during the spring, summer and fall and high range method (DL = 5 ng/L) during the winter.
- In general, mercury concentrations in Lake Winnipeg are low (median of 0.7 ng/L following Regression on Order Statistics [ROS]).
- Elevated mercury concentrations in the south basin (median of 1.0 ng/L) compared to the north basin (median of 0.4 ng/L).
- The highest concentrations measured at station W11 (Winnipeg River) and W12 (Red River).

Table 1. Total mercury concentrations in Lake Winnipeg surface waters measured during 2018 (fall) and 2019 (winter, spring, summer, and fall).

Station	Lake Winnipeg Basin	Minimum (ng/L)	Maximum (ng/L)	Count of Analyses	%BDL
W1	North	<0.5	<0.5	4	100
W2	North	<0.5	<0.5	4	100
W3	North	<0.5	0.5	4	50
W4	North	<0.5	0.6	4	50
W5	North	<0.5	0.7	4	25
W6	North	<0.5	0.6	4	50
W7	North	<0.5	1.0	4	25
W8	Narrows	<0.5	0.8	4	50
W9	South	0.7	1.4	4	0
W10*	South	0.9	1.6	15	0
W11	South	1.1	4.9	4	0
W12	South	0.7	7.4	4	0
W13	Narrows	0.7	1.0	4	0
W14	Narrows	0.9	1.2	4	0

Note: The symbol * represents the site selected for QA/QC.

Plans for 2020

- Continue long-term water quality monitoring of north basin and south basin in Winter, Spring, Summer, and Fall of 2020.
- In process of publishing the 2nd edition of the 'State of the Lake' Report.
- Working with ECCC to publish the next set of Lake Winnipeg Basin Indicator Fact Sheets (following the completion of the SOLR).
- Update the 2019 Nutrient Status Report.
- Further analysis of offshore and nearshore water quality data, and sediment quality data required.
- Update the Water Quality Standards, Objectives and Guidelines report.

Acknowledgments

Special thanks to the water quality management staff at Agriculture and Resource Development:

- Elaine Page
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Thank-you

Andrew Burton
Senior Water Quality Specialist
Agriculture and Resource Development
Email: Andrew.Burton@gov.mb.ca