LAKE WINNIPEG FOUNDATION

Truro Creek; Photo: Paul Mutch

PEMBINA VALLEY
WATERSHED DISTRICT

2020 regional report

LAKE WINNIPEG
community-based monitoring network

PEMBINA VALLEY
WATERSHED DISTRICT

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Lake Winnipeg Community-Based Monitoring Network: Overview

The Lake Winnipeg Community-Based Monitoring Network (LWCBMN), coordinated by the Lake Winnipeg Foundation (LWF), mobilizes citizens and watershed partners to collect water samples across Manitoba in order to measure phosphorus concentration. Phosphorus is the nutrient responsible for blue-green algae blooms on Lake Winnipeg. Phosphorus comes from diverse sources across the watershed, including municipal wastewater and agricultural runoff.

Different sub-watersheds contribute different proportions of Lake Winnipeg's total phosphorus load. With the help of a strong network of watershed partners and citizen scientists, this long-term monitoring program is identifying phosphorus hotspots – localized areas that contribute higher amounts of phosphorus to waterways than other areas. Targeting actions to reduce phosphorus loading in hotspots will reduce the amount of phosphorus entering Manitoba's lakes and rivers, and improve the health of Lake Winnipeg.

Snow melts, floods and heavy rainfall events are responsible for most of the phosphorus that is flushed from the land and carried into our waterways. LWCBMN samples frequently throughout the season, and particularly during the spring melt, to ensure we capture phosphorus runoff during these high-water events.

Most LWCBMN sampling is conducted at stations where water flow is continuously monitored by the Water Survey of Canada (WSC). By tracking flow online using the WSC's real-time data, the network can notify partners and citizen scientists across the watershed to ensure frequent sampling during peak flows.

Sites with flow data can be coupled with LWCBMN data to calculate **phosphorus loads**. We need several samples throughout the season, corresponding to changes in flow, to accurately calculate these loads. Phosphorus loads can subsequently be used to calculate **phosphorus export**, based on the area of the watershed.

Phosphorus load is the total amount of phosphorus flowing past a sample site over a given period of time, expressed as tonnes per year.

Phosphorus export is the amount of phosphorus exported by each hectare of land in a year, expressed as kg/ha/y.

Sample Collection & Site Map

Water samples are collected using a weighted sampling device that collects source water directly into a 500 mL Nalgene polyethylene bottle. The sampling device is lowered slowly into the water just before it hits the bottom, the bottle is filled, then slowly brought back to the surface. It is rinsed three times prior to sample collection. Next, a 60 mL Nalgene polyethylene bottle containing 1 mL 4N H_2SO_4 is filled with whole water from the collection bottle.

In 2020, 575 unfiltered water samples were collected and analyzed from 54 sites. Of these 54 LWCBMN sampling sites, 44 are located near flow-metered WSC stations, two are located near non-flow-metered WSC stations, one is located near a USGS station, and seven are not located near any stations.

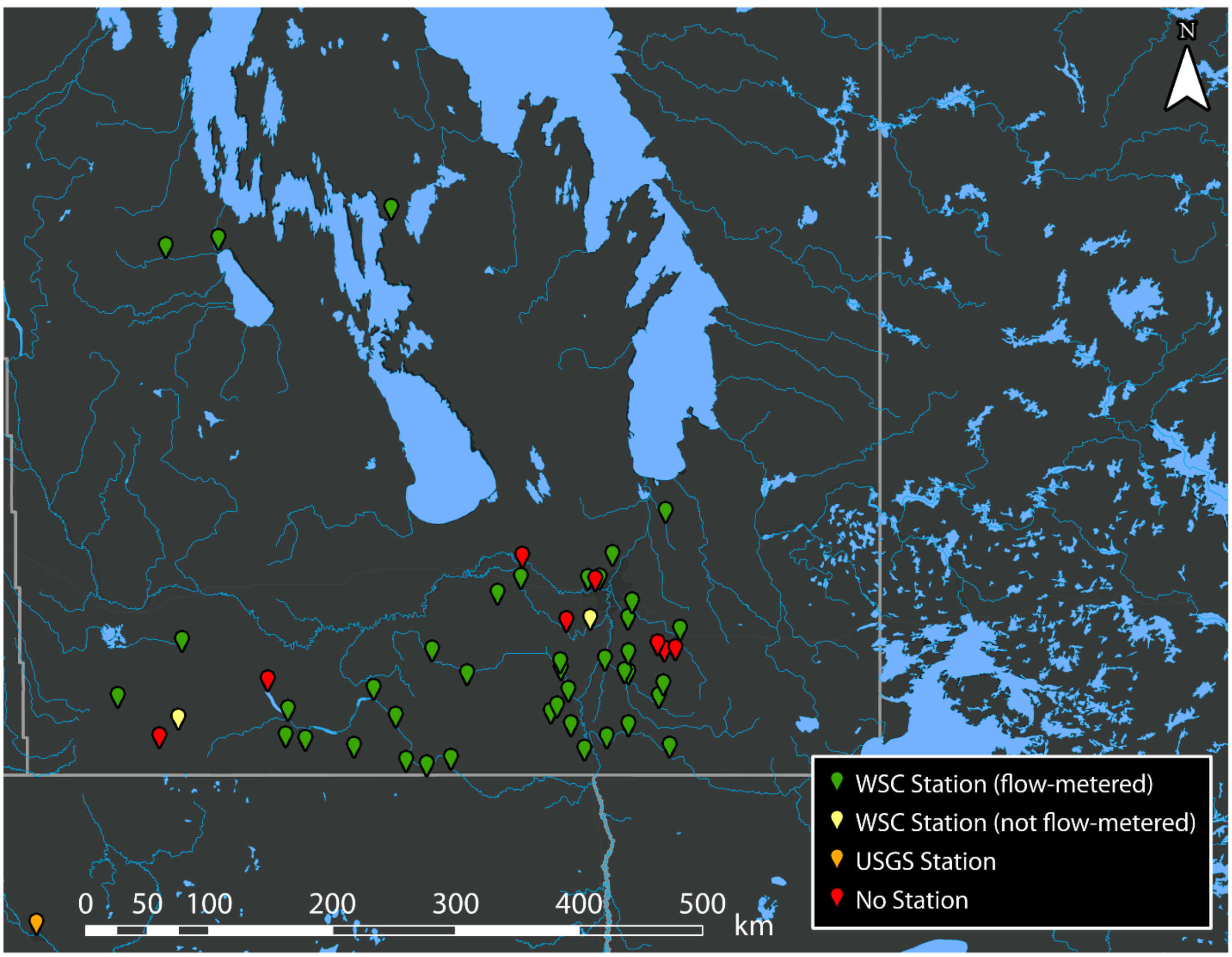


Figure 1: Map of LWCBMN sampling sites in 2020. Locations shown provided at least one sample. Colours indicate nearby station type.

Laboratory & Data Analysis

LWCBMN water samples are analysed for total phosphorus concentration. The analysis of a sample for total phosphorus (TP) is a two-step procedure involving first the chemical digestion/conversion of all P forms to orthophosphate (PO_4^{3-}) followed by the analysis of the concentration of PO_4^{3-}. The digestion procedure is patterned after USGS Water-Resources Investigations Report 03-4174. The concentration of PO_4^{3-} in the sample was determined following Murphy & Riley (1962). The result of this analytical method is determination of unfiltered total phosphorus in mg/L.

Laboratory analysis on LWCBMN water samples was conducted in partnership with Dr. Nora Casson at her laboratory at the University of Winnipeg. Quality assurance of laboratory methods for the determination of total phosphorus was completed on samples sent from Proficiency Testing Canada. Proficiency testing allows us to assess the quality of our results as compared to the results of other laboratories across the country. We received excellent passing grades of 92/100 in November 2023 and 94/100 in May 2024, further highlighting the consistency and accuracy of our laboratory methods.

Our laboratory results provide a record of the phosphorus concentrations for every day that water samples were collected, but we are equally interested in reporting the actual load of phosphorus each year in each watershed that we sample. To create this record, we multiply concentrations by the volume of water that flowed past the station every day, using flow data from Water Survey of Canada (WSC) stations.

WSC's real-time flow data subsequently undergoes additional quality assurance and quality control processes and is later published as historical flow data. Historical data is released by WSC as the official version of the data, with additional notes about unique site characteristics or considerations affecting data quality (e.g., the COVID-19 pandemic reduced field visits in 2020). Our 2020 data analysis used historical flow data.

For each station, gaps between concentration observations are filled by linear interpolation to create a continuous daily record. For the WSC flow record before or after the first or last water sample collected, we estimate the missing daily mean concentrations to be equal to the first or last measured concentration, respectively. These measured and estimated daily concentrations are then multiplied by daily flow to create a record of daily phosphorus loads.

Larger watersheds generate greater river flow and typically larger phosphorus loads. Comparing the intensity of phosphorus sources, especially among watersheds of varying sizes, is possible through the calculation of average load exported from each unit area of the watershed. Hence, we also report phosphorus export, which is simply the annual load divided by the watershed area that contributed to this load.

The export per unit area is indicative of the relative intensity of the sources generating phosphorus export, even among watersheds of different sizes. This is why we display maps of phosphorus export (and not load) in this report. Hotspots identified in these reports export several times more phosphorus per hectare than non-hotspot watersheds. Identifying hotspots can help government agencies to focus phosphorus reduction programs efficiently throughout the province.

LWCBMN By the Numbers - 2020

Table 1: Summary of 2020 LWCBMN sampling activity by region.

Region	Number of sites	Number of samples	Site with highest regional total phosphorus (TP) export (kg/ha/y)	Mean % of spring* water load	Mean % of spring* TP load
City of Winnipeg	3	23	Sturgeon Creek at St. James Bridge - 0.33	91.43	90.99
East Interlake	1	19	Grassmere Creek Drain near Middlechurch - 0.18	97.65	96.92
Inter-Mountain	2	20	Mossy River below outlet of Dauphin Lake - 0.0036	45.68	7.77
Pembina Valley	13	217	Mowbray Creek near Mowbray - 0.50	76.00	73.60
Redboine	9	128	La Salle River at Elie - 0.53	94.36	94.38
Seine Rat Roseau	13	133	Pansy Drain near Sarto - 1.52	70.17	79.78

*LWCBMN defines "Spring" as March 1 to May 31, inclusive.

Raw data (phosphorus concentration and water flow) from LWCBMN's 2020 field season is available online at LakeWinnipegDataStream.ca, an open access hub for sharing water data.

Pembina Valley Watershed District

The Pembina Valley Watershed District (PVWD) is located in southwestern MB along the Canada-U.S. border. Approximately half of the Pembina River basin is located in the U.S. The Pembina River is the main waterway in this region, with many tributaries and lakes flowing into it. Land use in PVWD is primarily agriculture, specifically cereal, oilseed and forage crops (2006 census). Other potential phosphorus sources include the ~780 livestock farms in the watershed (2006 census). Wastewater treatment plants and lagoons also contribute phosphorus to local waterways in PVWD. Major municipalities include Winkler, Morden and Manitou. In 2020, PVWD boundaries expanded to include the western tributaries of the Red River.

In partnership with LWCBMN, PVWD staff and volunteers sampled 12 sites in the PVWD region, all of which were near actively monitored flow-metered WSC stations.

PVWD Website (pvwd.ca)

PVWD Watershed Plans (pvwd.ca/watershed-planning)

Characteristics of the 2020 Field Season

2020 was a moderately dry year in southern Manitoba.[1]. As well, from March to May 2020, a historically important season for phosphorus export, most of southern Manitoba experienced severely to extremely dry conditions[2].

The mean peak discharge data across all LWCBMN sties with analyzed water samples was April 21, 2020 (with a standard deviation of 30.76 days). In 2020, an average of 77.06% of stream discharge occurred in spring (March 1 - May 31) across LWCBMN sites (with a standard deviation of 19.10%).

In 2020, the operational capacity of LWCBMN was reduced due to the COVID-19 pandemic. Sampling activities were maintained by LWF staff and watershed district partners at priority, long-term sites within the network. To prevent COVID-19 transmission, sampling protocols and equipment were adjusted for volunteers who wished to continue sampling. All historical streamflow data from WSC in 2020 includes a remark that “Due to measures in place to limit the spread of the coronavirus, regular visits to this station were reduced or no longer conducted throughout 2020. This may have impacted data quality in 2020”.

[1] https://www.gov.mb.ca/sd/pubs/water/drought/2020/drought_conditions_report_oct_2020.pdf

[2] https://www.gov.mb.ca/sd/pubs/water/drought/2020/drought_conditions_report_may_2020.pdf

Manitoba Watershed District Map

Manitoba's watershed districts are crucial partners contributing to the success of LWCBMN. In addition to assisting with sample collection, each district brings valuable community connections and a wealth of regional expertise to the network, helping us contextualize and better understand the data.

In 2020, five watershed districts participated in LWCBMN activities: East Interlake; Inter-Mountain; Pembina Valley, Redboine and Seine Rat Roseau.

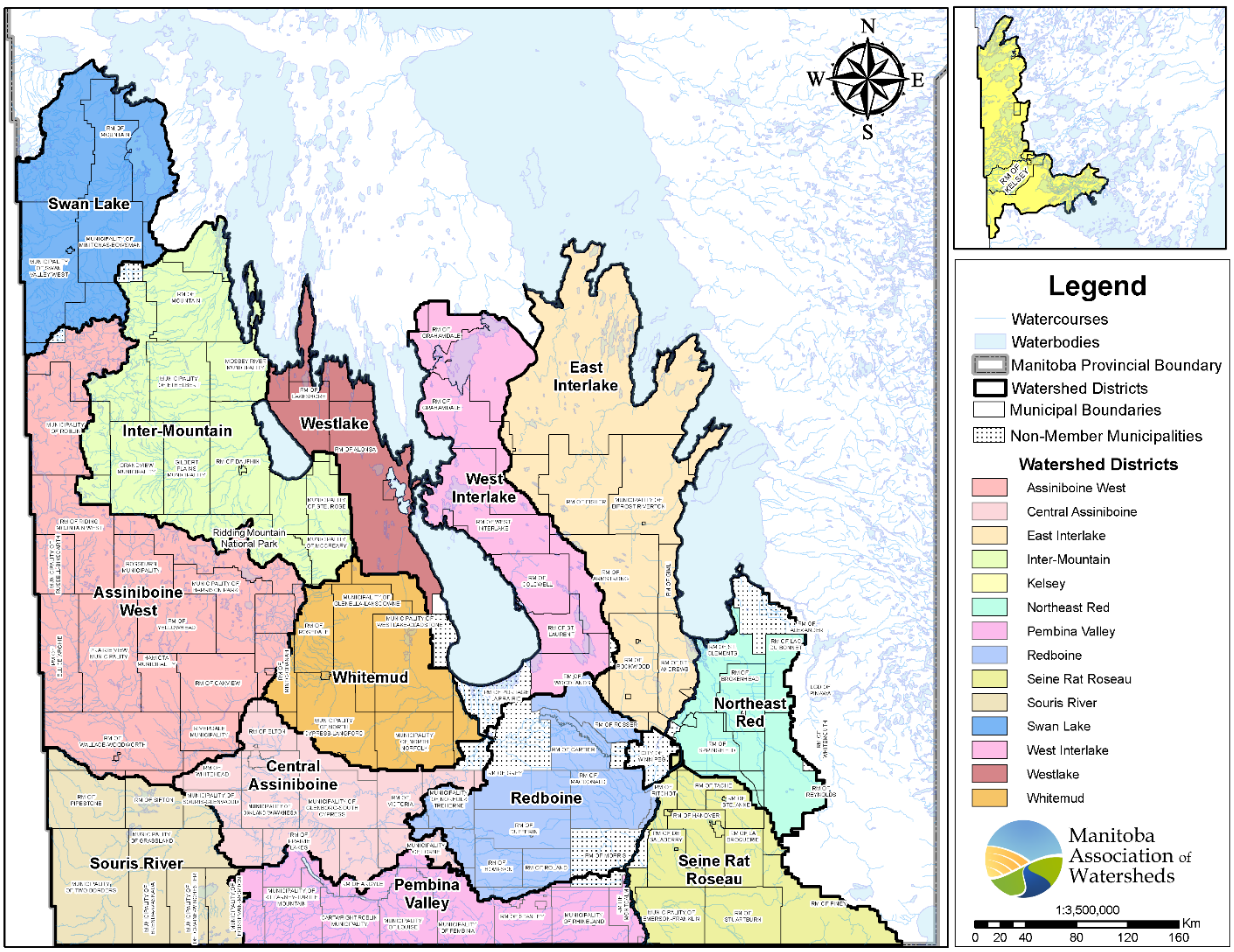


Figure 2: Manitoba Watershed District Boundaries. There are 14 total watershed districts. Map provided by Manitoba Association of Watersheds (updated July 2022).

2020 Results – PVWD Summary

Table 2: Summary of 2020 LWCBMN results in PVWD. Letters correspond to drainage areas in Figure 3. Data shown represents sites with sampling efforts adequate enough to calculate loads/exports. [1]See footnote for explanation of acronyms/abbreviations.

	Site Name	WSC Station	GDA (km^2)	IDA (km^2)	Gross/ Incr.	TP load (tonnes/y)	TP export (kg/ha/y)
A	Buffalo Creek near Rosenfeld	05OC019	797.00	*NA*	gross	10.43	0.13
B	Cypress Creek near Clearwater	05OB010	395.32	*NA*	gross	5.71	0.14
C	Deadhorse Creek near Rosenfeld	05OC016	924.00	*NA*	gross	7.77	0.084
D	Kronsgart Drain near Sewell	05OC024	61.65	*NA*	gross	2.93	0.48
E	Long River near Holmfield	05OA006	520.05	*NA*	gross	1.80	0.035
F	Mowbray Creek near Mowbray	05OB021	272.17	*NA*	gross	13.67	0.50
G	Pembina River above Lorne Lake	05OA010	1208.24	*NA*	gross	3.42	0.028
H	Pembina River near La Riviere	05OB001	5533.46	433.50	incr.	12.08	0.28
I	Pembina River downstream of Swan Lake Outlet	05OB019	5099.96	2976.36	incr.	14.70	0.045
J	Pembina River near Windygates	05OB007	7734.34	934.41	incr.	30.16	0.32
K	Riviere Aux Marais near Christie	05OC022	187.00	*NA*	gross	8.50	0.45
L	Snowflake Creek near Snowflake	05OB016	994.31	*NA*	gross	17.84	0.18

To compare 2020 results to other years of data, please see LWCBMN regional reports online at https://lakewinnipegfoundation.org/lwcbmn-regional-reports

[1] WSC = Water Survey of Canada.
GDA = gross drainage area (i.e., the total watershed area).
IDA = incremental drainage area (i.e., the total watershed area minus the total watershed area of any contained upstream sites with data adequate for load/export calculation).
Gross/Incr. = whether or not the adjacent TP load/export listed is from the gross or incremental ("Incr.") drainage area of a site.

2020 Results – Hotspot Map

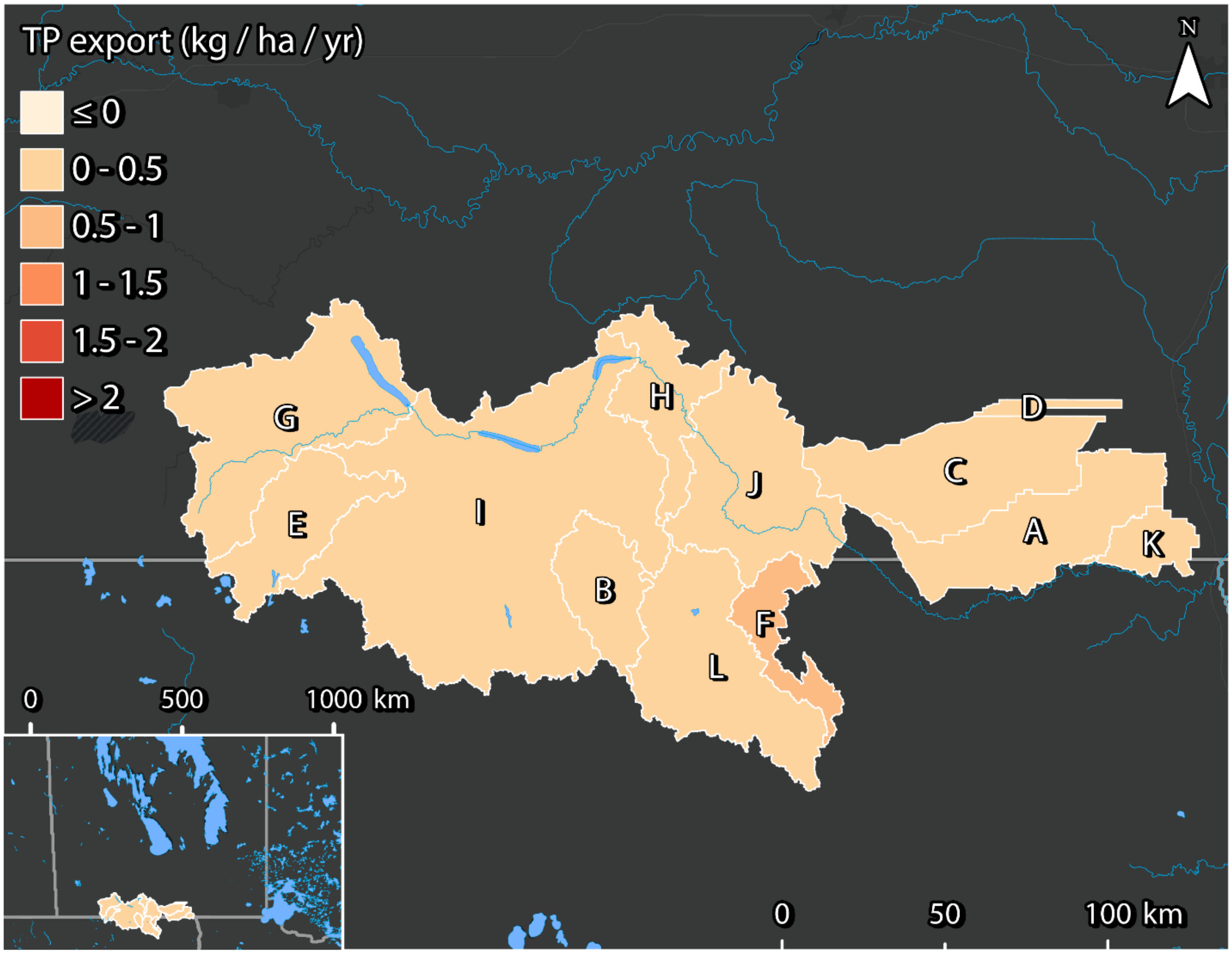


Figure 3: 2020 LWCBMN TP Export Hotspots in PVWD. Letters correspond to sites listed in Table 2.

2020 Results – Individual Sites

Mowbray Creek near Mowbray

Mowbray Creek is located south of the Pembina River. The majority of the Mowbray Creek drainage area is located in North Dakota. The drainage area for this sampling site drains a portion of the Rural Municipality of Mowbray, MB, as well as the city of Langdon, ND. This sampling site is located at Water Survey of Canada flow meter 05OB021, near Mowbray. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 3: Indices of discharge and phosphorus from the gross drainage area of Mowbray Creek near Mowbray (05OB021) in 2020.

Gross drainage area:	272.17 km^2
Peak discharge:	18.10 m^3 s^{-1} (2020-04-01)
Peak TP concentration:	1.43 mg/L (2020-07-02)
% of water load in spring:	78.94%
% of TP load in spring:	69.28%
Water load:	0.018 km^3 y^{-1}
TP load:	13.67 tonnes P y^{-1}
Water export:	65.14 mm y^{-1}
TP export:	0.50 kg P ha^{-1} y^{-1}

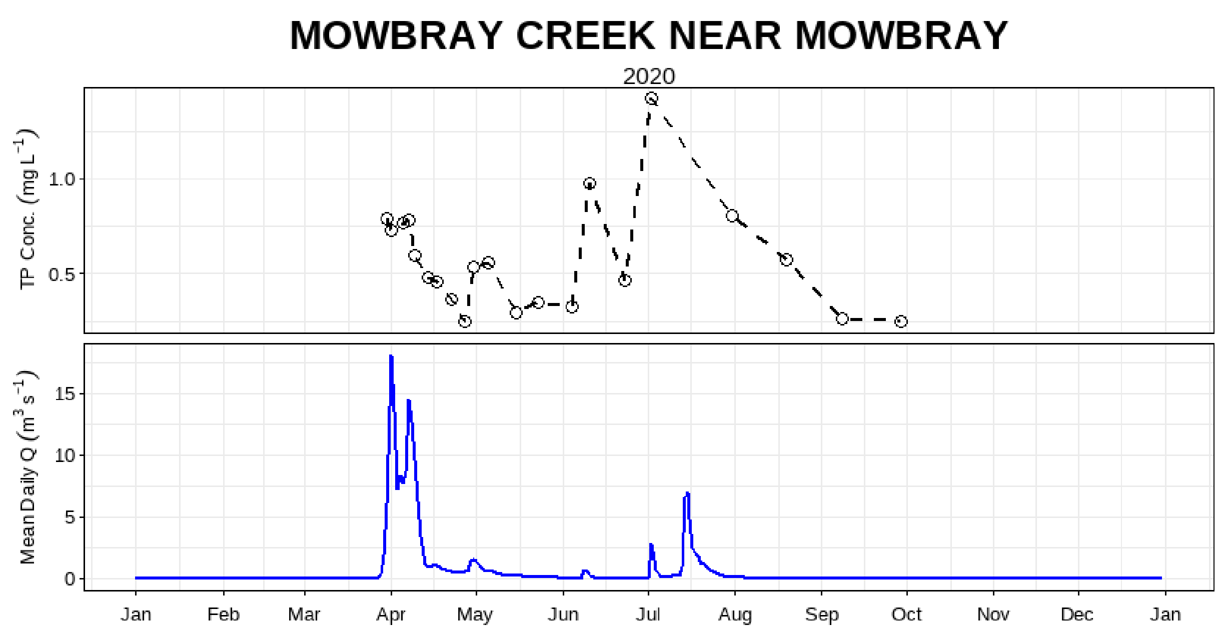


Figure 4: Mean daily discharge (m^3 s^{-1}) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Mowbray Creek near Mowbray (05OB021).

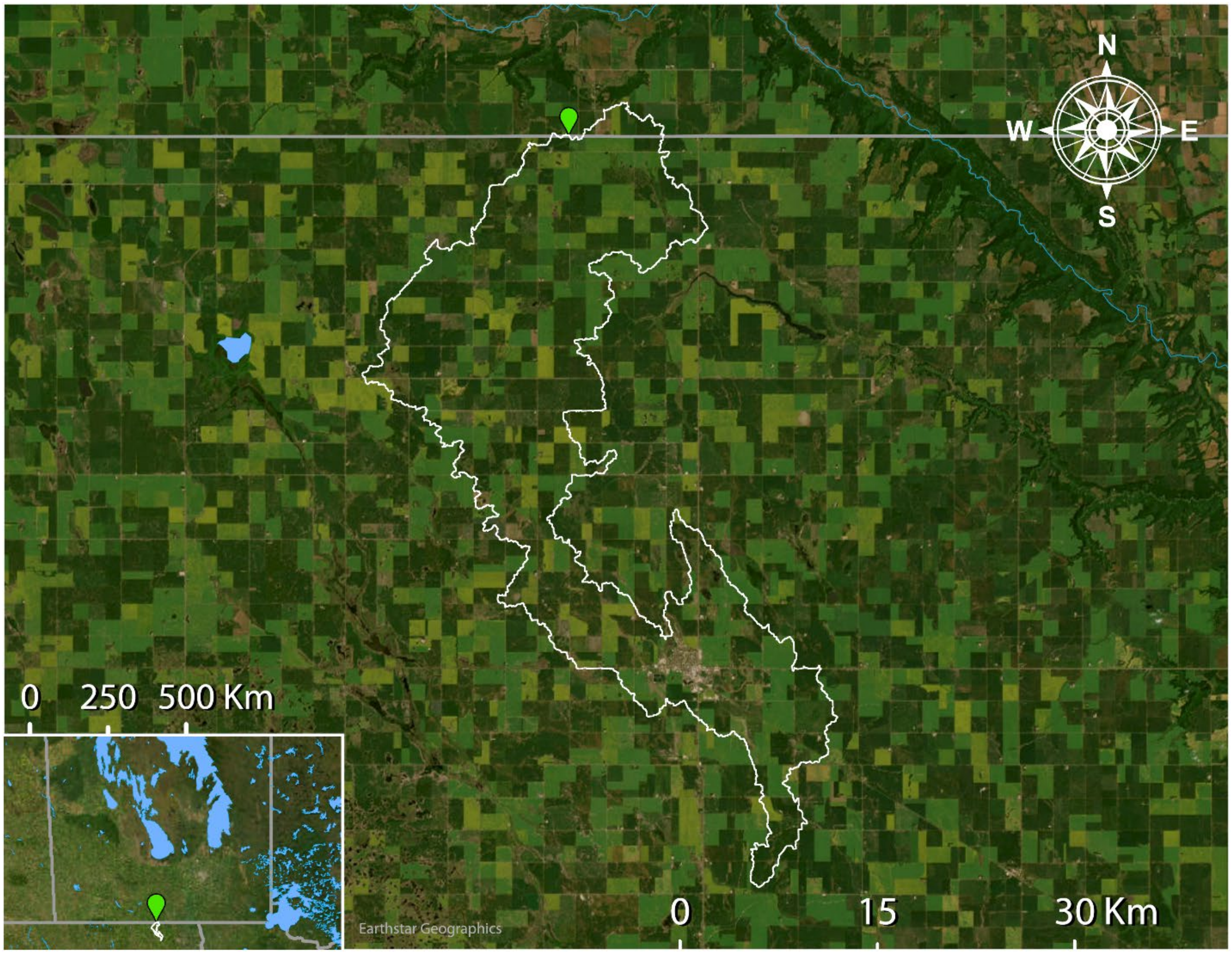


Figure 5: WSC station 05OB021 (green) and drainage area polygon (white - source: WSC). LWCBMN samples directly at the WSC station.

Snowflake Creek near Snowflake

Snowflake Creek is located south of the Pembina River. The majority of the Snowflake Creek drainage area is located in North Dakota. The drainage area for this sample site drains a largely agricultural area and a portion of the Rural Municipality of Snowflake, Man. This sampling site is located at Water Survey of Canada flow meter 05OB016, near Snowflake. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 4: Indices of discharge and phosphorus from the gross drainage area of Snowflake Creek near Snowflake (05OB016) in 2020.

Gross drainage area:	994.31 km^2
Peak discharge:	12.70 $m^3 s^{-1}$ (2020-04-10)
Peak TP concentration:	1.19 mg/L (2020-06-10)
% of water load in spring:	84.69%
% of TP load in spring:	78.59%
Water load:	0.033 $km^3 y^{-1}$
TP load:	17.84 tonnes P y^{-1}
Water export:	32.76 mm y^{-1}
TP export:	0.18 kg P $ha^{-1} y^{-1}$

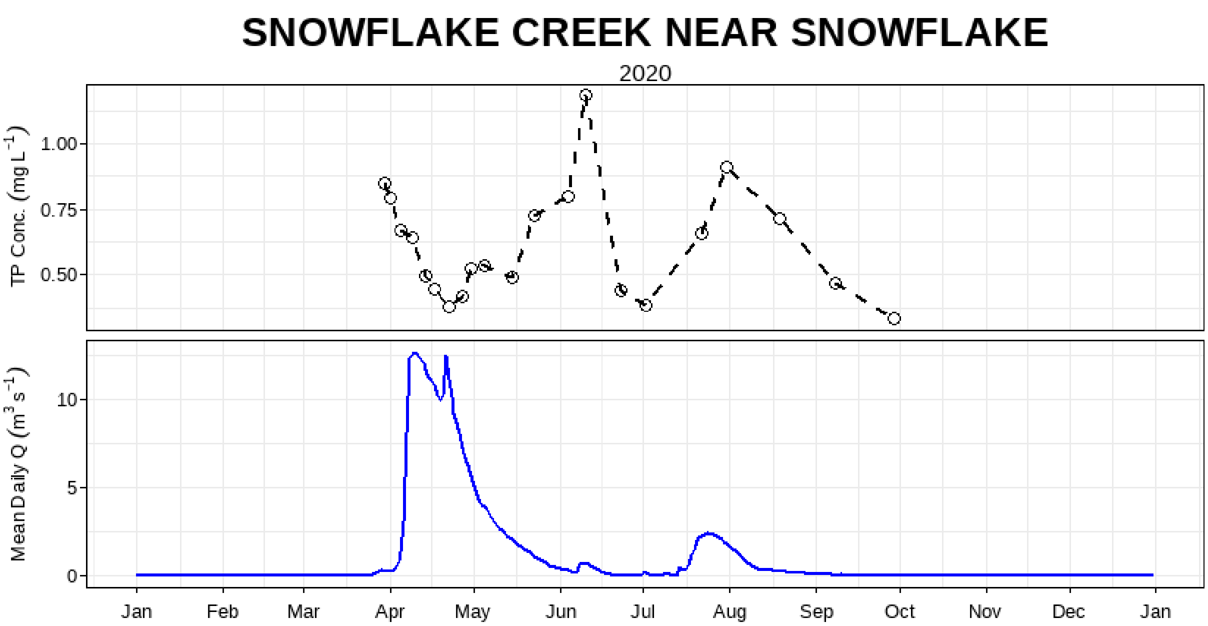


Figure 6: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Snowflake Creek near Snowflake (05OB016).

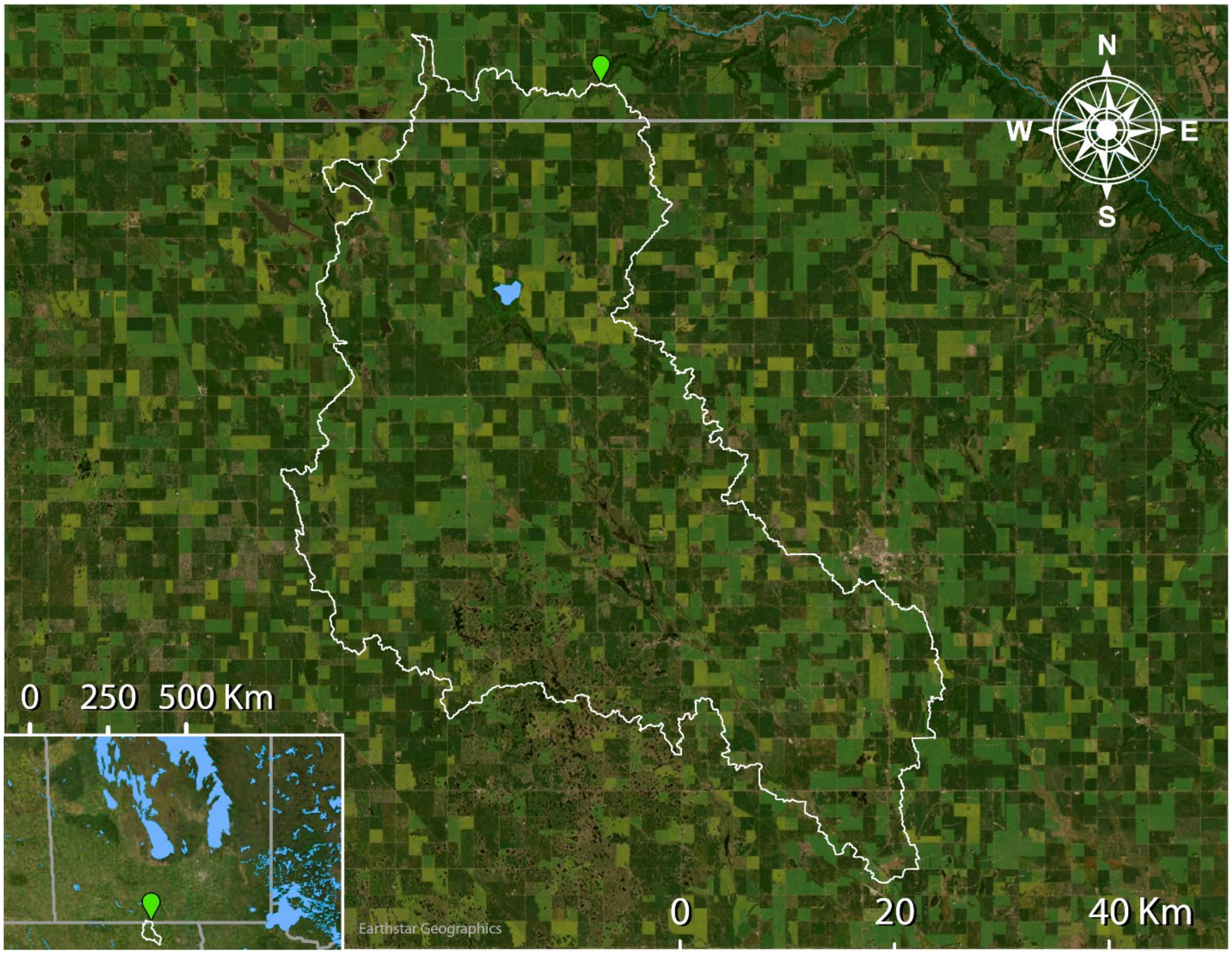


Figure 7: WSC station 05OB016 (green) and drainage area polygon (white - source: WSC). LWCBMN samples directly at the WSC station.

Cypress Creek near Clearwater

Cypress Creek is located south of the Pembina River. The drainage area for sampling site includes portions of Manitoba and North Dakota. It drains a largely agricultural area. This sampling site is located at Water Survey of Canada flow meter 05OB010, near Clearwater. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 5: Indices of discharge and phosphorus from the gross drainage area of Cypress Creek near Clearwater (05OB010) in 2020.

Gross drainage area:	395.32 km^2
Peak discharge:	8.35 $m^3\ s^{-1}$ (2020-04-08)
Peak TP concentration:	0.89 mg/L (2020-07-23)
% of water load in spring:	87.37%
% of TP load in spring:	85.89%
Water load:	0.0076 $km^3\ y^{-1}$
TP load:	5.71 tonnes P y^{-1}
Water export:	19.13 mm y^{-1}
TP export:	0.14 kg P $ha^{-1}\ y^{-1}$

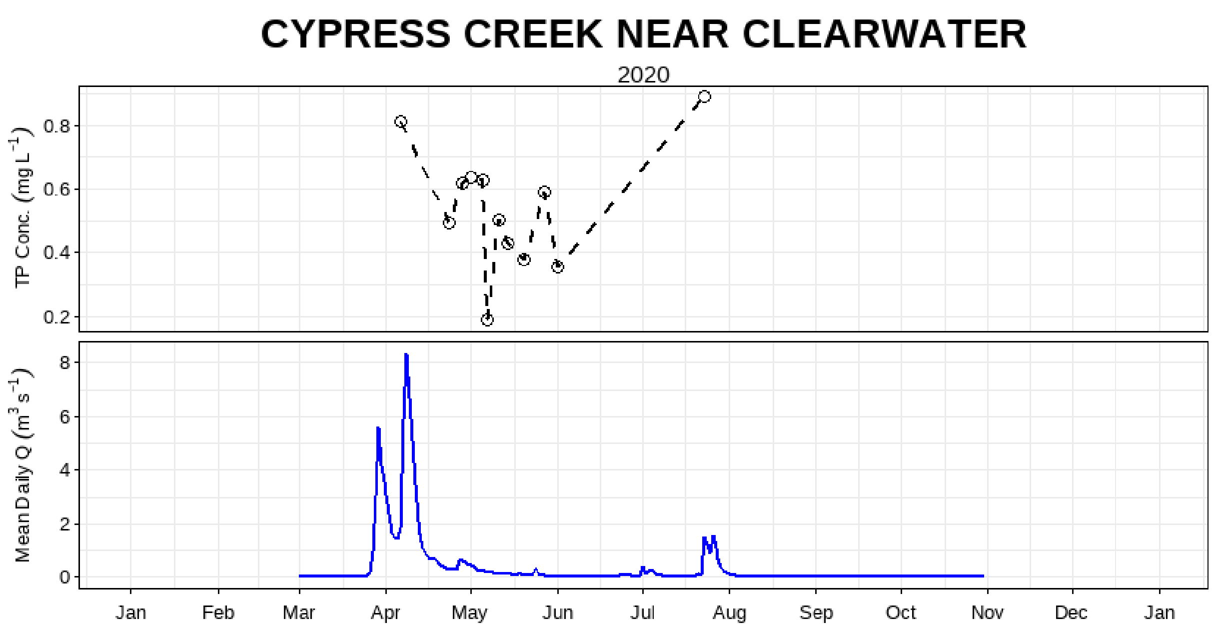


Figure 8: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Cypress Creek near Clearwater (05OB010).

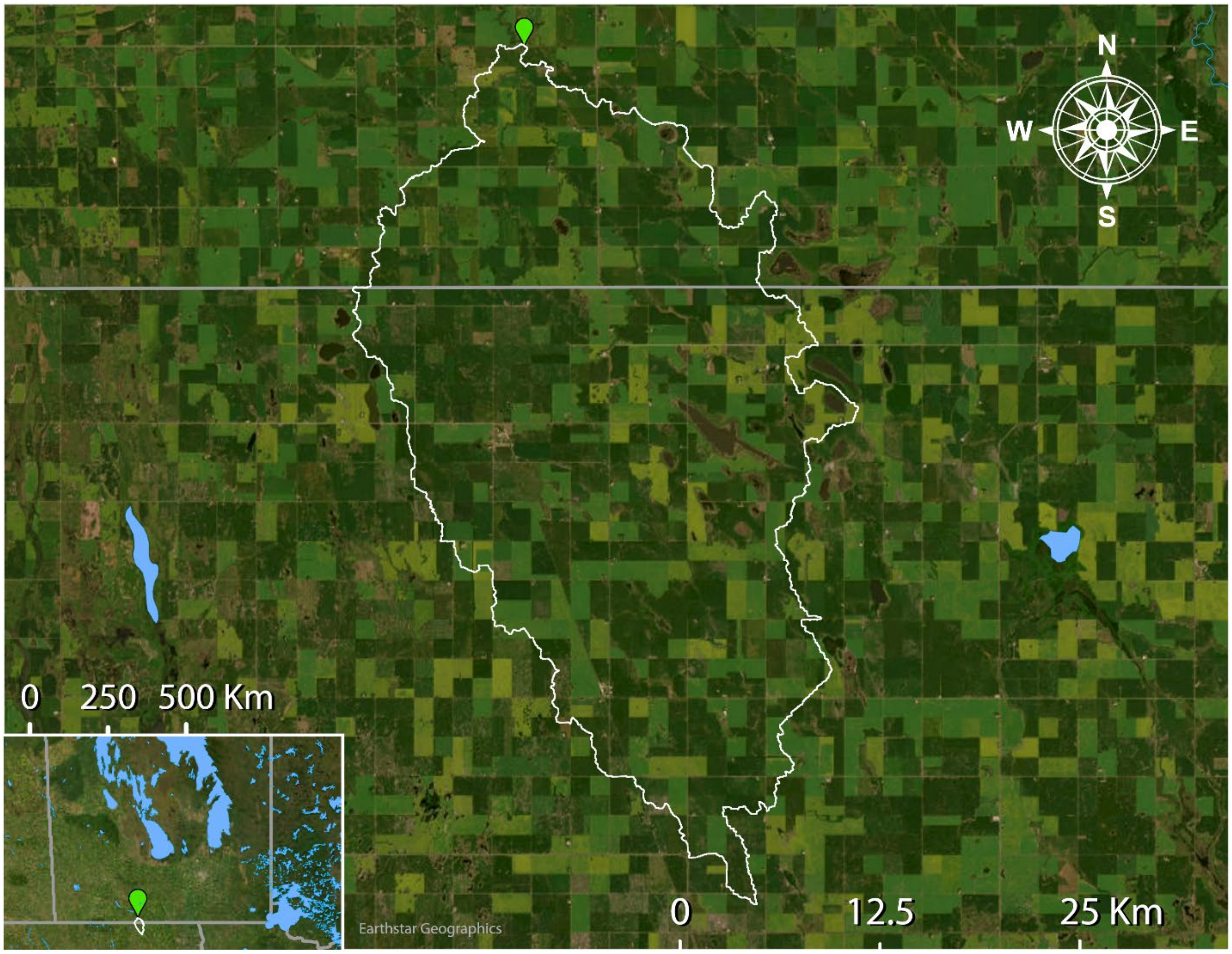


Figure 9: WSC station 05OB010 (green) and drainage area polygon (white – source: WSC). LWCBMN samples directly at the WSC station.

Long River near Holmfield

Long River is located south of Pembina River. The drainage area for this sampling site drains a largely agricultural area and a portion of the town of Killarney, MB. This sampling site is located at Water Survey of Canada station 05OA006, near Holmfield, MB. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 6: Indices of discharge and phosphorus from the gross drainage area of Long River near Holmfield (05OA006) in 2020.

Gross drainage area:	520.05 km^2
Peak discharge:	6.88 m^3 s^{-1} (2020-04-08)
Peak TP concentration:	0.23 mg/L (2020-04-06)
% of water load in spring:	93.36%
% of TP load in spring:	96.14%
Water load:	0.011 km^3 y^{-1}
TP load:	1.80 tonnes P y^{-1}
Water export:	21.55 mm y^{-1}
TP export:	0.035 kg P ha^{-1} y^{-1}

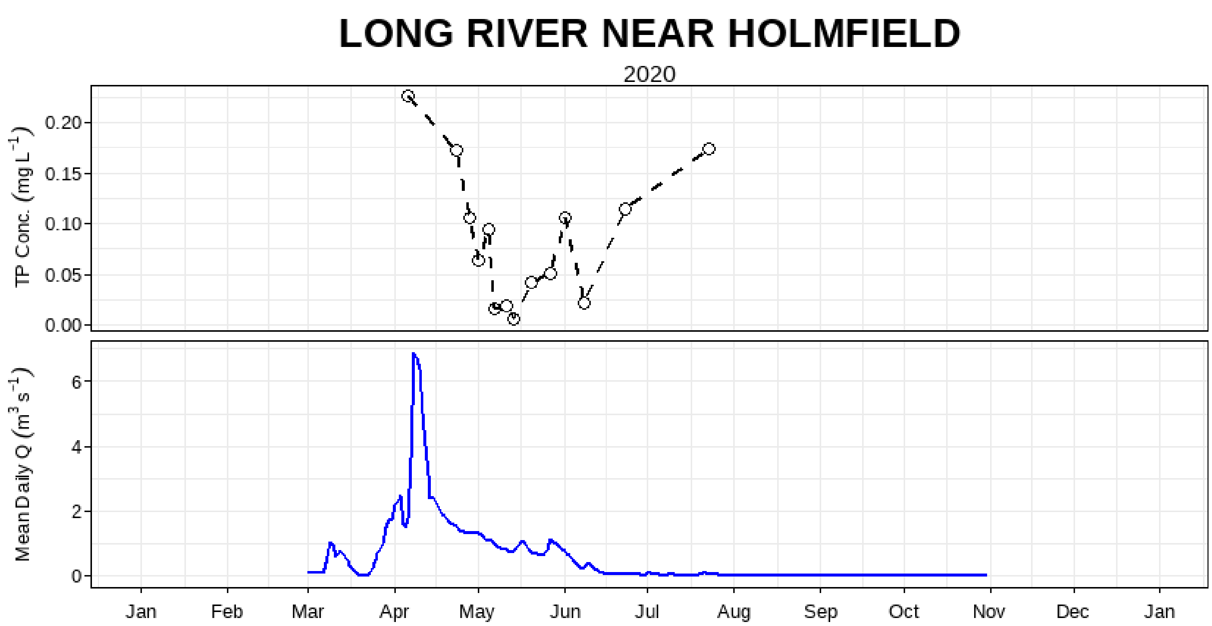


Figure 10: Mean daily discharge (m^3 s^{-1}) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Long River near Holmfield (05OA006).

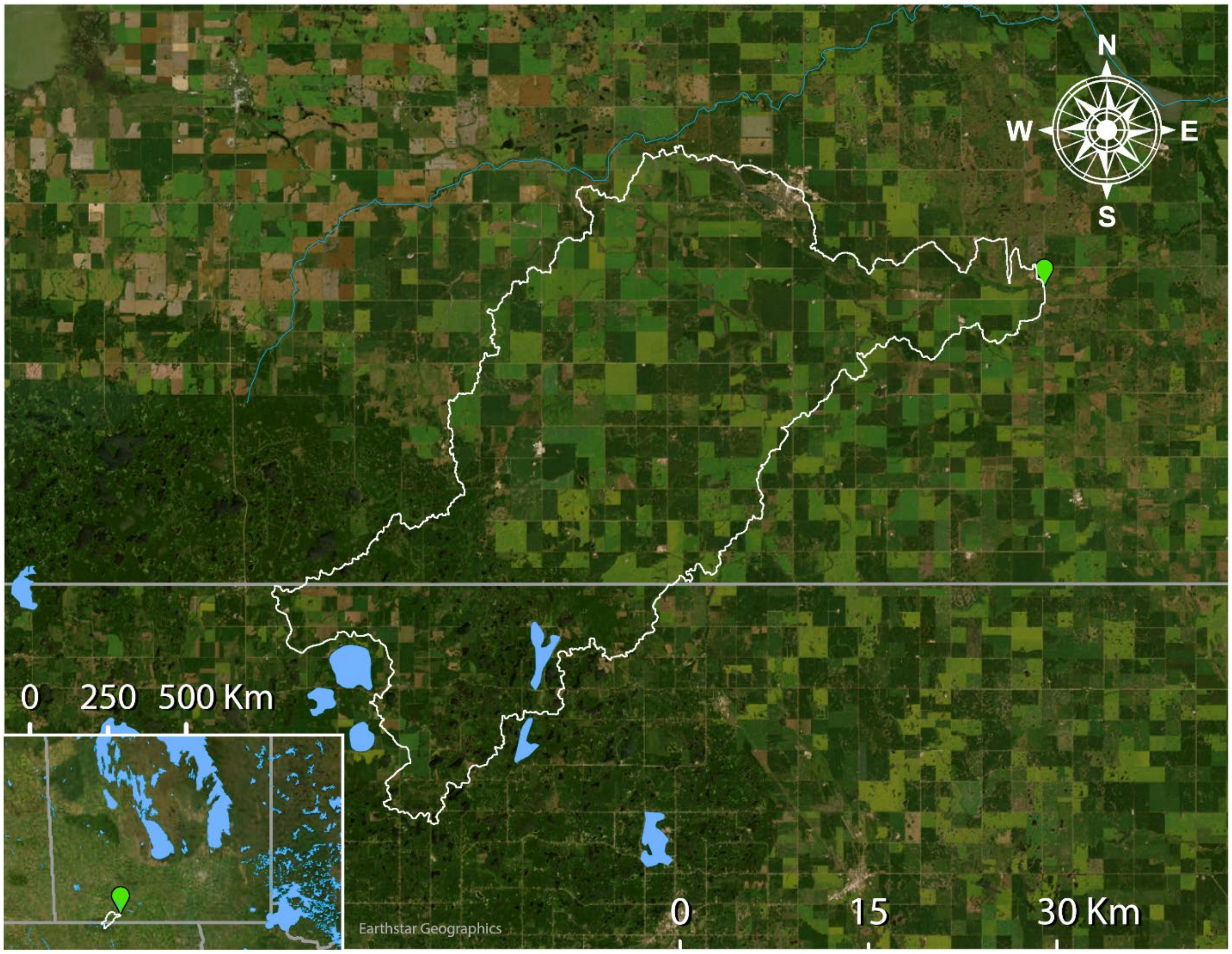


Figure 11: WSC station 05OA006 (green) and drainage area polygon (white – source: WSC). LWCBMN samples directly at the WSC station.

Pembina River above Lorne Lake

This reach of the Pembina River drains a large agricultural area. This sampling site is located at Water Survey of Canada flow meter 05OA010, northwest of Lorne Lake. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 7: Indices of discharge and phosphorus from the incremental drainage area of Pembina River above Lorne Lake (05OA010) in 2020.

Gross drainage area:	1208.24 km^2
Peak discharge:	7.79 $m^3 s^{-1}$ (2020-04-09)
Peak TP concentration:	0.40 mg/L (2020-04-06)
% of water load in spring:	89.74%
% of TP load in spring:	99.03%
Water load:	0.014 $km^3 y^{-1}$
TP load:	3.42 tonnes P y^{-1}
Water export:	11.57 mm y^{-1}
TP export:	0.028 kg P $ha^{-1} y^{-1}$

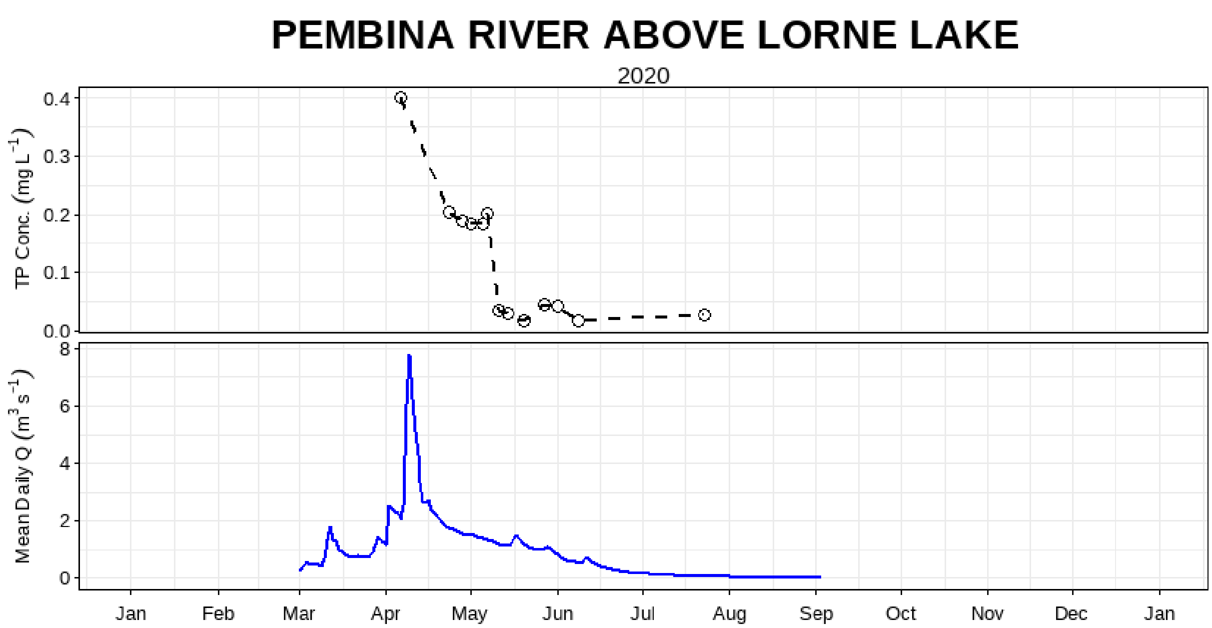


Figure 12: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Pembina River above Lorne Lake (05OA010).

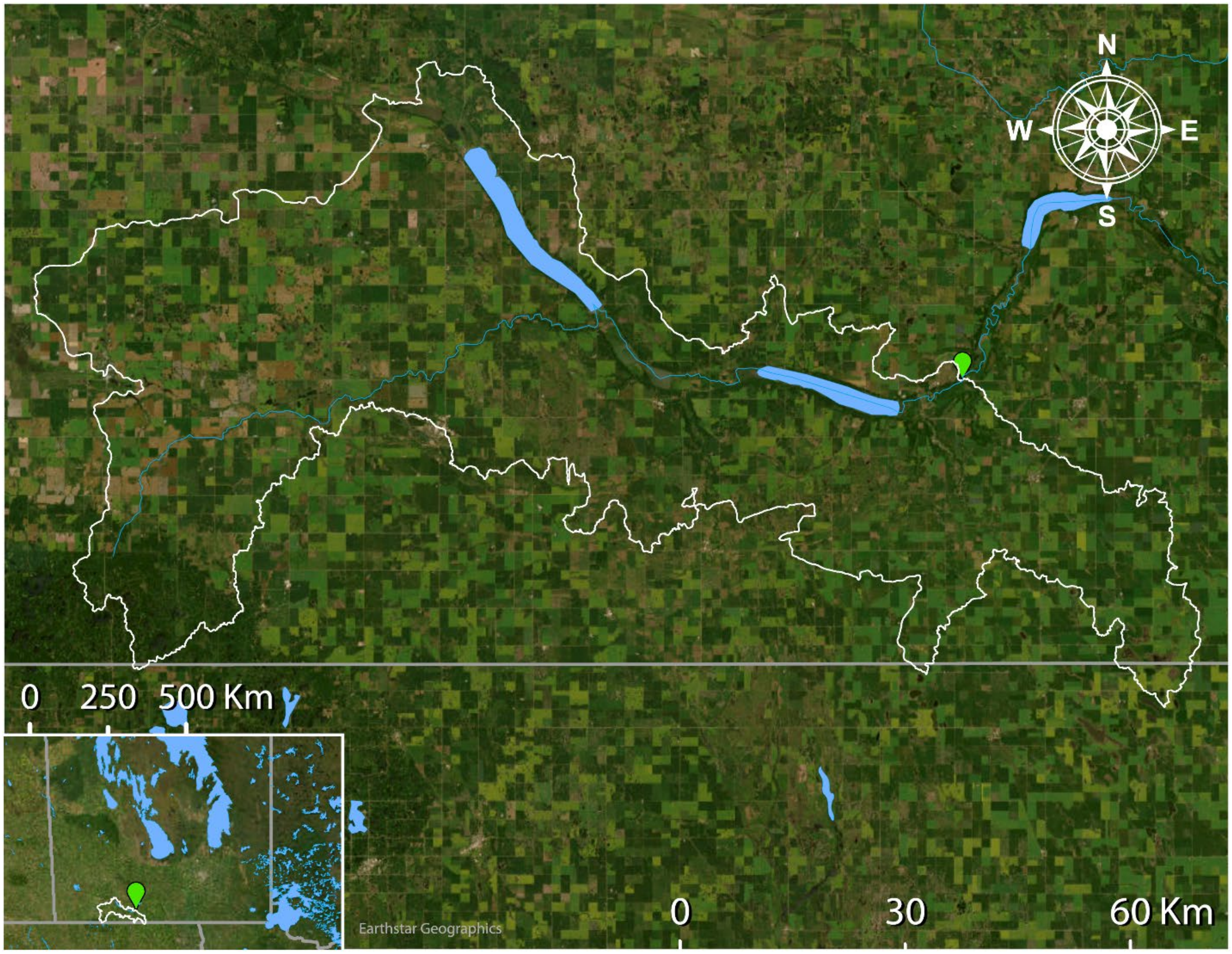


Figure 13: WSC station 05OB023 (green), and incremental drainage area polygon (white - source: WSC). See **Error! Reference source not found.** for upstream drainage areas used to calculate incremental area. LWCBMN samples directly at the WSC station.

Pembina River downstream of Swan Lake Outlet

The incremental drainage area for this stretch of the Pembina River contains Swan Lake First Nation. This sampling site is located at Water Survey of Canada station 05OB019, downstream of Swan Lake. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 8: Indices of discharge and phosphorus from the incremental drainage area of Pembina River downstream of Swan Lake Outlet (05OB019). See Supplemental Table 1 for gross calculations.

Incremental drainage area:	2976.36 km^2
Peak discharge:	12.60 $m^3 s^{-1}$ (2020-05-02)
Peak TP concentration:	0.50 mg/L (2020-04-06)
% of water load in spring:	63.39%
% of TP load in spring:	60.33%
[1]Incremental water load:	0.056 $km^3 y^{-1}$
[1]Incremental TP load:	14.70 tonnes P y^{-1}
[2]Incremental water export:	18.81 mm y^{-1}
[2]Incremental TP export:	0.049 kg P $ha^{-1} y^{-1}$

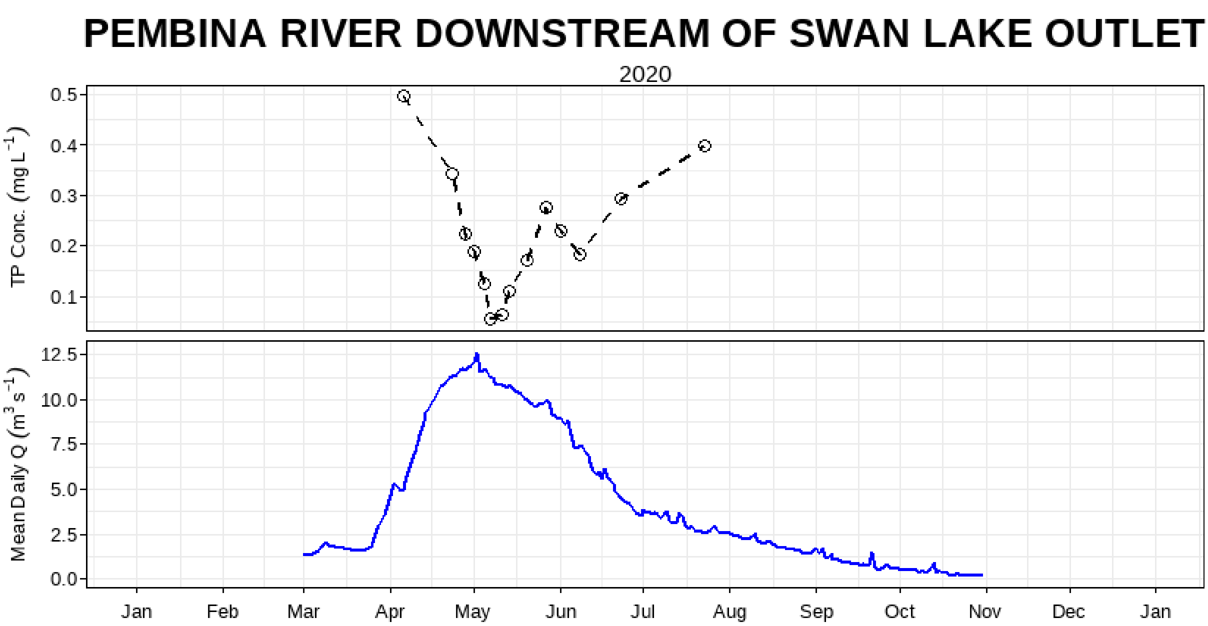


Figure 14: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Pembina River downstream of Swan Lake Outlet (05OB019).

[1] Incremental loads are calculated by subtracting gross "Long River near Holmfield", "Cypress Creek near Clearwater" and "Pembina River above Lorne Lake" values from gross "Pembina River downstream of Swan Lake Outlet" values.

[2] Incremental exports are calculated by dividing incremental loads by incremental drainage areas.

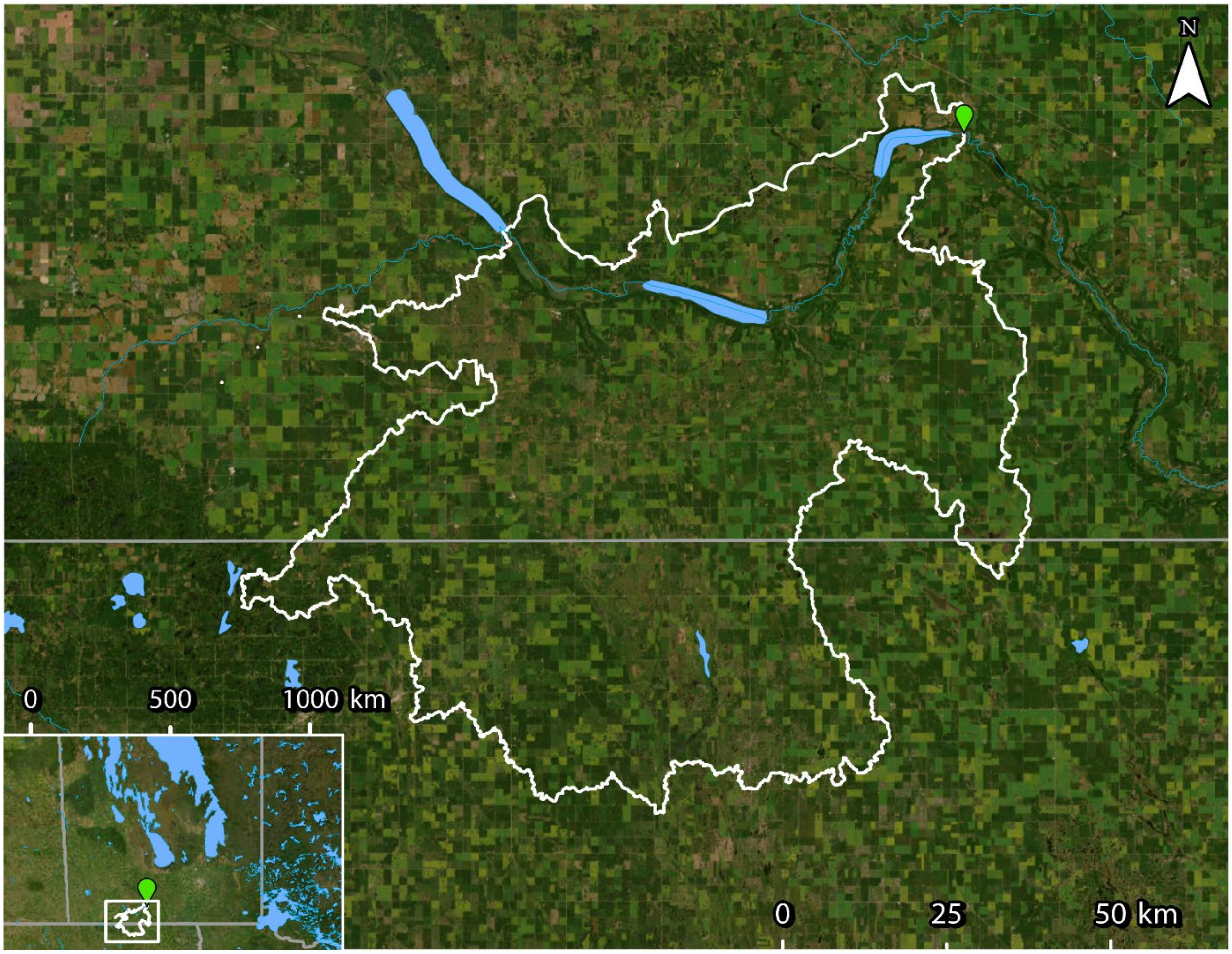


Figure 15: WSC station 05OB019 (green), and incremental drainage area polygon (white - source: WSC). See Supplemental Figure 1 for upstream drainage areas used to calculate incremental area. LWCBMN samples directly at the WSC station.

Pembina River near La Rivière

The incremental drainage area for this stretch of the Pembina River contains a largely agricultural area and includes the town of La Rivière, MB. This sampling site is located at Water Survey of Canada station 05OB001, near La Rivière. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 9: Indices of discharge and phosphorus from the incremental drainage area of Pembina River near La Rivière (05OB001). See Supplemental Table 2 for gross calculations.

Incremental drainage area:	433.50 km^2
Peak discharge:	13.40 $m^3 s^{-1}$ (2020-05-02)
Peak TP concentration:	1.44 mg/L (2020-03-30)
% of water load in spring:	72.19%
% of TP load in spring:	71.48%
[1]Incremental water load:	-0.0012 $km^3 y^{-1}$
[1]Incremental TP load:	12.08 tonnes P y^{-1}
[2]Incremental water export:	-2.88 mm y^{-1}
[2]Incremental TP export:	0.28 kg P $ha^{-1} y^{-1}$

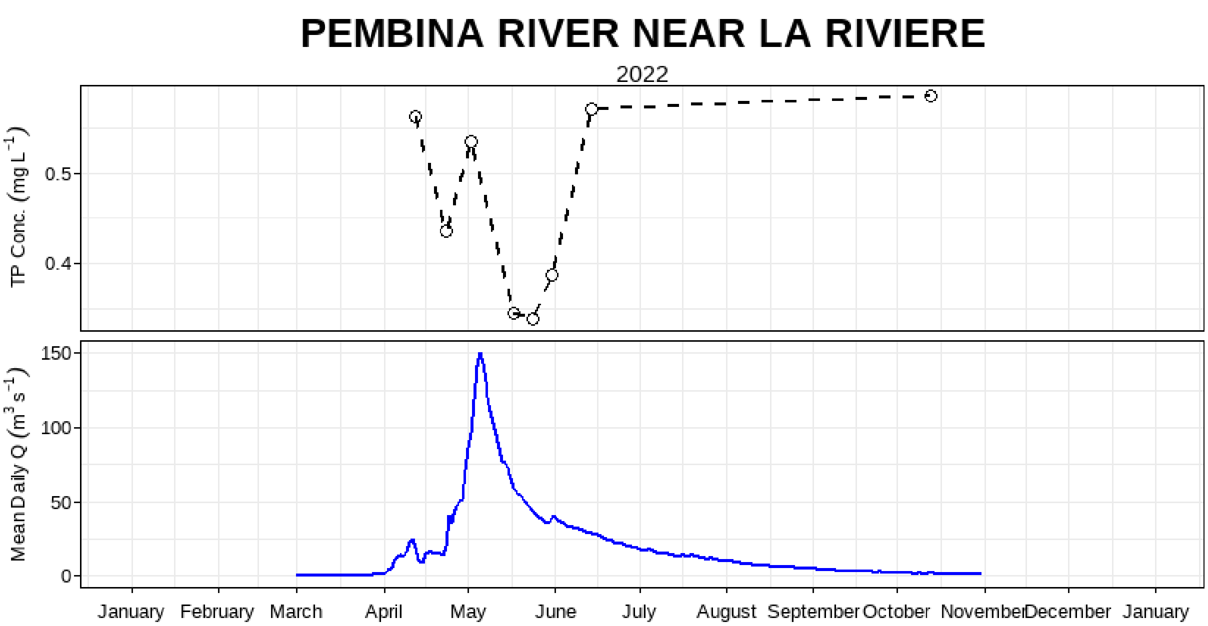


Figure 16: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Pembina River near La Rivière (05OB001).

[1] Incremental loads are calculated by subtracting gross "Pembina River downstream of Swan Lake" values from gross "Pembina River near La Rivière" values.

[2] Incremental exports are calculated by dividing incremental loads by incremental drainage areas.

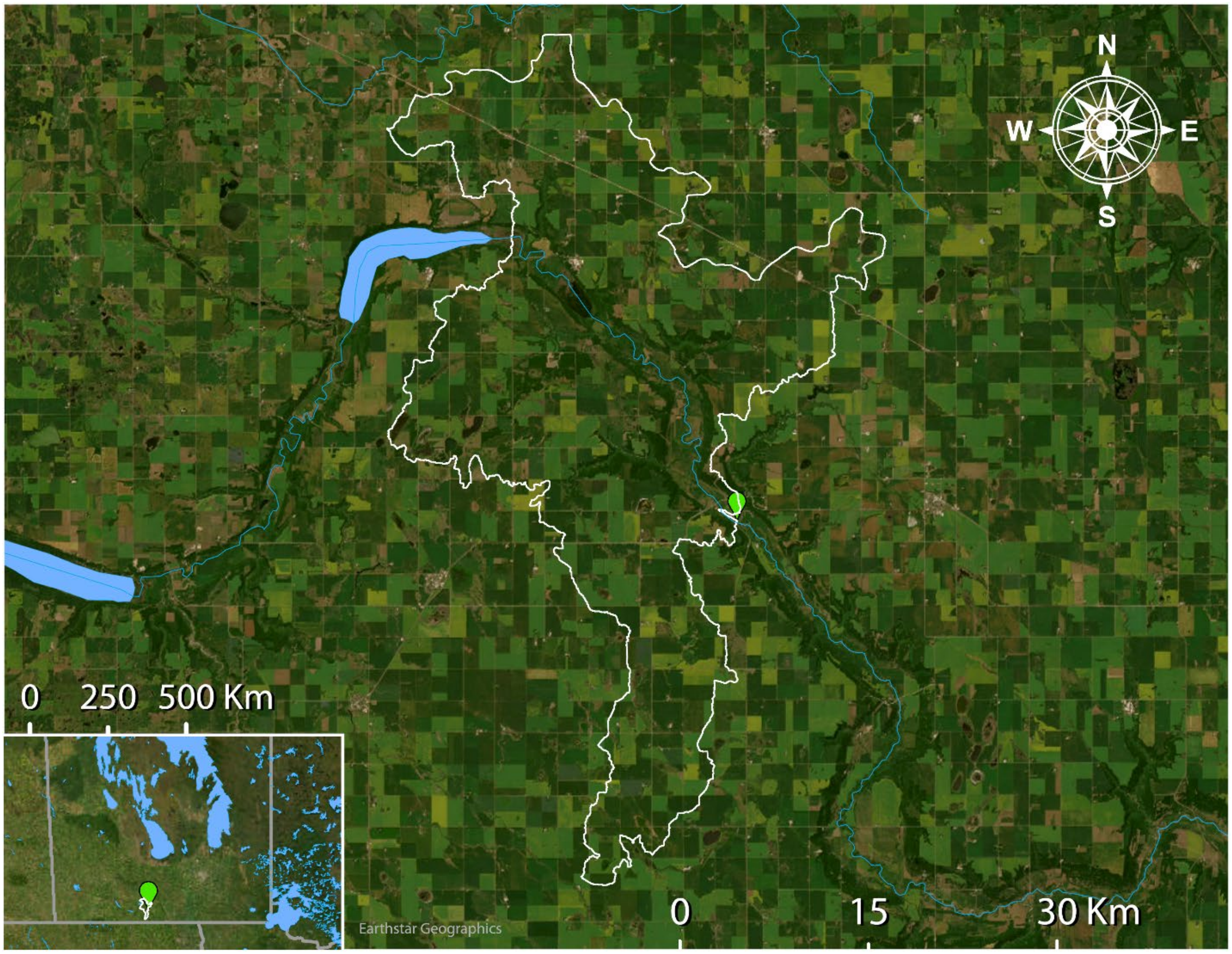


Figure 17: WSC station 05OB001 (green), and incremental drainage area polygon (white - source: WSC). See Supplemental Figure 2 for upstream drainage areas used to calculate incremental area. LWCBMN samples directly at the WSC station.

Pembina River near Windygates

The incremental drainage area for this stretch of the Pembina River contains a largely agricultural area. This sampling site is located at Water Survey of Canada station 05OB007, near Windygates, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 10: Indices of discharge and phosphorus from the incremental drainage area of Pembina River near Windygates (05OB007). See Supplemental Table 3 for gross calculations.

Incremental drainage area:	934.41 km^2
Peak discharge:	56.10 $m^3\ s^{-1}$ (2020-03-31)
Peak TP concentration:	0.95 mg/L (2020-04-09)
% of water load in spring:	66.41%
% of TP load in spring:	68.36%
[1]Incremental water load:	0.049 $km^3\ y^{-1}$
[1]Incremental TP load:	30.16 tonnes P y^{-1}
[2]Incremental water export:	52.60 mm y^{-1}
[2]Incremental TP export:	0.32 kg P $ha^{-1}\ y^{-1}$

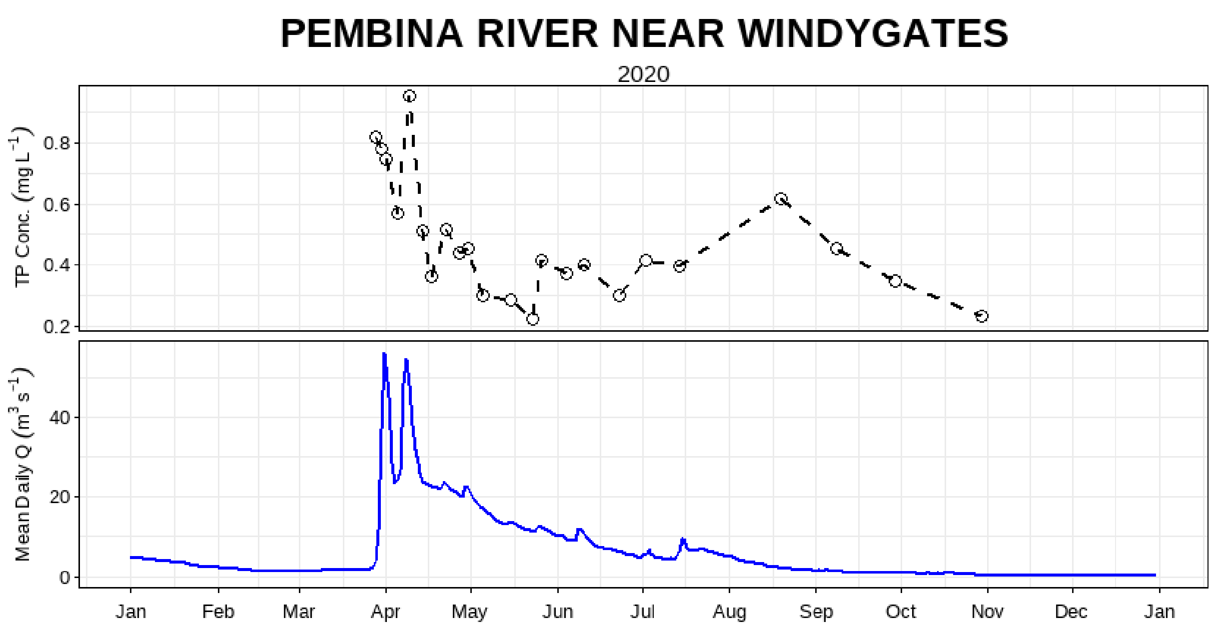


Figure 18: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Pembina River near Windygates (05OB007).

[1] Incremental loads are calculated by subtracting gross "Pembina River near La Rivière", "Mowbray Creek near Mowbray", and "Snowflake Creek near Snowflake" values from gross "Pembina River near Windygates" values.

[2] Incremental exports are calculated by dividing incremental loads by incremental drainage areas.

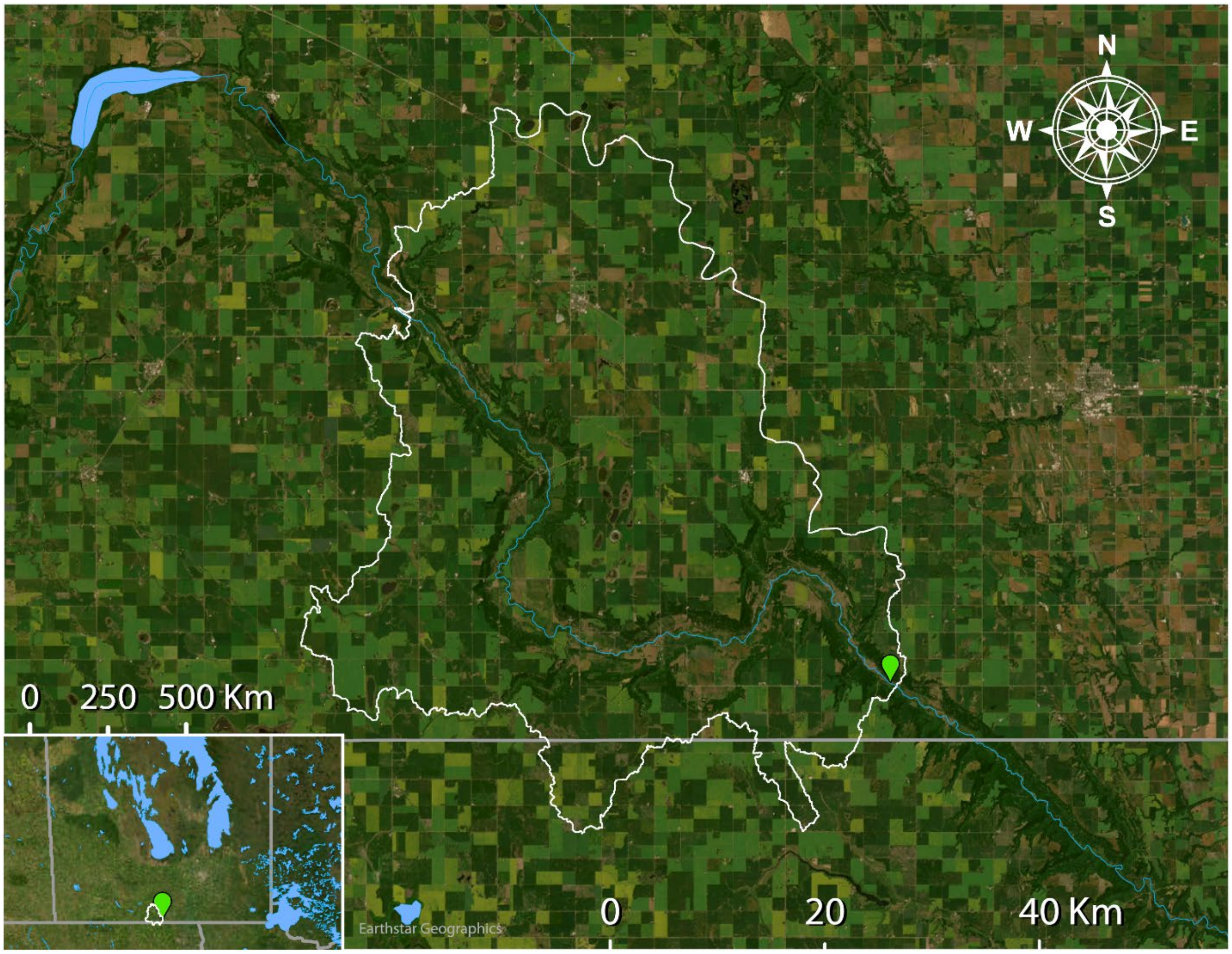


Figure 19: WSC station 05OB007 (green), and incremental drainage area polygon (white - source: WSC). See Supplemental Figure 3 for upstream drainage areas used to calculate incremental area. LWCBMN samples directly at the WSC station.

Buffalo Creek near Rosenfeld

Buffalo Creek is located downstream of Rosenfeld, MB and upstream of St. Jean Baptiste, MB. The gross drainage contains primarily agricultural land. This sampling site is located at Water Survey of Canada flow meter 05OC019, near Rosenfeld, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 11: Indices of discharge and phosphorus from the gross drainage area of Buffalo Creek near Rosenfeld (05OC019) in 2020.

Gross drainage area:	797 km^2
Peak discharge:	11.40 $m^3\ s^{-1}$ (2020-04-09)
Peak TP concentration:	1.09 mg/L (2020-06-09)
% of water load in spring:	82.09%
% of TP load in spring:	83.12%
Water load:	0.013 $km^3\ y^{-1}$
TP load:	10.43 tonnes P y^{-1}
Water export:	16.04 mm y^{-1}
TP export:	0.13 kg P $ha^{-1}\ y^{-1}$

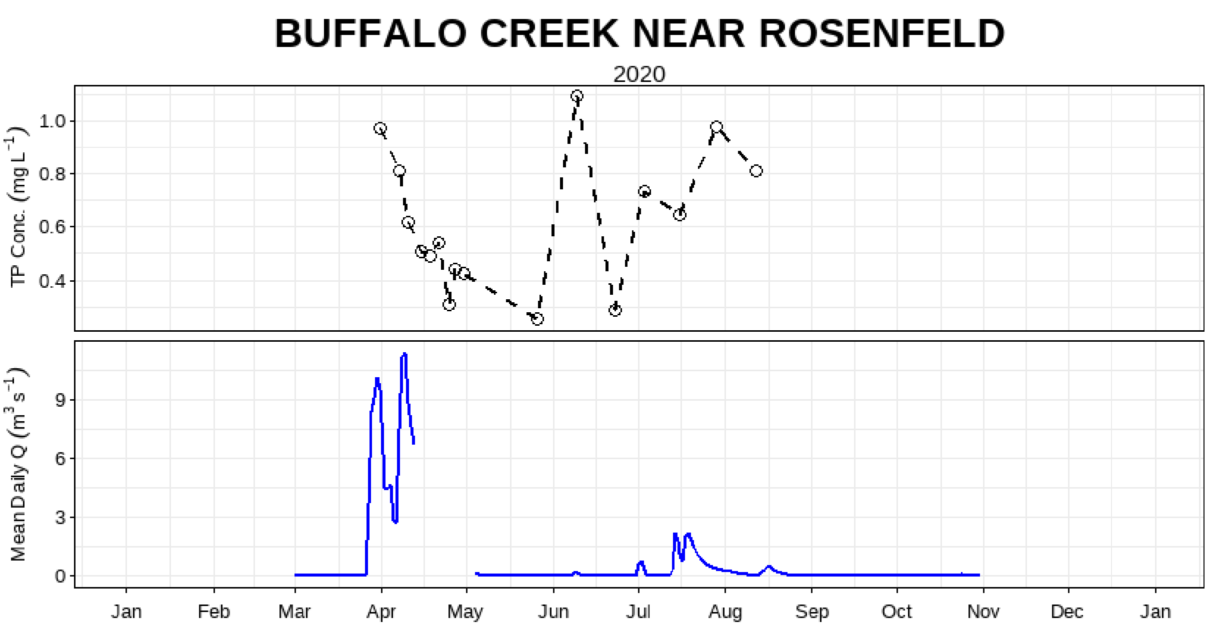


Figure 20: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Buffalo Creek near Rosenfeld (05OC019).

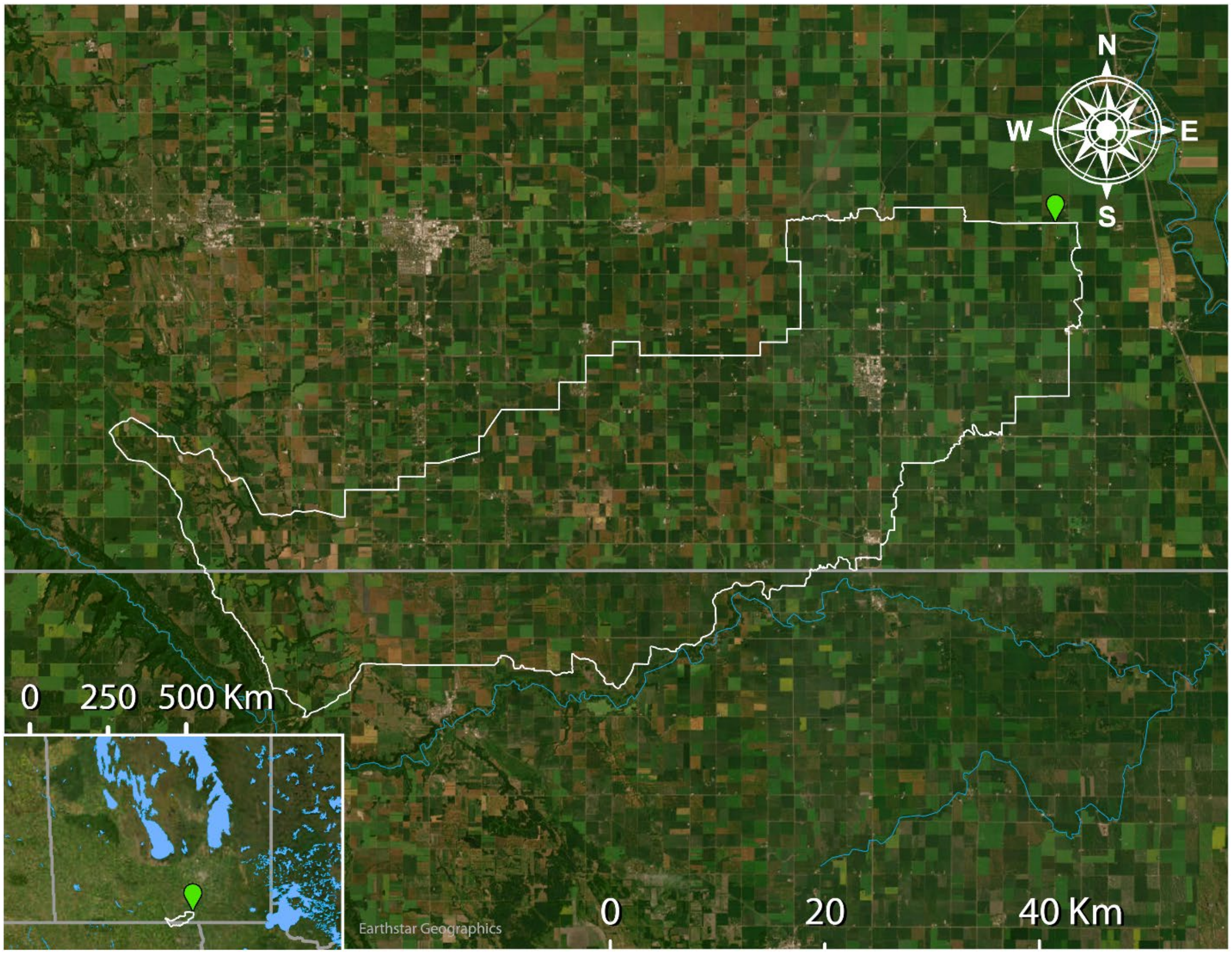


Figure 21: WSC station 05OC019 (green) and drainage area polygon (white - source: AAFC). LWCBMN samples directly at the WSC station.

Kronsgart Drain near Sewell

This sampling site is located upstream of Sewell, MB and drains a largely agricultural area. This sampling site is located at Water Survey of Canada station 05OC024, new Sewell, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 12: Indices of discharge and phosphorus from the gross drainage area of Kronsgart Drain near Sewell (05OC024) in 2020.

Gross drainage area:	61.65 km^2
Peak discharge:	3.38 $m^3\ s^{-1}$ (2020-07-14)
Peak TP concentration:	1.23 mg/L (2020-05-26)
% of water load in spring:	41.15%
% of TP load in spring:	72.44%
Water load:	0.0045 $km^3\ y^{-1}$
TP load:	2.93 tonnes P y^{-1}
Water export:	72.44 mm y^{-1}
TP export:	0.48 kg P $ha^{-1}\ y^{-1}$

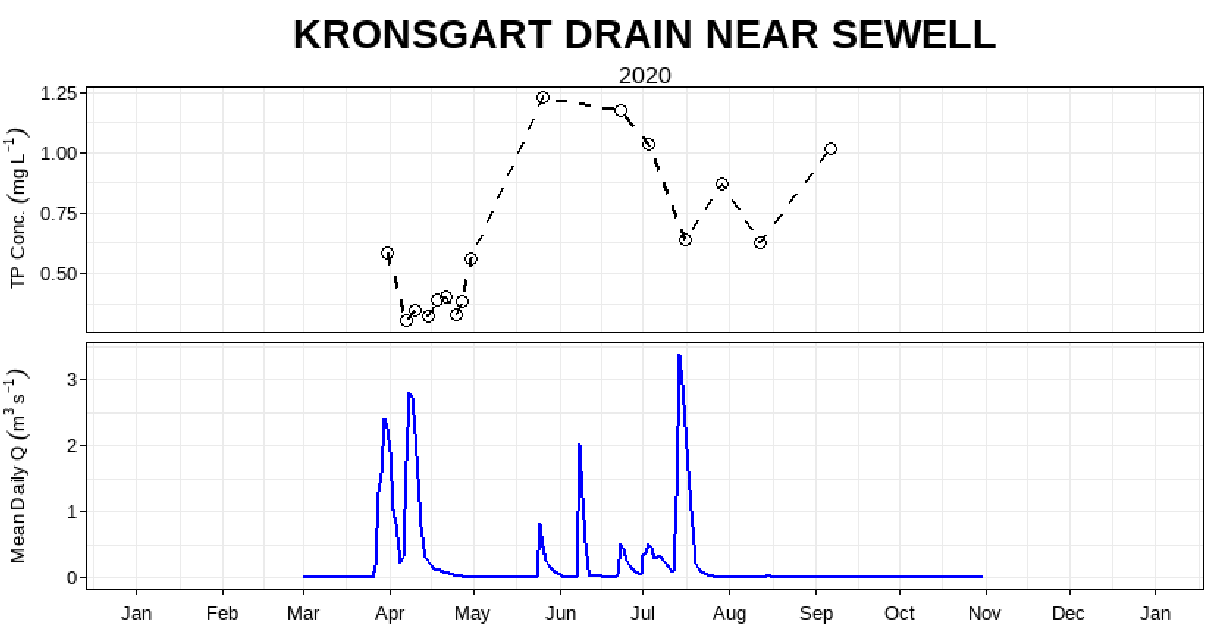


Figure 22: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Kronsgart Drain near Sewell (05OC024).

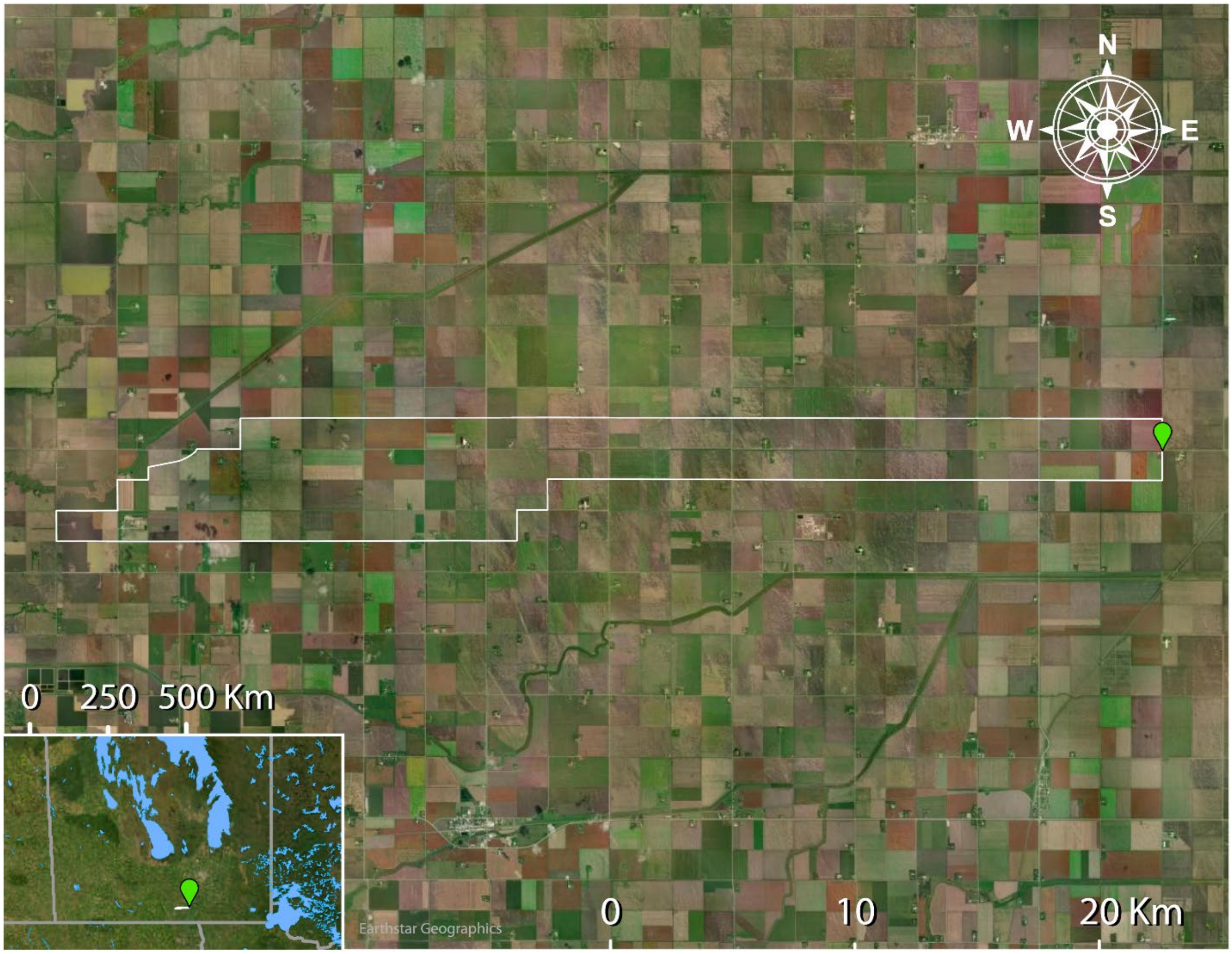


Figure 23: WSC station 05OC024 (green) and drainage area polygon (white – source: AAFC). LWCBMN samples directly at the WSC station.

Rivière aux Marais near Christie

The Rivière aux Marais near Christie sampling site drains a primarily agricultural area. The sampling site is located at Water Survey of Canada station 05OC022, near Halbstadt, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 13: Indices of discharge and phosphorus from the gross drainage area of Rivière aux Marais near Christie (05OC022) in 2020.

Gross drainage area:	187 km^2
Peak discharge:	8.03 $m^3 s^{-1}$ (2020-04-09)
Peak TP concentration:	2.07 mg/L (2020-07-29)
% of water load in spring:	70.31%
% of TP load in spring:	63.65%
Water load:	0.0082 $km^3 y^{-1}$
TP load:	8.5 tonnes P y^{-1}
Water export:	43.77 mm y^{-1}
TP export:	0.45 kg P $ha^{-1} y^{-1}$

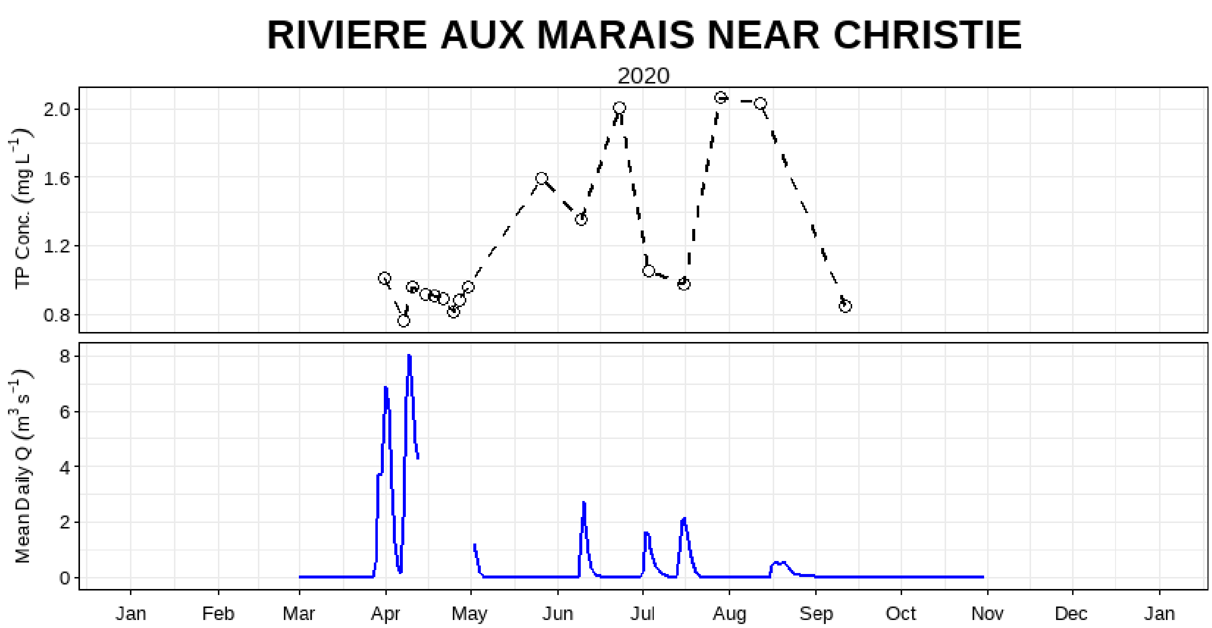


Figure 24: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Rivière aux Marais near Christie (05OC022).

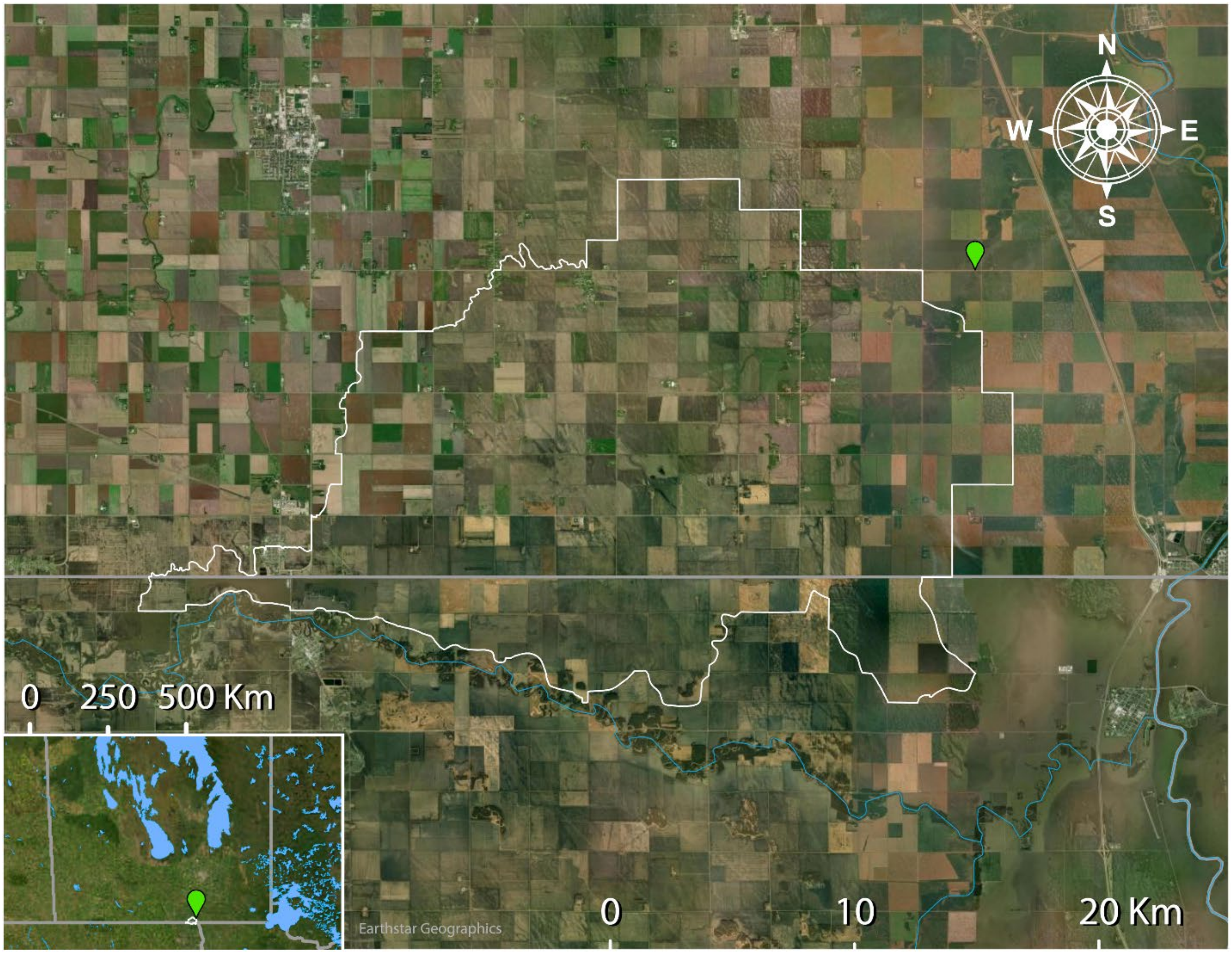


Figure 25: WSC station 05OC022 (green) and drainage area polygon (white – source: AAFC). LWCBMN samples directly at the WSC station.

Deadhorse Creek near Rosenfeld

The gross drainage area for this site contains primarily agricultural area, and includes the city and wastewater lagoon of Morden, MB, as well as the wastewater lagoons of Winkler and Plum Coulee, MB. It is located downstream of the inlet where the Plum Drain enters Deadhorse Creek. This sampling site is located at Water Survey of Canada flow meter 05OC016, near Rosenfeld, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 14: Indices of discharge and phosphorus from the gross drainage area of Deadhorse Creek near Rosenfeld (05OC016) in 2020.

Gross drainage area:	924 km^2
Peak discharge:	23.50 m^3 s^{-1} (2020-04-08)
Peak TP concentration:	0.81 mg/L (2020-07-29)
% of water load in spring:	68.65%
% of TP load in spring:	66.16%
Water load:	0.017 km^3 y^{-1}
TP load:	7.77 tonnes P y^{-1}
Water export:	17.94 mm y^{-1}
TP export:	0.084 kg P ha^{-1} y^{-1}

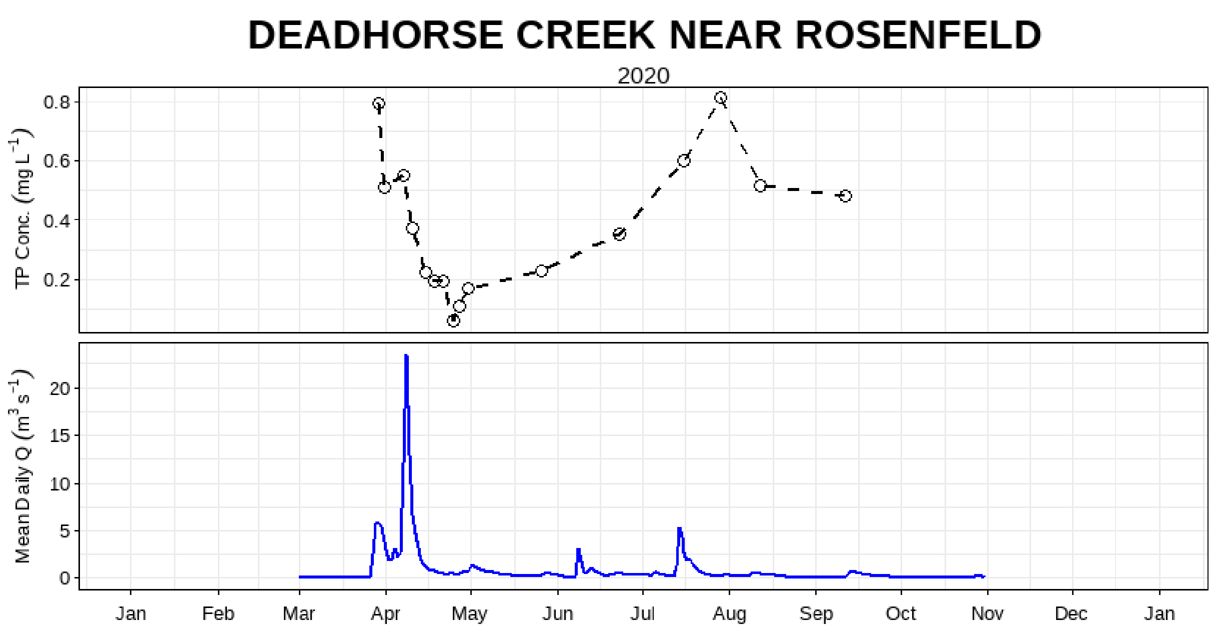


Figure 26: Mean daily discharge (m^3 s^{-1}) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Deadhorse Creek near Rosenfeld (05OC016).

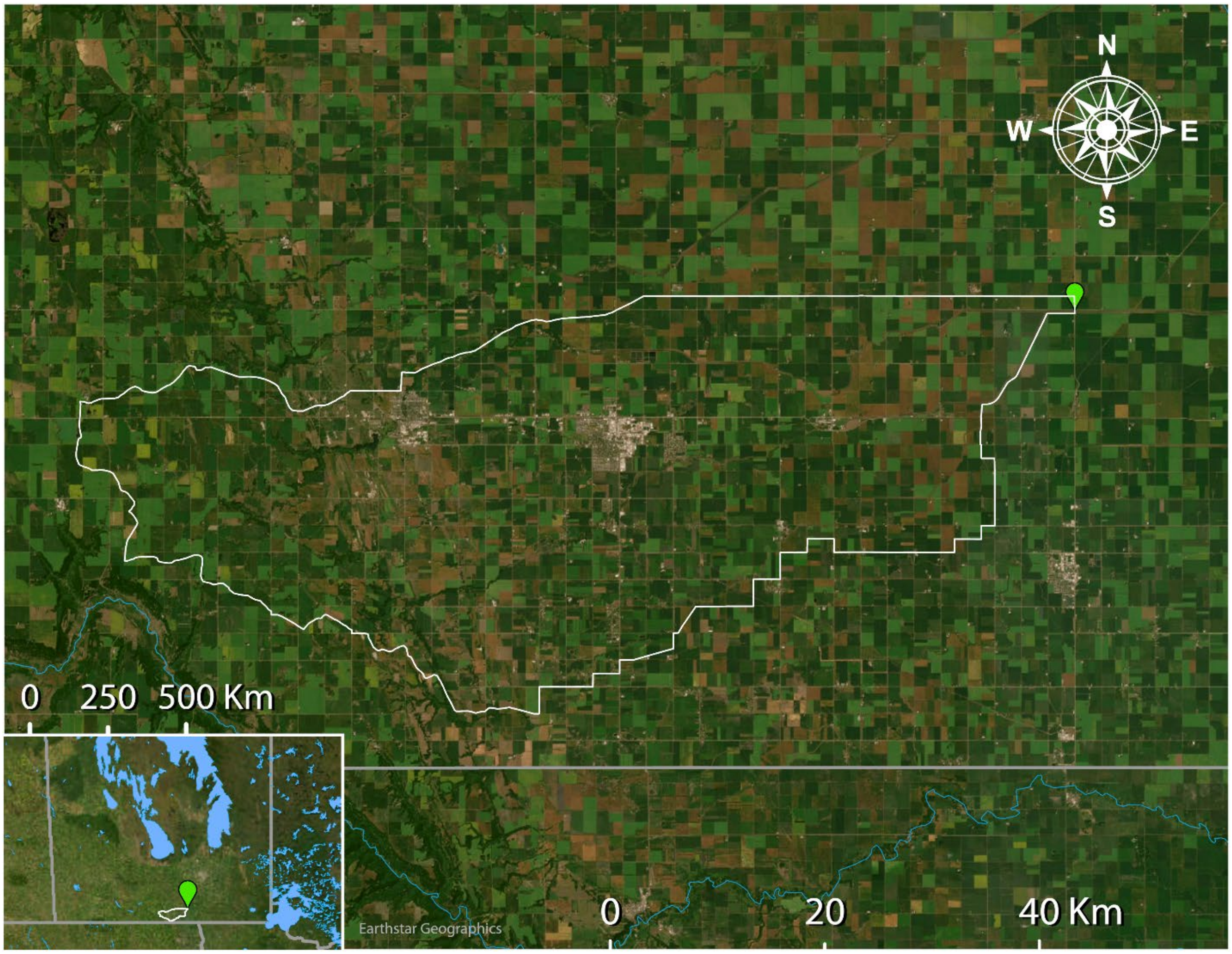


Figure 27: WSC station 05OC016 (green) and drainage area polygon (white – source: AAFC). LWCBMN samples directly at the WSC station.

Sites without monitored discharge

Badger Creek near Cartwright

Badger Creek is located south of the Pembina River. The majority of the Badger Creek drainage area is located in North Dakota, and includes the Rural Municipality of Cartwright, MB, and the city of Rolla, ND. This sampling site is located at Water Survey of Canada station 05OA007, near Cartwright. In 2020, there is only water level data, so we cannot do load or export calculations

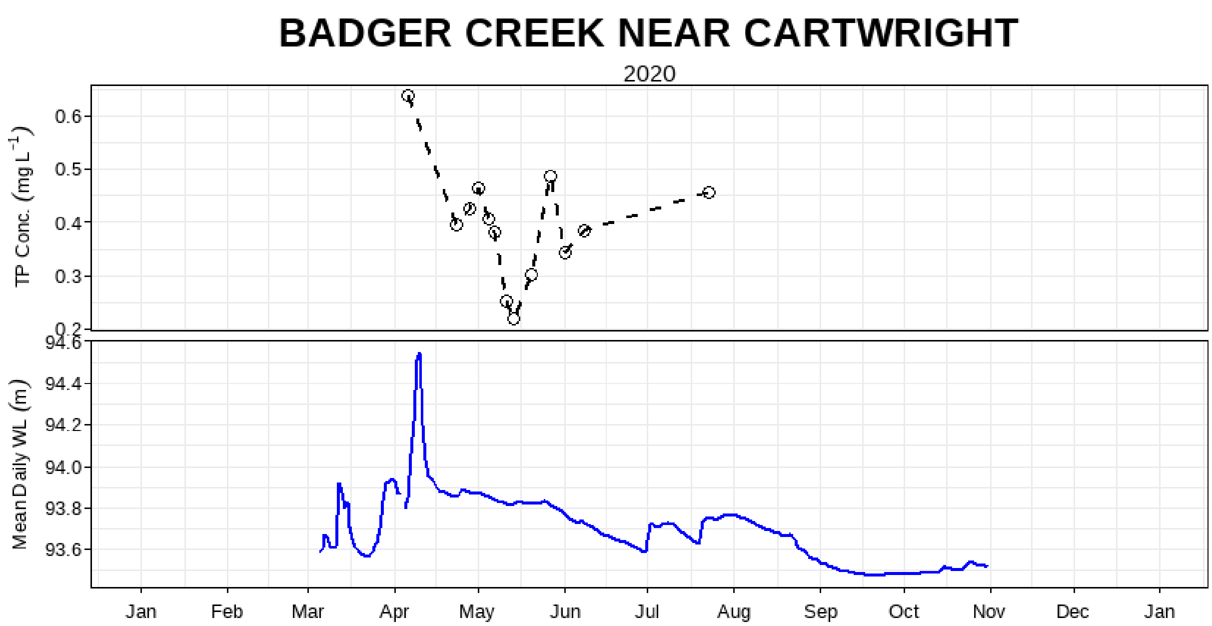


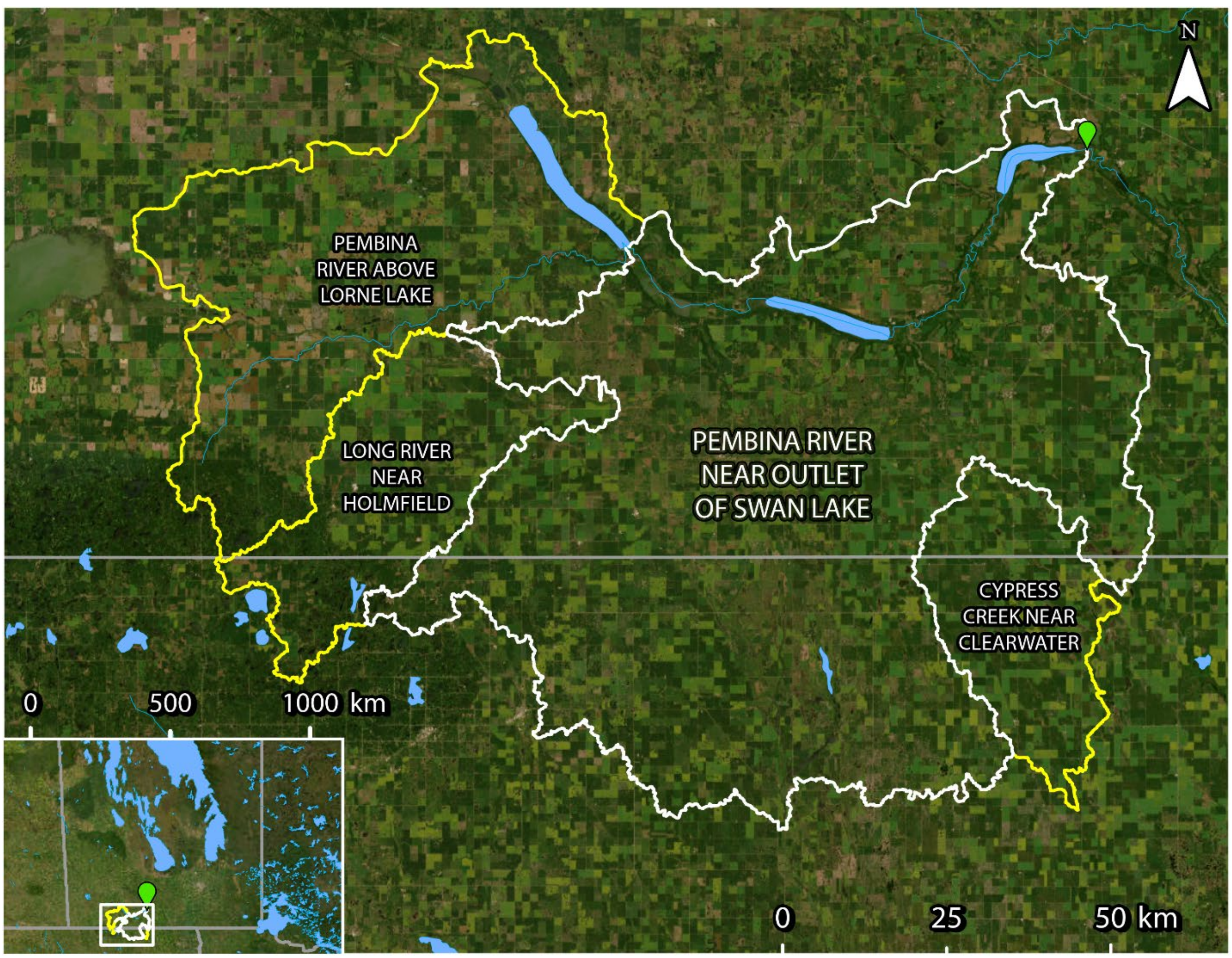
Figure 28: Water depth (m) and total phosphorus concentration (mg/L) at Badger Creek near Cartwright (05OA007) in 2020.

Incremental Calculations

Pembina River downstream of Swan Lake Outlet

Supplemental Table 1: Indices of discharge and phosphorus from the gross drainage area of Pembina River downstream of Swan Lake Outlet (05OB019) in 2020.

Gross drainage area:	5099.96 km^2
Water load:	0.089 $km^3\ y^{-1}$
TP load:	25.63 tonnes P y^{-1}
Water export:	17.40 mm y^{-1}
TP export:	0.050 kg P $ha^{-1}\ y^{-1}$

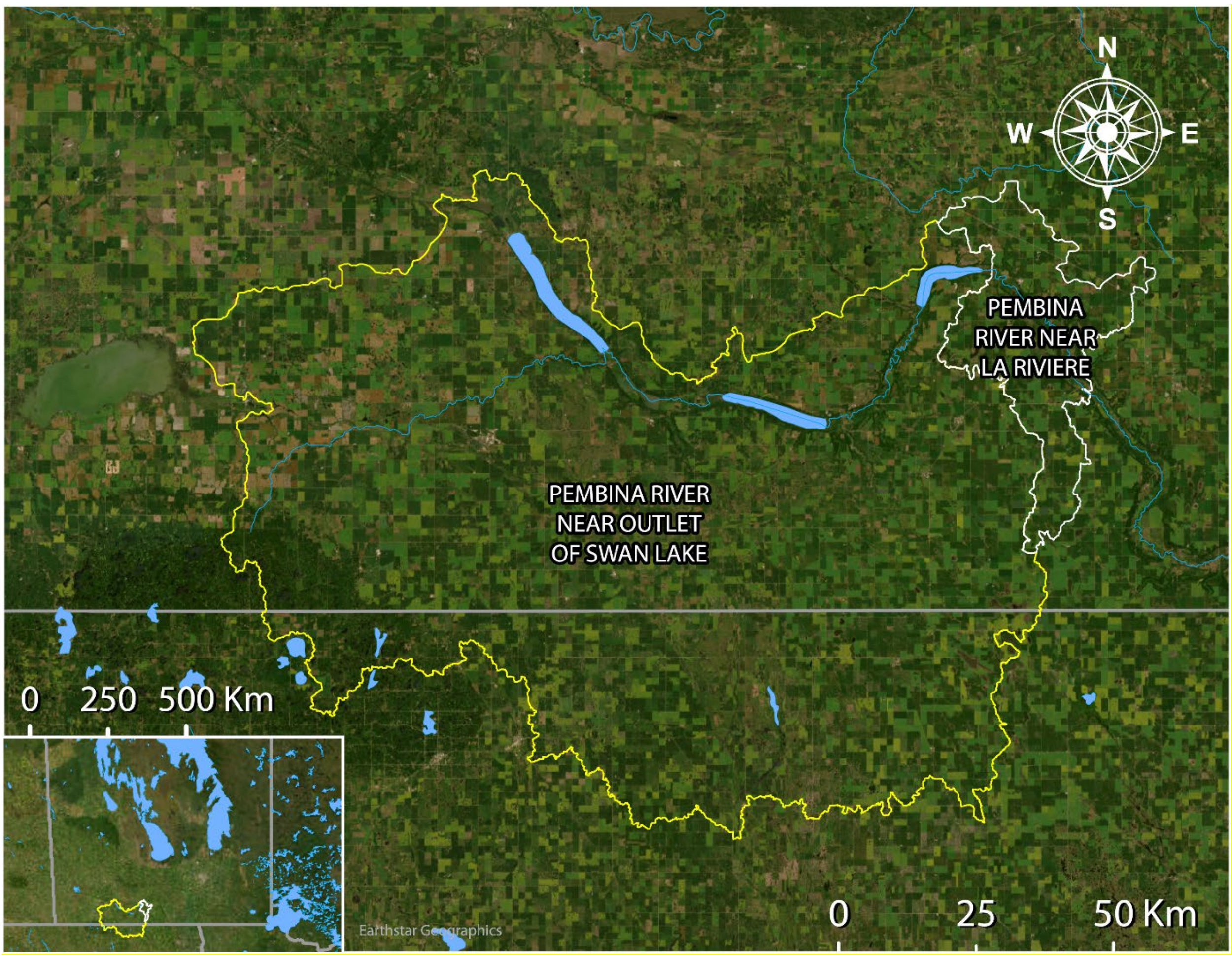


Supplemental Figure 1: Incremental drainage area in white and upstream drainage area in yellow. Incremental loads are calculated by subtracting gross “Long River near Holmfield”, “Cypress Creek near Clearwater” and “Pembina River above Lorne Lake” values from gross “Pembina River downstream of Swan Lake Outlet” values.

Pembina River near La Rivière

Supplemental Table 2: Indices of discharge and phosphorus from the gross drainage area of Pembina River near La Rivière (05OB001) in 2020.

Gross drainage area:	5533.46 km^2
Water load:	0.087 $km^3\ y^{-1}$
TP load:	37.71 tonnes P y^{-1}
Water export:	15.81 mm y^{-1}
TP export:	0.068 kg P $ha^{-1}\ y^{-1}$

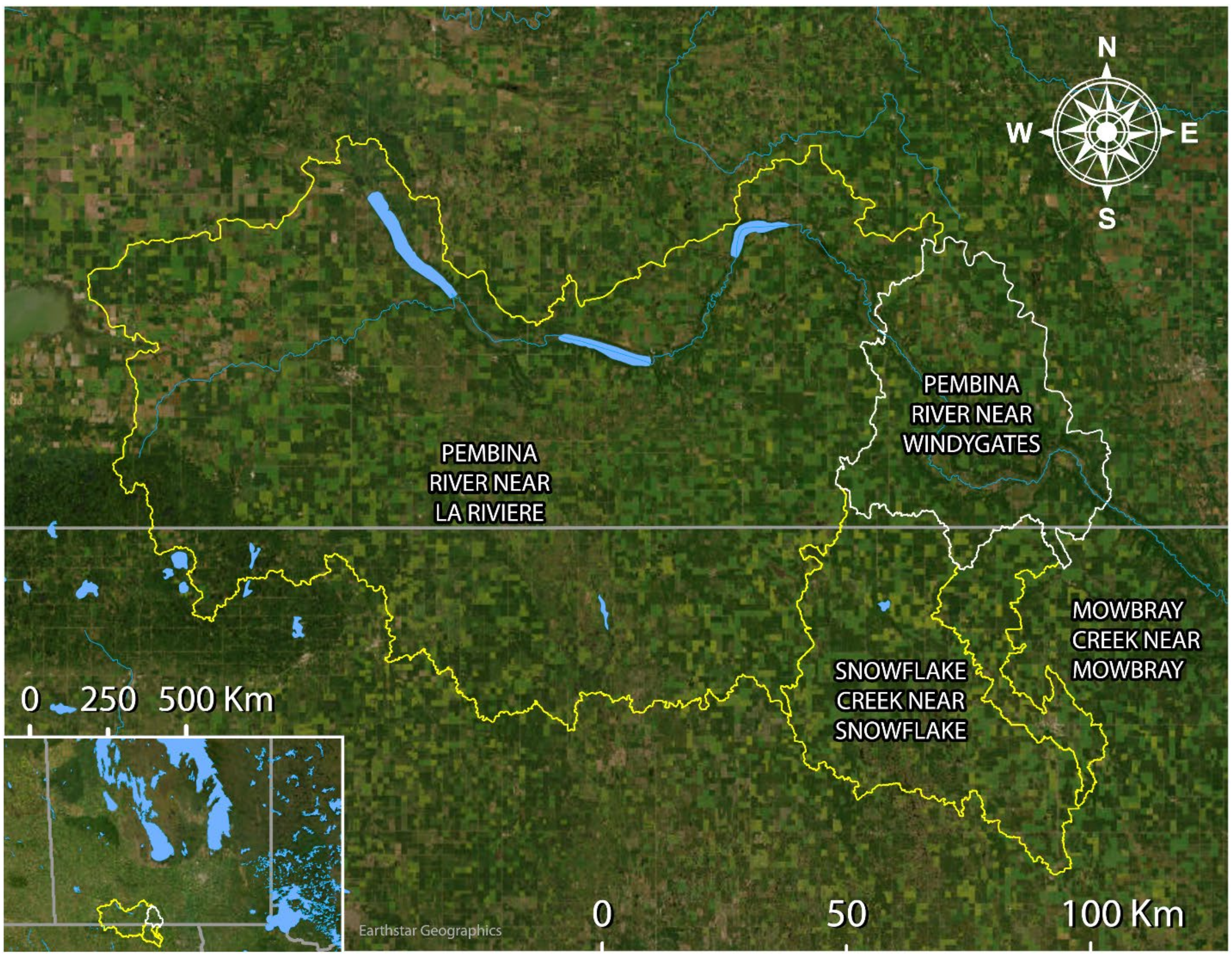


Supplemental Figure 2: Incremental drainage area in white and upstream drainage area in yellow. Incremental loads are calculated by subtracting gross “Pembina River downstream of Swan Lake” values from gross “Pembina River near La Rivière” values.

Pembina River near Windygates

Supplemental Table 3: Indices of discharge and phosphorus from the gross drainage area of Pembina River near Windygates (05OB007) in 2020.

Gross drainage area:	7734.34 km^2
Water load:	0.19 km^3 y^{-1}
TP load:	99.38 tonnes P y^{-1}
Water export:	24.17 mm y^{-1}
TP export:	0.13 kg P ha^{-1} y^{-1}



Supplemental Figure 3: Incremental drainage area in white and upstream drainage areas in yellow. Incremental loads are calculated by subtracting gross “Pembina River near La Rivière”, “Mowbray Creek near Mowbray”, and “Snowflake Creek near Snowflake” values from gross “Pembina River near Windygates” values.

Map Sources

Drainage area polygons

Primarily, and whenever possible, drainage area polygons were taken from the Water Survey of Canada's (WSC) National Hydrometric Network Basin Polygons. Released on July 15, 2022, this prerelease version of the dataset contains drainage area polygons for over 7300 of the 7896 active and discontinued WSC stations. According to WSC, this dataset will continue to be updated as new polygons are added. For our analysis, we used drainage areas from this dataset.

Link: https://catalogue.ec.gc.ca/geonetwork/srv/eng/catalog.search#/metadata/0c121878-ac23-46f5-95df-eb9960753375

Secondarily, when no WSC drainage area polygons were available, or when it was necessary to enable accurate incremental calculations, we used drainage area polygons from the Total Gross Drainage Areas of the Agriculture and Agri-Food Canada (AAFC)'s Watersheds Project – 2013

Link: https://open.canada.ca/data/en/dataset/67c8352d-d362-43dc-9255-21e2b0cf466c

Due to the required use of drainage area polygons from two different datasets, some polygons may slightly overlap. Hotspot maps, as a result, have a few instances where a drainage area is visually cut off. However, most of these instances are very minor, and we display all watersheds in their full extent on each sampling site's individual section.

Map layers

Satellite imagery used in all maps is from the World Imagery map layer (Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community). World Imagery provides one meter or better satellite and aerial imagery in many parts of the world and lower resolution satellite imagery worldwide.

Lake and river map data used in all maps is from North America Environmental Atlas (Lakes, Rivers). The North American Environmental Atlas – Lakes & Rivers datasets display area hydrographic features (Lakes: major lakes and reservoirs; Rivers: major rivers, streams, and canals) of North America at a reference spatial scale of 1:1,000,000. Credits: Commission for Environmental Cooperation (CEC). 2023. "North American Atlas – Lakes and Rivers". Natural Resources Canada (NRCan), Instituto Nacional de Estadística y Geografía (INEGI), Comisión Nacional del Agua (CONAGUA), U.S. Geological Survey (USGS). Ed. 3.0, Vector digital data [1:1,000,000].

The **Lake Winnipeg Community-Based Monitoring Network** (LWCBMN) is a collaborative, long-term phosphorus monitoring program designed to identify localized phosphorus hotspots where action is required to improve Lake Winnipeg water quality. LWCBMN mobilizes citizen volunteers and watershed partners to collect water samples across Manitoba, generating robust water-quality data that is useful to community practitioners, academic researchers, government scientists and policy-makers alike. Focusing research, resources and action in phosphorus hotspots is necessary to reduce phosphorus loading to Lake Winnipeg.

LWCBMN is delivered in partnership with Manitoba's watershed districts, LWF's science advisors, volunteer citizen scientists and Dr. Nora Casson's laboratory at the University of Winnipeg. Thank you to all who make this network possible!

The **Lake Winnipeg Foundation** (LWF) advocates for change and coordinates action to improve the health of Lake Winnipeg. Combining the commitment of our grassroots membership and the expertise of our science advisors, LWF is nationally recognized for our unique capacity to link science and action. Our goal is to ensure policy and practices informed by evidence are implemented and enforced.

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