LAKE WINNIPEG FOUNDATION

Assiniboine River; Photo: Paul Mutch

SEINE RAT ROSEAU
WATERSHED DISTRICT

2022 regional report

LAKE WINNIPEG
community-based monitoring network

SEINE RAT ROSEAU 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 into the water just before it hits the bottom, the bottle is filled, then 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 2022, 1588 unfiltered water samples were collected and analyzed from 110 sites. Of these 110 LWCBMN sampling sites, 92 are located near flow-metered WSC stations, five are located near non-flow-metered WSC stations, and one is located near a USGS station, and twelve are not located near any stations.

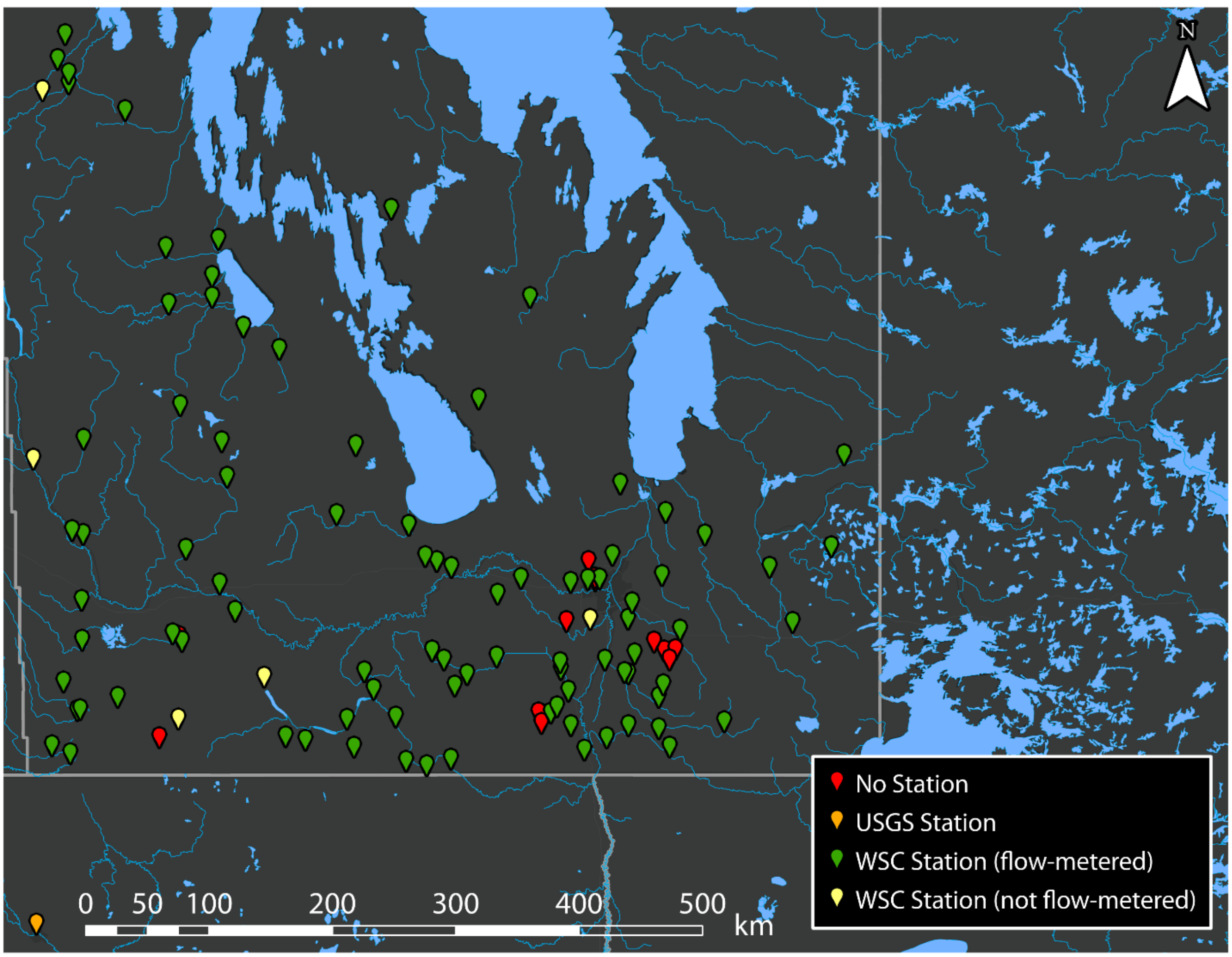


Figure 1: Map of LWCBMN sampling sites in 2022. Locations shown provided at least one sample. Colours indicate nearby station type.

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. The Water Survey of Canada (WSC) records daily flows at most of our stations. 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 - 2022

Table 1: Summary of 2022 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
Assiniboine West	10	170	Little Saskatchewan River near Minnedosa (0.44)	58.63	60.54
Central Assiniboine	2	48	Cypress River near Bruxelles (1.37)	87.85	80.32
City of Winnipeg	5	103	Omand's Creek near Empress Street (1.45)	87.84	91.60
East Interlake	3	24	Netley Creek near Petersfield (0.91)	67.88	81.05
Inter-Mountain	7	110	Ochre River near Ochre River (2.72)	66.73	77.45
Northeast Red	4	34	Devil's Creek near Libau (1.31)	63.71	68.56
Pembina Valley	16	216	Rivière aux Marais near Christie (3.22)	80.87	83.45
Redboine	15	195	South Tobacco Creek near Miami (3.99)	80.86	84.10
Souris River	13	122	Elgin Creek near Souris (0.26)	63.41	54.70
Seine Rat Roseau	19	333	Joubert Creek at St-Pierre-Jolys (2.74)	70.73	74.38
Swan Lake	6	90	Birch River near Birch River (0.83)	79.69	92.88
West Interlake	2	39	Burnt Lake Drain Northwest of Lundar (0.077)	19.56	17.44
Whitemud	4	54	Big Grass River near Glenella (0.78)	59.70	56.13
Winnipeg River	4	50	Bird River outlet of Bird Lake (0.20)	47.54	48.72

*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.

Seine Rat Roseau Watershed District

The Seine Rat Roseau Watershed District (SRRWD) is located east of the Red River, extending almost to Ontario and to the United States. SRRWD consists of three major sub-watersheds: the Seine, Rat and Roseau River watersheds. The primary land use in SRRWD is agriculture, specifically cereal crops and livestock. The Seine River watershed has the most intensively developed hog industry of all watersheds in Manitoba (Seine River Integrated Watershed Management Plan, 2010). In addition to agricultural activities, wastewater treatment plants and lagoons in municipalities throughout SRRWD contribute phosphorus to local waterways. Major municipalities include Steinbach, St-Pierre-Jolys and Lorette.

In partnership with LWCBMN, SRRWD staff and volunteers sampled 19 sites in the SRRWD region, of which 15 were near actively monitored flow-metered WSC stations. For the sites where flow is not measured, useful information can be drawn from the phosphorus concentrations; however, we cannot calculate the phosphorus load because we cannot multiply the phosphorus concentration by the volume of water flowing by sampling the site.

[SRRWD Website (srrwd.ca)](srrwd.ca)

[SRRWD Watershed Plans (srrwd.ca/watershed-plans)](srrwd.ca/watershed-plans)

Characteristics of the 2022 Field Season

The 2022 field season was historically wet. The winter of 2021-2022 provided most of southern Manitoba with 150+ cm of snow, the third highest amount of snowfall since 1872. Additionally, record precipitation in April and May saw large amounts of rain and snow falling on mostly frozen, impermeable soils. Specifically, in the month of April, southern Manitoba and the US portion of the Red River watershed received 400-600% of their normal precipitation (120-160 mm). Flooding was a huge issue across the southern part of the province, where almost all LWCBMN sites are located. The mean peak discharge date across all LWCBMN sites with analyzed water samples was May 10, 2022 (with a standard deviation of 19 days). In 2022, an average of 65.83% of stream discharge occurred in the spring (March 1 – May 31) across LWCBMN sites (with a standard deviation of 21.10%). During the period of extreme flooding, safety concerns prevented sampling from occurring at some sites. As a result, some load/export calculations may be less accurate than they would be had sampling remaining frequent during these times.

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 2022, 12 watershed districts participated in LWCBMN activities: Assiniboine West, Central Assiniboine, East Interlake; Inter-Mountain; Northeast Red, Pembina Valley, Redboine, Souris River, Seine Rat Roseau, Swan Lake, West Interlake, and Whitemud.

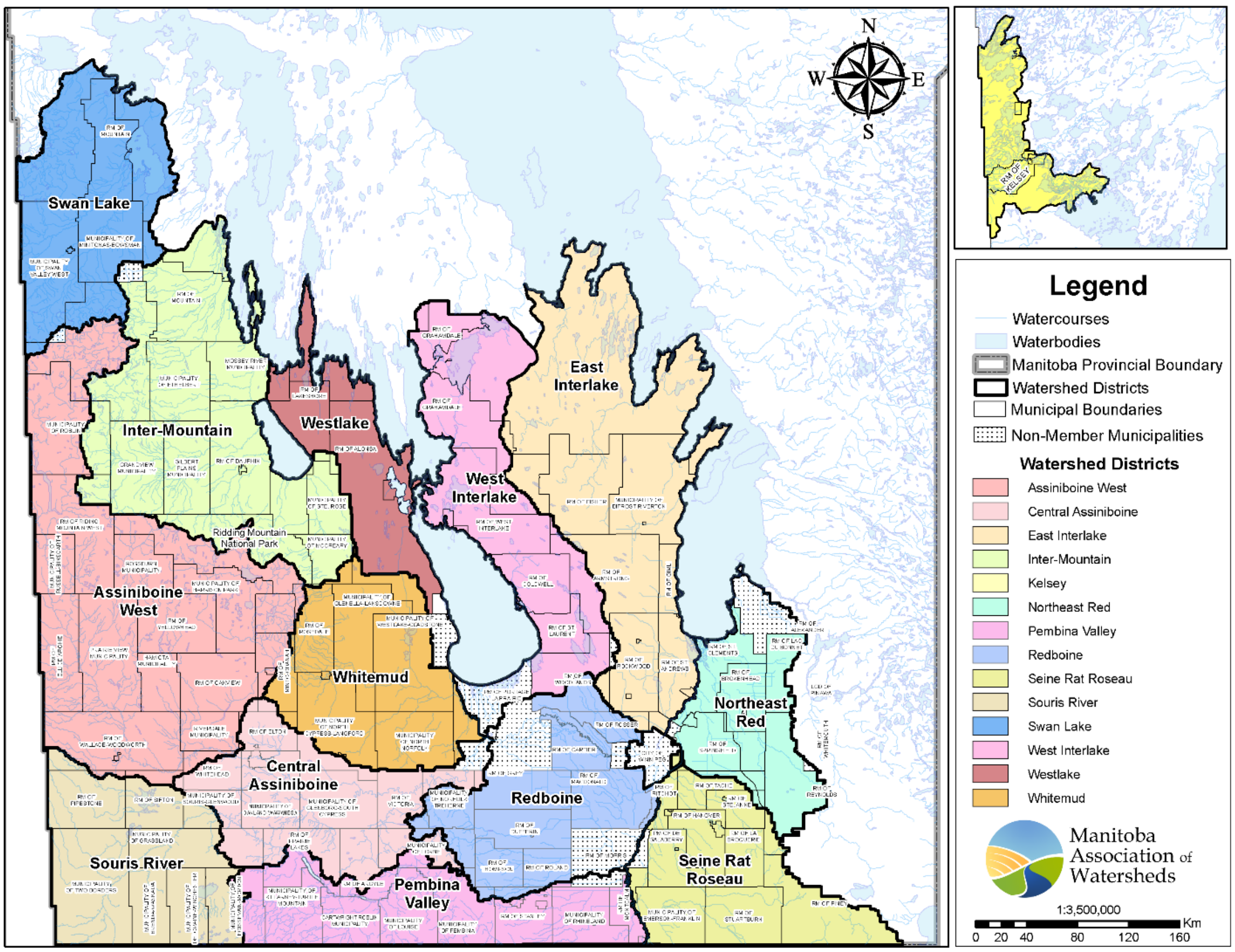


Figure 2: Manitoba Watershed District Boundaries. There are 14 total watershed districts. Map provided by Manitoba Association of Watersheds (updated July 2022).

2022 Results – SRRWD Summary

Table 2: Summary of 2022 LWCBMN results in SRRWD. 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	Joubert Creek at St-Pierre-Jolys	05OE007	348.29	140.09	Incr.	38.37	2.74
B	Joubert Creek near Pansy	05OE015	208.20	NA	gross	20.57	0.99
C	Main Drain near Dominion City	05OD028	203.47	NA	gross	32.49	1.60
D	Manning Canal near Île-des-Chênes	05OE006	480.77	NA	gross	95.31	1.98
E	Marsh River near Otterburne	05OE010	399.60	NA	gross	31.58	0.79
F	Pansy Drain near Sarto	05OE014	44.31	NA	gross	4.89	1.10
G	Rat River near St-Pierre-Jolys	05OE001-05OE007	1074.86	651.92	Incr.	28.48	0.44
H	Rat River near Sundown	05OE004	423	NA	gross	2.38	0.056
I	Roseau River at Gardenton	05OD004	3992	NA	gross	88.59	0.22
J	Roseau River near Dominion City	05OD001	4607.32	177.29	Incr.	13.13	0.74
K	Seine River near Prairie Grove + Seine River Diversion near Île-des-Chênes	05OE011+ 05OH009	1747.94	701.43	Incr.	69.10	0.99
L	Seine River near Ste. Anne	05OH007	554.82	NA	gross	47.06	0.85
M	Tourond Creek near Tourond	05OE009	210.07	165.76	Incr.	23.32	1.41
N	Vita Drain near Stuartburn	05OD034	438.29	NA	gross	3.07	0.07

To compare 2022 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.

2022 Results – Hotspot Map

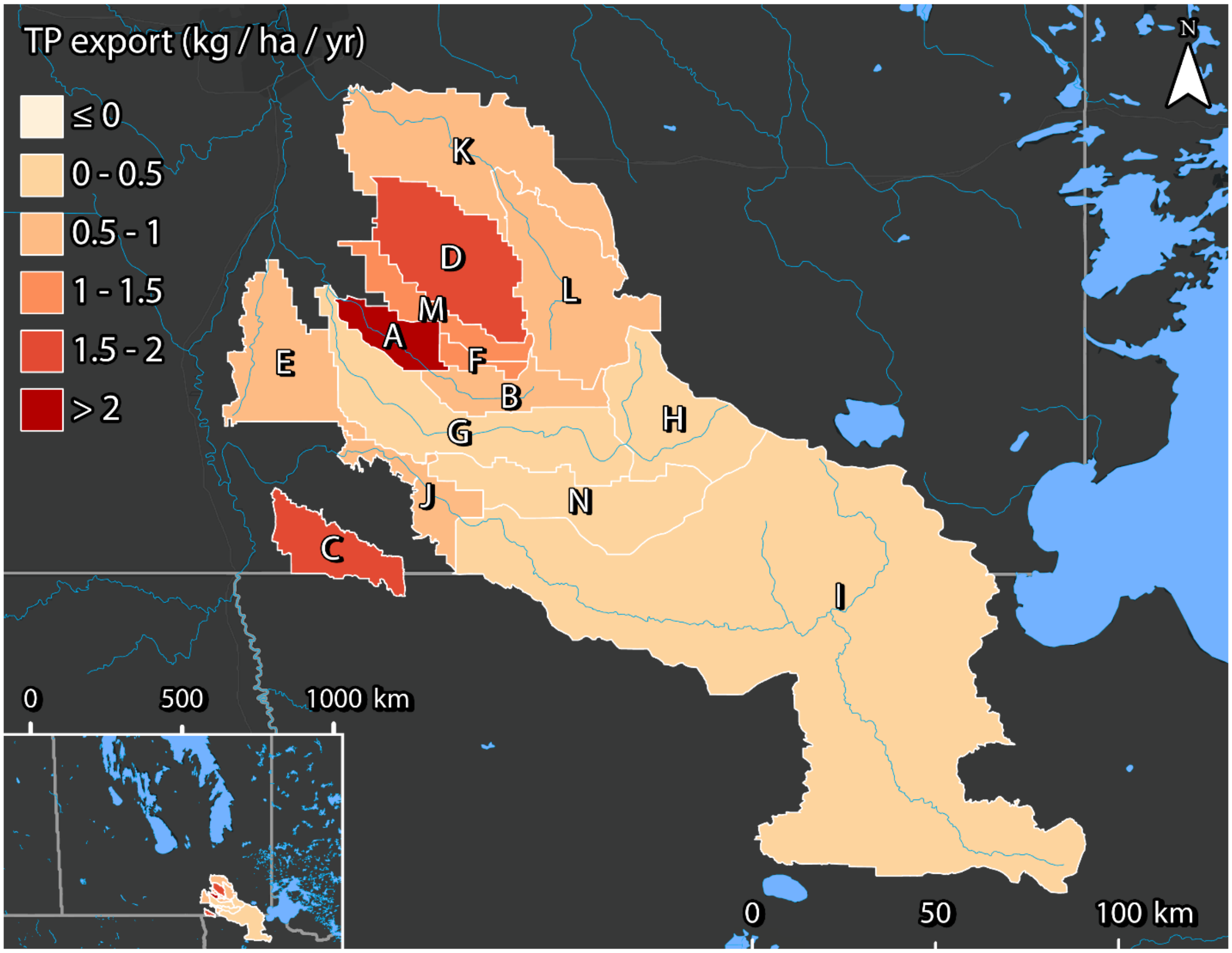


Figure 3: 2022 LWCBMN TP Export Hotspots in SRRWD. Letters correspond to sites listed in Table 2.

2022 Results – Individual Sites

Seine River near Ste. Anne

The upper Seine River sampling site drains a largely forested area of approximately. The drainage area includes a portion of Sandilands Provincial Forest. This sampling site is located at Water Survey of Canada flow meter 05OH007, near Ste. Anne, MB. 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 Seine River near Ste. Anne (05OH007) in 2022.

Gross drainage area:	554.82 km^2
Peak discharge:	70.25 $m^3\ s^{-1}$ (2022-07-22)
Peak TP concentration:	0.98 mg/L (2022-04-03)
% of water load in spring:	58.58%
% of TP load in spring:	66.33%
Water load:	0.14 $km^3\ y^{-1}$
TP load:	47.06 tonnes P y^{-1}
Water export:	258.49 mm y^{-1}
TP export:	0.85 kg P $ha^{-1}\ y^{-1}$

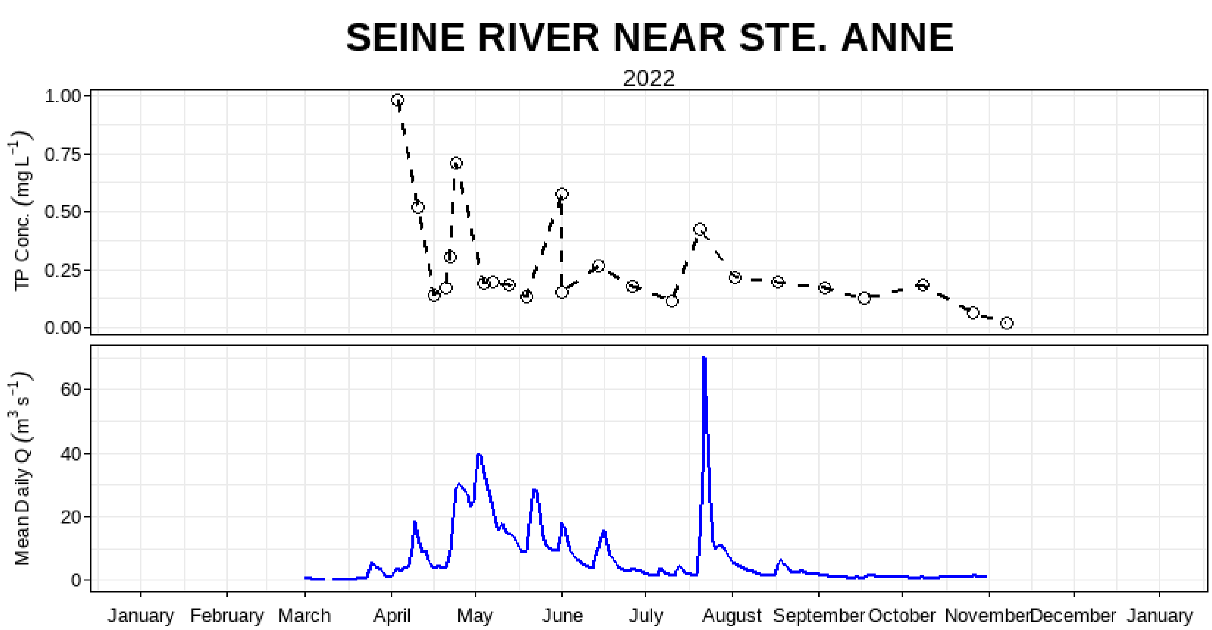


Figure 4: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Seine River near Ste. Anne (05OH007).

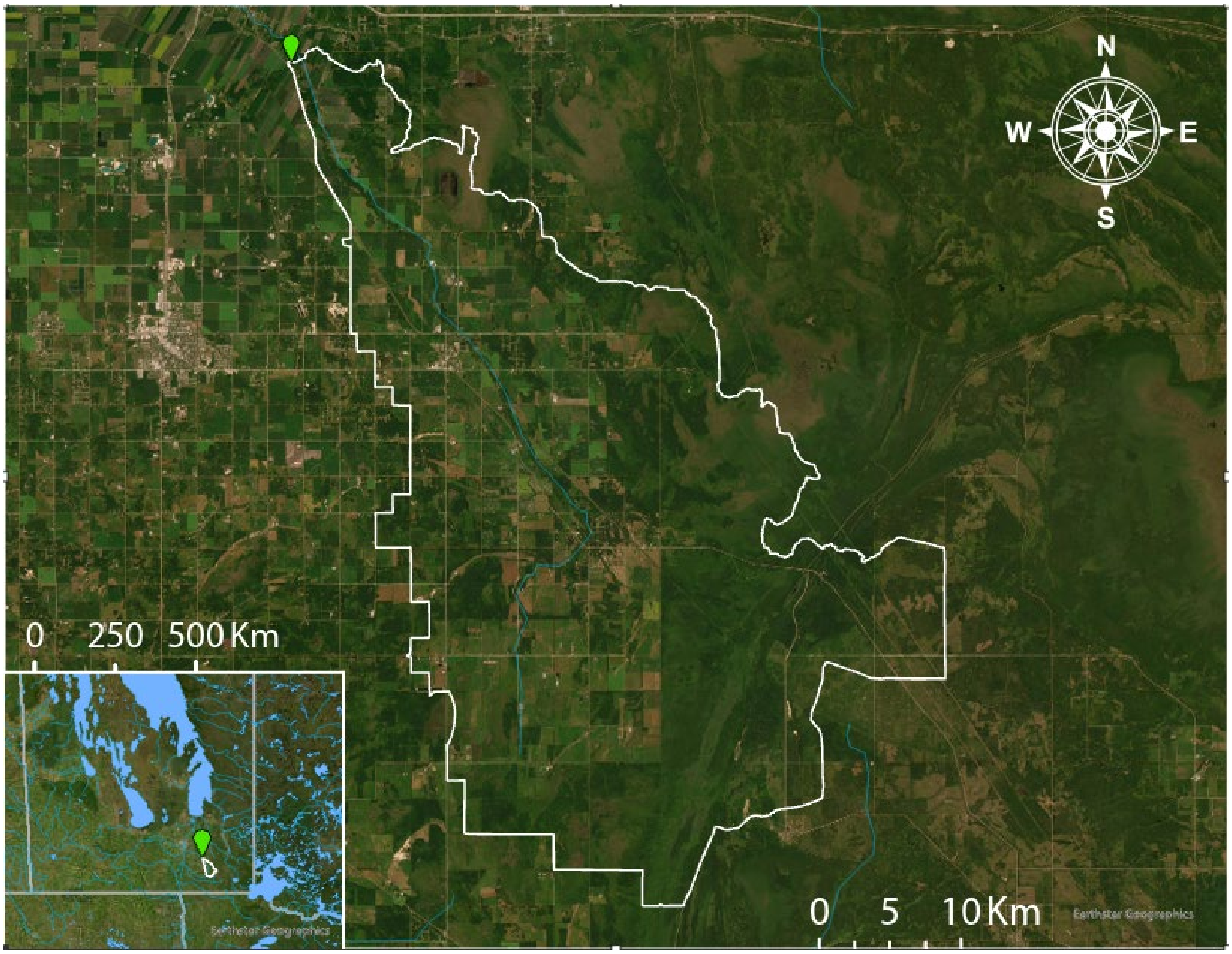


Figure 5: WSC station 05OH007 (green) and drainage area polygon (white - source: WSC). LWCBMN samples directly at the WSC station.

Manning Canal near Île-des-Chênes

The Manning Canal is a sub-watershed of the larger Seine River watershed. The Manning Canal drains a largely agricultural area which includes dense livestock and crop land as well as the growing city of Steinbach. This sampling site is located at Water Survey of Canada flow meter 05OE006, near Île-des-Chênes, MB. 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 Manning Canal near Île-des-Chênes (05OE006) in 2022.

Gross drainage area:	480.77 km^2
Peak discharge:	65.15 $m^3\ s^{-1}$ (2022-04-24)
Peak TP concentration:	2.08 mg/L (2022-04-08)
% of water load in spring:	70.07%
% of TP load in spring:	77.23%
Water load:	0.087 $km^3\ y^{-1}$
TP load:	95.31 tonnes P y^{-1}
Water export:	180.02 mm y^{-1}
TP export:	1.98 kg P $ha^{-1}\ y^{-1}$

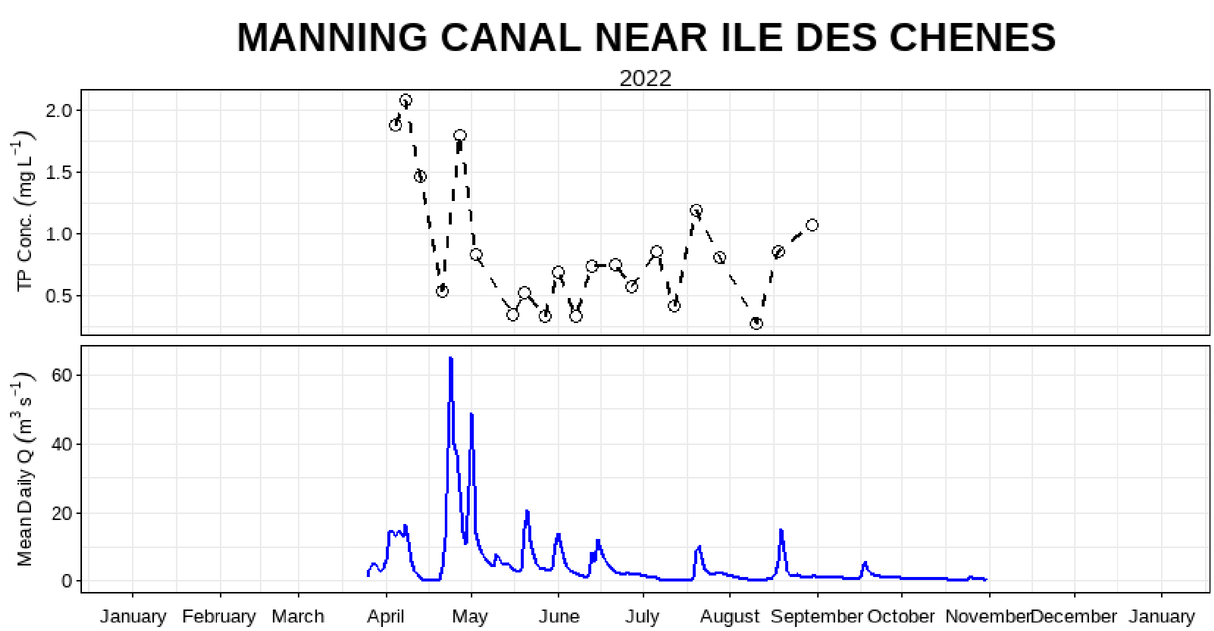


Figure 6: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Manning Canal near Île-des-Chênes (05OE006).

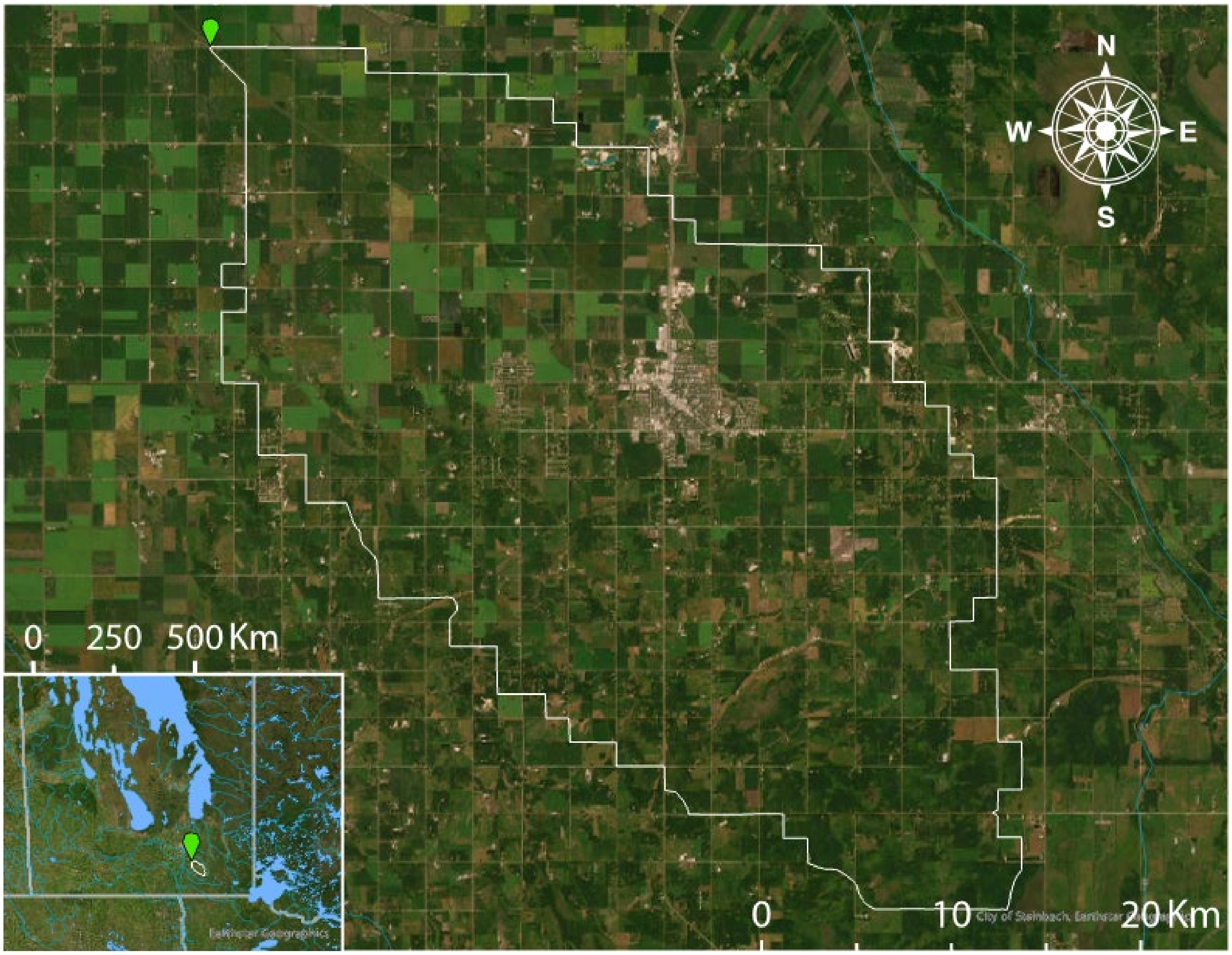


Figure 7: WSC station 05OE006 (green) and drainage area polygon (white - source: AAFC). LWCBMN samples directly at the WSC station.

Seine River near Prairie Grove and the Seine River Diversion near Île-des-Chênes

Together, the Seine River near Prairie Grove, MB, and the Seine River Diversion sampling sites drain a largely agricultural area. Water flowing down the Seine River towards Prairie Grove is diverted into the Seine River Diversion when water levels and flows are high. Both sampling sites share a drainage area, therefore, phosphorus and water loads are added together to accurately calculate the phosphorus export for the drainage area. The Prairie Grove and Diversion sites are located at Water Survey of Canada flow meters 05OH009 and 05OE011, respectively. The sampling efforts at these sites provided adequate coverage to calculate TP loads and exports.

Table 5: Peak discharge & TP concentration from Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011).

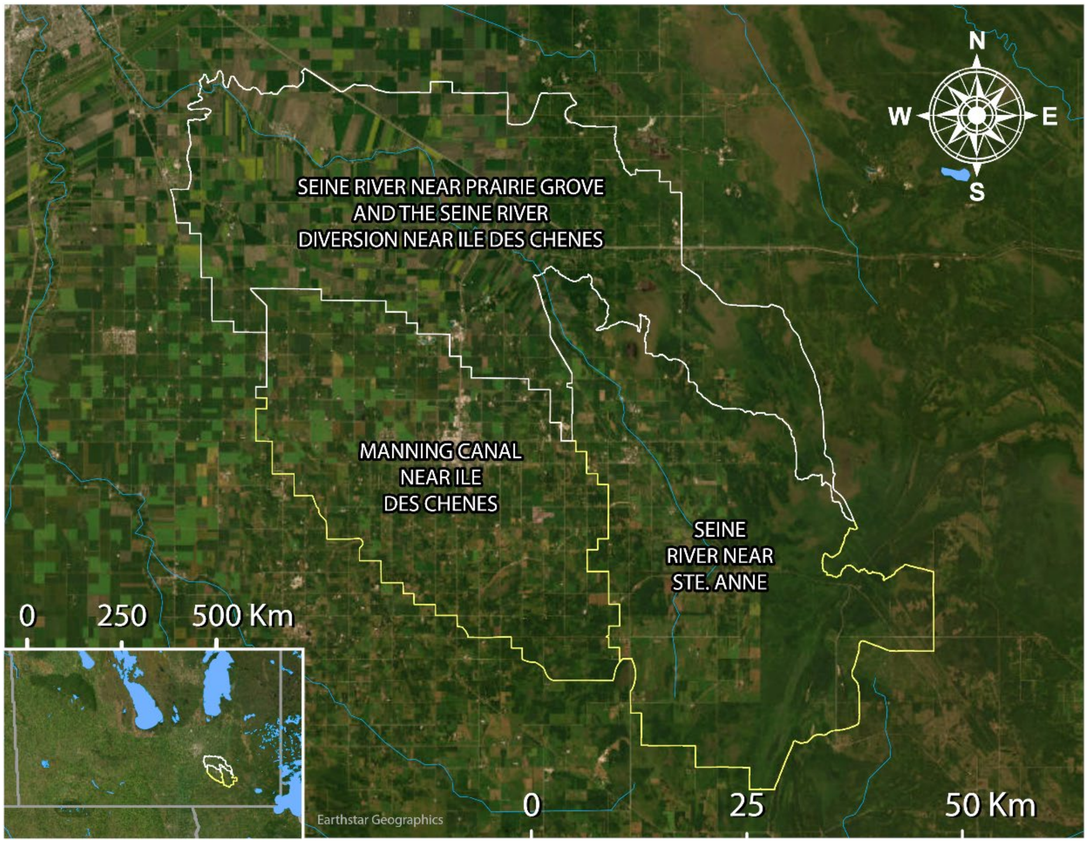
Site:	Seine River near Prairie Grove	Seine River near Île-des-Chênes
Station:	05OH009	05OE011
Peak discharge:	42.95 m^3 s^{-1} (2022-04-25)	150.163 m^3 s^{-1} (2022-04-24)
Peak TP concentration:	1.31 mg/L (2022-04-08)	1.72 mg/L (2022-03-28)

Table 6: Indices of discharge and phosphorus from the combined incremental drainage area of Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011). See

Seine River near Prairie Grove and the Seine River Diversion near Île-des-Chênes

Supplemental Table 1: Indices of discharge and phosphorus from the combined gross drainage area and stream discharge of Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011).

Gross drainage area:	1747.94 km^2
Water load:	0.32 km^3 y^{-1}
TP load:	211.47 tonnes P y^{-1}
Water export:	246.88 mm y^{-1}
TP export:	1.65 kg P ha^{-1} y^{-1}

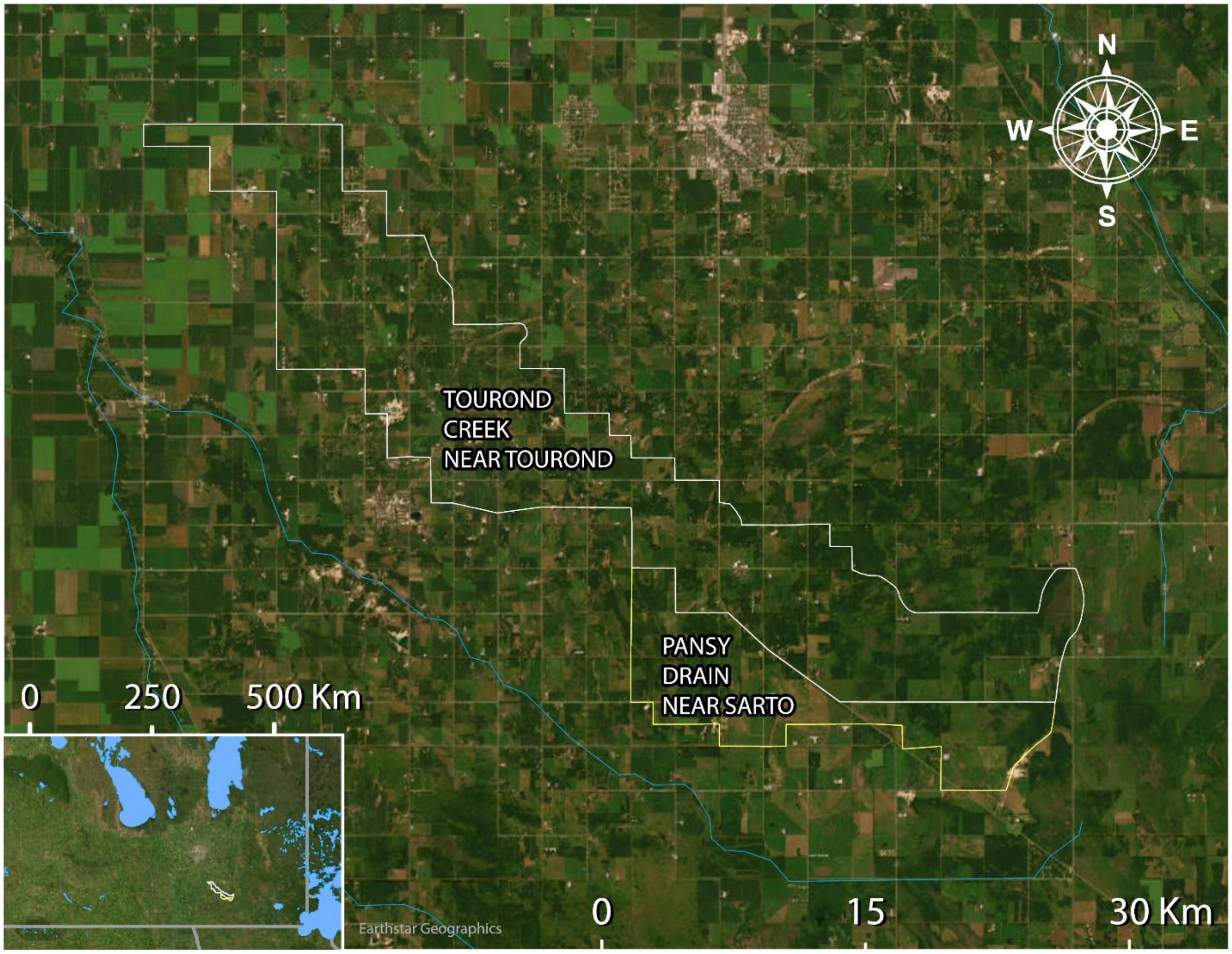


Supplemental Figure 1: Incremental drainage area in white (combined area of WSC stations Seine River near Prairie Grove and the Seine River Diversion near Île-des-Chênes) and upstream drainage areas in yellow (Manning Canal near Île-des-Chênes and Seine River near Ste. Anne). The combined incremental drainage area for Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011) was calculated by adding the former two gross drainage areas together and subtracting the upstream gross drainage areas of Manning Canal near Île-des-Chênes (05OE006) and Seine River near Ste. Anne (05OH007).

Tourond Creek near Tourond

Supplemental Table 2: Indices of discharge and phosphorus from the gross drainage area of Tourond Creek near Tourond (05OE009) in 2022.

Gross drainage area:	210.07 km^2
Water load:	0.031 $km^3\ y^{-1}$
TP load:	28.21 tonnes P y^{-1}
Water export:	147.95 mm y^{-1}
TP export:	1.34 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 "Pansy Drain near Sarto" values from gross "Tourond Creek near Tourond" values.

Joubert Creek at St-Pierre-Jolys

Supplemental Table 3: Indices of discharge and phosphorus from the gross drainage area of Joubert Creek near St-Pierre-Jolys (05OE007) in 2022.

Gross drainage area:	348.29 km^2
Water load:	0.075 $km^3\ y^{-1}$
TP load:	58.94 tonnes P y^{-1}
Water export:	215.80 mm y^{-1}
TP export:	1.69 kg P $ha^{-1}\ y^{-1}$

for gross calculations.

Incremental drainage area:	701.43 km^2
% of water load in spring:	73.63%
% of TP load in spring:	86.31%
[1]Incremental water load:	0.092 $km^3\ y^{-1}$
[1]Incremental TP load:	69.10 tonnes P y^{-1}
[2]Incremental water export:	131.69 mm y^{-1}
[2]Incremental TP export:	0.99 kg P $ha^{-1}\ y^{-1}$

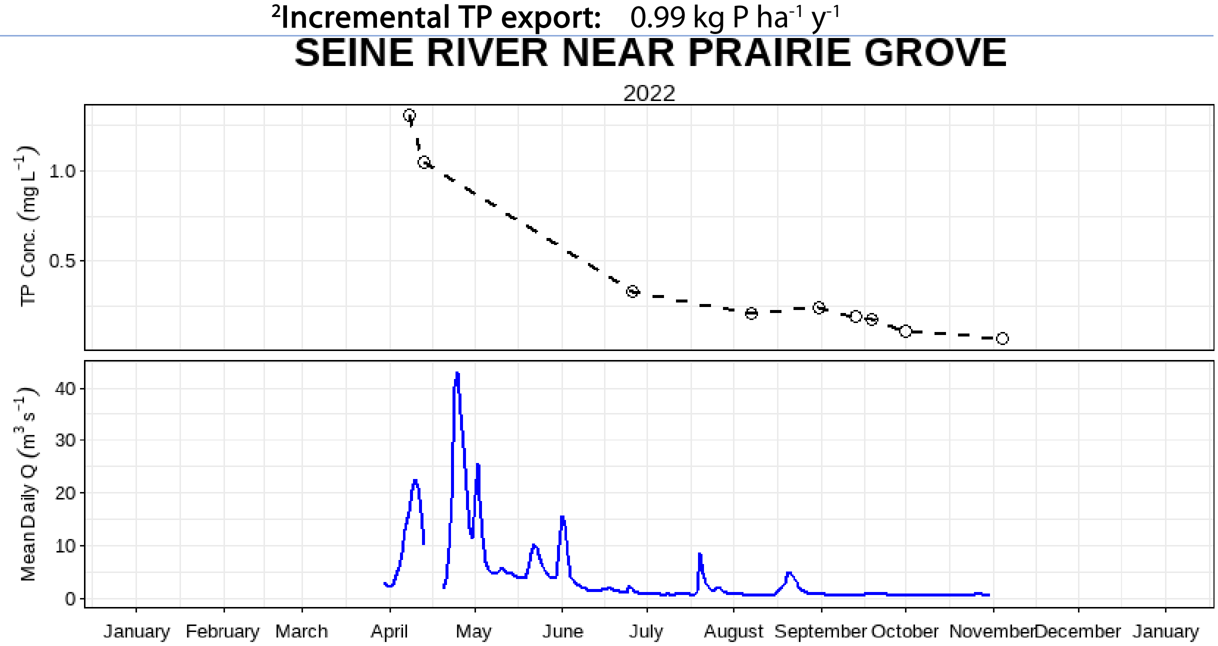


Figure 8: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Seine River near Prairie Grove (05OH009).

[1] Incremental loads are calculated by subtracting gross "Manning Canal near Île-des-Chênes" and "Seine River near Ste. Anne" values from the combined values of gross "Seine River near Prairie Grove" and "Seine River near Île-des-Chênes".

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

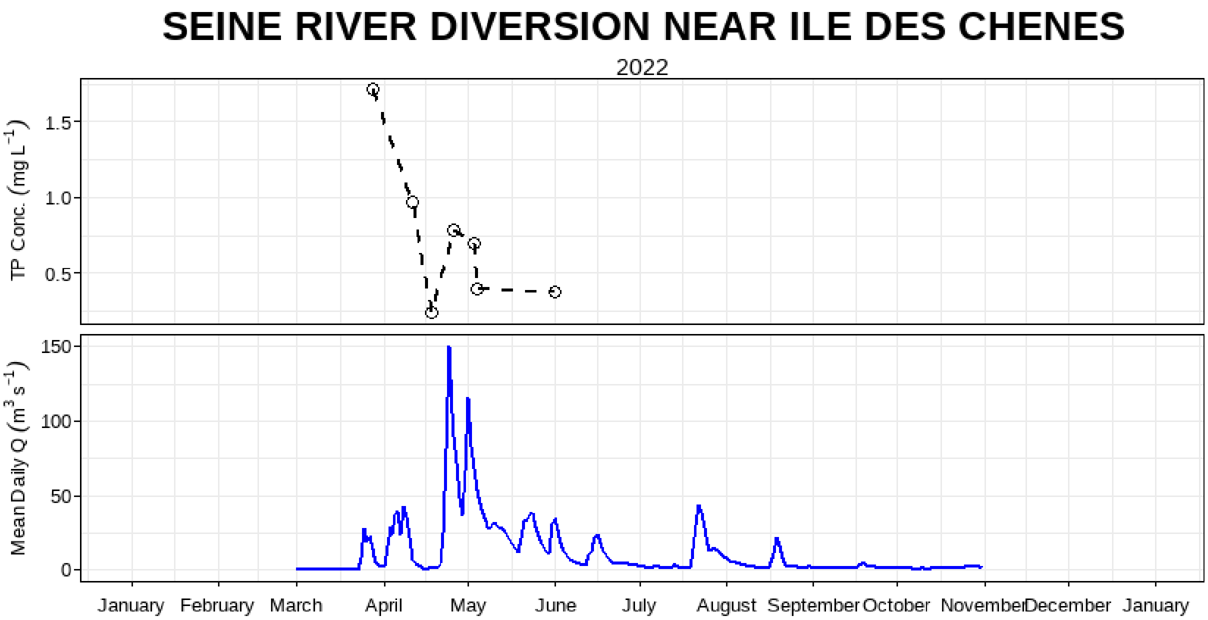


Figure 9: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration ($mg L^{-1}$) over the 2022 sampling season at Seine River Diversion near Île-des-Chênes (05OE011).

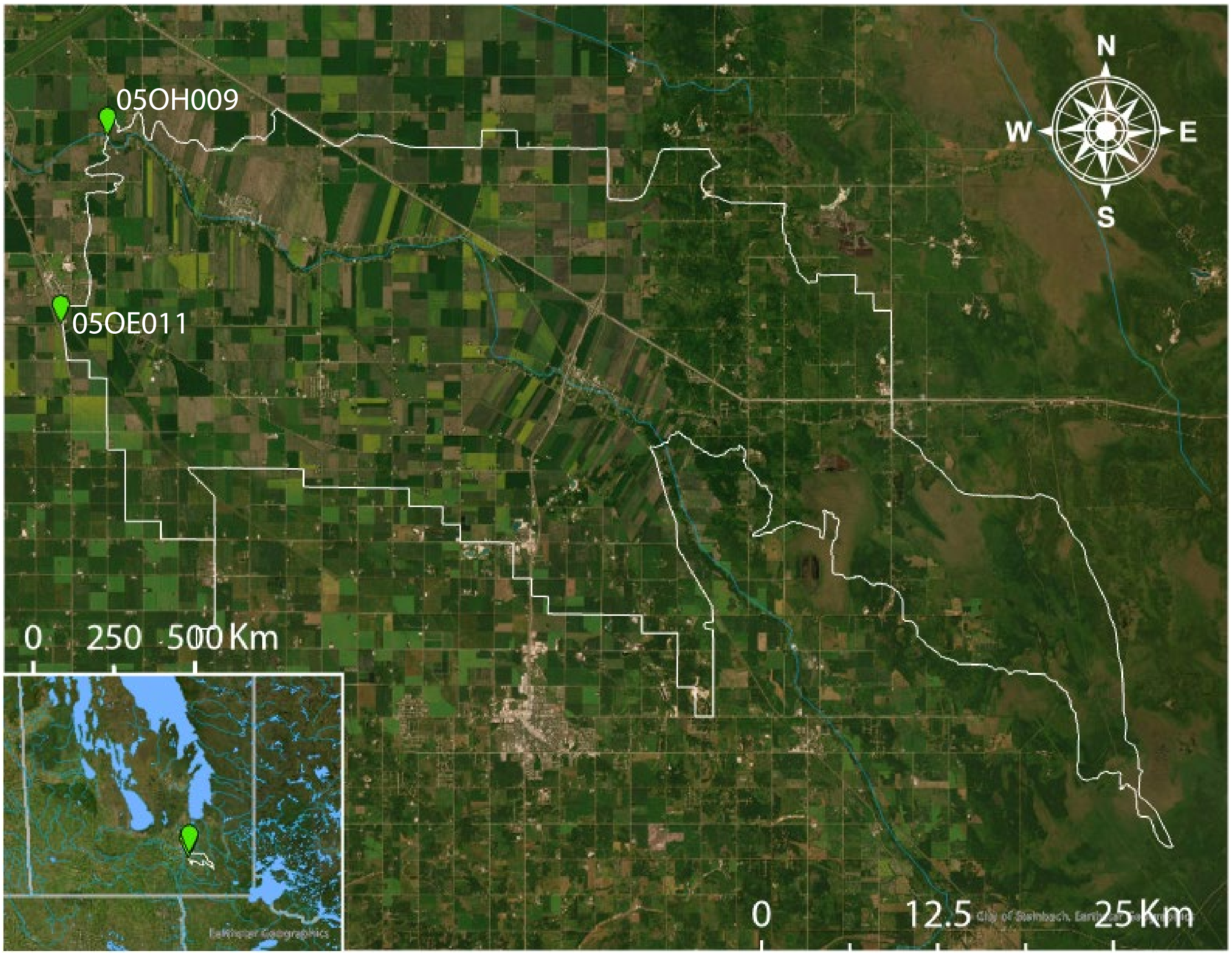


Figure 10: WSC stations 05OE011 & 05OH009 (green) and combined drainage area polygon for each respective station (white - source: 05OE011 [AAFC], 05OH009 [WSC]). LWCBMN samples directly at both WSC stations. See Supplemental Figure 1 for upstream drainage areas used to calculate incremental area.

Pansy Drain near Sarto

The sampling site is located at Water Survey of Canada flow meter 05OE014, near Sarto, MB. Pansy drain flows north into Tourond Creek, before flowing into the Red River south of Saint Adolphe, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 7: Indices of discharge and phosphorus from the gross drainage area of Pansy Drain near Sarto (05OE014) in 2022.

Gross drainage area:	44.31 km^2
Peak discharge:	2.84 $m^3\ s^{-1}$ (2022-05-01)
Peak TP concentration:	1.57 mg/L (2022-04-14)
% of water load in spring:	69.58%
% of TP load in spring:	71.87%
Water load:	0.0053 $km^3\ y^{-1}$
TP load:	4.89 tonnes P y^{-1}
Water export:	119.57 mm y^{-1}
TP export:	1.10 kg P $ha^{-1}\ y^{-1}$

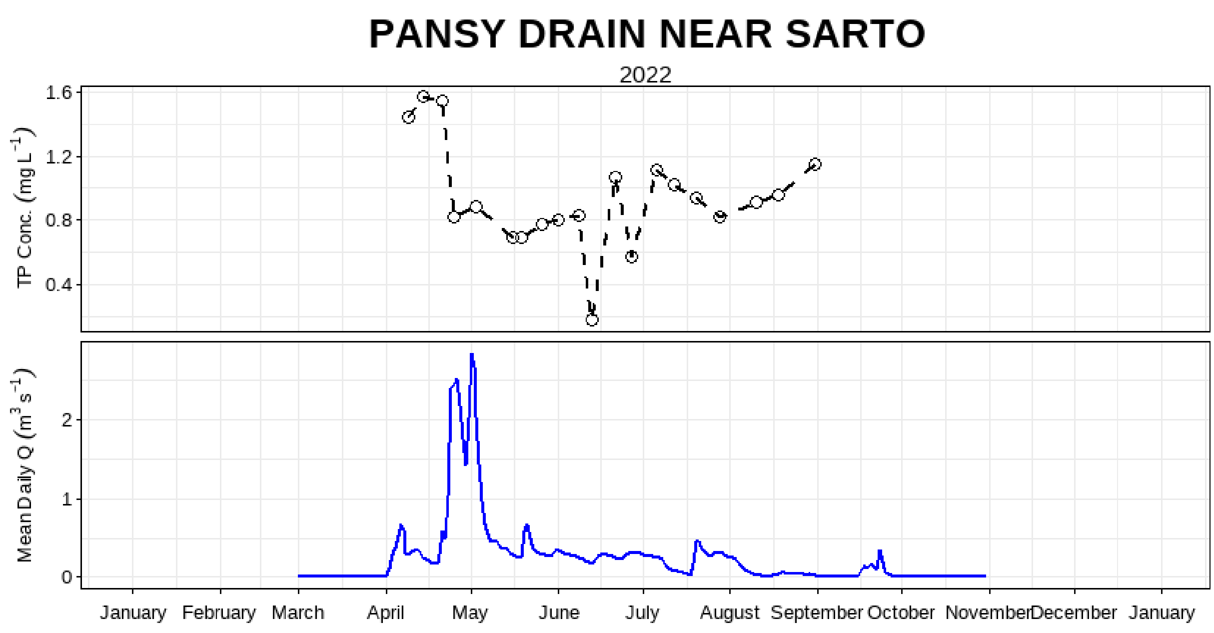


Figure 11: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Pansy Drain near Sarto (05OE014).

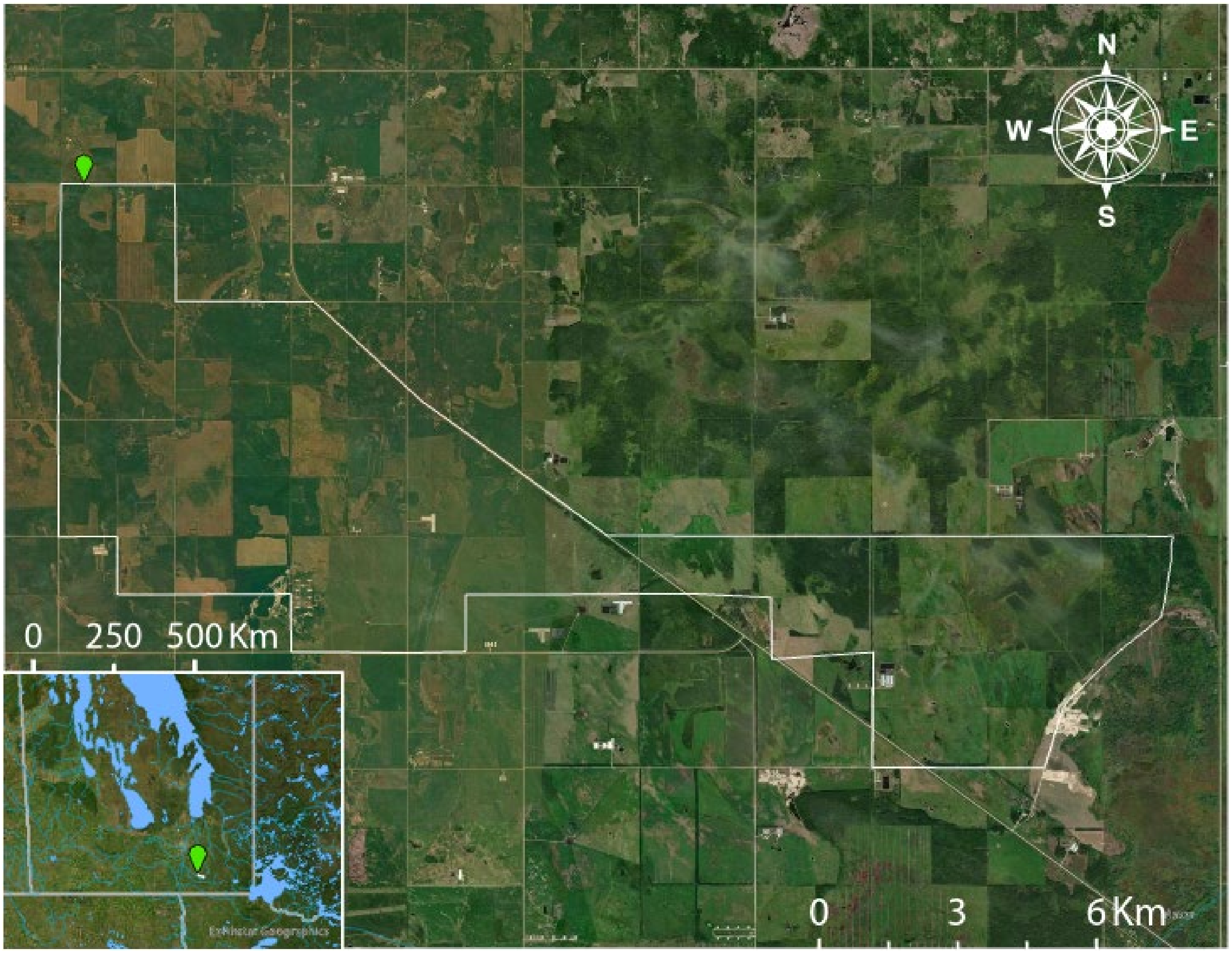


Figure 12: WSC station 05OE014 (green) and drainage area polygon (white – source: AAFC). LWCBMN samples directly at the WSC station.

Tourond Creek near Tourond

Tourond Creek drains a largely agricultural area before flowing into the Red River south of Saint Adolphe, MB. This sampling site is located at Water Survey of Canada flow meter 05OE009, near Tourond, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 8: Indices of discharge and phosphorus from the incremental drainage area of Tourond Creek near Tourond (05OE009) in 2022.

Incremental drainage area:	165.76 km^2
Peak discharge	18.71 $m^3\ s^{-1}$ (2022-04-24)
Peak TP concentration	2.17 mg/L (2022-07-12)
% of water load in spring:	82.34%
% of TP load in spring:	82.46%
[1]Incremental water load:	0.026 $km^3\ y^{-1}$
[1]Incremental TP load:	23.32 tonnes P y^{-1}
[2]Incremental water export:	155.53 mm y^{-1}
[2]Incremental TP export:	1.41 kg P $ha^{-1}\ y^{-1}$

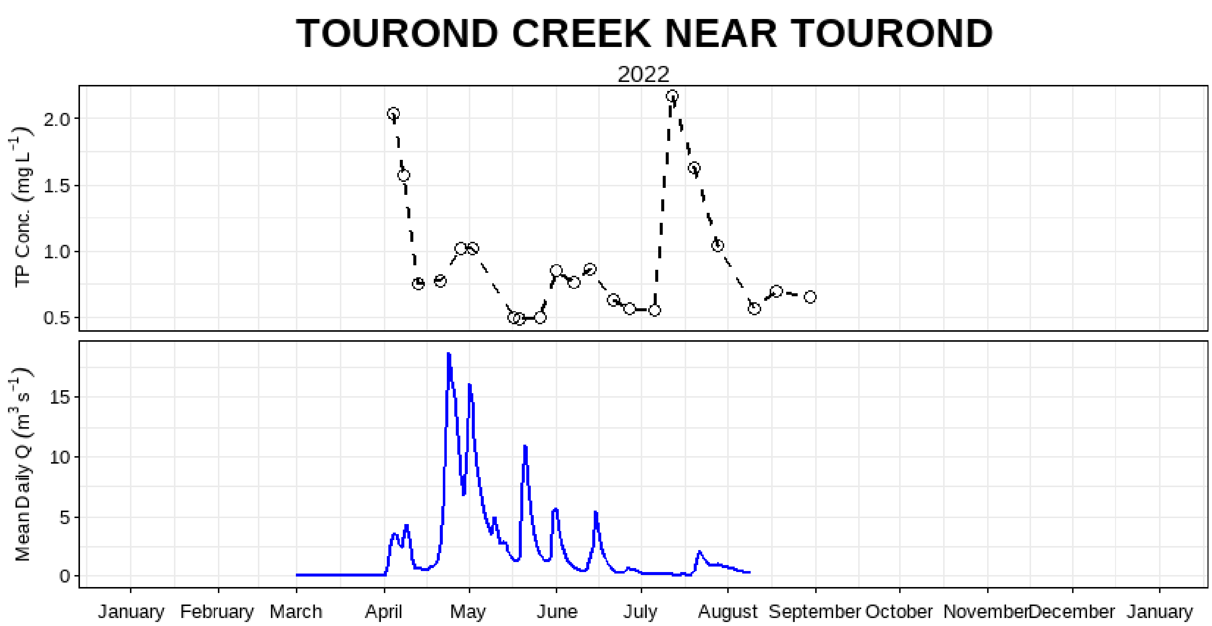


Figure 13: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Tourond Creek near Tourond (05OE009).

[1] Incremental loads are calculated by subtracting gross "Pansy Drain near Sarto" values from gross "Tourond Creek near Tourond" values.
[2] Incremental exports are calculated by dividing incremental loads by incremental drainage areas.

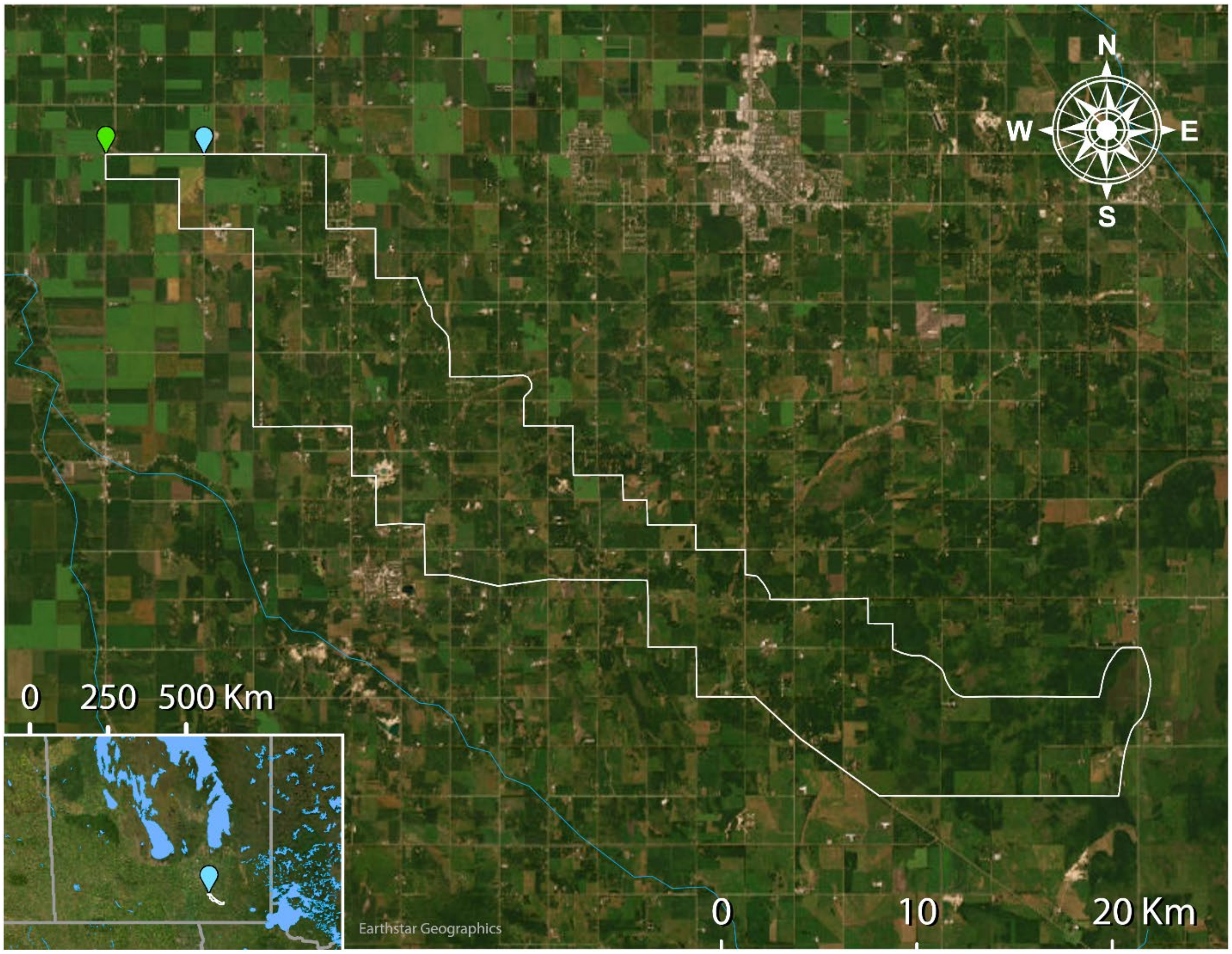


Figure 14: WSC station 05OE009 (green), sampling site (blue), and incremental drainage area polygon (white - source: AAFC). See Supplemental Figure 2 for upstream drainage areas used to calculate incremental area. LWCBMN samples roughly 3 km east of the WSC station as of 2022. Between the WSC station and sampling site, there are no new tributaries or major hydrological changes to the waterway.

Joubert Creek near Pansy

This sampling site is the most upstream sampling site on the Joubert Creek, a tributary of the Rat River. The area that drains into this site consists of pasture and forage crop land. This sampling site is located at Water Survey of Canada flow meter 05OE015, near Pansy, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 9: Indices of discharge and phosphorus from the gross drainage area of Joubert Creek near Pansy (05OE015) in 2022.

Gross drainage area:	208.2 km^2
Peak discharge:	20.21 $m^3\ s^{-1}$ (2022-05-01)
Peak TP concentration:	2.05 mg/L (2022-04-04)
% of water load in spring:	77.76%
% of TP load in spring:	69.75%
Water load:	0.043 $km^3\ y^{-1}$
TP load:	20.57 tonnes P y^{-1}
Water export:	204.16 mm y^{-1}
TP export:	0.99 kg P $ha^{-1}\ y^{-1}$

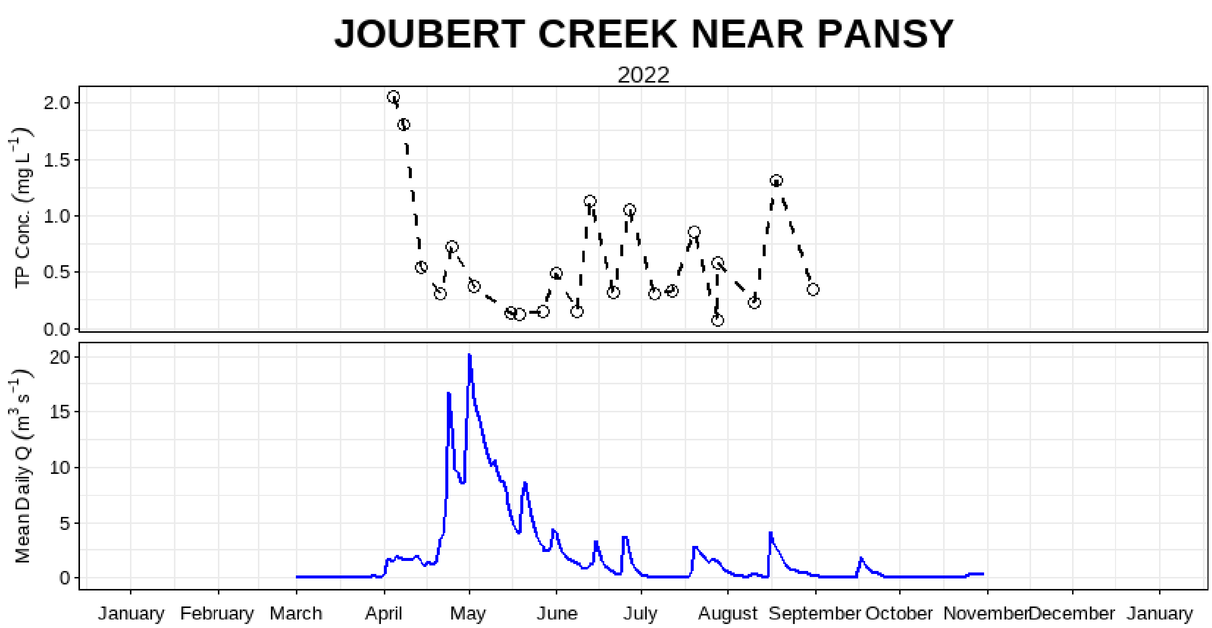


Figure 15: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Joubert Creek near Pansy (05OE015).

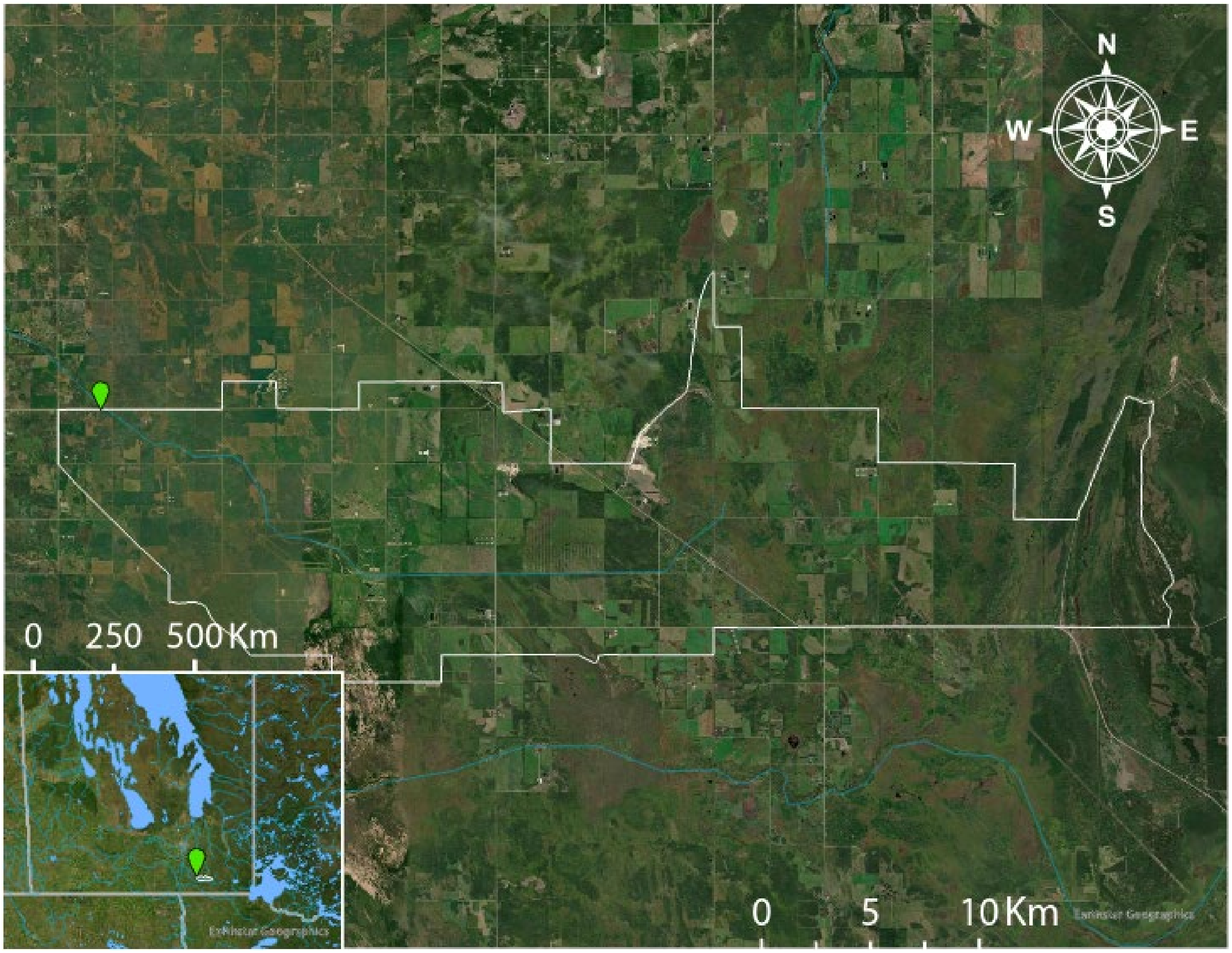


Figure 16: WSC station 05OE015 (green), and drainage area polygon (source: AAFC). LWCBMN samples directly at the WSC station.

Joubert Creek at St-Pierre-Jolys

This sampling site is located just before Joubert Creek flows into the Rat River. The incremental area that drains into this sample site is primarily pasture and forage cropland, as well as a portion of the community of St-Pierre-Jolys, MB. This sampling site is located at Water Survey of Canada flow meter 05OE007, near St-Pierre-Jolys. 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 Joubert Creek near St-Pierre-Jolys (05OE007). See Supplemental Table 3 for gross calculations.

Incremental drainage area:	140.08 km^2
Peak discharge	30.35 $m^3\ s^{-1}$ (2022-05-02)
Peak TP concentration	1.87 mg/L (2022-03-26)
% of water load in spring:	78.75%
% of TP load in spring:	79.85%
[1]Incremental water load:	0.033 $km^3\ y^{-1}$
[1]Incremental TP load:	38.37 tonnes P y^{-1}
[2]Incremental water export:	233.11 mm y^{-1}
[2]Incremental TP export:	2.74 kg P $ha^{-1}\ y^{-1}$

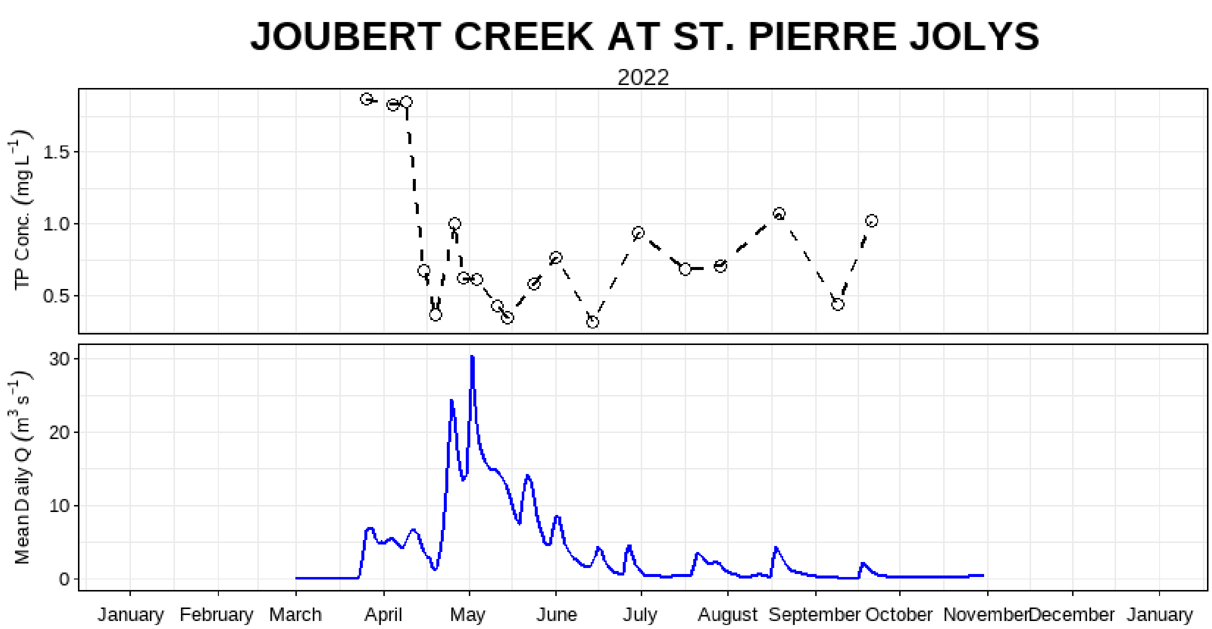


Figure 17: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Joubert Creek near St-Pierre-Jolys (05OE007).

[1] Incremental loads are calculated by subtracting gross "Joubert Creek near Pansy" values from gross "Joubert Creek near St-Pierre-Jolys" values.

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

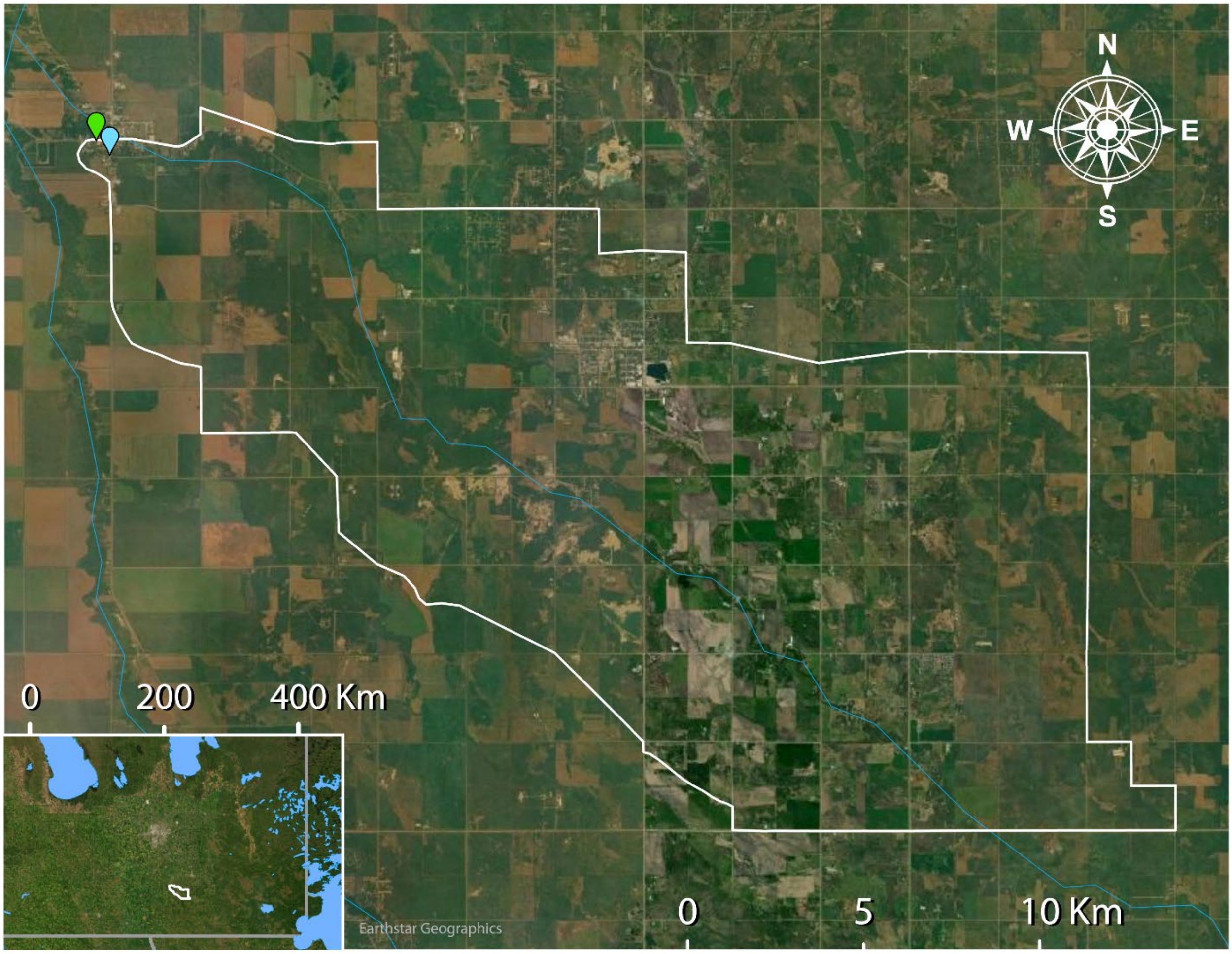


Figure 18: WSC station 05OE007 (green), sampling site (blue) and incremental drainage area polygon (white - source: WSC). See Supplemental Figure 3 for upstream drainage areas used to calculate incremental area. LWCBMN samples ~350m upstream of the WSC station. Between the WSC station and sampling site, there are no new tributaries or major hydrological changes to the waterway.

Rat River near Sundown

This sampling site is the most upstream sampling site on the Rat River. The area that drains into this site drains a largely forested area with some pasture land. This sampling site is located at Water Survey of Canada flow meter 05OE004, near Sundown, 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 Rat River near Sundown (05OE004) in 2022.

Gross drainage area:	423 km^2
Peak discharge:	26.83 $m^3\ s^{-1}$ (2022-05-02)
Peak TP concentration:	0.072 mg/L (2022-04-10)
% of water load in spring:	77.46%
% of TP load in spring:	78.11%
Water load:	0.060 $km^3\ y^{-1}$
TP load:	2.38 tonnes P y^{-1}
Water export:	140.80 mm y^{-1}
TP export:	0.056 kg P $ha^{-1}\ y^{-1}$

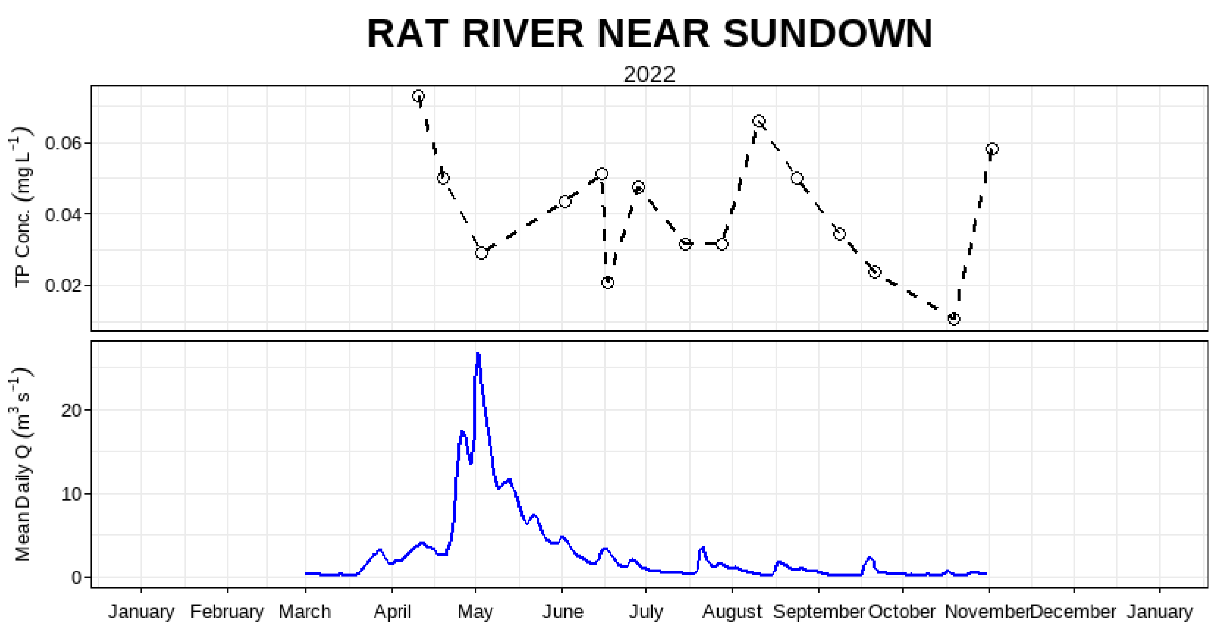


Figure 19: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Rat River near Sundown (05OE004).

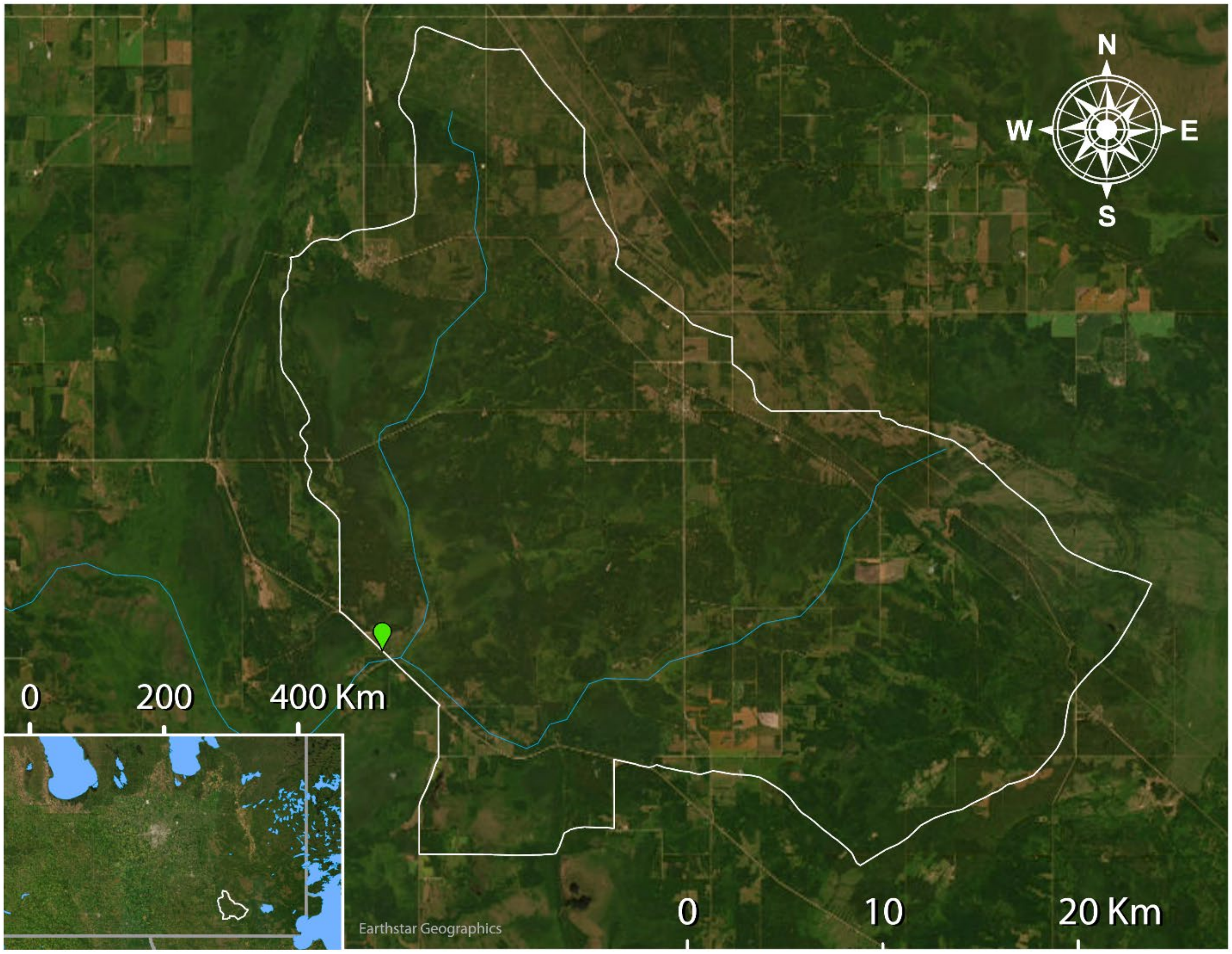


Figure 20: WSC station 05OE004 (green) and drainage area polygon (white - source: AAFC). LWCBMN samples directly at the WSC station.

Rat River near St-Pierre-Jolys

This sampling site is located near Water Survey of Canada station 05OE001, just upstream from where Joubert Creek flows into the Rat River. This drainage area contains the community of St-Pierre-Jolys, MB. Discharge was estimated by subtracting Joubert Creek near St-Pierre-Jolys discharge (05OE007) from Rat River near Otterburne (05OE001). The sampling effort provided excellent coverage to calculate TP loads and exports. However, it should be noted that there is a gap in the real-time flow data in late spring. This is likely due to the extensive flooding which occurred in 2022. As a result, TP loads and exports may be underestimations.

Table 12: Indices of discharge and phosphorus from the incremental drainage area of Rat River near St-Pierre-Jolys (05OE001-05OE007). See Supplemental Table 4 for gross calculations.

Incremental drainage area:	651.92 km^2
Peak discharge:	45.66 $m^3 s^{-1}$ (2022-04-26)
Peak TP concentration:	0.59 mg/L (2022-04-23)
% of water load in spring:	47.07%
% of TP load in spring:	65.08%
[1]Incremental water load:	0.090 $km^3 y^{-1}$
[1]Incremental TP load:	28.48 tonnes P y^{-1}
[2]Incremental water export:	138.74 mm y^{-1}
[2]Incremental TP export:	0.44 kg P $ha^{-1} y^{-1}$

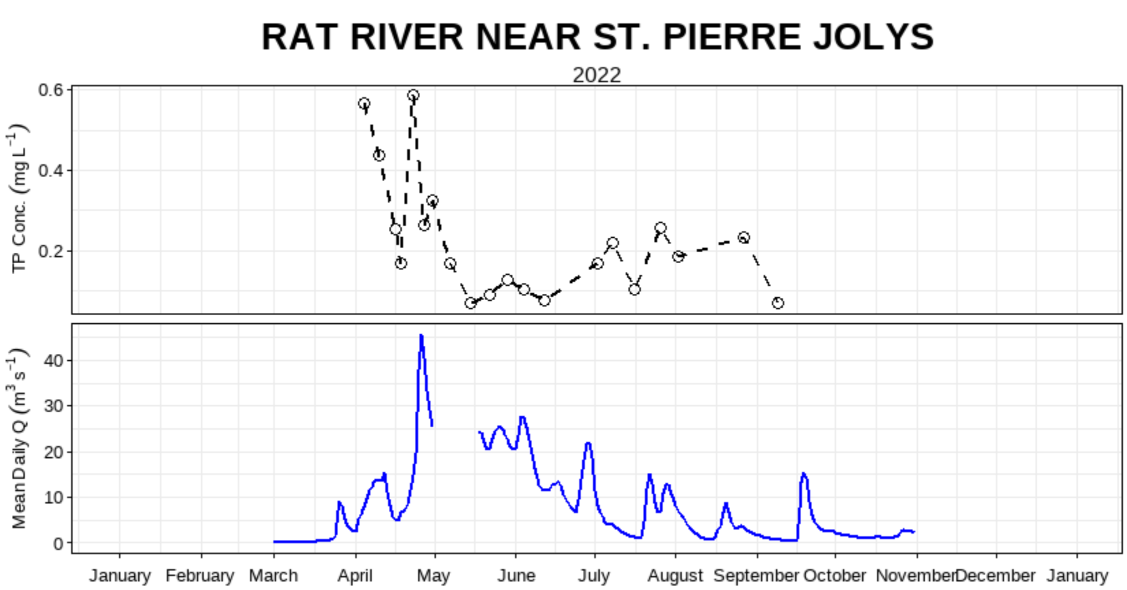


Figure 21: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Rat River near St-Pierre-Jolys (estimated by calculating the flow at WSC station 05OE001 – 05OE007).

[1] Incremental loads are calculated by subtracting gross "Rat River near Sundown" values from gross "Rat River near St-Pierre-Jolys" values.

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

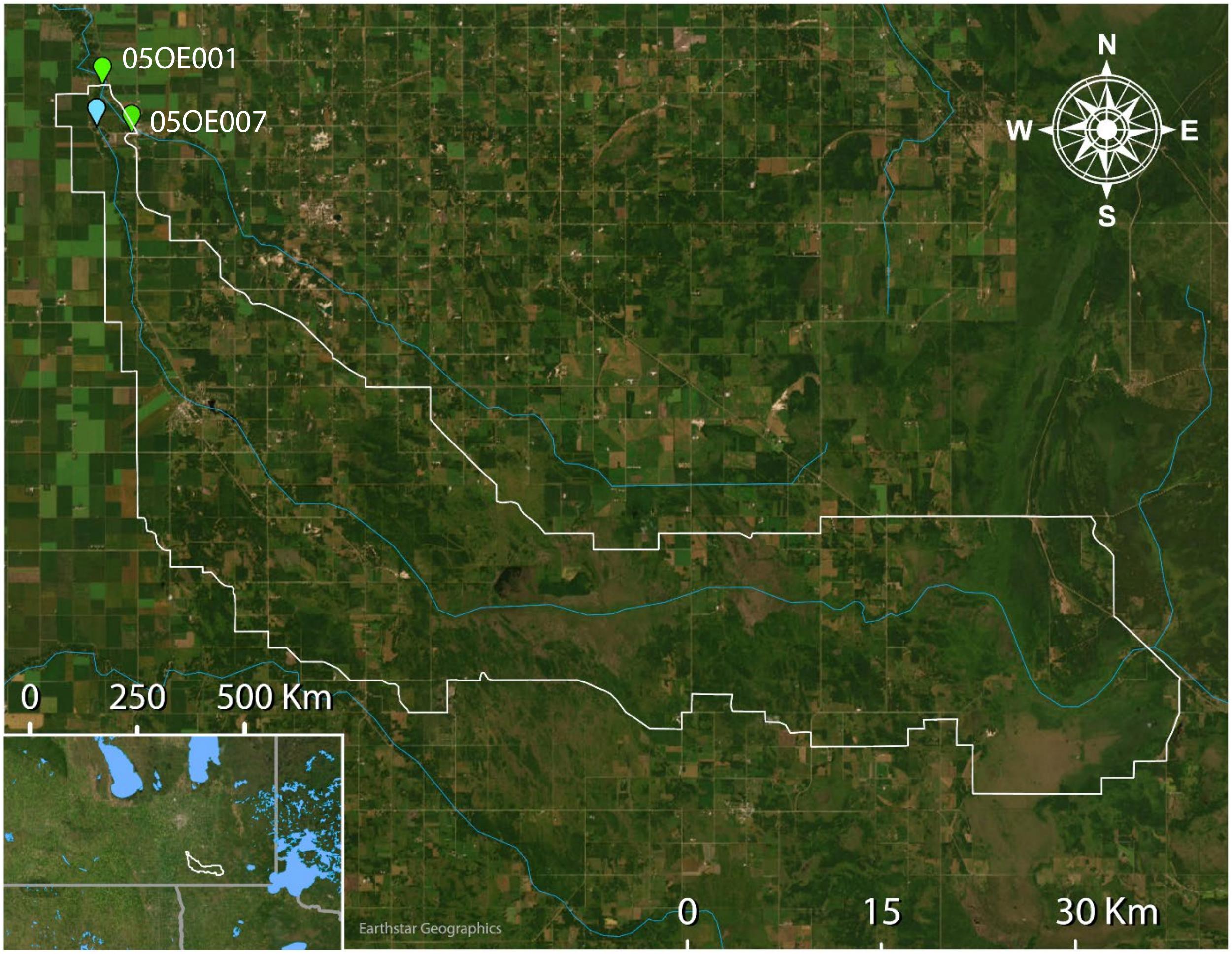


Figure 22: WSC stations 05OE001 & 05OE007 (green), sampling site (blue), and subtracted incremental drainage area polygon (source: AAFC). Since LWCBMN samples ~2 km upstream of 05OE001 (before Joubert Creek connects to Rat River), the area upstream of 05OE007 is subtracted from 05OE001 to estimate flow at the sampling site. See Supplemental Figure 4 for upstream drainage areas used to calculate incremental area

Marsh River near Otterburne

The Marsh River sampling site drains an area consisting mainly of agricultural land. This sampling site is located directly upstream of where the Marsh River flows into the Rat River. The sampling site is located at Water Survey of Canada flow meter 05OE010, near Otterburne, MB. The sampling effort provided excellent coverage to calculate TP loads and exports. However, it should be noted that there is a gap in the real-time flow data in late spring. This is likely due to the extensive flooding which occurred in 2022. As a result, TP loads and exports may be underestimations.

Table 13: Indices of discharge and phosphorus from the gross drainage area of Marsh River near Otterburne (05OE010) in 2022.

Gross drainage area:	399.6 km^2
Peak discharge:	49.79 $m^3\ s^{-1}$ (2022-04-24)
Peak TP concentration:	1.12 mg/L (2022-07-12)
% of water load in spring:	76.57%
% of TP load in spring:	75.29%
Water load:	0.044 $km^3\ y^{-1}$
TP load:	31.58 tonnes P y^{-1}
Water export:	111.12 mm y^{-1}
TP export:	0.79 kg P $ha^{-1}\ y^{-1}$

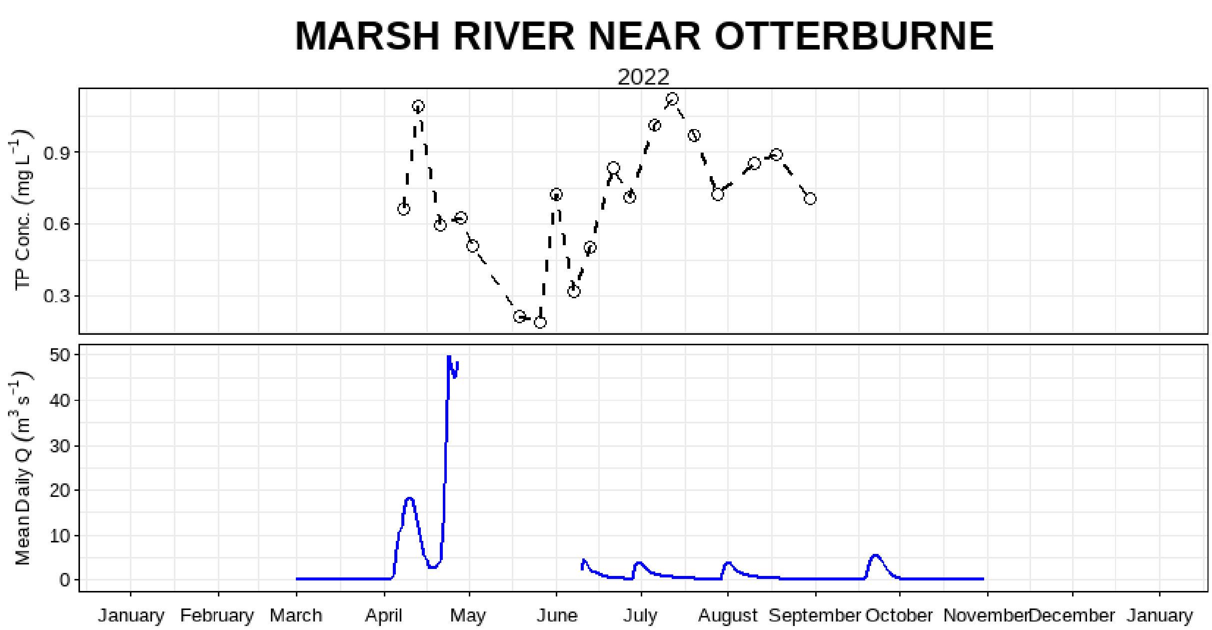


Figure 23: Mean daily discharge ($m^3\ s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Marsh River near Otterburne (05OE010).

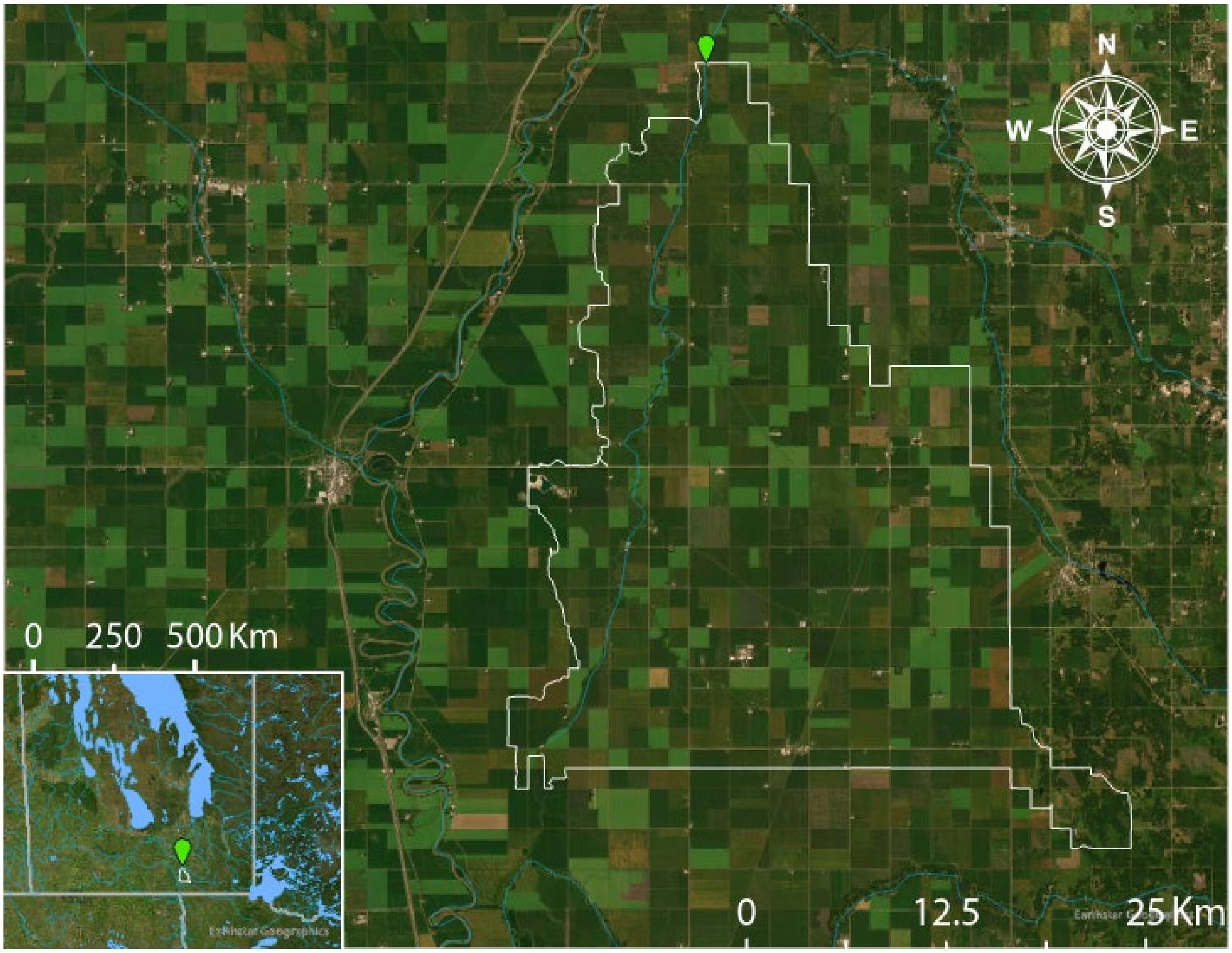


Figure 24: WSC station 05OE010 (green) and drainage area polygon (white – source: AAFC). LWCBMN samples directly at the WSC station.

Roseau River at Gardenton

This sampling site is the most upstream sampling site on the Roseau River. The majority of this drainage area is located in Minnesota and Ontario. This drainage area is not densely populated and is largely forested. This sampling site is located at Water Survey of Canada flow meter 05OD004, near Gardenton, 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 Roseau River at Gardenton (05OD004) in 2022.

Gross drainage area:	3992 km^2
Peak discharge:	94.15 $m^3 s^{-1}$ (2022-05-31)
Peak TP concentration:	0.27 mg/L (2022-04-08)
% of water load in spring:	56.57%
% of TP load in spring:	42.62%
Water load:	0.63 $km^3 y^{-1}$
TP load:	88.59 tonnes P y^{-1}
Water export:	158.78 mm y^{-1}
TP export:	0.22 kg P $ha^{-1} y^{-1}$

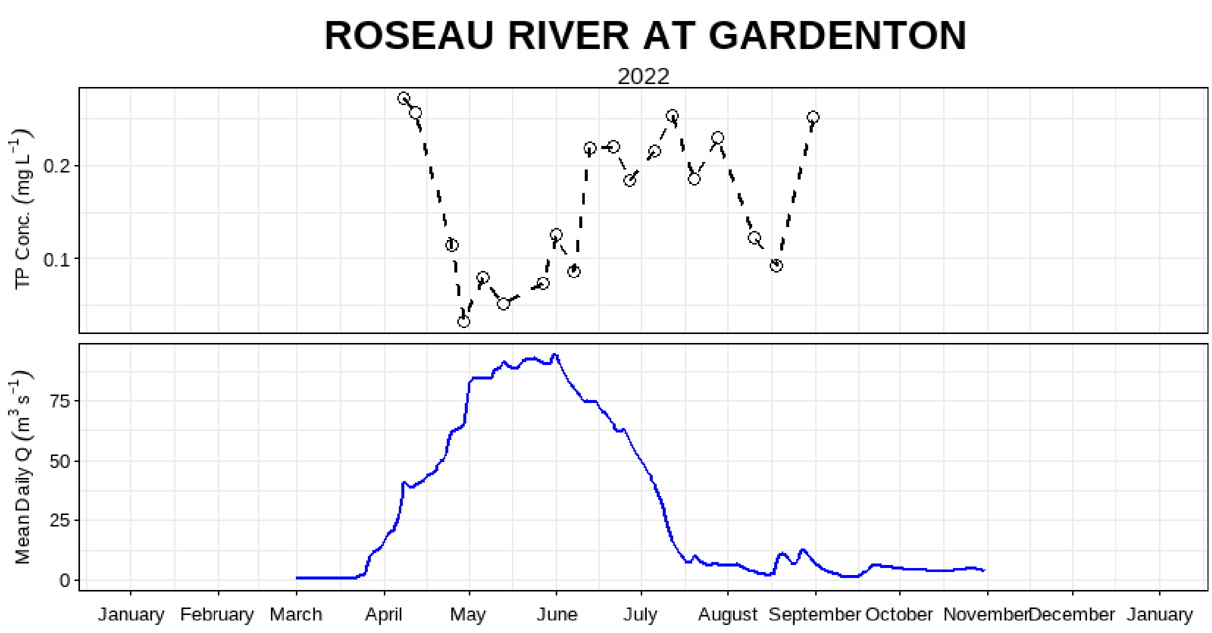


Figure 25: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Roseau River near Gardenton (05OD004).

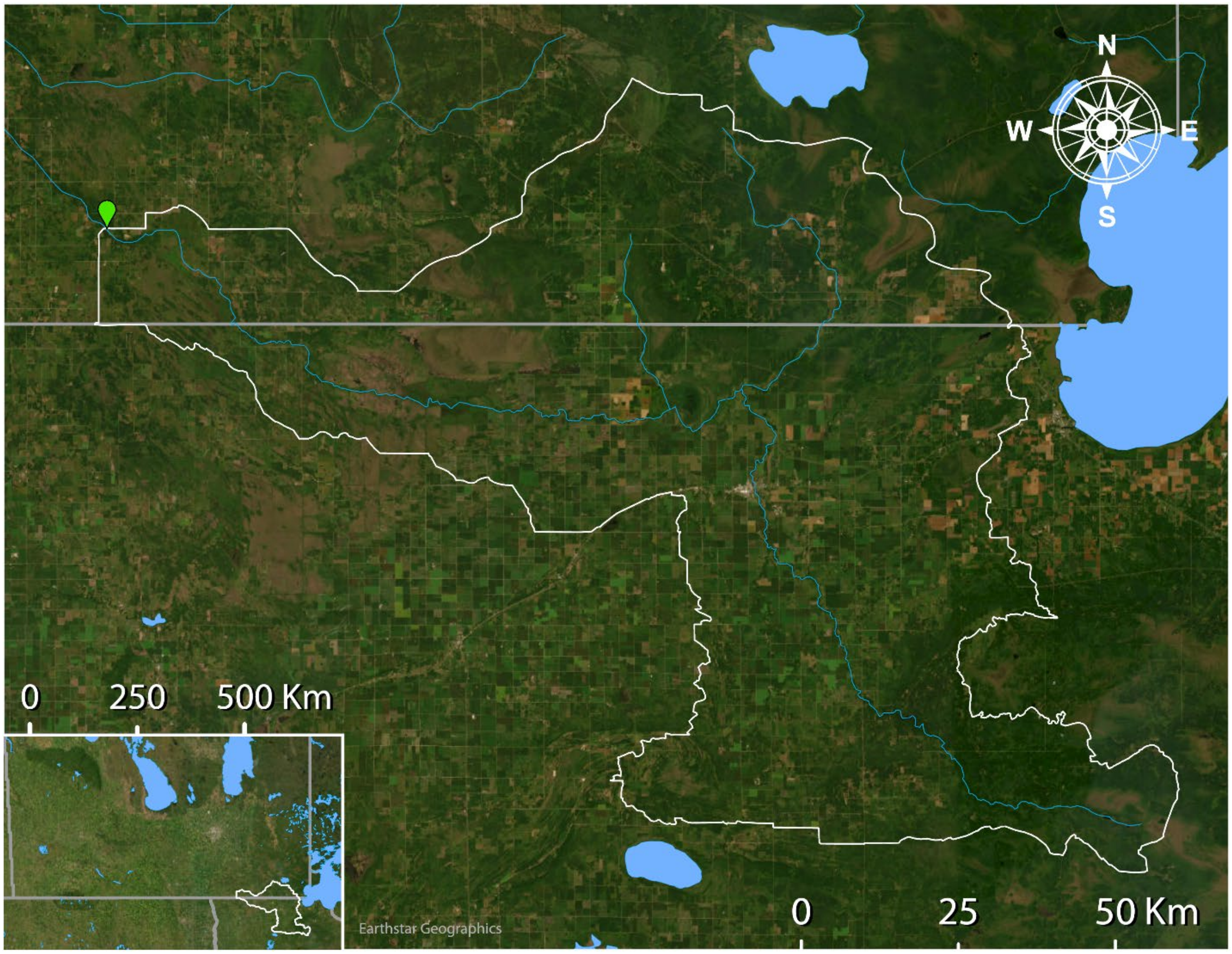


Figure 26: WSC station 05OD004 (green) and drainage area polygon (white – source: AAFC). LWCBMN samples directly at the WSC station.

Vita Drain near Stuartburn

This sampling site is located directly upstream from where the Vita Drain flows into the Roseau River. The gross drainage area drains largely forested land, with some agriculture and the community of Vita, MB. This sampling site is located at Water Survey of Canada flow meter 05OD034, near Stuartburn, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 15: Indices of discharge and phosphorus from the gross drainage area of Vita Drain near Stuartburn (05OD034) in 2022.

Gross drainage area:	438.29 km^2
Peak discharge:	17.87 m^3 s^{-1} (2022-04-24)
Peak TP concentration:	0.22 mg/L (2022-04-08)
% of water load in spring:	72.54%
% of TP load in spring:	78.53%
Water load:	0.044 km^3 y^{-1}
TP load:	3.07 tonnes P y^{-1}
Water export:	100.10 mm y^{-1}
TP export:	0.070 kg P ha^{-1} y^{-1}

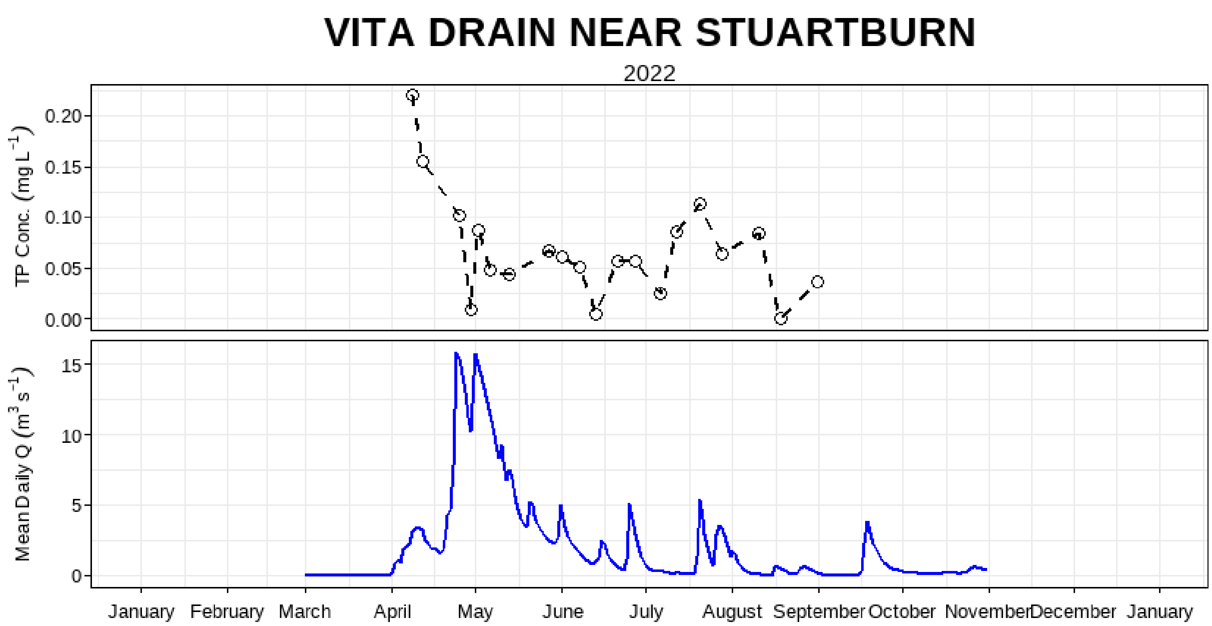


Figure 27: Mean daily discharge (m^3 s^{-1}) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Vita Drain near Stuartburn (05OD034).

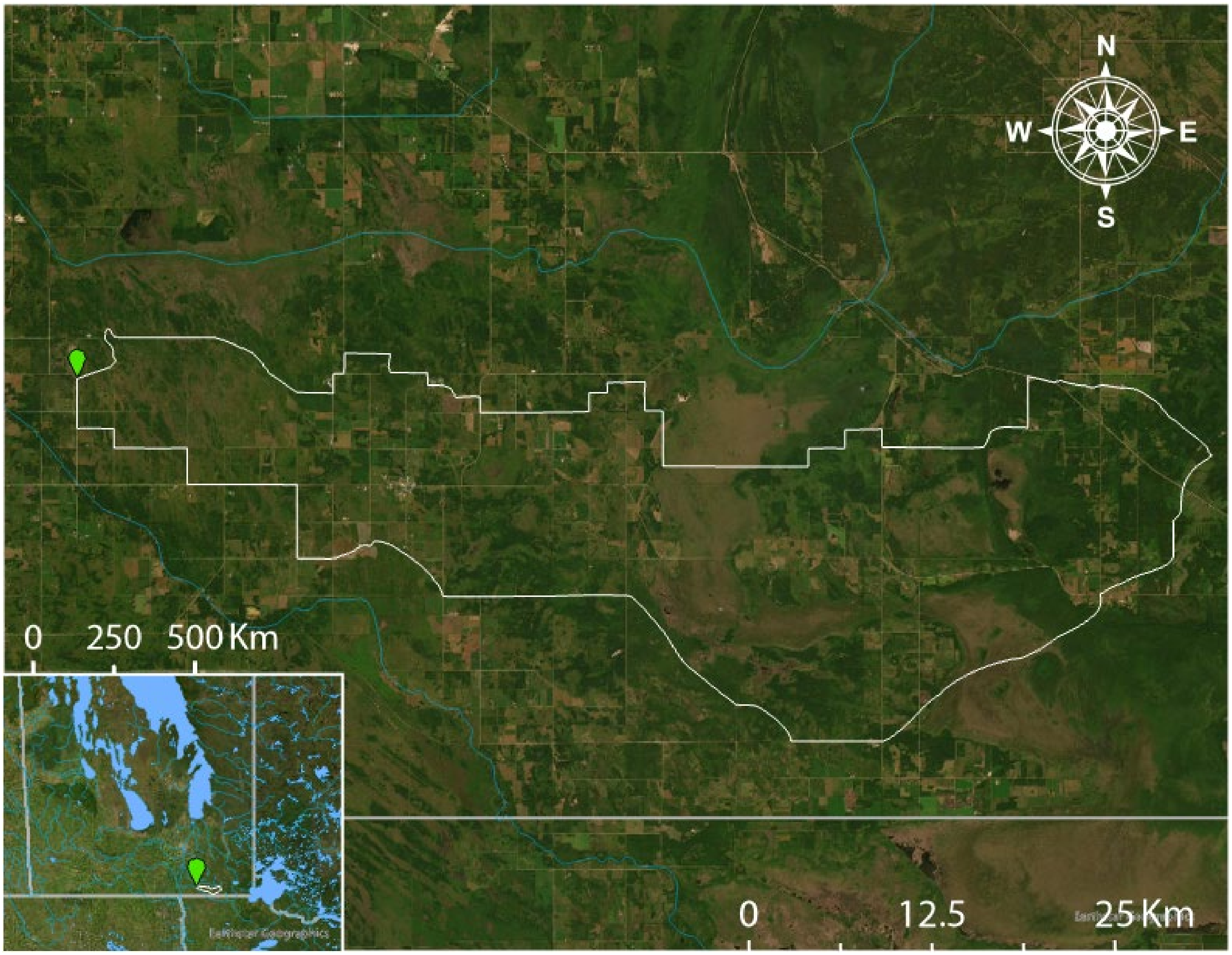


Figure 28: WSC station 05OD034 (green) and drainage area polygon (white – source: AAFC). LWCBMN samples directly at the WSC station.

Roseau River near Dominion City

This downstream stretch of the Roseau River drains a largely forested incremental drainage area and the community of Stuartburn, MB. This sampling site is located at Water Survey of Canada flow meter 05OD001, near Dominion City, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 16: Indices of discharge and phosphorus from the incremental drainage area of Roseau River near Dominion City (05OD001). See Supplemental Table 5 for gross calculations.

Incremental drainage area:	177.29 km^2
Peak discharge:	118.73 $m^3 s^{-1}$ (2022-06-01)
Peak TP concentration:	0.40 mg/L (2022-04-08)
% of water load in spring:	57.03%
% of TP load in spring:	57.89%
[1]Incremental water load:	0.066 $km^3 y^{-1}$
[1]Incremental TP load:	13.13 tonnes P y^{-1}
[2]Incremental water export:	372.59 mm y^{-1}
[2]Incremental TP export:	0.74 kg P $ha^{-1} y^{-1}$

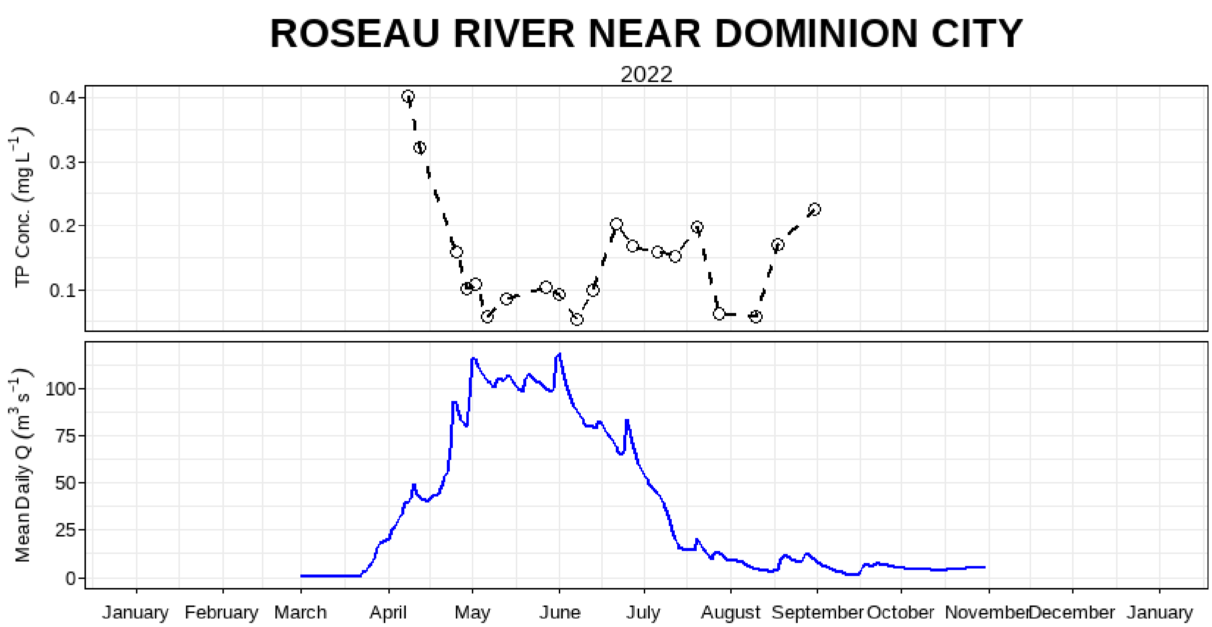


Figure 29: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Roseau River near Dominion City (05OD001).

[1] Incremental loads are calculated by subtracting gross "Roseau River at Gardenton" and "Vita Drain near Stuartburn" values from gross "Roseau River near Dominion City" values.

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

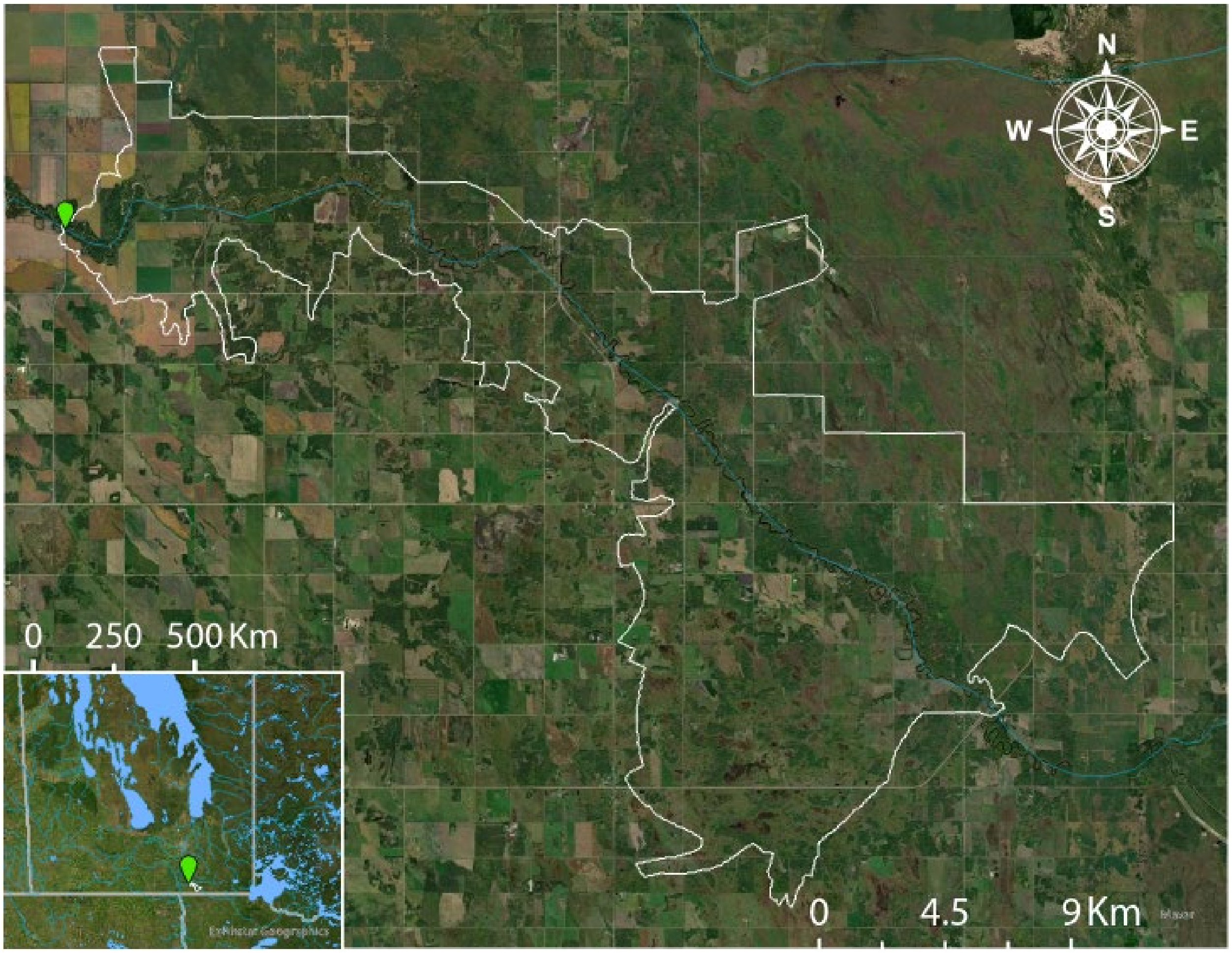


Figure 30: WSC station 05OD001 (green) and drainage area polygon (white - source: WSC & AAFC, combined[1]). LWCBMN samples directly at the WSC station. See Supplemental Figure 5 for upstream drainage areas used to calculate incremental area.

[1] This polygon is an amalgamation of the WSC and AAFC polygon. This is necessary as the AAFC part (the right side) matches up cleanly with the upstream sites. Due to the AAFC polygon far overextending from where the WSC station is, for accuracy's sake it was necessary to use the WSC polygon for the left side of this polygon.

Main Drain near Dominion City

The majority of this drainage area is located in Manitoba, with a small portion extending into the United States. This sampling site drains a more densely agricultural area than the other sampling sites in the Roseau River watershed. This sampling site is located at Water Survey of Canada flow meter 05OD028, near Dominion City, MB. The sampling effort provided excellent coverage to calculate TP loads and exports. However, it should be noted that there is a gap in the real-time flow data in late spring. This is likely due to the extensive flooding which occurred in 2022. As a result, TP loads and exports may be underestimations.

Table 17: Indices of discharge and phosphorus from the gross drainage area of Main Drain near Dominion City (05OD028) in 2022.

Gross drainage area:	203.47 km^2
Peak discharge:	36.54 $m^3 s^{-1}$ (2022-04-24)
Peak TP concentration:	1.26 mg/L (2022-07-20)
% of water load in spring:	86.48%
% of TP load in spring:	86.21%
Water load:	0.036 $km^3 y^{-1}$
TP load:	32.49 tonnes P y^{-1}
Water export:	177.53 mm y^{-1}
TP export:	1.60 kg P $ha^{-1} y^{-1}$

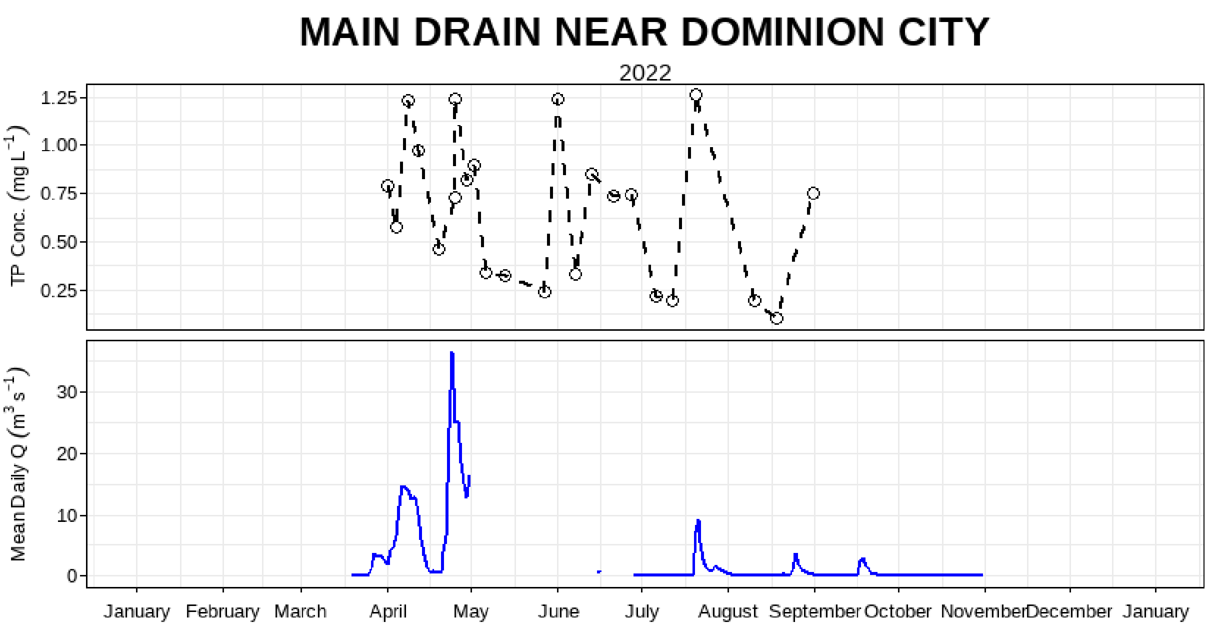


Figure 31: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2022 sampling season at Main Drain near Dominion City (05OD028).

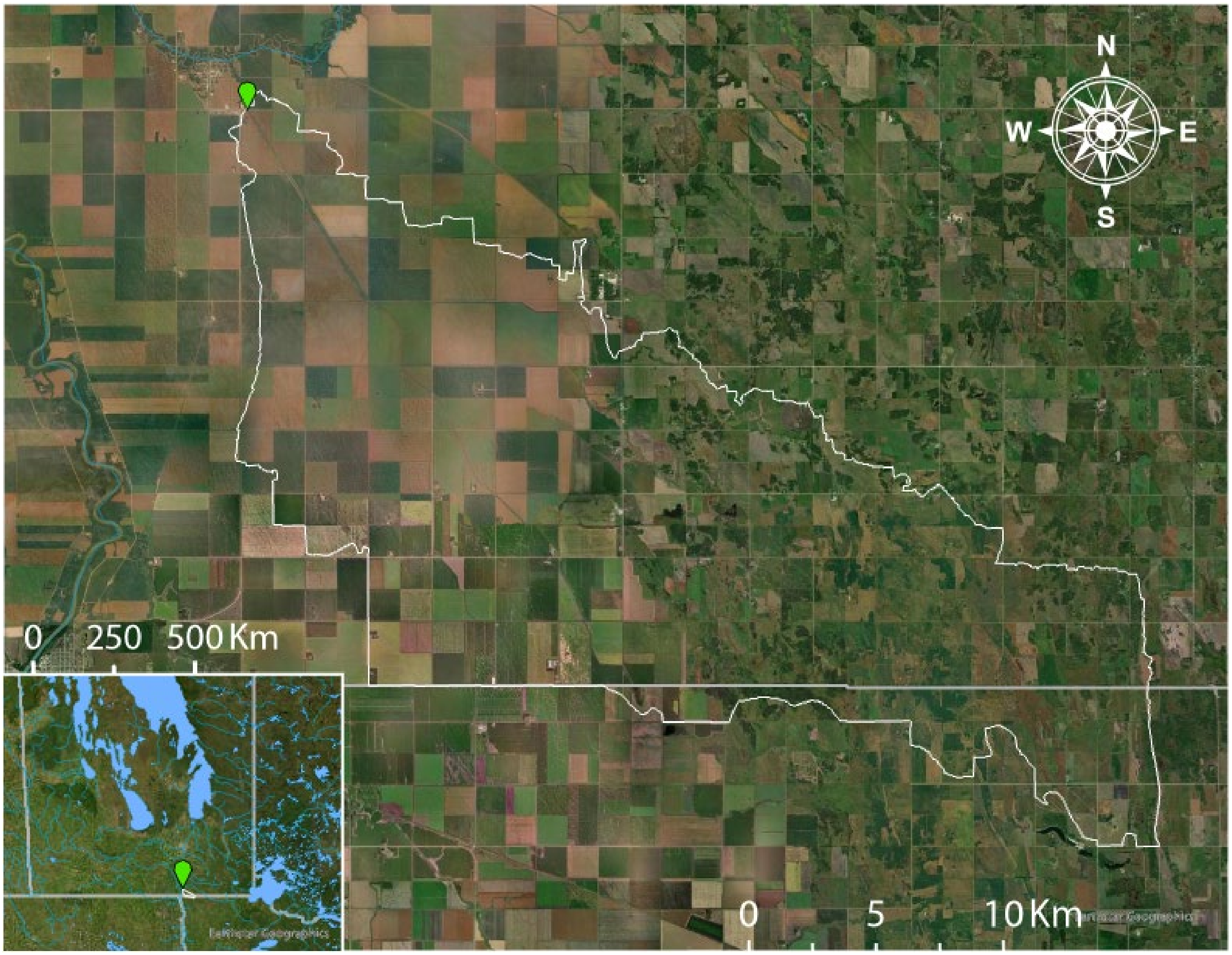


Figure 32: WSC station 05OD028 (green) and drainage area polygon (white – source: WSC). LWCBMN samples directly at the WSC station.

City of Steinbach sampling sites

Located in the Manning Canal drainage area, Steinbach, MB, the third largest city in Manitoba, is home to 15,829 residents (Statistics Canada, 2016 Census). Urban areas like Steinbach can contribute to phosphorus loads through urban runoff, as impervious surfaces such as roads, parking lots and sidewalks do not retain water, and wastewater effluent.

Volunteers collected samples at two sites upstream and two sites downstream of Steinbach. Upstream 2 and Downstream 2 are on the mainstem that receives water from Steinbach and its wastewater lagoons. Upstream 1 and Downstream 1 are on a tributary to the mainstem that flows directly through the city and into the mainstem. The Downstream 1 sampling site is located slightly downstream from the city proper, while Downstream 2 is located downstream of Steinbach's wastewater lagoons, enabling wastewater contributions to be assessed.

Based on the data currently available, it is not possible to determine how much Steinbach is contributing to the phosphorus load of the Manning Canal drainage area due to the lack of discharge data for these three sites. In other words, we cannot calculate phosphorus loads and exports because flow is not measured. In 2019, LWCBMN installed water level meters at all four sampling sites, the first step towards enabling us to calculate phosphorus loads and exports. In 2020, LWCBMN will begin collecting flow data at these sites to establish a discharge curve, based on the relationship between flow and water level. Once the curve is established, we can use water level data to retroactively calculate the flow at these sites for 2019.

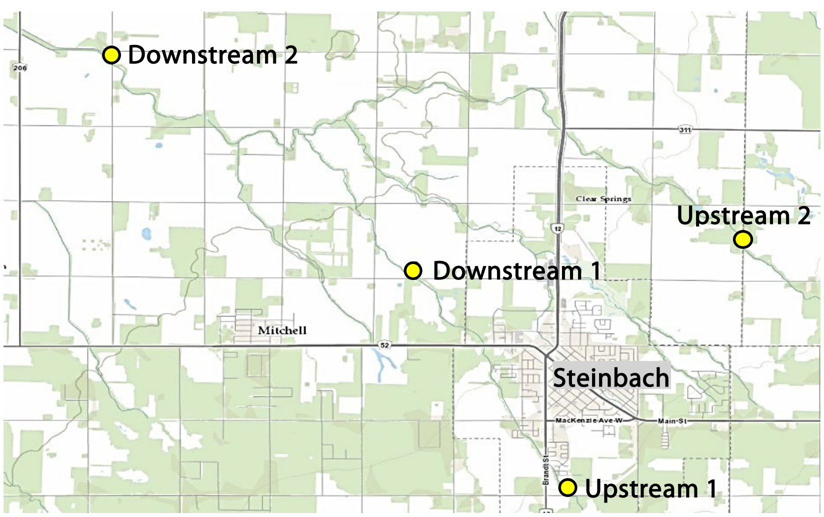


Figure 33: Map of sampling sites upstream and downstream of the City of Steinbach.

Steinbach - Downstream 2

This sampling site is located in the Manning Canal watershed. It is the most downstream of the Steinbach sites, and receives water from Steinbach and the Steinbach wastewater lagoons.

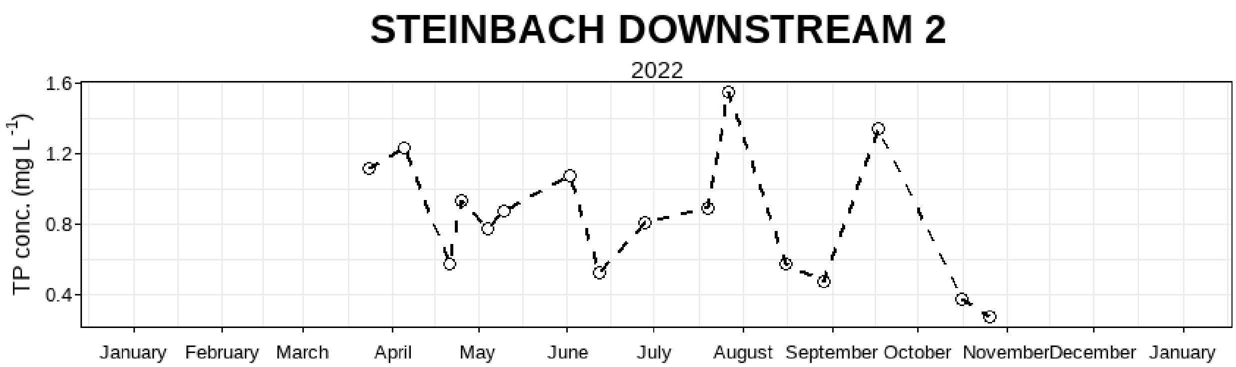


Figure 34: Total phosphorus concentration at Steinbach Downstream 2 in 2022.

Steinbach – Upstream 2

This sampling site is located in the Manning Canal watershed, situated upstream of the Steinbach wastewater lagoons and the Steinbach Downstream 2 sampling site.

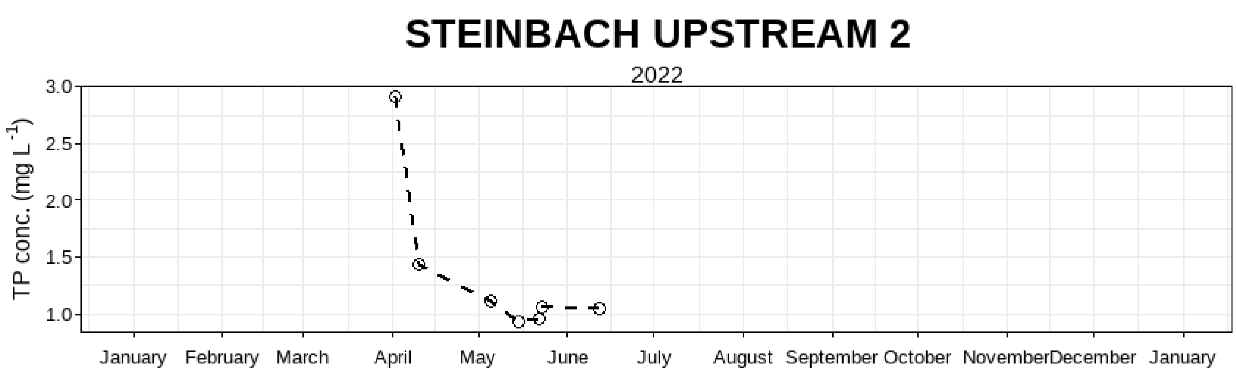


Figure 35: Total phosphorus concentrations and water level over the 2019 sampling season Steinbach Upstream 2.

Steinbach – Mainstem

This sampling site is located in the Manning Canal watershed, directly downstream of Steinbach. This sampling site is situated on a tributary that flows through the city.

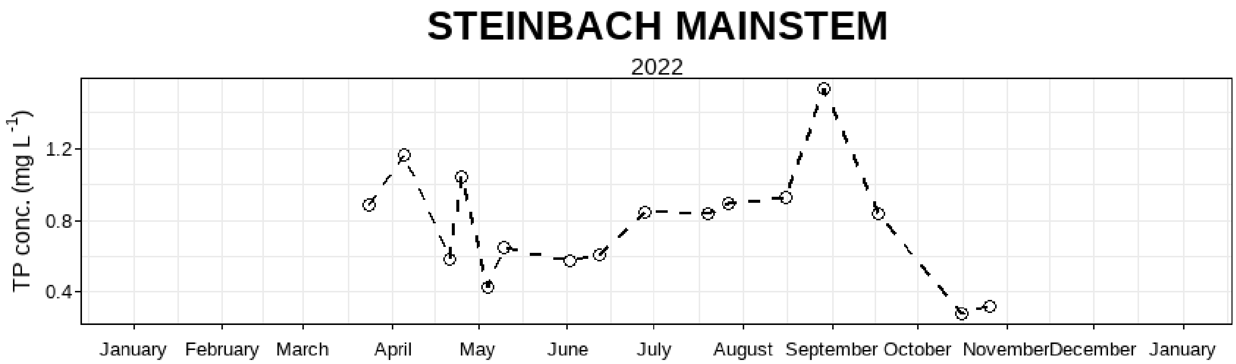


Figure 36: Total phosphorus concentrations and water level at Steinbach Mainstem

Steinbach – Mainstem Upstream

This sampling site is located in the Manning Canal watershed, directly upstream of Steinbach. It is situated on a tributary that flows through the city.

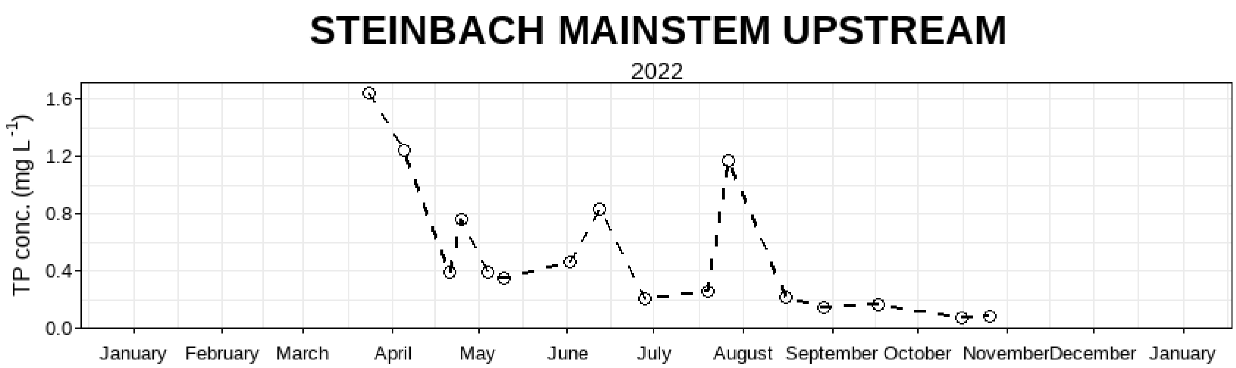


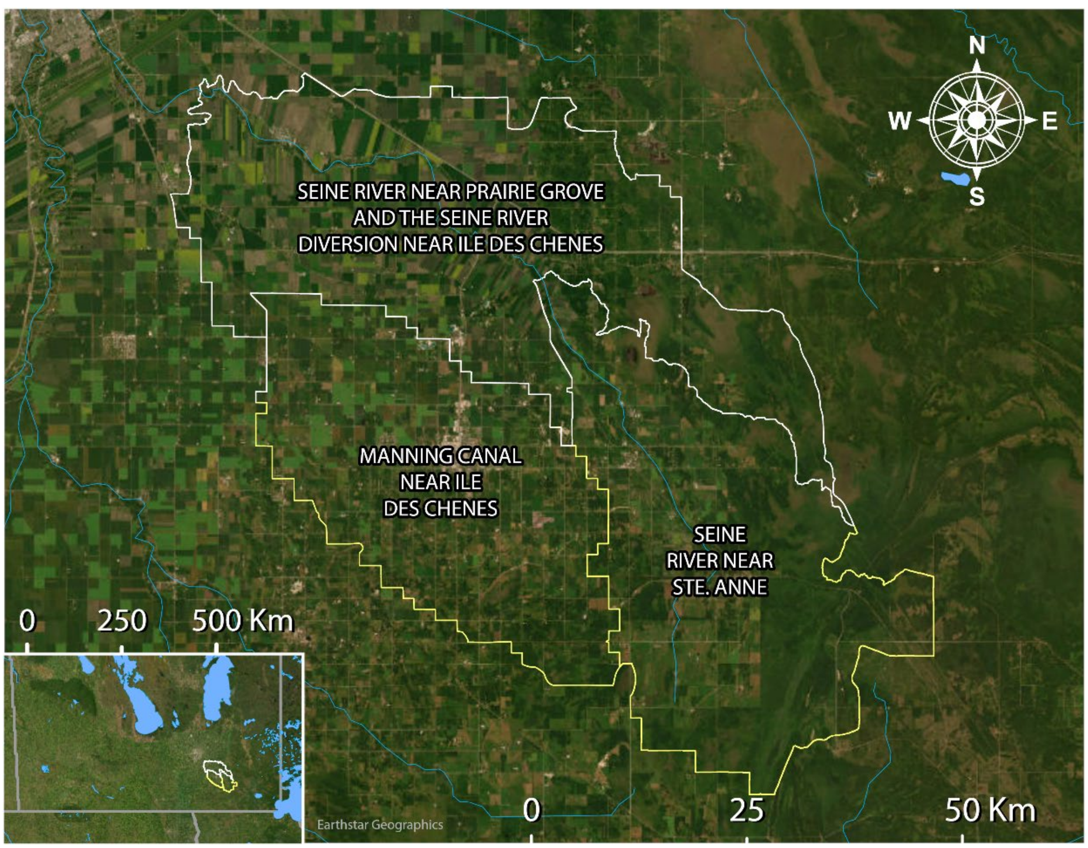
Figure 37: Total phosphorus concentration and water level at Steinbach Mainstem Upstream.

Incremental Calculations

Seine River near Prairie Grove and the Seine River Diversion near Île-des-Chênes

Supplemental Table 1: Indices of discharge and phosphorus from the combined gross drainage area and stream discharge of Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011).

Gross drainage area:	1747.94 km^2
Water load:	0.32 $km^3\ y^{-1}$
TP load:	211.47 tonnes P y^{-1}
Water export:	246.88 mm y^{-1}
TP export:	1.65 kg P $ha^{-1}\ y^{-1}$

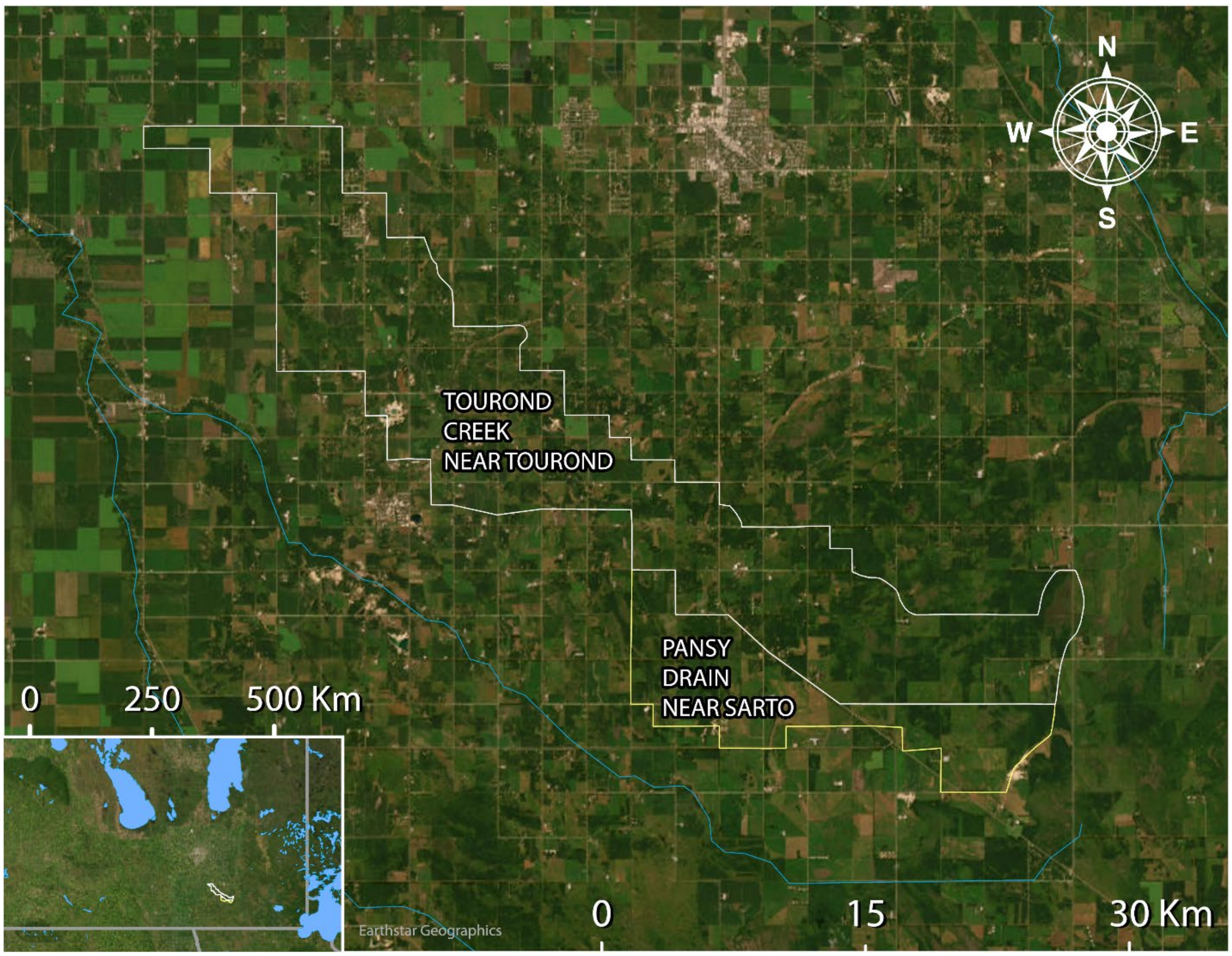


Supplemental Figure 1: Incremental drainage area in white (combined area of WSC stations Seine River near Prairie Grove and the Seine River Diversion near Île-des-Chênes) and upstream drainage areas in yellow (Manning Canal near Île-des-Chênes and Seine River near Ste. Anne). The combined incremental drainage area for Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011) was calculated by adding the former two gross drainage areas together and subtracting the upstream gross drainage areas of Manning Canal near Île-des-Chênes (05OE006) and Seine River near Ste. Anne (05OH007).

Tourond Creek near Tourond

Supplemental Table 2: Indices of discharge and phosphorus from the gross drainage area of Tourond Creek near Tourond (05OE009) in 2022.

Gross drainage area:	210.07 km^2
Water load:	0.031 km^3 y^{-1}
TP load:	28.21 tonnes P y^{-1}
Water export:	147.95 mm y^{-1}
TP export:	1.34 kg P ha^{-1} y^{-1}

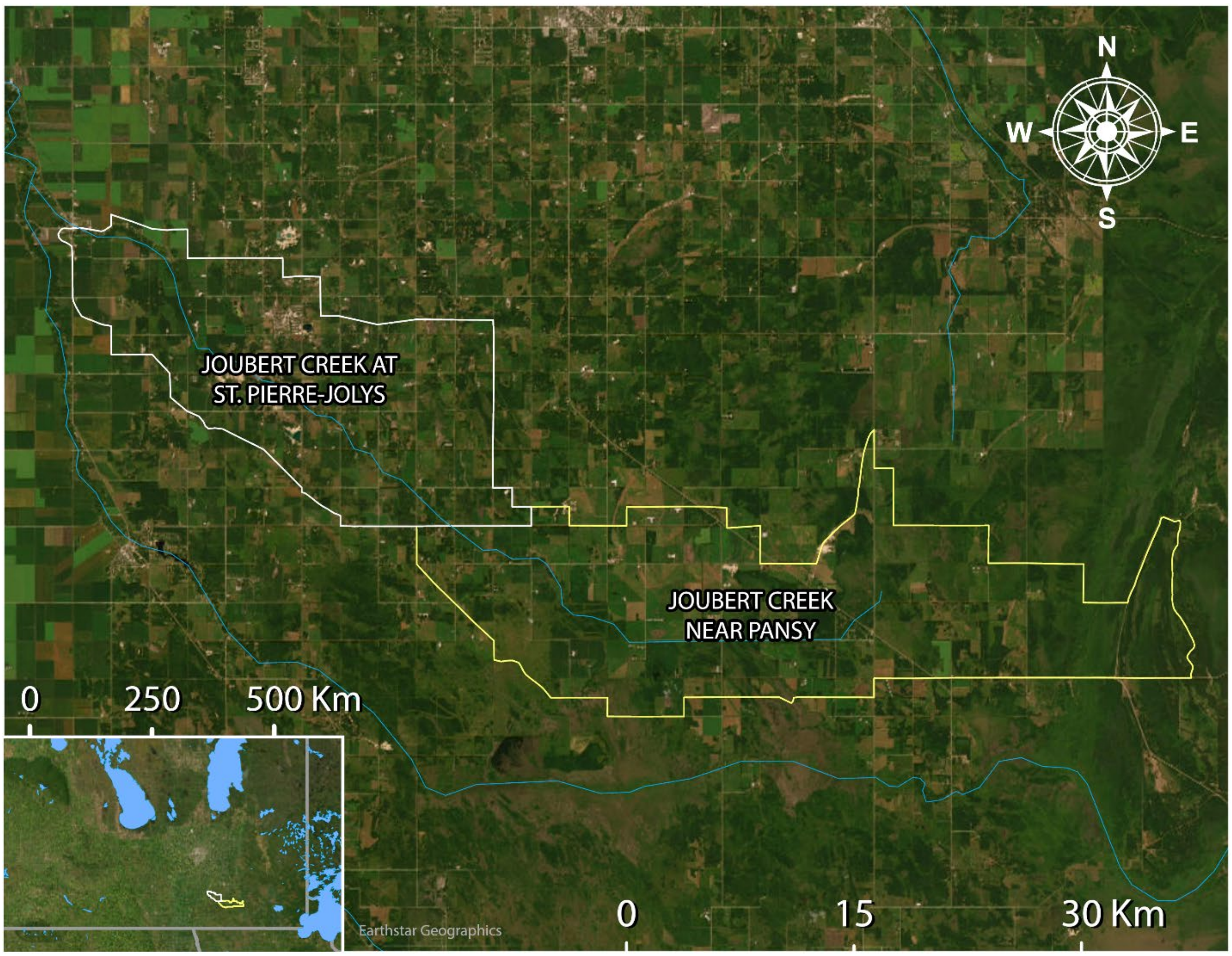


Supplemental Figure 2: Incremental drainage area in white and upstream drainage area in yellow. Incremental loads are calculated by subtracting gross "Pansy Drain near Sarto" values from gross "Tourond Creek near Tourond" values.

Joubert Creek at St-Pierre-Jolys

Supplemental Table 3: Indices of discharge and phosphorus from the gross drainage area of Joubert Creek near St-Pierre-Jolys (05OE007) in 2022.

Gross drainage area:	348.29 km^2
Water load:	0.075 $km^3\ y^{-1}$
TP load:	58.94 tonnes P y^{-1}
Water export:	215.80 mm y^{-1}
TP export:	1.69 kg P $ha^{-1}\ y^{-1}$

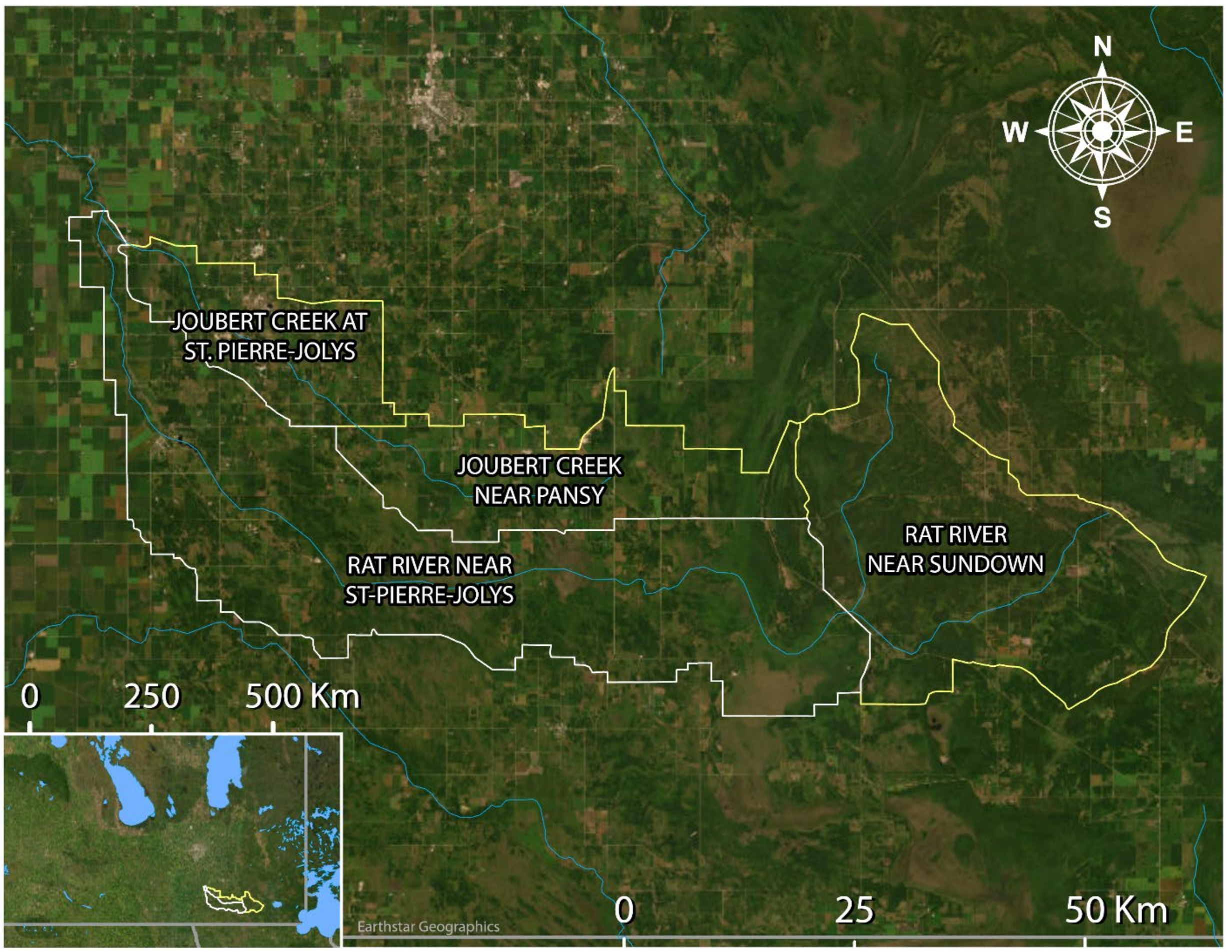


Supplemental Figure 3: Incremental drainage area in white and upstream drainage area in yellow. Incremental loads are calculated by subtracting gross “Joubert Creek near Pansy” values from gross “Joubert Creek near St-Pierre-Jolys” values.

Rat River near St-Pierre-Jolys

Supplemental Table 4: Indices of discharge and phosphorus from the gross drainage area of Rat River near St-Pierre-Jolys (05OE001-05OE007) in 2022.

Gross drainage area:	1074.86 km^2
Water load:	0.15 $km^3\ y^{-1}$
TP load:	30.86 tonnes P y^{-1}
Water export:	139.56 mm y^{-1}
TP export:	0.29 kg P $ha^{-1}\ y^{-1}$

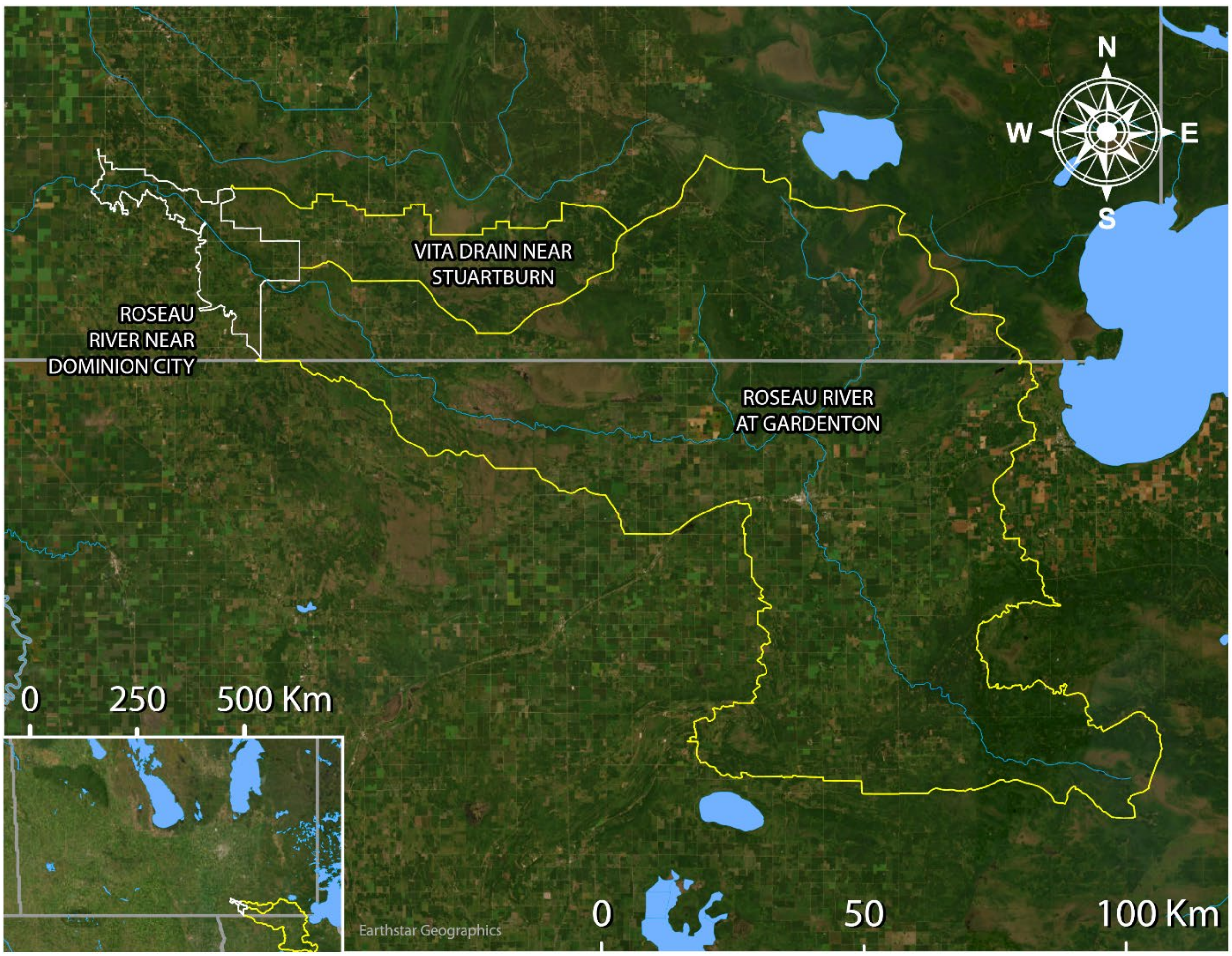


Supplemental Figure 4: Incremental drainage area in white and upstream incremental drainage areas in yellow. The incremental area for Rat River near St-Pierre-Jolys was calculated by subtracting the upstream gross drainage area of Joubert Creek at St-Pierre-Jolys (which contains Joubert Creek near Pansy) and Rat River near Sundown. Because station 05OE001 is used to calculate flow (by subtracting 05OE007) but we sample upstream of where Joubert Creek flows into Rat River, it is necessary to subtract the gross drainage area of Joubert Creek at St-Pierre-Jolys from Rat River near St-Pierre-Jolys.

Roseau River near Dominion City

Supplemental Table 5: Indices of discharge and phosphorus from the gross drainage area Roseau River near Dominion City (05OD001) in 2022.

Gross drainage area:	4607.32 km^2
Water load:	0.74 $km^3\ y^{-1}$
TP load:	104.80 tonnes P y^{-1}
Water export:	161.43 mm y^{-1}
TP export:	0.23 kg P $ha^{-1}\ y^{-1}$



Supplemental Figure 5: Incremental drainage area in white and upstream incremental drainage areas in yellow. Incremental loads are calculated by subtracting gross “Roseau River at Gardenton” and “Vita Drain near Stuartburn” values from gross “Roseau River near Dominion City” 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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Canada | Manitoba | Manitoba Hydro

RBC Tech for Nature | eco canada | TD Friends of the Environment Foundation

Lake Winnipeg Foundation

107 - 62 Hargrave St, Winnipeg, MB, R3C 1N1
Treaty 1 Territory & Homeland of the Métis Nation
info@lakewinnipegfoundation.org | 204-956-0436