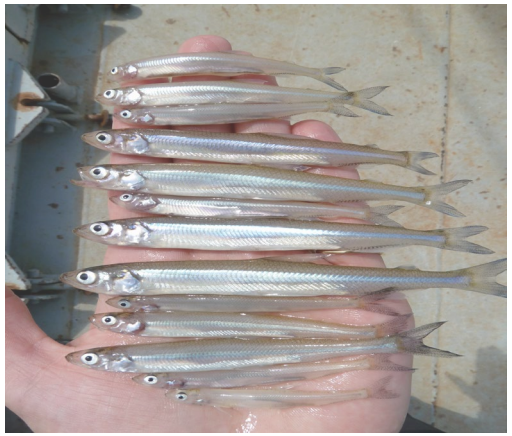
LAKE WINNIPEG: NUTRIENTS AND LOADS

STATUS REPORT

1994-2021



Manitoba

Lake Winnipeg: Nutrients and Loads

In 2020 and 2021, a number of adjustments were made to lake sampling frequency and protocols due to public health restrictions and variable lake water levels, resulting in reduced access to north basin sites in spring and summer. However, an annual comparison of mean lake-wide TP and TN concentrations when including only sites visited in 2021 compared to all sites normally included in the calculations showed a negligible effect (a difference of 0.001 to 0.002 mg/L) from 1999 to 2021.

Total Phosphorus Concentrations in Lake Winnipeg

The south basin of Lake Winnipeg is rich in phosphorus and is considered hypereutrophic with long-term mean total phosphorus (TP) concentrations almost 3 times higher in the south basin and narrows (0.104 mg/L) as compared to the north basin (0.039 mg/L) of the lake (Figure 1).

Within those samples collected in 2021, the annual mean total phosphorus concentration of the south basin and narrows (0.124 mg/L) exceeded the phosphorus concentration target of 0.05 mg/L, although the north basin was slightly below the target (0.047 mg/L).

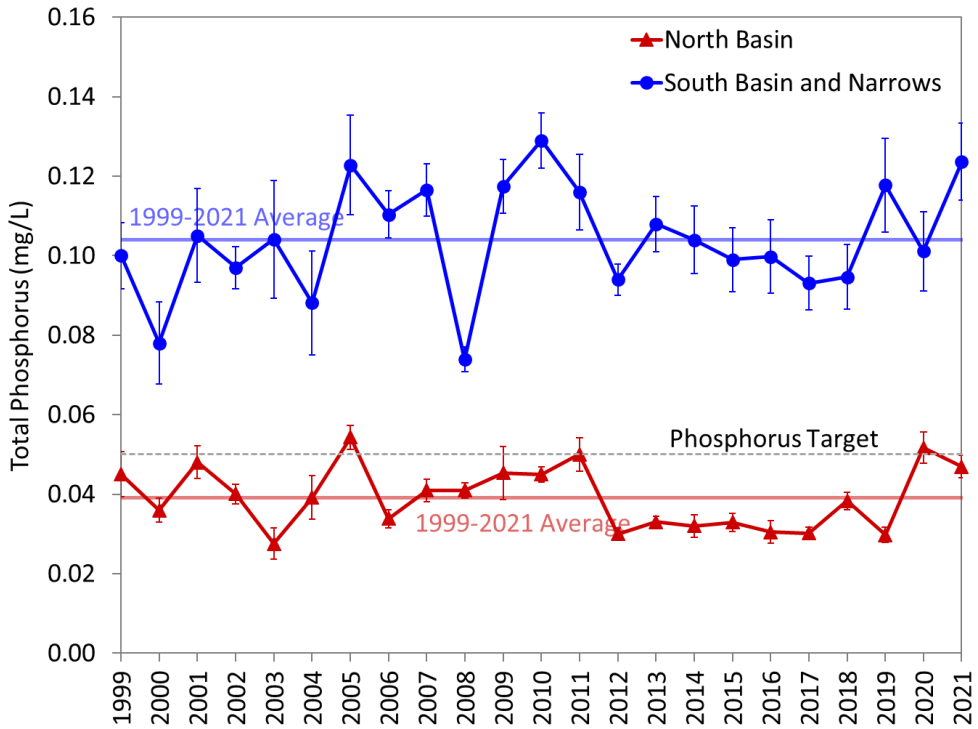


Figure 1. Total phosphorus concentrations in the north basin and south basin and narrows of Lake Winnipeg, 1999 to 2021.

Total Nitrogen Concentrations in Lake Winnipeg

Lake Winnipeg is also rich in total nitrogen with higher long-term mean concentrations in the south basin and narrows (0.81 mg/L) as compared to the north basin (0.60 mg/L) of the lake (Figure 2). The large between-year variability in nitrogen may be driven by a number of factors in Lake Winnipeg including nitrogen fixation and denitrification processes, nitrogen loading from tributary rivers, internal loading and wind-induced resuspension.

From 1999 to 2021, there are no clear trends in total nitrogen in Lake Winnipeg, although nitrogen concentrations since 2012 have remained below the long-term mean in both the north basin and the south basin and narrows. In 2021, mean total nitrogen concentrations in the north basin (0.53 mg/L), as well as the south basin and narrows (0.70 mg/L), were both below the total nitrogen target concentration of 0.75 mg/L.

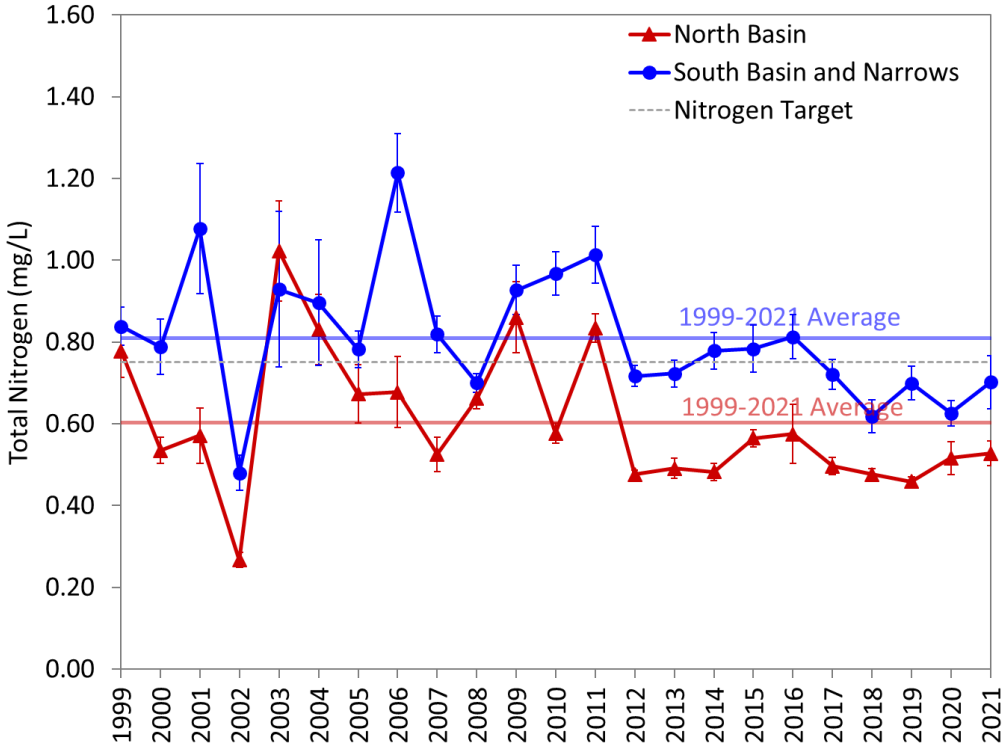


Figure 2. Total nitrogen concentrations in the north basin and south basin and narrows of Lake Winnipeg, 1999 to 2021.

Most nutrients reach Lake Winnipeg through four major river basins - the Red River, Winnipeg River, Saskatchewan River and Dauphin River (Figure 3). The Red River Basin drains the fertile soils of the Red River Valley region, an area that is dominated by annual crop agriculture and prone to major flood events. The Red River is the single largest nutrient source to Lake Winnipeg accounting for almost 70 percent of the total phosphorus and 34 percent of the total nitrogen load despite the fact that it only accounts for about 15 percent of the total inflow to the lake on average.

Although the Winnipeg River contributes over 40 percent of the flows to Lake Winnipeg, nutrient loads from the river are comparatively lower because of the relatively low nutrient concentrations in the river. Atmospheric deposition and nitrogen fixation are also estimated to comprise a portion of the nutrient load to Lake Winnipeg given the large surface area and nitrogen fixing cyanobacteria blooms in the lake that vary from year to year.

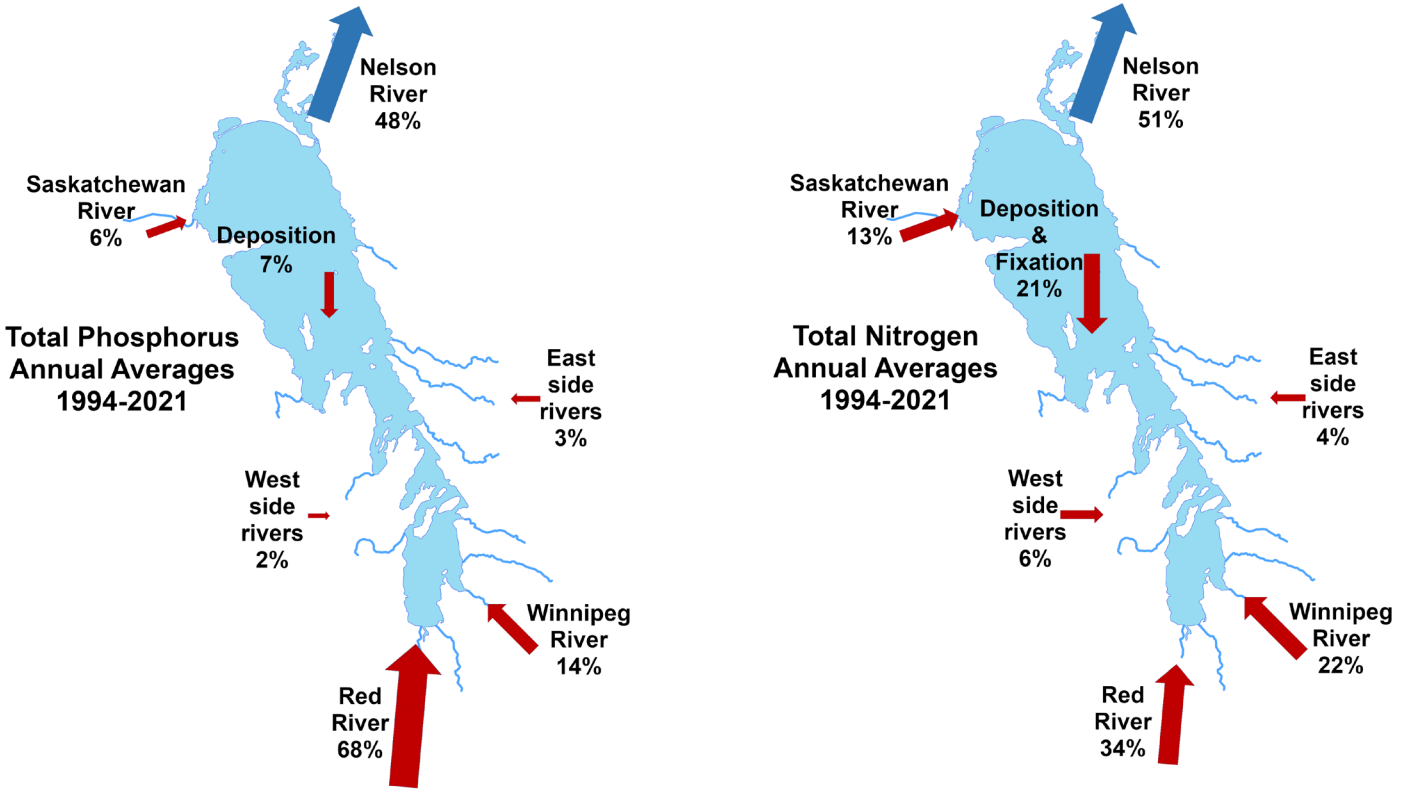


Figure 3. Average percent phosphorus and nitrogen loading from the major contributors to Lake Winnipeg (1994-2021 average).

In the 1990s, a wet cycle began in the Red River Basin including many years of high flows with more water and nutrients transported to Lake Winnipeg as compared to the historic record. Notable exceptions occurred in the drier years of 2002, 2003, 2012, 2015, 2018, and 2021. Between 1994 and 2021, the Red River was the single largest contributor of phosphorus to Lake Winnipeg, contributing almost 5,000 tonnes of phosphorus per year on average (Figure 4). Total phosphorus loads ranged from approximately 600 tonnes to 8,100 tonnes of phosphorus per year and generally followed patterns in streamflow with the highest loads transported in the wettest years (1997, 2005 and 2011) and the lowest loads in dry years (2003, 2012, 2018 and 2021). With the exception of 2019, phosphorus loads in the Red River have generally been at or below the long-term average since 2012. Phosphorus loads increased substantially in 2019 but flows returned to near normal (107%) with loads below the long-term average in 2020 and then during the 2021 drought, reached the lowest flows and annual load (617 tonnes) in the period of record.

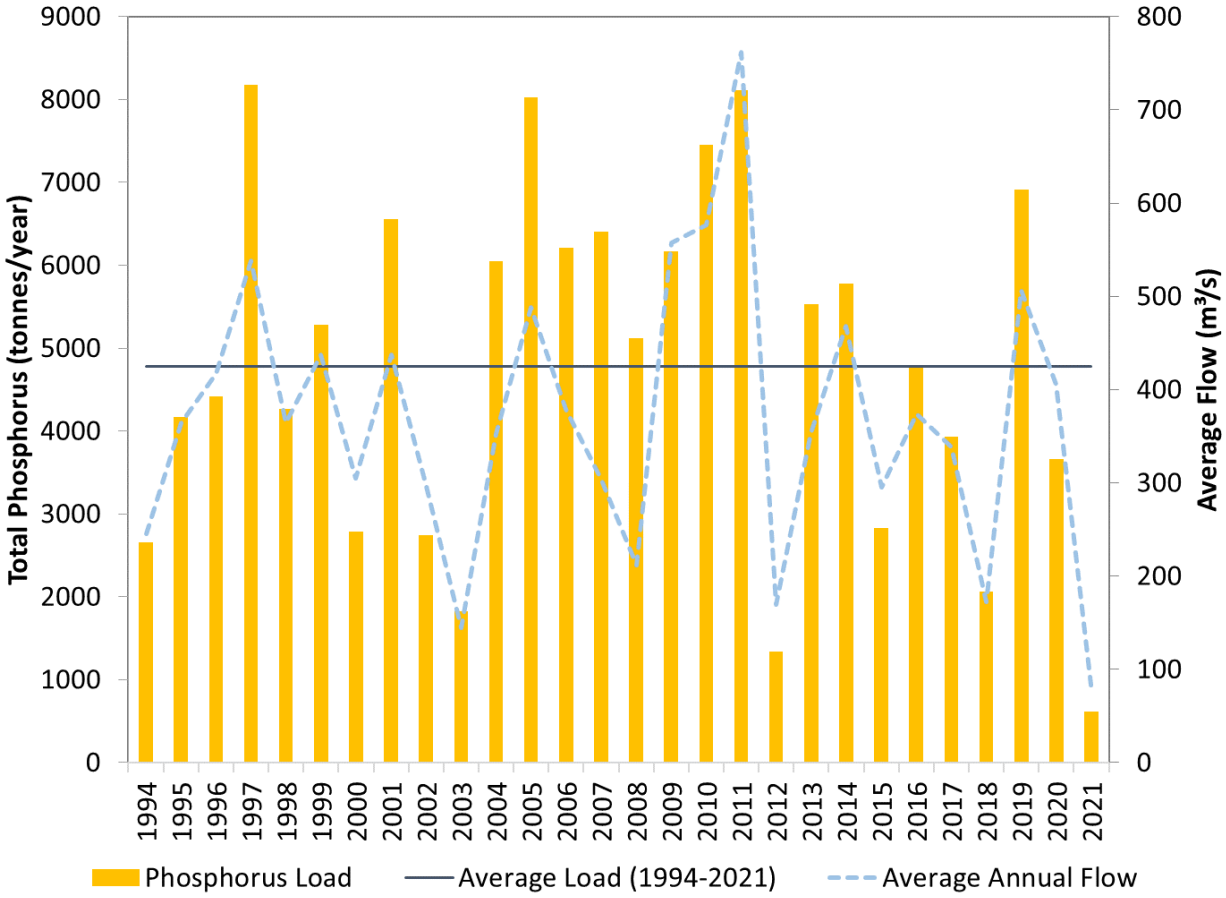


Figure 4. Annual total phosphorus loads (tonnes/year) and flows in the Red River (at Selkirk), 1994 to 2021.

The Red River was also the single largest contributor of nitrogen to Lake Winnipeg, contributing almost 30,000 tonnes of nitrogen per year on average (Figure 5). Total nitrogen loads ranged from approximately 6,700 tonnes to nearly 64,000 tonnes of nitrogen per year and generally followed patterns in streamflow with the highest loads transported in wet years (2011) and lowest loads in dry years (2002, 2003, 2012, 2018, and 2021). Similar to phosphorus loads, nitrogen loads in the Red River have generally been at or below the long-term average since 2012 with the exception of 2019 when the nitrogen load was about 37,600 tonnes largely due to high flows and loads during the fall. Flows and loads returned to near normal in 2020 and as with phosphorus, in 2021 were the lowest in the period of record (6,700 tonnes of nitrogen) with an annual average flow of only 83 m^3/s (17% of the long-term annual average).

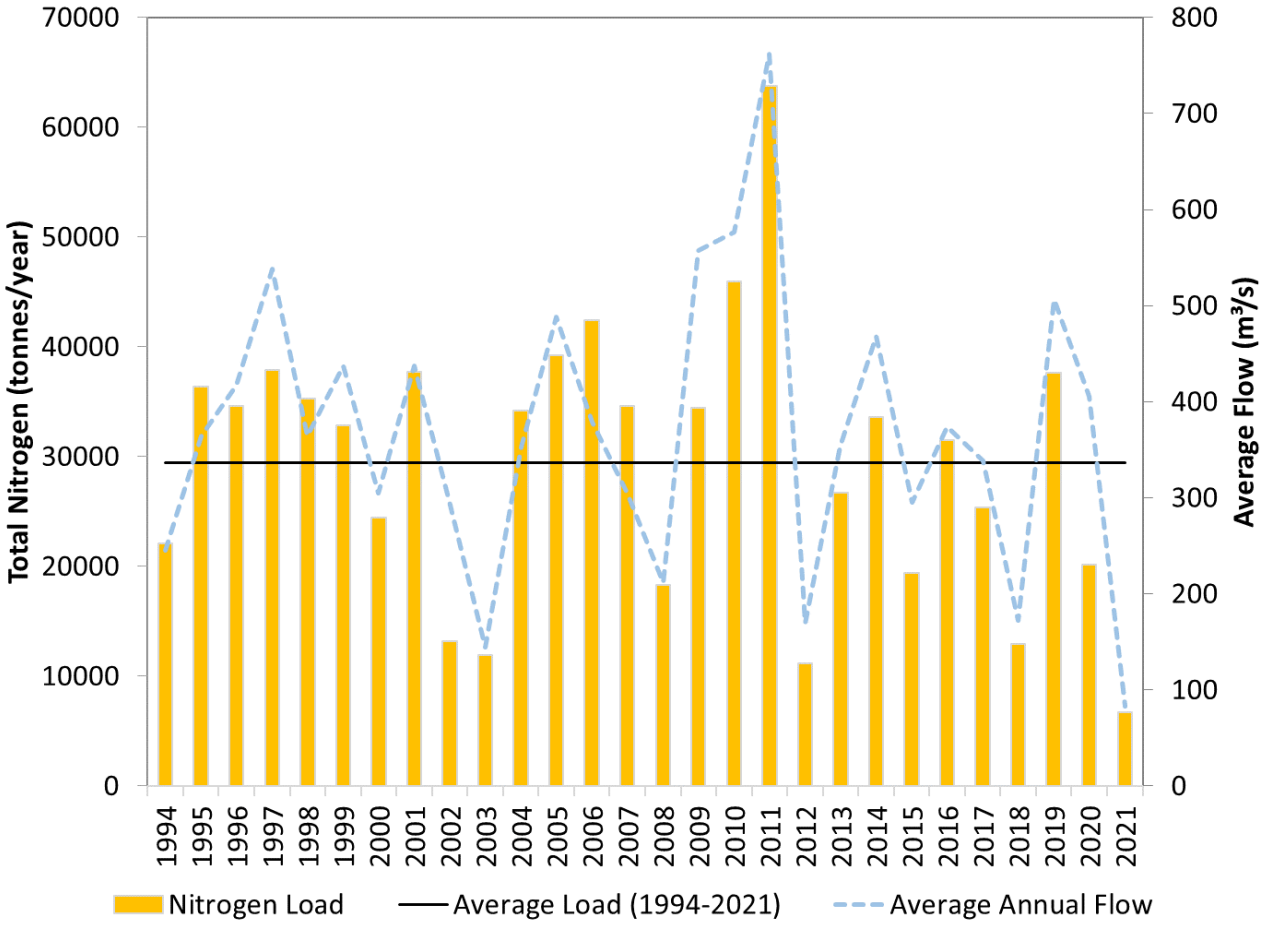


Figure 5. Annual total nitrogen loads (tonnes/year) and flows in the Red River (at Selkirk), 1994 to 2021.

The Winnipeg River is the second largest source of phosphorus to Lake Winnipeg contributing approximately 1,000 tonnes of phosphorus per year on average (Figure 6) or approximately 14 percent of the total phosphorus load to Lake Winnipeg (Figure 3). Total phosphorus loads ranged from approximately 330 tonnes to just over 1,400 tonnes of phosphorus per year and generally followed patterns in streamflow. In 2021, the total phosphorus load in the Winnipeg River was the lowest in the period of record at 330 tonnes, 33 percent of the long-term average (flows were 42% of the long-term average).

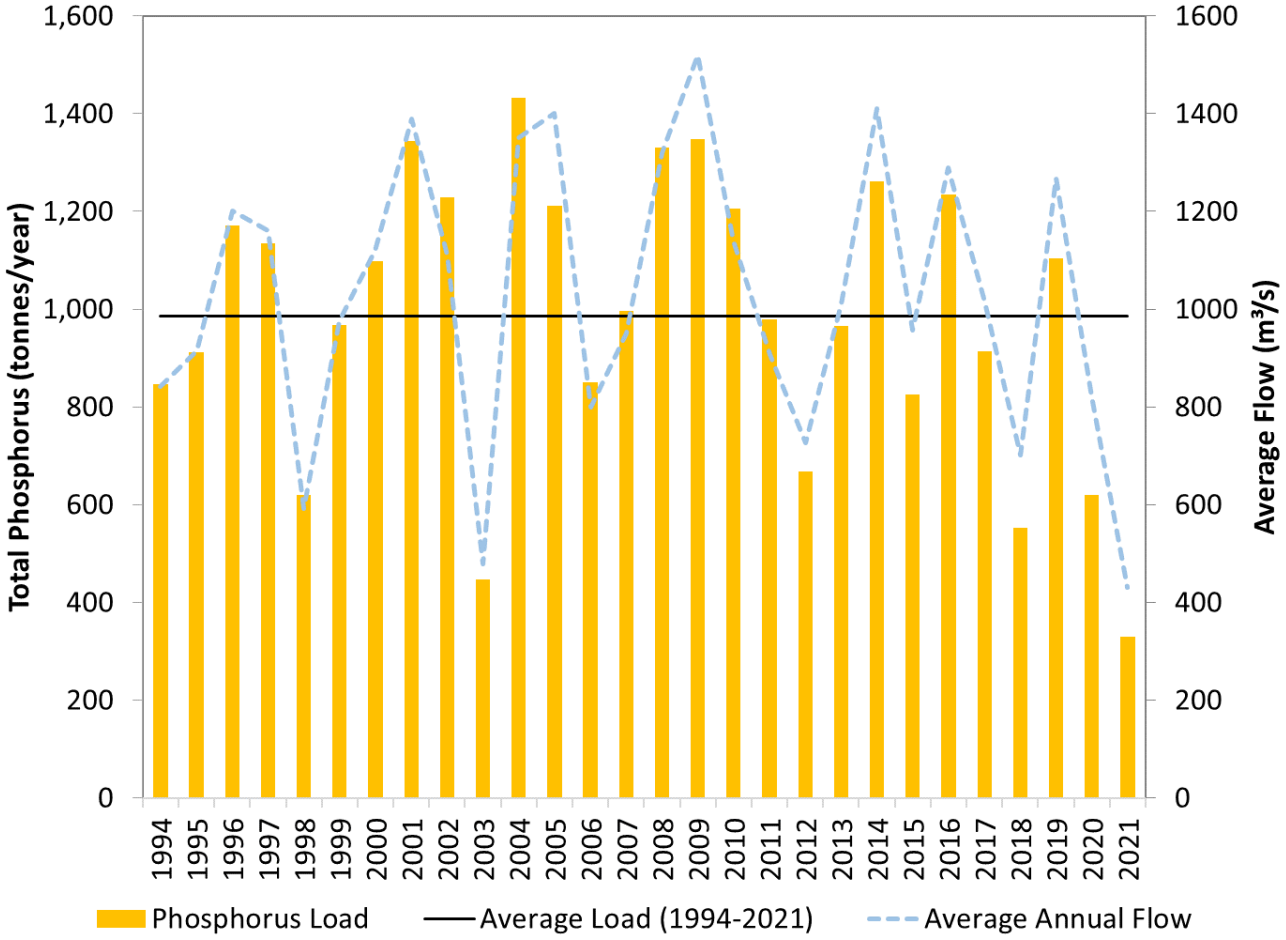


Figure 6. Annual total phosphorus loads (tonnes/year) and flows in the Winnipeg River (at Pine Falls), 1994 to 2021.

The Winnipeg River is also the second largest source of nitrogen to Lake Winnipeg, contributing just under 20,000 tonnes of nitrogen per year on average or about 22 percent of the total nitrogen load to Lake Winnipeg (Figure 3). Total nitrogen loads ranged from approximately 5,800 tonnes to just over 33,000 tonnes of nitrogen per year and generally followed patterns in streamflow. In 2021, the total nitrogen load in the Winnipeg River was approximately 5,800 tonnes, 30 percent of the long-term average (flows were about 42% of the long-term average). Total nitrogen loads in the Winnipeg River have been below the average in nine of the last twelve years of the period of record.

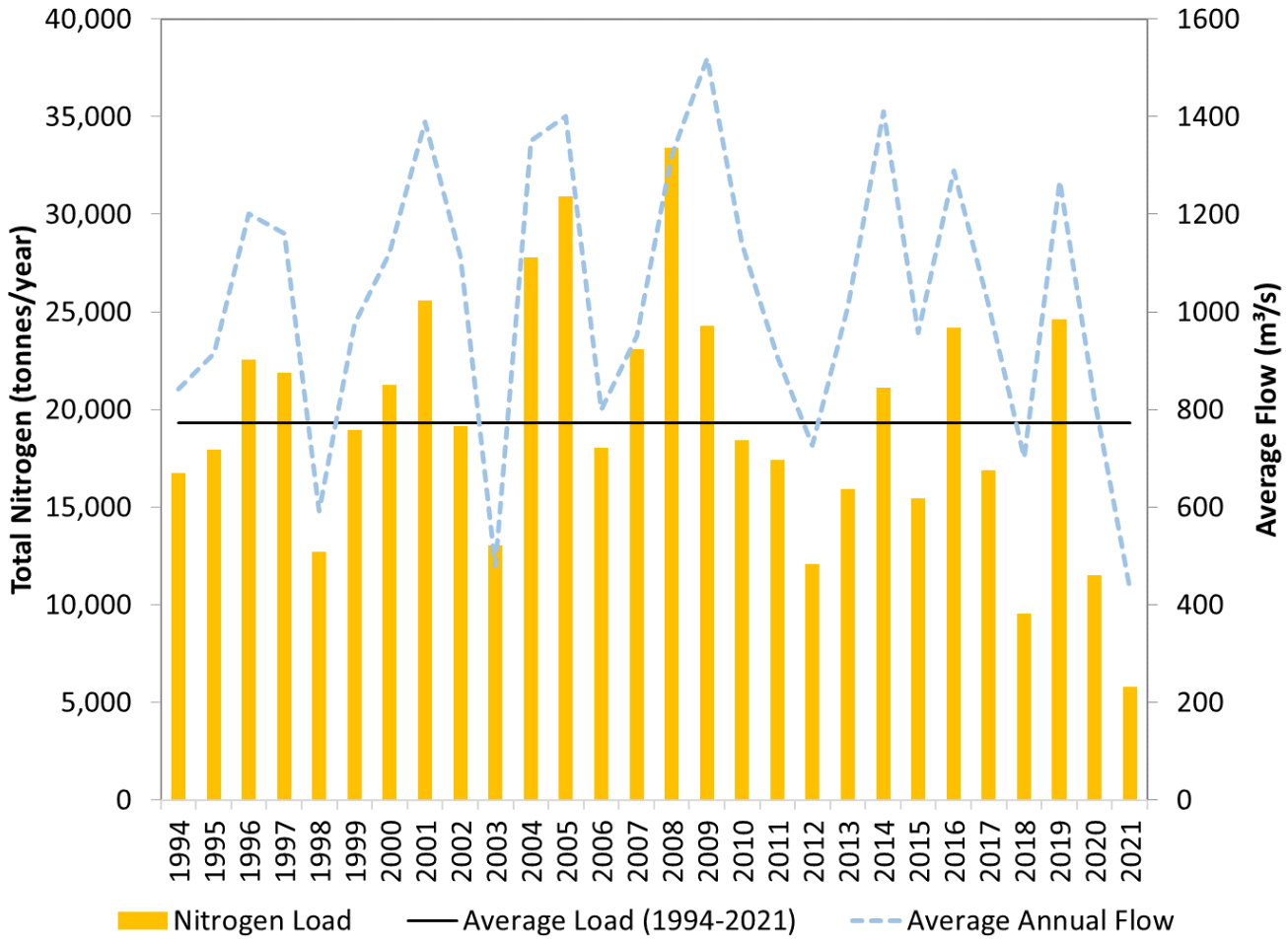


Figure 7. Annual total nitrogen loads (tonnes/year) and flows in the Winnipeg River (at Pine Falls), 1994 to 2021.

The Saskatchewan River comprises about 6 percent of the total phosphorus load to Lake Winnipeg and contributes approximately 400 tonnes of phosphorus per year on average (Figure 8). There is high inter-annual variability in total phosphorus, with annual loads ranging from approximately 90 tonnes to just over 800 tonnes of phosphorus per year. Phosphorus loads generally followed patterns in streamflow with the highest loads transported in wet years (2011) and lowest loads in dry years (2001). Flows are generally higher in the most recent period of record as compared to the earlier period and phosphorus loads have generally been near to or above the average in the most recent period of record. Flows and the total phosphorus load in the Saskatchewan River both decreased below the long-term average in 2021 but much less so than the other main Lake Winnipeg tributaries. The 2021 annual load estimate was 275 tonnes of phosphorus (67% of the long-term average load).

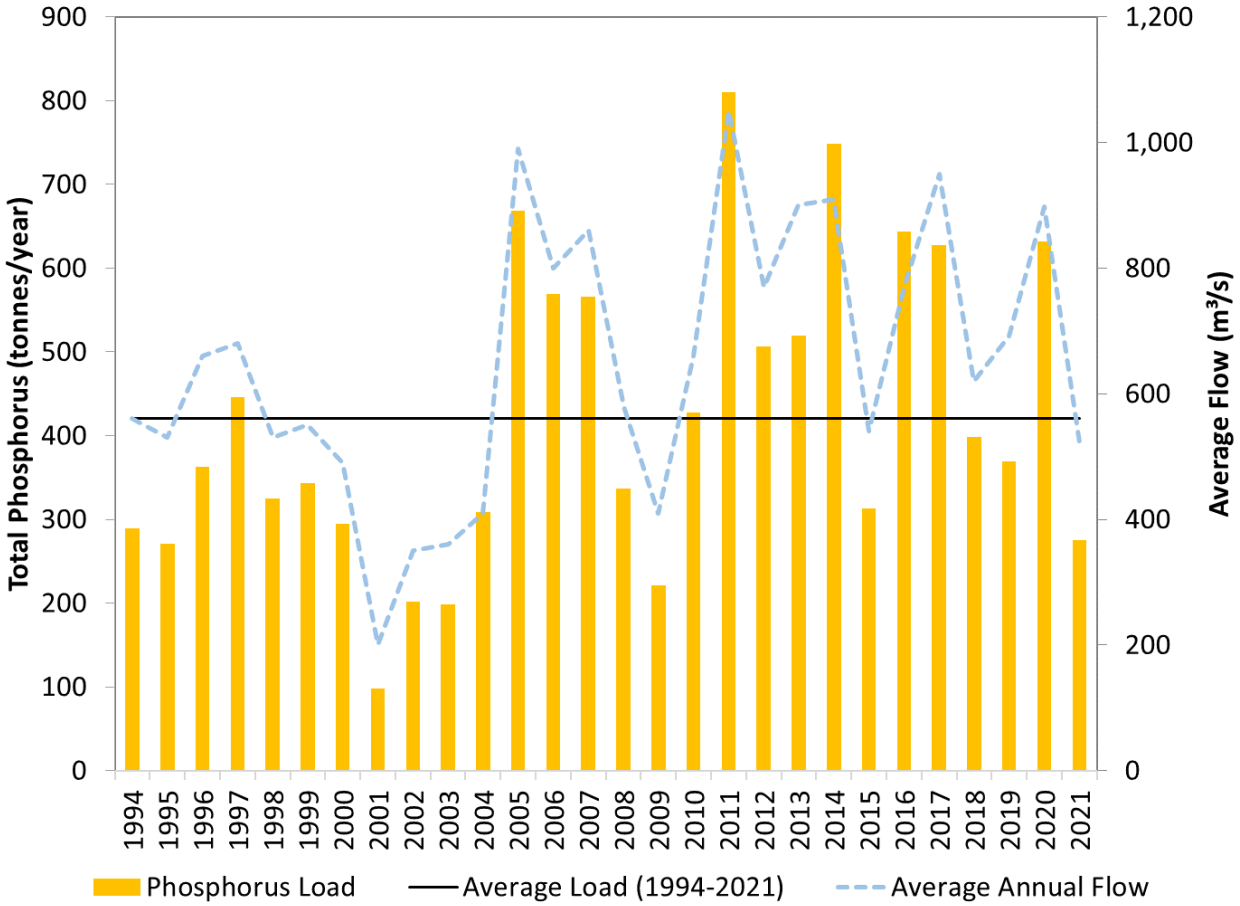


Figure 8. Annual total phosphorus loads (tonnes/year) and flows in the Saskatchewan River (at Grand Rapids), 1994 to 2021.

The Saskatchewan River comprises about 13 percent of the total nitrogen load to Lake Winnipeg (Figure 3) and contributes just over 11,000 tonnes of nitrogen per year on average (Figure 9). There is high inter-annual variability in total nitrogen, with annual loads ranging from approximately 3,000 tonnes to just over 20,000 tonnes of nitrogen per year. Nitrogen loads generally followed patterns in streamflow with the highest loads transported in wet years (2011, 2014) and lowest loads in dry years (2001-2003 and 2009). Total nitrogen loads have generally been well above average in the most recent period of record because of higher flows over the same period. As with phosphorus, total nitrogen loads have decreased with flows in 2021 although to a lesser extent (annual nitrogen load about 77% of the long-term average).

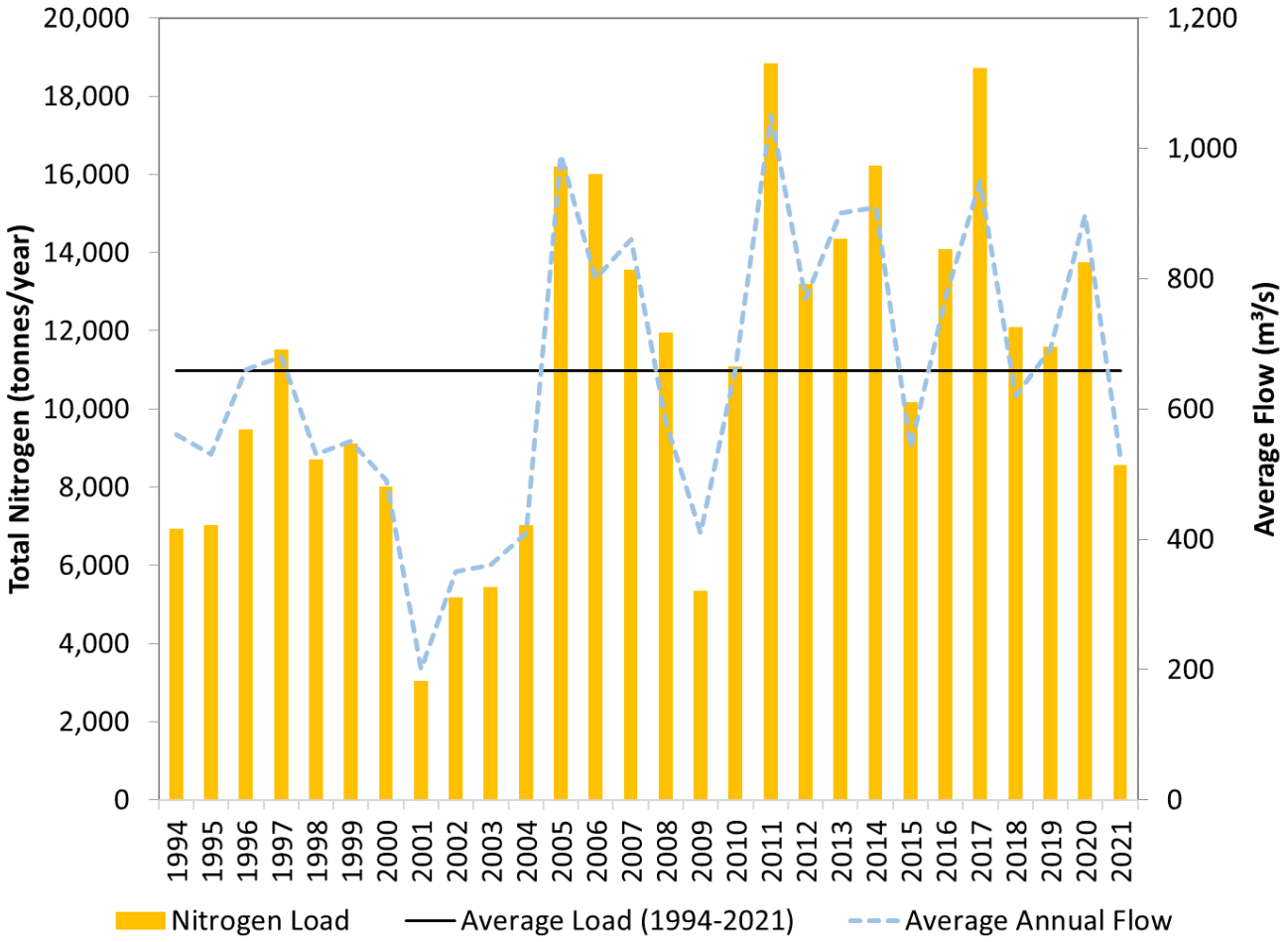


Figure 9. Annual total nitrogen loads (tonnes/year) and flows in the Saskatchewan River (at Grand Rapids), 1994 to 2021.

Dauphin River – Phosphorus Loads

The Dauphin River comprises a very small fraction of the total phosphorus load to Lake Winnipeg, contributing approximately 79 tonnes of phosphorus per year on average (Figure 10). There is high inter-annual variability in total phosphorus, with annual loads ranging from approximately 15 tonnes to nearly 250 tonnes of phosphorus per year. Phosphorus loads generally followed patterns in streamflow with the highest loads transported in wet years (2011) and lowest loads in dry years (2002 to 2004 and 2021). In 2021, the total phosphorus load in the Dauphin River was about 15 tonnes, well under the long-term average. Flows remained high on the Dauphin River from 2011 to 2017 but flows and phosphorus loads have dropped well below the average for 2019 to 2021.

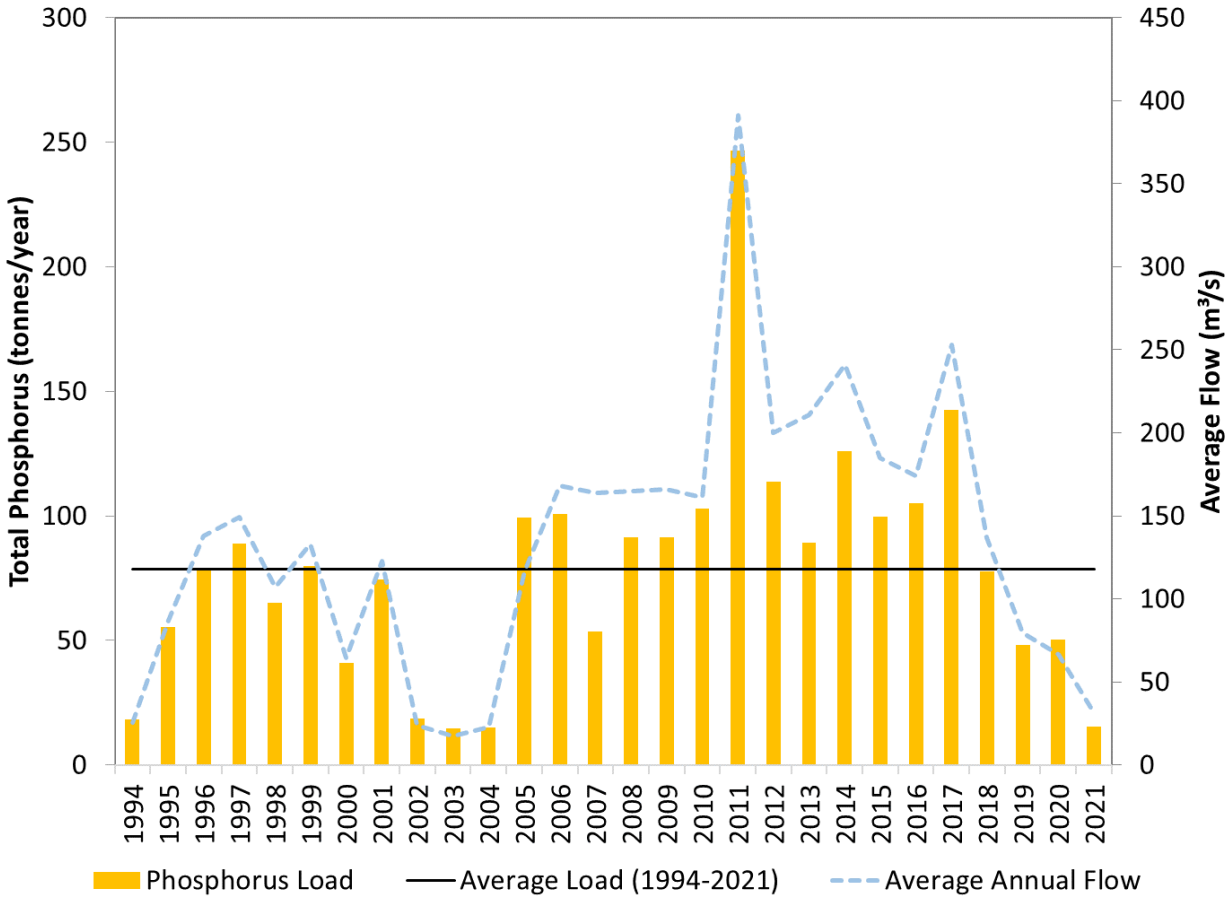


Figure 10. Annual total phosphorus loads (tonnes/year) and flows in the Dauphin River, 1994 to 2021.

As with total phosphorus, the Dauphin River comprises a very small fraction of the total nitrogen load to Lake Winnipeg, contributing approximately 5,100 tonnes of nitrogen per year on average (Figure 11). As with phosphorus, there is high inter-annual variability in total nitrogen, with annual loads ranging from approximately 900 tonnes to just over 13,000 tonnes of nitrogen per year. Nitrogen loads generally followed patterns in streamflow with the highest loads transported in wet years (2011) and lowest loads in dry years (2002 to 2004 and again in 2021). In 2021, the total nitrogen load in the Dauphin River was just over 1,400 tonnes, about 27 percent of the long-term average. Flows remained high on the Dauphin River from 2011 to 2017 with above average nitrogen loads. However, flows have declined resulting in below average total nitrogen loads in 2018 through 2021.

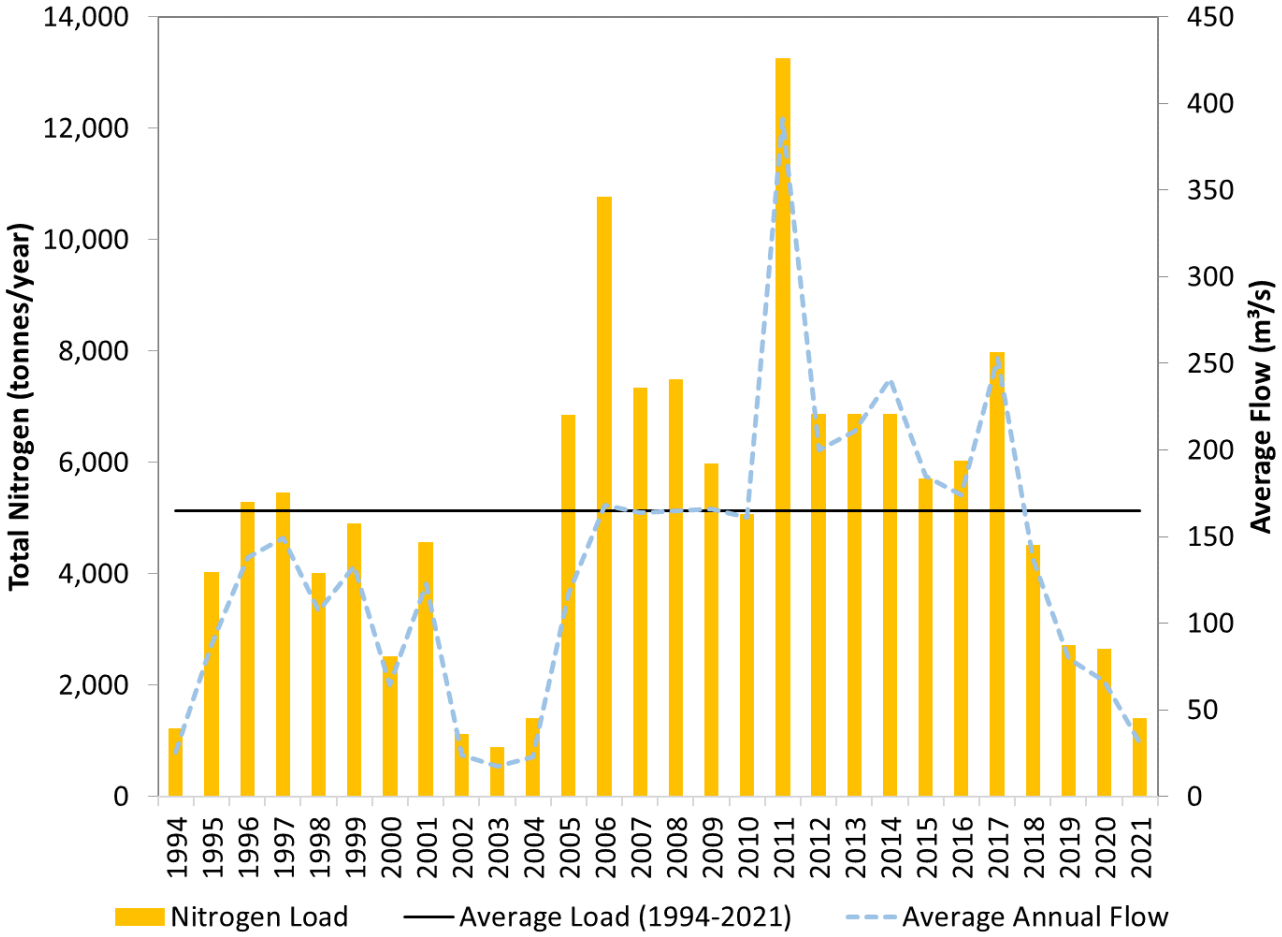


Figure 11. Annual total nitrogen loads (tonnes/year) and flows in the Dauphin River, 1994 to 2021.

References

Environment Canada and Manitoba Water Stewardship. 2011. State of Lake Winnipeg: 1999 to 2007. 209 pp. https://www.gov.mb.ca/water/pubs/water/lakes-beaches-rivers/state_of_lake_winnipeg_rpt_technical_high_resolution.pdf

Environment and Climate Change Canada and Manitoba Agriculture and Resource Development. 2020. State of Lake Winnipeg 2nd edition. 175 pp. https://www.gov.mb.ca/water/pubs/water/lakes-beaches-rivers/state_lake_wpg_report_tech.pdf

Methods

All nutrient loads calculated per the 2020 State of Lake Winnipeg report (Environment and Climate Change Canada and Manitoba Agriculture and Resource Development 2020) as detailed in appendix 7.1 of the 2011 State of Lake Winnipeg report (Environment Canada and Water Stewardship 2011) with water quality data from Manitoba Environment and Climate and flow data from Water Survey of Canada.

Total phosphorus concentrations measured by Manitoba Environment and Climate from April 2001 through March 2009 in Lake Winnipeg and its tributaries have been adjusted to account for a change in laboratory analysis technique. Concentrations measured during this period were approximately 12 percent higher than observed with the laboratory technique used in 2000 and in 2009 through the present.

Trophic status classifications (e.g., hypereutrophic) are following the limits from the Organization for Economic Co-Operation and Development 1982 guidelines referenced within the Environment Canada and Manitoba Water Stewardship (2011) State of Lake Winnipeg report (1st edition). Details on estimates of annual atmospheric deposition of phosphorus and atmospheric deposition + biological fixation of nitrogen are outlined in the Environment Canada and Manitoba Water Stewardship (2011) State of Lake Winnipeg report (1st edition): https://manitoba.ca/water/pubs/water/lakes-beaches-rivers/state_of_lake_winnipeg_rpt_technical_high_resolution.pdf

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