Proposed Nutrient Concentration Objectives and Loading Targets for the Red River at the US/Canada Boundary

International Red River Board – Water Quality Committee

Background

Excessive nutrients such as phosphorus and nitrogen and resulting increase in the frequency and severity of algal blooms is one of the greatest water quality challenges facing the international Red River watershed and downstream Lake Winnipeg. While all jurisdictions within the watershed have various regulatory frameworks, as well as plans and approaches to reduce the contribution of nutrients to water, the development of an enhanced, coordinated, and systematic strategy is desirable.

Since September 2011, with the support of the International Joint Commission (including through the International Watershed Initiatives funding), the International Red River Board's Water Quality Committee has been undertaking work to address nutrients in the Red River. The mission is to develop a collaborative, science and watershed-based approach to managing nutrients in the Red River and its watershed with the goal of restoring and protecting aquatic ecosystem health and water uses in the Red River watershed and Lake Winnipeg. The strategy has a number of guiding principles:

- Efforts, decisions and outcomes will be based on and supported by scientifically defensible methods and research.
- An integrated watershed perspective and approach will be used in priority setting and decision making.
- Coordinated, cooperative and collaborative processes will be used where appropriate and desirable. Notwithstanding, it is understood that jurisdictional independence will be maintained and that jurisdictional participation is voluntary.
- The strategy and its objectives will be goal/outcome based with particular focus on the protection and/or restoration of aquatic ecosystems and water uses.
- Synergies between sub basins and sub watersheds in the Red River watershed will be recognized and considered.
- Lake Winnipeg is the end point and receiving surface water body for the Red River. Efforts and decisions should strive to benefit both Lake Winnipeg and local water quality.
- Information exchange and input between the jurisdictions will be coordinated where possible.
- The Parties will use a consensus-based approach to decision making (for the purpose of this document consensus-based means "unanimous" in that all parties agree on the decision).

The strategy includes six components:

- Component One – Seek Endorsement of the Proposed Approach from the International Red River Board
- Component Two - Develop a Shared Understanding of Jurisdictions' Nutrient Regulatory Frameworks and Identify Current Nutrient Reduction Actions, Activities and Plans for the Red River Watershed
- Component Three - Recommend and Implement Nutrient Load Allocation and/or Water Quality Targets for Nutrients
- Component Four - Monitor and Report on Progress towards Meeting Water Quality Targets and Nutrient Load Allocations
- Component Five - Facilitate ongoing technical, scientific and methodological dialogue and information sharing relevant to nutrients and nutrient loading in the Red River watershed including exchanging information on the goals and scientific basis for the long-term ecologically relevant objectives for Lake Winnipeg.
- Component Six - Adapt the nutrient management strategy based on progress and ongoing evaluation.

In particular, Component Three includes working collaboratively to develop recommendations for nutrient load allocations and/or water quality targets for nutrients along the Red River including at the international boundary and at sub watershed discharge points in the Red River watershed. The strategy indicates that work to develop recommendations for nutrient targets will be coordinated with other work underway across the watershed including the development of nutrient objectives for Lake Winnipeg and could include water quality modelling and additional research to better understand the nutrient stressor and response relationship in the Red River.

Proposed Approach to Developing Recommendations for Nutrient Load Allocations/Water Quality Targets

As a first step to developing recommendations for nutrient load allocations/water quality targets, the Committee with support from the International Watersheds Initiative (International Joint Commission funding) used the services of an outside contractor to conduct a literature review of the available scientific methods for setting nitrogen and phosphorus water-quality targets and to provide recommendations on the method(s) most appropriate for the Red River.

Multiple technical approaches were reviewed by RESPEC (RESPEC 2013). One category of approaches uses "reference condition" and includes techniques such as using data from reference sites, modeling the "reference condition", estimating the "reference condition" from all sites within a class, and paleolimnological techniques to reconstruct the reference condition through historical data. The second category of approaches involves stressor-response relationships. With this approach, conceptual models are developed, exploratory data analysis is used to understand the system and suggest statistical approaches for modeling, and then stressor-response relationships are modeled using empirical data. Other approaches reviewed included considering downstream water resources, maintaining existing water-quality conditions, and using literature values.

RESPEC's review described a number of disadvantages with several methods that would make them unsuitable for the Red River. For example, a lack of applicable reference sites for the Red River would make it difficult to apply any of the reference approaches. Similarly, the use of literature values is only recommended where there is clear evidence that the stream/river/lake of interest is similar enough to the waterbodies used to derive the published value. Given the unique conditions in the Red River (high turbidity, variable flows, ice-covered/ice free seasons, etc), it was expected to be difficult to find similar systems with established nutrient objectives/targets. Finally, given the water quality challenges in the Red River and Lake Winnipeg, maintaining existing conditions was not considered an option.

Ultimately, two integrated approaches to developing recommendations for nutrient targets to address the goals of the nutrient management strategy were recommended by RESPEC:

- A stressor-response modeling approach to develop recommendations for nutrient concentration objectives for the Red River
- A “downstream” approach based on the nutrient targets for Lake Winnipeg to develop recommendations for nutrient loading targets

It was recognized that these two approaches may yield different results and that the proposed objectives and targets should be integrated to ensure compatibility. In this report we refer to proposed nutrient **concentration objectives** to protect the Red River and proposed **nutrient loading targets** to protect downstream waterbodies such as Lake Winnipeg.

The reports from this study were accepted by the International Red River Board and the International Joint Commission and are available on the Board’s web site.

Stressor Response Model – Recommended Nutrient Concentration Objectives

Based on the recommendation that a dual approach be taken to set nutrient targets for the Red River at the US/Canada border, a stressor response model was developed for the international Red River. The model was developed by RESPEC with funding from the International Watersheds Initiative. The modelling work began with an experts workshop held in December 2014, followed by two webinars to engage experts who were unable to travel to the December workshop. Attendees included local, regional, and federal water quality professionals and academics (see the list of participants in Appendix C of RESPEC 2016). The workshop attendees set out the initial conceptual model for the Red River and assessed available data. The workshop and initial modelling work by RESPEC identified a lack of algae data and in particular, periphyton data for the Red River. In a first of its kind example of collaboration across international boundaries, several agencies (Minnesota Pollution Control Agency, Manitoba Sustainable Development, Environment and Climate Change Canada, North Dakota Department of Health and the Buffalo-Red River Watershed Management District) worked together to sample phytoplankton, periphyton and water chemistry at 30 sites in the Red River with sites located on both sides of the US-Canada border (Figure 1). Periphyton were sampled from artificial substrate with protocols developed by RESPEC.

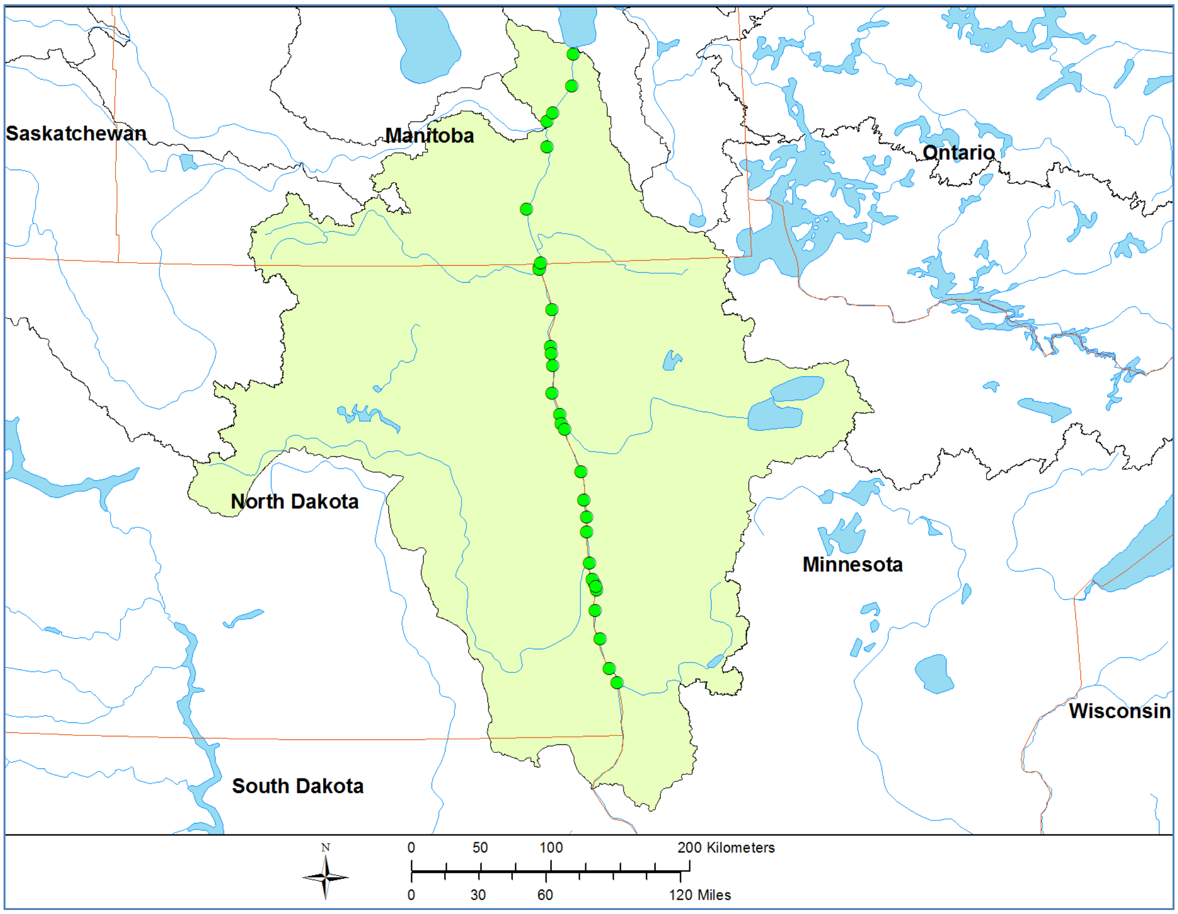
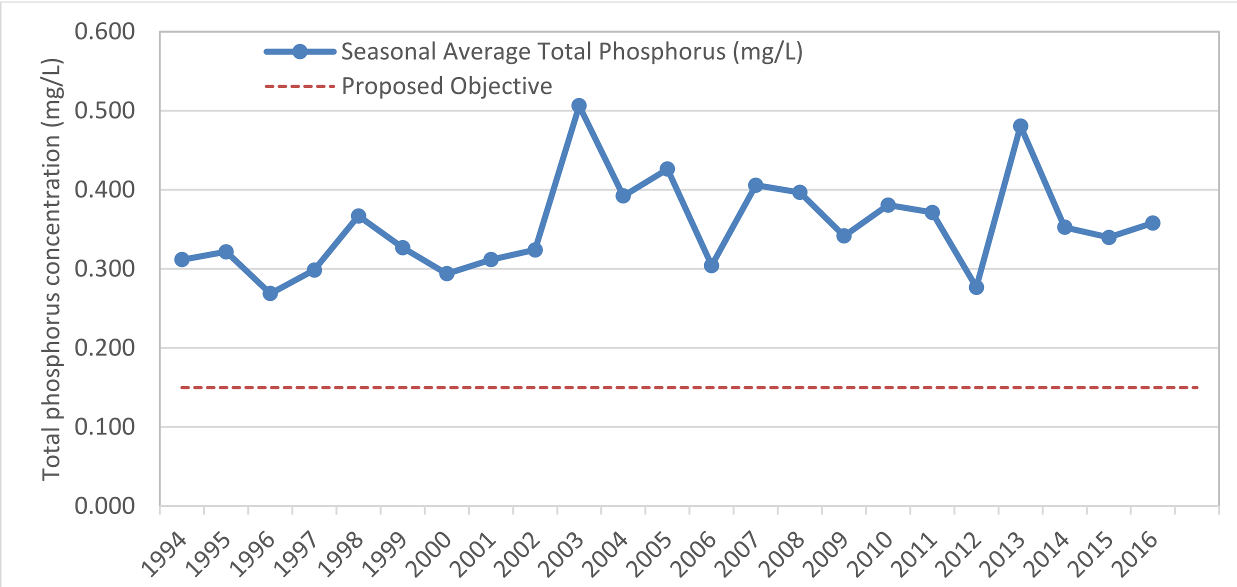


Figure 1. Periphyton, phytoplankton and water chemistry monitoring stations along the international Red River.

Results from the international, collaborative effort were used to develop a stressor-response model for the international Red River (RESPEC 2016). RESPEC noted from water quality data provided by agencies participating in the study (Minnesota Pollution Control Agency, Manitoba Sustainable Development, Environment and Climate Change Canada, etc.) that there was a nutrient gradient along the international Red River. With data on phytoplankton and periphyton provided through the summer 2015 collaborative monitoring program, RESPEC noted differences in the response of algae quantity and quality. A response in the quantity of algae was apparent in both the phytoplankton (free floating algae) and periphyton (attached algae) abundance. Given the high total suspended solids concentrations in the Red River which reduces light penetration, the periphyton quantity was significantly repressed. However, the response of periphyton quality was not suppressed by total suspended solids concentrations because a significant negative quality response was seen with increasing nutrients starting at the first peak in nutrients adjacent to the Fargo/Moorhead urban area. Overall, periphyton was found to reach nuisance levels toward the mouth of the river that coincided with the highest concentration of nutrients. Phytoplankton was found to reach nuisance concentrations (100-150 mg/m^2) in close proximity to highly developed urban areas with an occasional abundance of blue-green algae.

RESPEC then used multivariate analyses to determine that periphyton and phytoplankton responded significantly to varying nutrient concentrations, both in terms of the quality and quantity of the algal communities. With information from these analyses, nutrient objectives were determined by using the results from sites least influenced by high total phosphorus and total nitrogen effects. Substantial consideration was also given to results from sites meeting regional regulatory limits on primary productivity measures. This process resulted in recommended nutrient concentration objectives of 0.15 milligrams per liter (mg/L) for total phosphorus and 1.15 mg/L for total nitrogen.



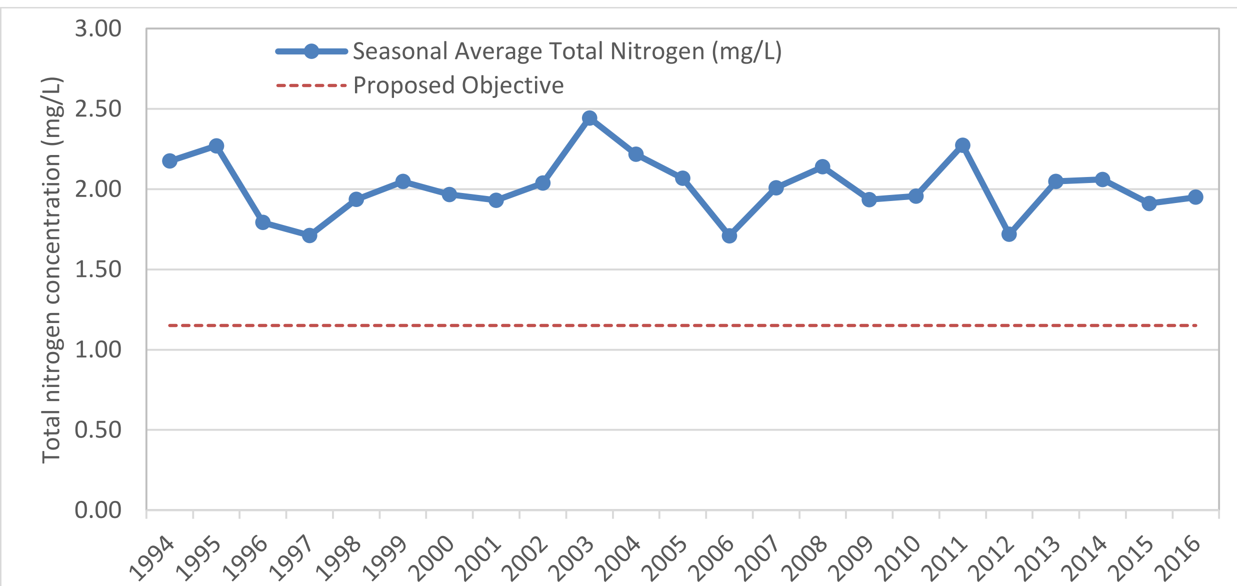


Figure 2. Seasonal average total phosphorus and total nitrogen concentrations in the Red River at Emerson compared to the proposed concentration objectives for phosphorus (top) and nitrogen (bottom). Data from Environment and Climate Change Canada.

Current nitrogen and phosphorus concentrations at the US/Canada border exceed the proposed nutrient concentration objectives. Seasonal average concentrations (April 1-October 31) calculated for 1994 through 2016 exceed the proposed nutrient concentration objectives (Figure

2). Exceedances are not unexpected given water quality challenges in the Red River and downstream in Lake Winnipeg.

Following a review by members of the Water Quality Committee, participating agencies and IJC staff, the International Red River Board and the International Joint Commission accepted the stressor response report from RESPEC and the report was made available on the Board's web site.

The RESPEC report (2016) was subsequently peer reviewed in 2018/19 by Walter Dodds and Helen Baulch under contract through the International Joint Commission. Dodds and Baulch concluded that the nutrient objectives suggested were within a range of reasonable numbers that could be detected from available data and that the approach used was consistent with that recommended by agencies such as the US EPA. Dodds and Baulch also supported the use of both phosphorus and nitrogen concentration objectives and the use of artificial periphyton substrata to understand the potential for algal growth in the Red River.

Dodds and Baulch did note that the RESPEC recommended nutrient concentration objectives are significantly higher than baseline nutrient concentrations observed in the absence of anthropogenic influences by a number of other studies in similar ecozones (0.013 to 0.054 mg/L Total Phosphorus and 0.165 to 0.589 mg/L Total Nitrogen, from Smith et al. (2003) and Dodds and Oakes (2004)). They also note that the recommended concentration objectives exceed those criteria proposed by Chambers et al. (2012) for the Canadian Prairies. One of the challenges with developing nutrient objectives for large prairie rivers that have significant anthropogenic disturbance in their watersheds is the lack of suitable reference or comparable sites. Approaches to developing nutrient objectives that make use of ecozone or regional objectives are also less relevant. RESPEC noted this in their comprehensive 2013 report that considered reference, ecozone and regional approaches (among others) and recommended the stressor response modelling approach for the Red River. However the concern expressed by Dodds and Baulch that the proposed nutrient concentration objectives could be above those that would be expected to protect biotic integrity and water quality in the Red River is noted. Additional perspective on comparison to other concentrations and objectives, including historical Red River water quality, is described below. Clearly, ongoing adaptive management will be required to assess the effectiveness of the proposed concentration objectives. Dodds and Baulch also note the lack of certainty around the nutrient concentration objectives proposed and suggest that additional data may be available in the future to further assess the proposed targets. While the reviewers confirmed that the multivariate approaches used were appropriate, given data availability additional statistical analyses are not possible at this time. The Water Quality Committee will consider future opportunities to incorporate additional data and statistical analysis as part of the Component Six of the Nutrient management Strategy (see below).

Downstream Approach – Nutrient Loading Targets

Manitoba Sustainable Development has developed draft nutrient targets for Lake Winnipeg and the tributaries to the lake including the Red River. The draft targets are based on a number of pieces of information collected over the past almost 20 years including:

- Manitoba Sustainable Development and Environment and Climate Change Canada along with many partners summarized information on physical, chemical and biological characteristics of the lake in a report on the State of Lake Winnipeg.

- A group of stakeholders reviewed nutrient and algae issues on Lake Winnipeg and compiled information on setting long term, ecologically relevant nutrient objectives for the lake.
- Manitoba Sustainable Development studied preliminary nutrient loads to Lake Winnipeg and examined trends in nutrient concentrations in rivers and streams flowing into Lake Winnipeg. The work demonstrated that there are many small sources of nutrients to Lake Winnipeg and that nutrient concentrations are increasing in many streams across Manitoba.
- Dr. Peter Leavitt from the University of Regina and his research partners used sedimentary records to study historical nutrient concentrations and algal abundance and community composition in Lake Winnipeg. Dr. Leavitt concluded that total phosphorus concentrations in Lake Winnipeg increased from 0.015 mg/L in the 1800s to 0.05 mg/L in the early 1990s to more than 0.1 mg/L in the present day. Dr. Leavitt recommended that total phosphorus concentrations be reduced back to 1990s levels of 0.05 mg/L to reduce the frequency and severity of cyanobacteria blooms (http://www.manitoba.ca/sd/pubs/water/lakes-beaches-rivers/report_lake_wpg_paleolimnology.pdf and also Bunting et al. 2016).
- Dr. Greg McCullough and others observed that runoff from the Red River watershed rose abruptly in the mid-1990s. With a phosphorus balance model for Lake Winnipeg, Dr. McCullough and his colleagues demonstrated that increases in streamflow in the Red River along with increased nutrient loading contributed to the mid-1990s increase in phosphorus in Lake Winnipeg (McCullough et al. 2012).
- David Donald and his colleagues demonstrated that large lakes and reservoirs in the Saskatchewan, Dauphin, and Winnipeg watersheds within the Lake Winnipeg basin retained large quantities of nitrogen and phosphorus (Donald et al. 2015). Of all major tributaries, the Red River watershed discharged the largest quantities of nutrients into Lake Winnipeg, had the highest nutrient concentrations, and retained the lowest quantity of nutrients. While nutrient management initiatives within the Saskatchewan, Dauphin and Winnipeg watersheds could have local benefits, Donald and his colleagues concluded that nutrient management initiatives upstream of these lakes and reservoirs would have minimal nutrient reduction benefit for Lake Winnipeg. They recommended that the Red River watershed should be of primary importance for nutrient management strategies and nutrient reduction.
- Environment and Climate Change Canada developed a water quality model for Lake Winnipeg (Zhang and Yerubandi 2012) and Manitoba Sustainable Development used the model to predict how Lake Winnipeg would respond to changes in phosphorus and nitrogen concentrations and streamflow in four main rivers flowing into the lake (Dauphin, Red, Winnipeg and Saskatchewan Rivers).

Objectives for the lake are based on the concentration of nitrogen and phosphorus measured in the south (including the narrows) and north basins of the lake and are intended to be applied as an annual average for the open water season (Table 1).

Table 1. Draft phosphorus and nitrogen concentration objectives for the south and north basin of Lake Winnipeg.

Basin	Phosphorus Concentration Objective (mg/L)	Nitrogen Concentration Objective (mg/L)
South Basin	0.05	0.75
North Basin	0.05	0.75

Nutrient load targets for the rivers flowing into Lake Winnipeg are based on both the nutrient concentration and the streamflow in the river. River nutrient load targets represent the total load of nitrogen and phosphorus carried by the river over a one year period (Table 2).

Table 2. Total phosphorus and nitrogen loading targets for the Red River at Selkirk, Manitoba.

	Total Phosphorus Load Target (tonnes per year)	Total Nitrogen Load Target (tonnes per year)
Red River (at Selkirk)	2,800	19,050

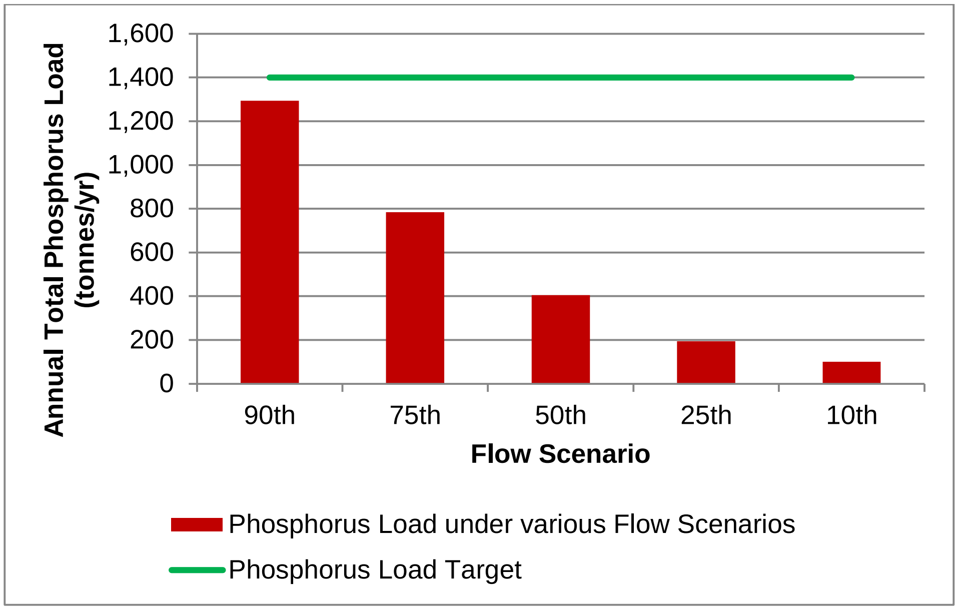
Manitoba Sustainable Development's work identified nutrient load targets at the most downstream long term monitoring station on the Red River, at Selkirk, Manitoba (Table 2). However, the Committee was tasked with developing nutrient targets at the US/Canada border. Therefore, the nutrient loads at Selkirk, Manitoba needed to be allocated between Canada and the US. The Committee considered a number of methods for allocating the load including dividing the US-Canada allocation by the proportion of the watershed in each jurisdiction (55.9 % Canada and 44.1 % US), by the proportion of average flow contributed from each jurisdiction (39 % Canada and 61% US), or dividing by the portion of the nutrient load contributed by each jurisdiction. For the proportion of the nutrient load, two options were available – average nutrient loads calculated by Sustainable Development at Selkirk and at Emerson, Manitoba or proportions of nutrient loads calculated by the International Joint Commission led SPARROW model (Benoy et al. 2016). Since the SPARROW work focused on the base year 2001 and the average nutrient loads covered a longer period (1994 to 2014), the committee recommended splitting the nutrient allocations for nitrogen and phosphorus based approximately on the 1994 to 2014 calculated proportional loads (total phosphorus 51.5% Canada and 48.5 % US, nitrogen 45.1 % Canada and 54.9 % US). For simplicity and because the proportions were close to 50-50, the Committee recommends allocating 50 % of the loads to each country such that 50 % of the nutrient load target calculated at Selkirk, Manitoba would be allocated to the US as measured at the long term water quality monitoring station at Emerson, Manitoba (Table 3).

Table 3. Total phosphorus and nitrogen loading targets for the Red River at the US/Canada border (Emerson, Manitoba)

	Total Phosphorus Load Target (tonnes per year)	**Total Nitrogen Load Target (tonnes per year)**
Red River (at Emerson)	1,400	9,525

Reconciling the Stressor Response Concentration Objectives and the Downstream Derived Nutrient Load Targets

The dual approach to setting nutrient targets resulted in both proposed concentration objectives and nutrient load allocation targets at the US/Canada border at Emerson. The Committee conducted an analysis to examine how the loads and concentrations compared under a range of flow conditions. The proposed concentration objectives for the Red River (0.15 mg/L TP and 1.15 mg/L TN) were combined with a range of flow scenarios including historical (1994 to 2018) and the 90th, 75th, 50th, 25th and 10th percentile flows. Resulting hypothetical nutrient loads were compared to proposed nutrient load allocation targets at the US/Canada border (Figures 3 and 4). Under all but the 90th percentile flows for nitrogen and high flow historical years (1997, 1999, 2009, 2010, 2011 for nitrogen and phosphorus plus 1998, 2000, 2001 and 2005 for nitrogen), achieving the proposed concentration objectives would meet the proposed nutrient load targets at the US/Canada border.



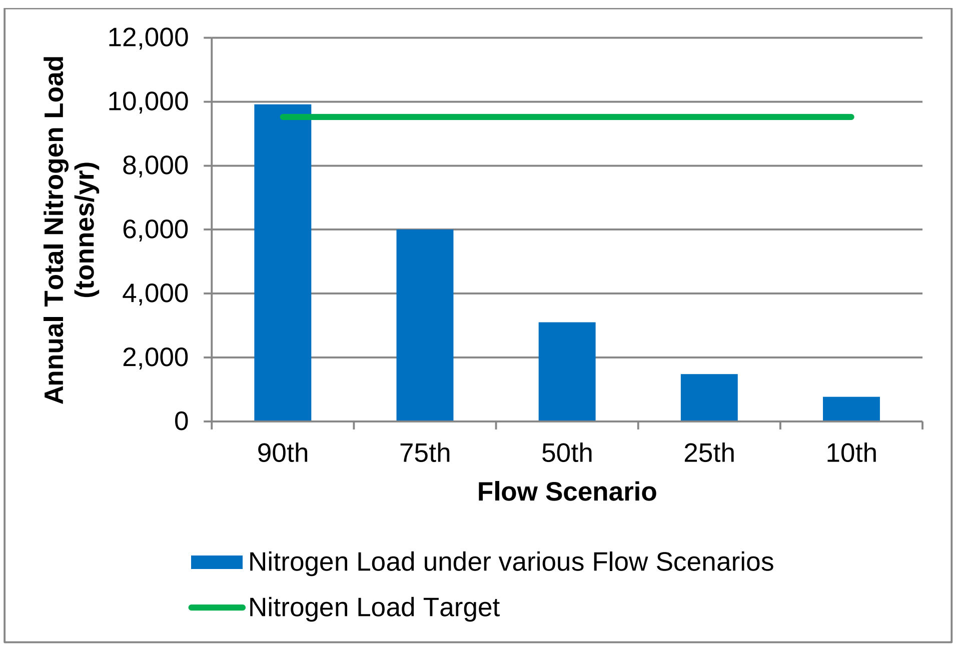


Figure 3. Hypothetical nutrient loads based on meeting the proposed concentration objectives under five flow scenarios at the US/Canada border (Red or Blue bars). Includes proposed nutrient loading targets (green line) for phosphorus (top) and nitrogen (bottom).

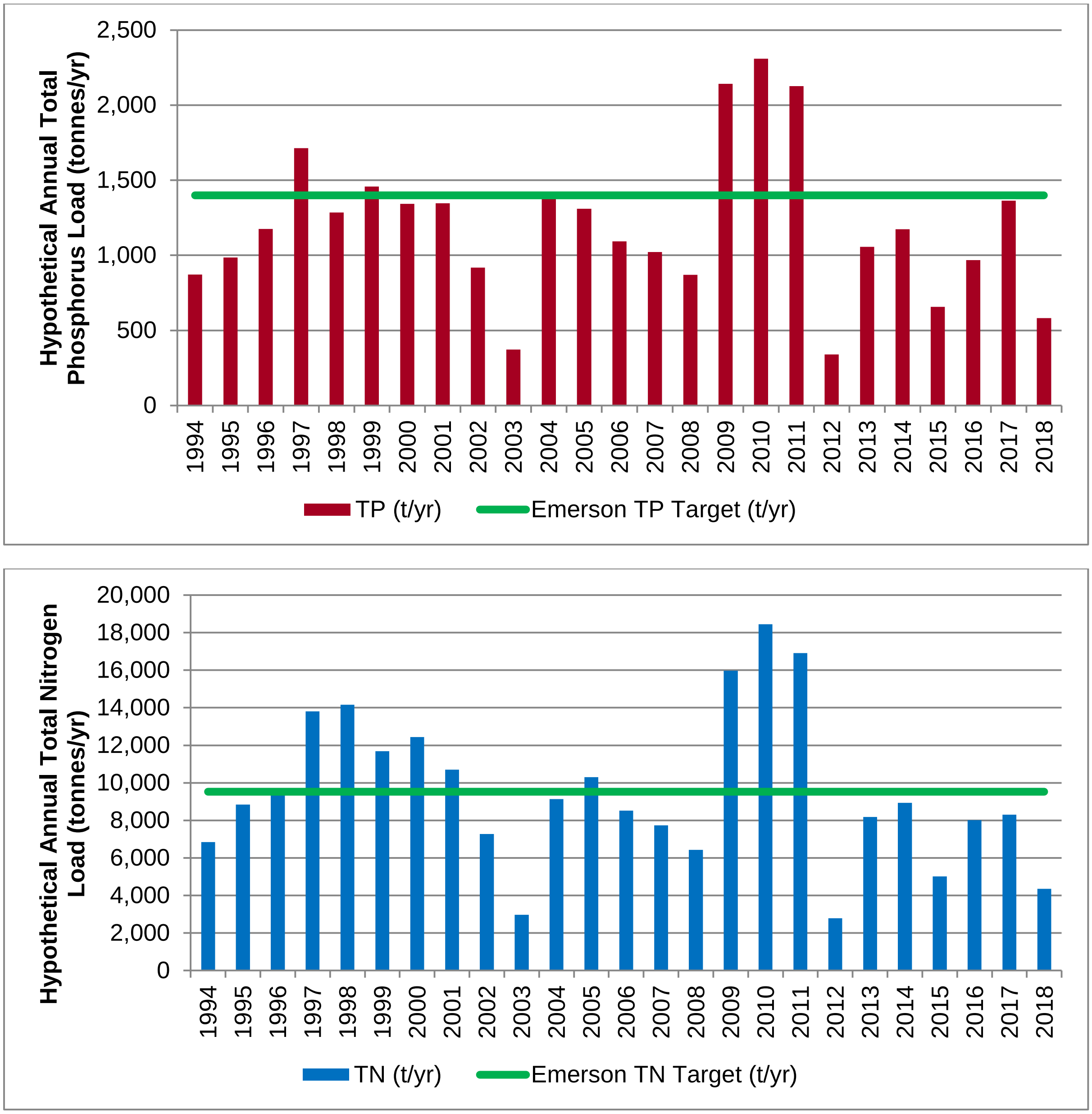


Figure 4. Hypothetical nutrient loads based on meeting the proposed concentration objectives under the historical flow scenario at the US/Canada border. Includes proposed nutrient load targets (green line) for phosphorus (top) and nitrogen (bottom).

<u>Application</u>

The proposed dual approach includes recommended nutrient concentration objectives and nutrient load targets at the US/Canada border. The Committee proposes different application of the concentration objectives vs. the load targets.

For the concentration objectives, the Committee proposes that the 0.15 mg/L total phosphorus and 1.15 mg/L total nitrogen objectives be applied only during the open water/growing season in the Red River between April 1st and October 30th each year. Seasonal averages for each year would be compared to the concentration objectives. A seasonal approach recognises the different ecological periods in the Red River characterized by the ice-covered vs. open water seasons, different flow regimes during the two periods (more stable flows during ice-covered season) and the higher water temperatures during the open water season that support biological growth including algae. The seasonal application of nutrient concentration objectives has been used elsewhere including by the Prairie Provinces Water Board (PPWB 2015), the Bow River Basin in Alberta (https://brbc.ab.ca/our-activities/bow-basin-watershed-management-plan), the North Saskatchewan River (https://www.nswa.ab.ca/wp-content/uploads/2018/05/Proposed-Site-Specific-Water-Quality-Objectives-for-the-Mainstem-of-the-North-Saskatchewan-River.pdf), and Montana (Montano Department of Environmental Quality 2015). Proposed concentration objectives are also comparable to those concentrations observed in the headwaters region of the Red River during the study and to those objectives applied elsewhere including in Minnesota (South River Nutrient Region, Phosphorus, total – less than or equal to 0.150 mg/L) and Montana (Northwestern Great Plains 0.150 mg/L TP and 1.3 mg/L TN).

For the nutrient load targets, the Committee proposes that the targets be compared to the five year running average nutrient loads measured for the Red River at the US/Canada border at Emerson. Nutrient loads vary from year to year and are strongly dependent on flow. Averaging across multiple years allows for a better understanding of changing nutrient concentrations and the results of nutrient reduction activities. An example of application to water quality and flow data collected at Emerson, Manitoba by Environment and Climate Change Canada is presented in Figure 5. Nutrient loads presented in Figure 5 calculated by Manitoba Sustainable Development with methods described in the 2011 State of Lake Winnipeg report.

Environment and Climate Change Canada monitors water quality and quantity at the US/Canada border at Emerson and these data will provide nutrient concentrations to compare to the nutrient concentration objectives and will be used to calculate running five year average nutrient loads for comparison to the nutrient load targets.

Implementation and Adaptive Management

Nutrient concentrations have increased in the Red River over the last several decades (for example, Jones and Armstrong 2001) and reducing nutrient concentrations in the Red River and loading downstream is expected to be a long-term endeavour that could take more than a decade. Current nutrient concentrations in the Red River at the US/Canada border are well above the proposed concentration objectives and load targets (see for example, Figures 2 and 5).

Preliminary results from a recent U.S. Geological Survey (USGS) and Water Quality Committee trend analysis project, funded largely by the International Watershed Initiative, helps to put nutrient objectives in perspective of recent and historical trends of TP and TN for the Red River at Emerson. The trend analysis is being performed by the USGS using QWTREND, a statistical time-series model for analyzing complex flow-related variability and trends in constituent concentrations and loads (Vecchia, 2000, 2003, 2005, 2019 in draft). Final results will be published in a USGS Investigations Report expected in late 2019. Preliminary trend results are plotted along with the proposed nutrient concentration objectives in Figure 6. Generally, for the Red River at Emerson from 1970-2017, the flow-averaged trend of TP concentrations has increased and the flow-averaged trend in TN concentrations overall has decreased for the same period (Figure 6). The points in Figure 6 are flow-adjusted concentrations that are estimated by QWtrend and the solid line is the flow-averaged trend through time. For both TP and TN, a 2-period trend model was used with an early period (1980-1995) and a later period (2000-2015). Trend analysis time periods were selected based on several factors: data from 1970-1980 were too sparse to analyze for trends; a significant step (abrupt) trend was detected for TN because of a change in analytical method on October 1, 1993; generalized likelihood ratio tests (Vecchia, 2005, appendix 1) were used to determine if the 2-period trend was a significantly better fit than no trend (null model); and for comparison between TP and TN, consistent trend periods were used. A significant (P-value < 0.01) uptrend in TP of 35% was detected for the early period and another significant uptrend of 26% was detected for the late period (Figure 6A). The concentration of the flow-averaged trend increased from 0.18 mg/L in 1980 to 0.24 mg/L in 1995 to 0.30 mg/L in 2015 (Figure 6A). In contrast, for the early period, TN significantly decreased by 23% and for the late period a nonsignificant (P-value > 0.05) increase of about 7% was detected and concentration of the flow-averaged trend decreased from 2.22 mg/L in 1980 to 1.71 mg/L in 1995 and increased to 1.84 mg/L in 2015 (Figure 6B).

Annual loads from QWTREND for TP and TN for the Red River at Emerson are presented in Figure 7 along with the proposed nutrient load targets. The points in Figure 7 are model-estimated loads, which demonstrate the annual variability in loads due to the variability in streamflow. The solid lines on Figure 7 are the flow-averaged loads which is sometimes referred to as “flow-normalized” load. In other words, this is the hypothetical annual load if flow conditions had been the same year after year for the entire analysis period. The variability is much less for the flow-averaged load because flow has been considered. As indicated by the trend line, the annual flow-averaged TP load has increased from 1,460 tonnes per year in 1980 to 2,480 tonnes per year in 2015 (Figure 7A). The annual flow-averaged TN load has decreased from 16,300 tonnes per year in 1980 to 13,500 tonnes per year in 2015 (Figure 7B).

While reducing nutrient concentrations and loads will take time, the proposed objectives and targets provide important benchmarks for measuring progress. Work towards reducing nutrients at the international boundary will be achieved through the ongoing nutrient reduction strategies and approaches within each jurisdiction and also through collaborative initiatives like the Red River Basin Commission’s Water Quality Strategic Plan for the Red River Basin.

Per Component Six of the International Red River Board’s nutrient management strategy, the Committee will also continue to review and adapt the proposed objectives and targets where required. Progress towards meeting the objectives and targets will be assessed annually at the board’s August/September meeting and as part of the board’s annual report.

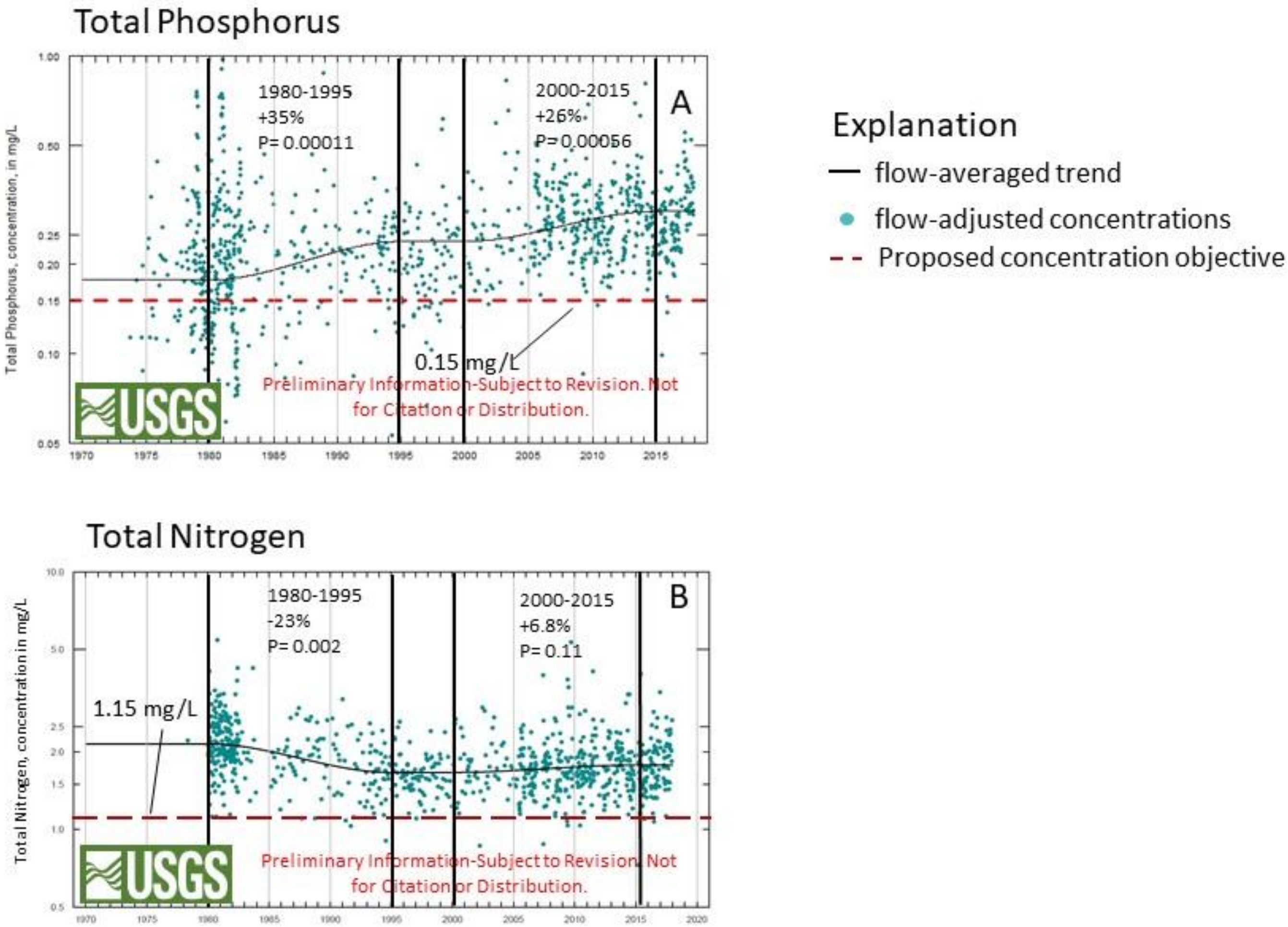


Figure 6. Trends in TP (A) and TN (B) for the Red River at Emerson for 1970-2017

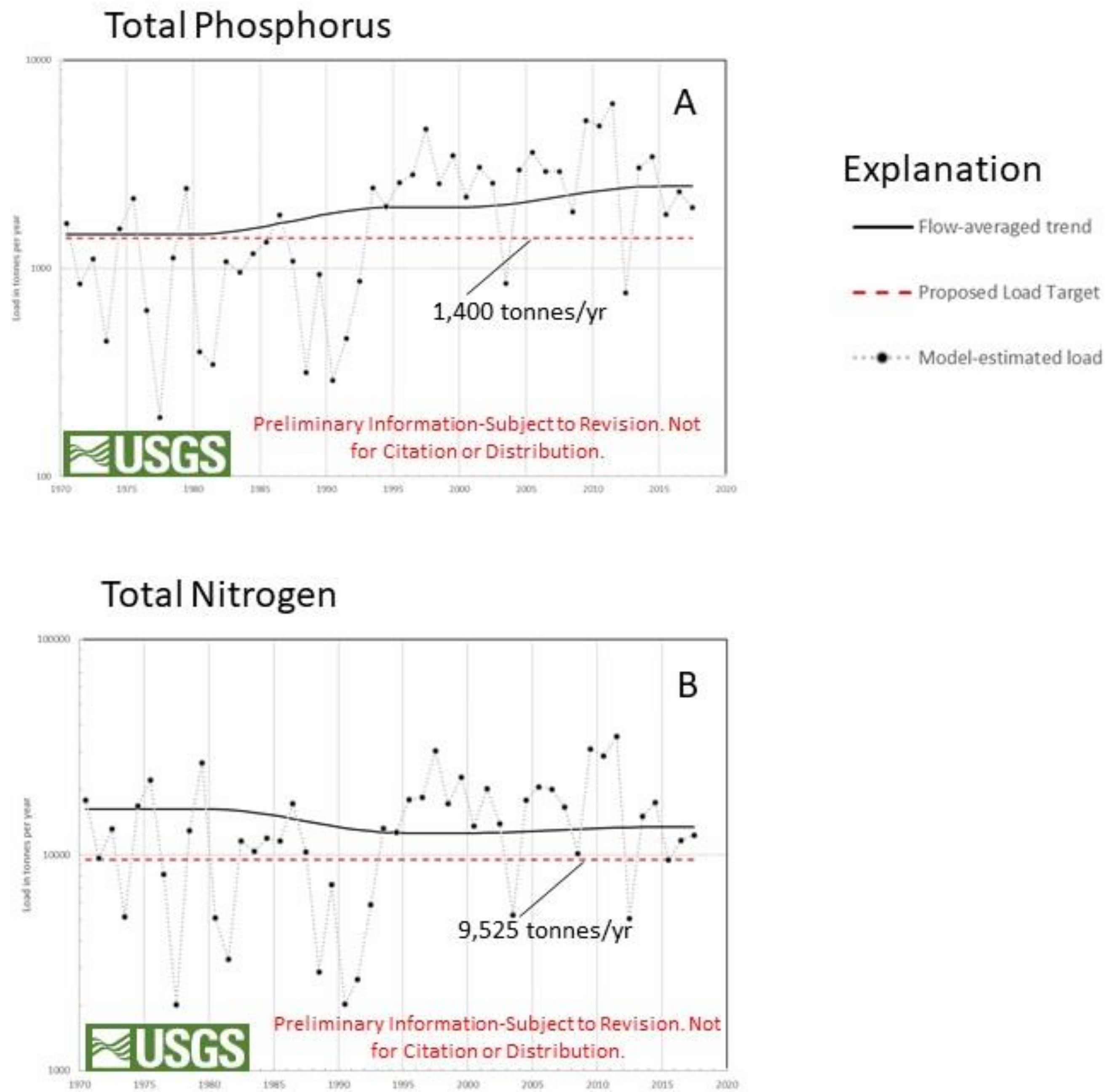


Figure 7. Annual loads of TP (A) and TN (B) for the Red River at Emerson for 1970-2017

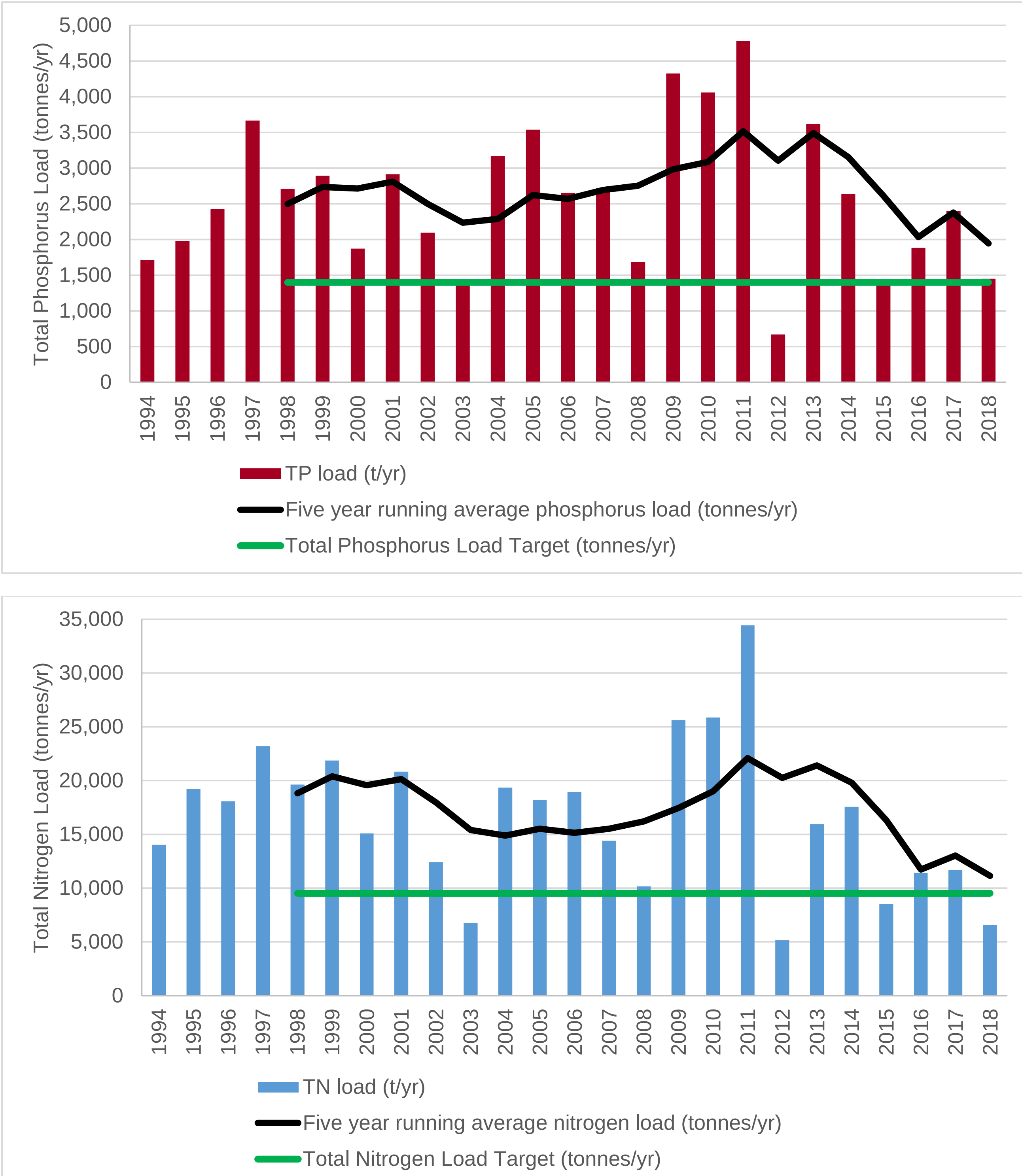


Figure 5. Annual total nutrient loads compared to the running five year average and the proposed nutrient load targets for the years 1994 through 2016 on the Red River at the US/Canada border (Emerson) for phosphorus (top) and nitrogen (bottom).

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