A Nutrient Loading Model for Lake Winnipeg
to estimate the impacts of various nutrient management strategies

Page, S.J.[1] , Hesslein, R.[1] , McCullough, G.[2] , Stainton, M.[1]

1. Fisheries and Oceans Canada: Winnipeg, MB 2. University of Manitoba, Centre for Earth Observation Sciences

Overview

Over the past few decades, scientists have observed significant changes in the state of Lake Winnipeg, which has in turn spawned an environmental awareness for many Manitobans and Canadians. Since the 1990s, algal blooms on this great lake have increased in size, frequency and intensity: a threatening indicator of a deteriorating ecosystem. While these algal blooms have often been linked to increased human activities in the watershed (e.g. municipal sewage, septic fields, industrial discharge, livestock manure, agriculture, urban runoff) , climate related events may be having a more significant and pressing influence on their occurrence and extent .

We employ a STELLA based nutrient loading model which simulates lake nutrient concentrations (carbon, nitrogen and phosphorus) from 1913 to 2006 based on historical river inputs. In addition, we then use the same model to predict future lake concentrations based on various flow regimes as well as to estimate the impact of various proposed nutrient management strategies.

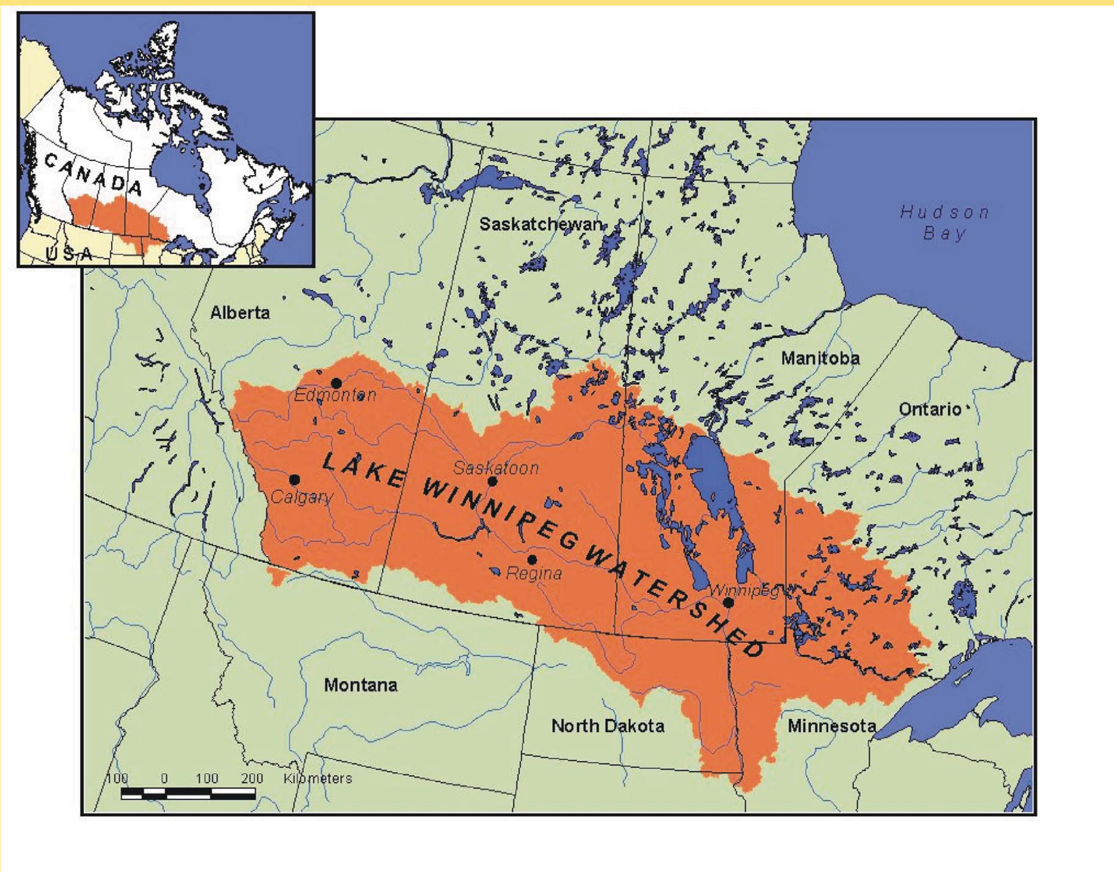

Figure 1: The Lake Winnipeg watershed (953,000 km²). At 40:1, Lake Winnipeg has the largest land drainage to lake surface area ratio of any of the great lakes of the world

Figure 2: Lake Winnipeg and its tributaries. It is the 10th largest body of freshwater in the world, in terms of surface area (24,500 km²). Over 95% of its inflow comes from 3 rivers: Red, Winnipeg and Saskatchewan River

Proposed Nutrient Management Strategies

Various Nutrient Reduction Objectives have been proposed to mitigate the eutrophication of Lake Winnipeg:

1) Reduction of nitrogen loading by 13% and phosphorus loading to the lake by 10%

2) Return Lake Winnipeg to a prior condition (i.e. "1970 loading conditions")

3) Remove nitrogen and phosphorus from point sources (i.e. manage urban effluent: 400 tonnes-P Winnipeg)

4) Managing the lake to a target phosphorus concentrations (eg 25ug/L TP)

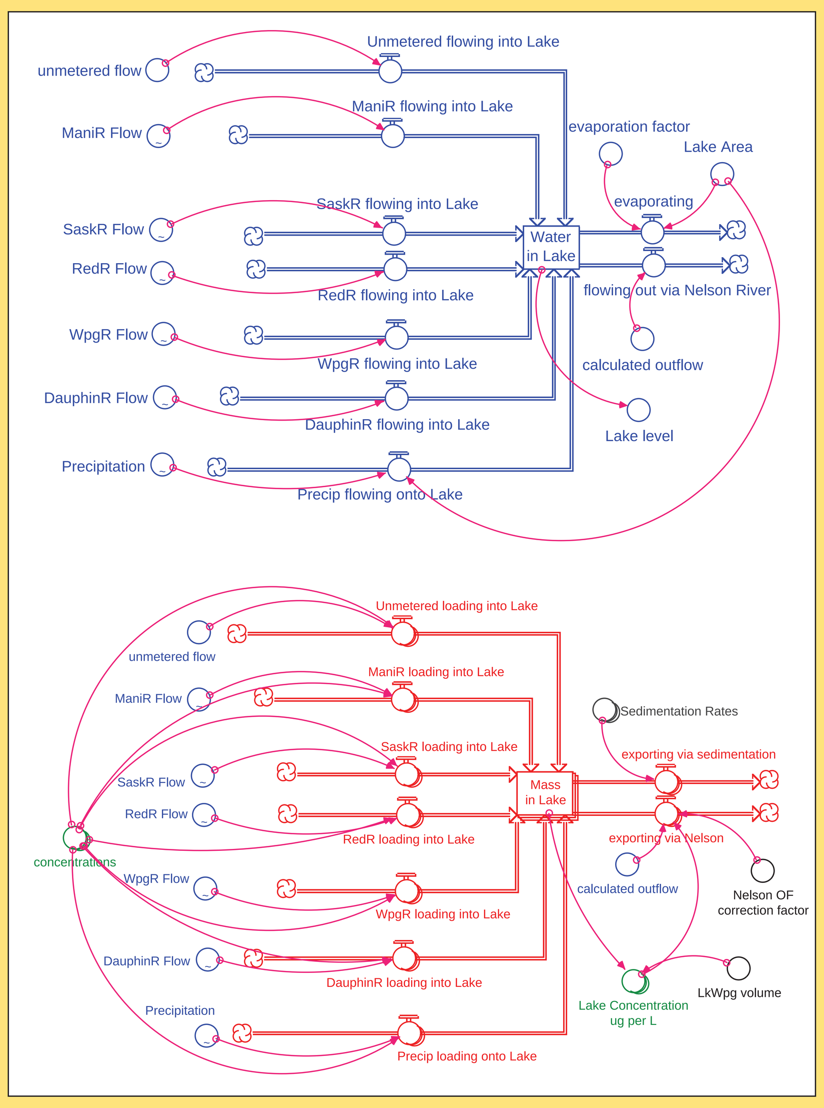

Figure 3: Nurient Loading Model. Upper section (blue) focuses on the water budget while the lower section estimates the mass loading (red) and lake concentrations (green)

Model Description

Various agencies have been collecting hydrometric data on or around Lake Winnipeg since the early 1910s. Sampling for water chemistry did not commence until 1969, and only in a select few tributaries. Since 1999, a more thorough sampling program has been initiated, providing current data for model calibration.

The model estimates all sources of nutrient inputs based on calculated loading from nutrient *concentration* versus *discharge* versus *time* analysis. Because we know the discharge data from each of the inputs (km³/month) and have generated modeled concentrations of the nutrients in each input (ug/L), we are able to assertain an estimate of the monthly loading (tonnes) to the Lake.

As each of the mitigation strategies deals with a reduction in loading of nutrients to Lake Winnipeg, the model provides insights into the effectiveness of each proposed approach.

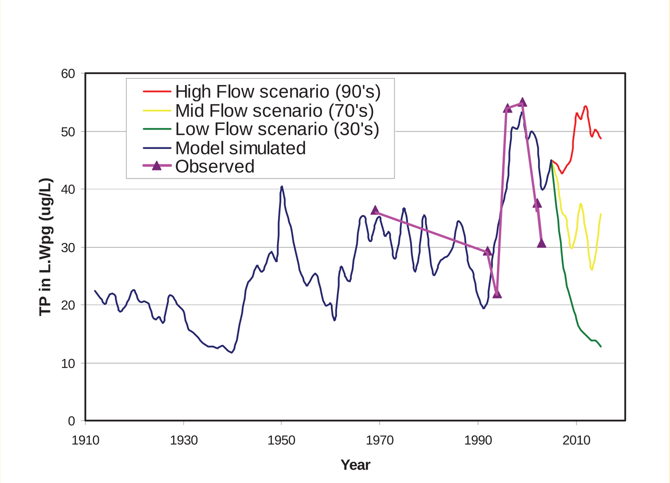

Figure 4: model estimated historical total phosphorus concentrations compared with observed values. Also shown are predicted total phosphorus concentrations for the next decade under three flow scenarios.

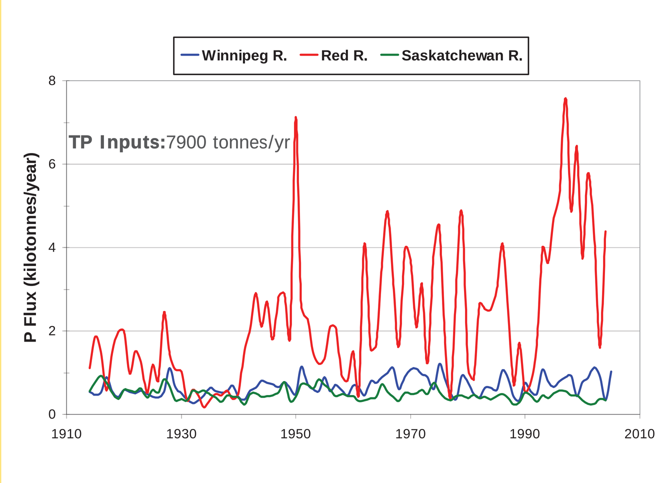

Figure 5: historical % contribution of each of the major tributaries

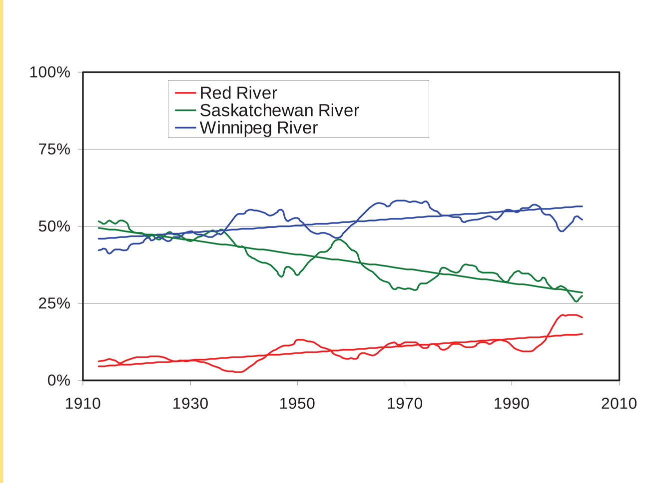

Figure 6: phosphorus fluxes into Lake Winnipeg from the three main tributaries

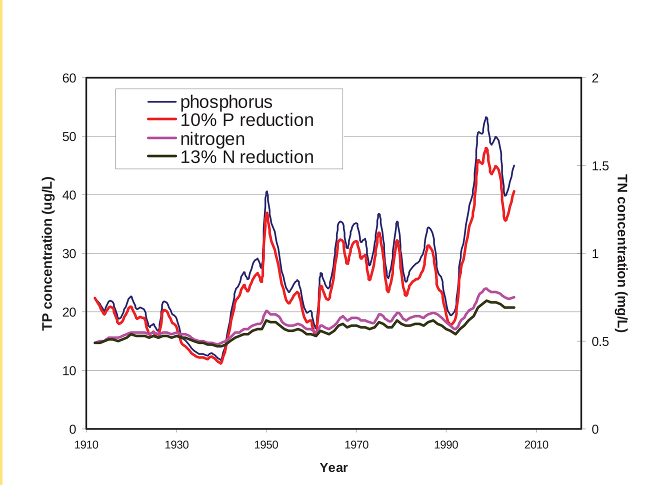

Figure 7: model simulated response to reducing nitrogen and phosphorus loading by 13% and 10% respectively (nutrient management strategy #1)

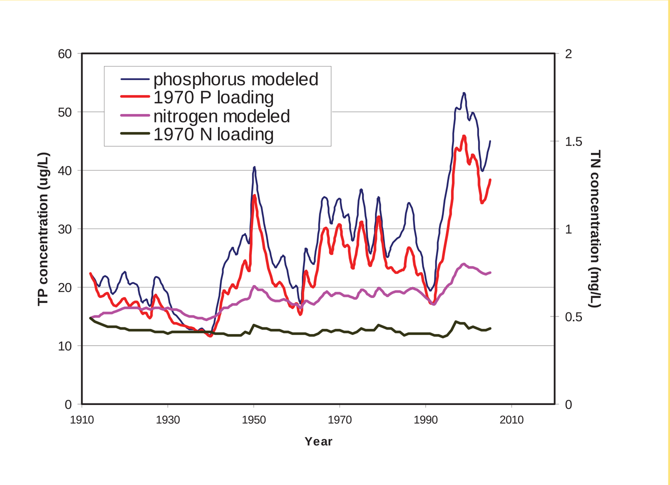

Figure 8: model simulated response to returning the nutrient loading to Lake Winnipeg to a prior condition (based on 1970 loadings)
(nutrient management strategy #2)

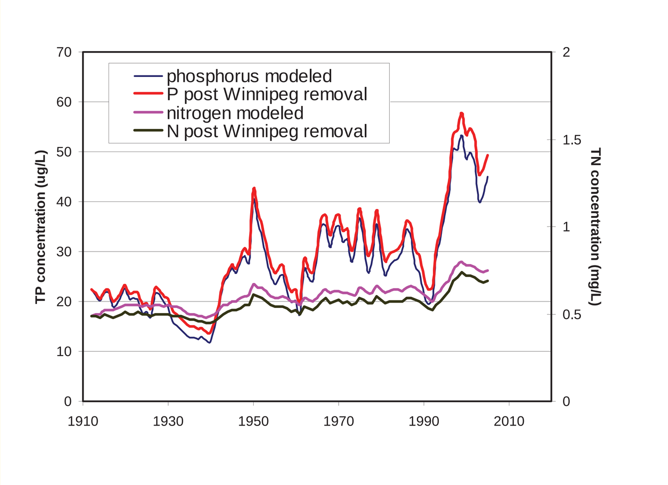

Figure 9: model simulated response to removing nitrogen and phosphorus from point sources. The City of Winnipeg contributes 400 tonnes of P and 3600 tonnes of N annually. (nutrient management strategy #3)

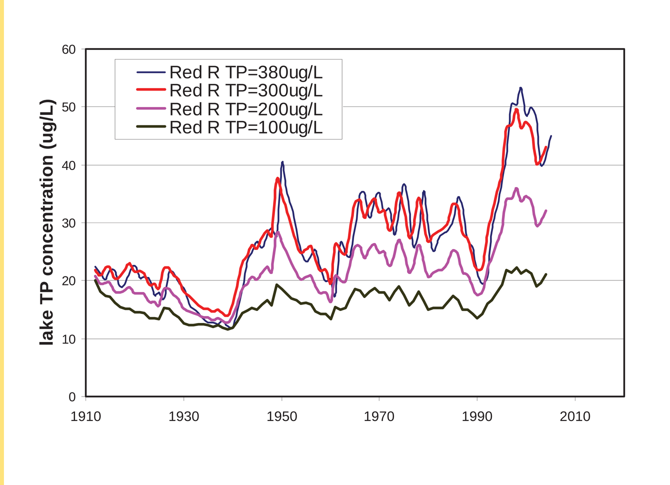

Figure 10: Lake phosphorus response to various mean annual concentrations of the Red River. Current TP concentrations are 380ug/L

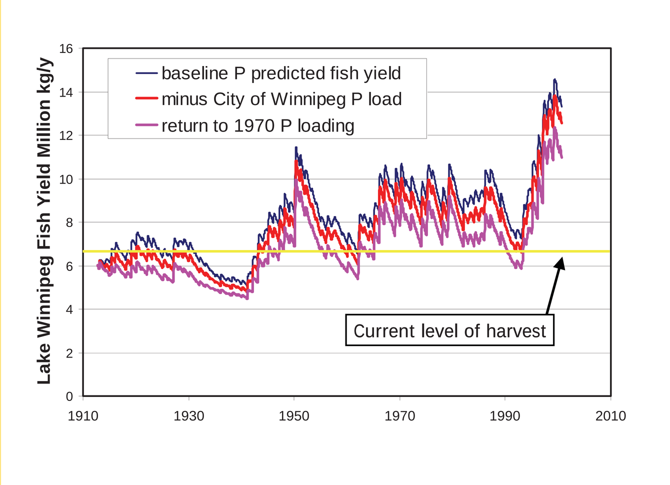

Figure 11: Lake Winnipeg modeled Fish Yield based on lake phoshorus concentrations

Results

Model results predict whole lake validation TP data very well (figure 4). Model data and validation data are within 10%

Model simulated fluxes illustrate that the Red River is the dominate tributary loading nutrients to the Lake (figure 5)

The increase in phosphorus concentration in Lake Winnipeg is fully explained by mixing this higher proportion of P-rich Red River water into the lake. This is attributed to changes in flow of Red River, relative to the other major river inputs (figure 6)

All three proposed nutrient management strategies did not change the lake nutrient concentrations significantly (figures 7, 8, and 9)

To lower Lake Winnipeg P to 25ug/L under current high flow conditions of the Red River requires lowering mean annual concentration to 100 ug/L (figure 10)

Depending on the total annual loading of phosphorus, nutrient management strategies may have an adverse effect on annual fish yields (figure 11)

Conclusions

While there is no doubt that there has been an increase anthropogenic impacts on Lake Winnipeg in recent decades, we conclude that the dominant factor driving recent increases in frequency and size of cyanophyte blooms has been the increase in flow of the phosphorus rich waters of the Red River relative to other Lake Winnipeg tributaries.

Lowering Lake Winnipeg phosphorus concentration may be difficult. As we implement our management strategies, we must take into consideration that some areas of the watershed have a larger impact than others, and focus our efforts accordingly. But if these recently observed climatic and human-induced changes do in fact continue, adaptation may become just as important as mitigation.