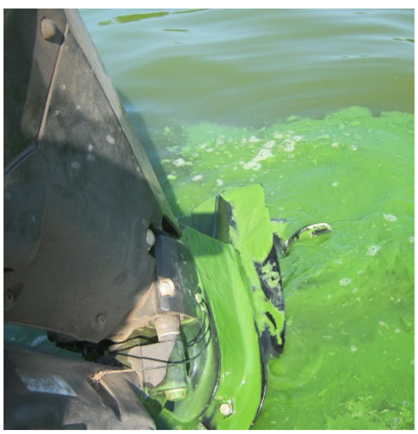
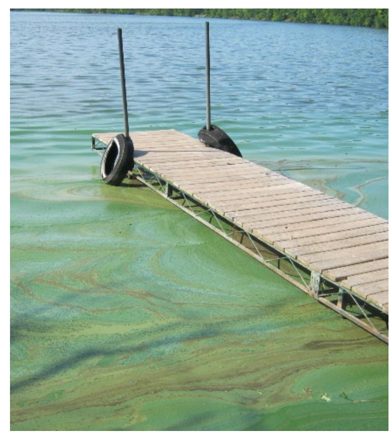
Staples Lake

Phosphorus Loading Study





Wisconsin Department of Natural Resources
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INTRODUCTION

Staples Lake is a 340-acre drainage lake located in Polk and Barron Counties. It has a maximum depth of 17 feet. The lake is hypereutrophic and was listed as impaired for total phosphorus in the 2018 303(d) Impaired Waters List. In 2019, the Wisconsin Department of Natural Resources (DNR) conducted a phosphorus loading study on Staples Lake. The goal of the study was to determine whether the lake's high phosphorus concentration is a result of external loading from the watershed or internal loading from the lake sediment. The results of the study are described in this report.

ABOUT THE WATERSHED

Staples Lake is located in the Staples Creek/Apple River Watershed (HUC 12). Approximately 11,500 acres of land drain to the lake, with forest and agriculture predominating the landscape (Figure 1) (Wiscland 2). Staples Lake has two primary surface water inputs: Staples Creek, an 8-mile intermittent stream and Long Lake, a 61-acre seepage lake with a maximum depth of 44 feet. There are no point sources in the watershed.

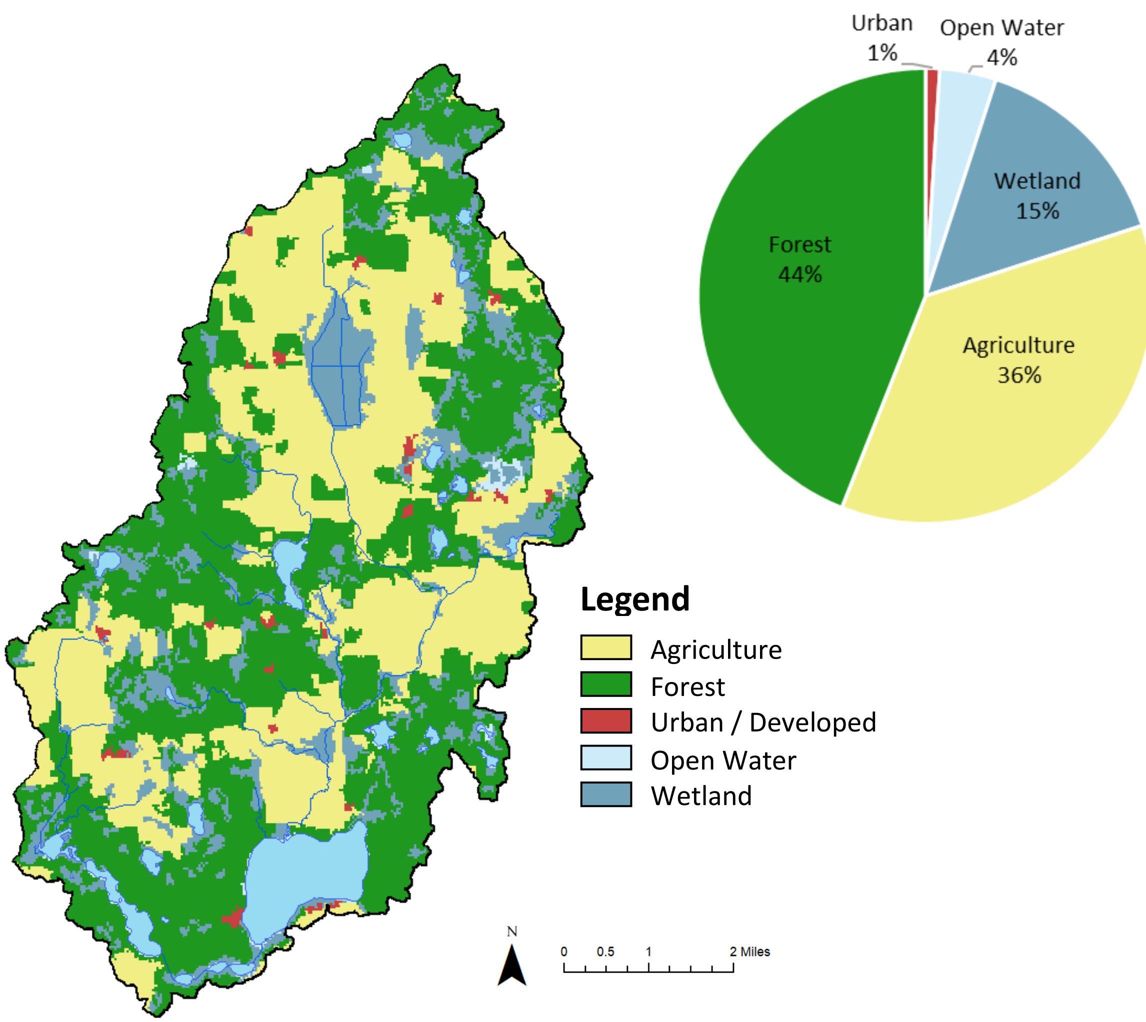


Figure 1: Staples Creek / Apple River watershed land use

METHODS

In order to estimate the external and internal phosphorus load to Staples Lake, water quality monitoring and flow monitoring was conducted at multiple sites in the watershed between March and October. The sampling sites included two upstream Staples Creek locations, Staples Lake, and the lake's two inlets and outlet (Figure 2). Pressure transducers were also installed at the inlets and outlet of the lake to continuously monitor stage. Total phosphorus and stream flow were measured monthly on Staples Creek, and bi-weekly at the inlets and outlet. Water quality monitoring for Staples lake included bi-weekly sampling of top and bottom phosphorus, iron, water clarity, temperature, and dissolved oxygen. External loading was estimated using the USGS Load Estimator, and internal loading was estimated using the Jensen Shallow Lake Model.

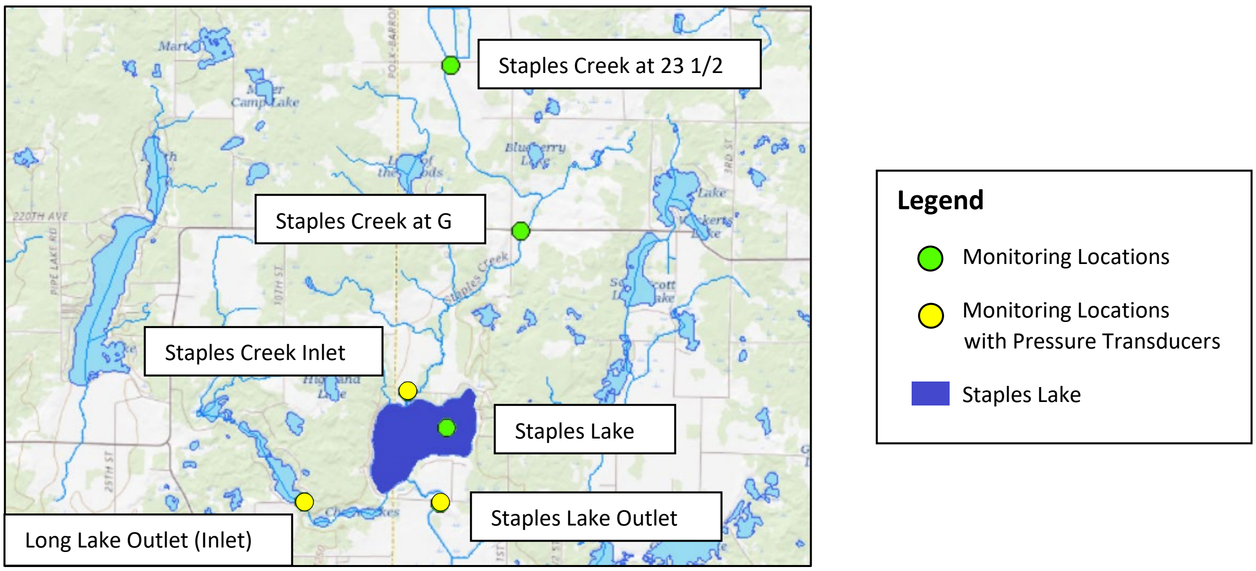


Figure 2: Monitoring locations

RESULTS

Staples Creek

Due to gaps in the dataset, official results for Staples Creek at G and 23 ½ will not be included in this report. During low flow conditions, it was noted that stagnant pools would often form under bridges, potentially accumulating large concentrations of phosphorus. As a result, the samples collected on Staples Creek during the summer when low flows were recorded, may not provide a representative measurement of total phosphorus concentrations in the waterbody. However, the samples collected in spring when higher flows were present, can still provide some insight into the watershed. Two samples collected on May 15th recorded an average total phosphorus concentration of 270 ug/L, suggesting that high volumes of phosphorus are running off the landscape during spring. However, further exploration is needed to verify this statement.

Inlets

The monitoring results for the Staples Lake inlets can be seen in Figures 3-6.

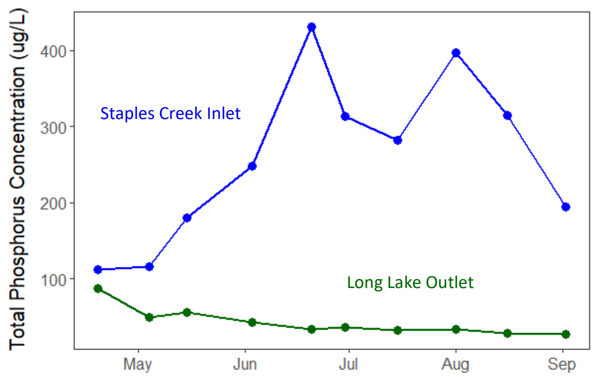


Figure 3: Total phosphorus concentration (ug/L) for Staples Creek Inlet and Long Lake Outlet

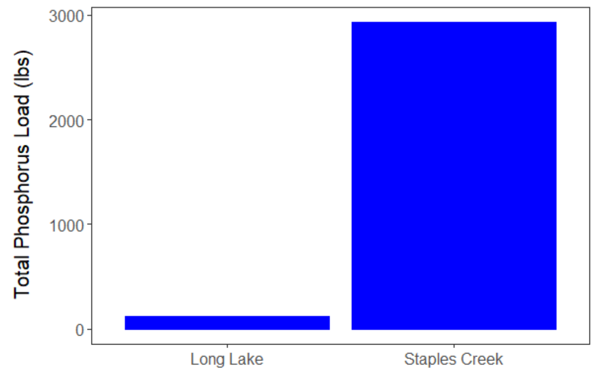


Figure 4: Estimated annual total phosphorus load (lbs) for Staples Creek and Long Lake

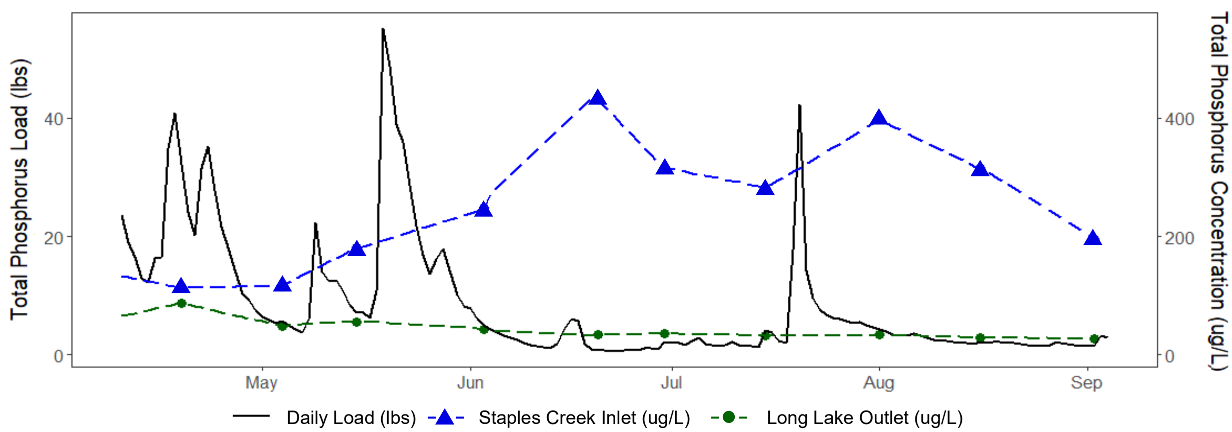


Figure 5: Combined daily total phosphorus load (lbs) of both inlets overlaid with the total phosphorus concentrations (ug/L) of Staples Creek Inlet and Long Lake Outlet

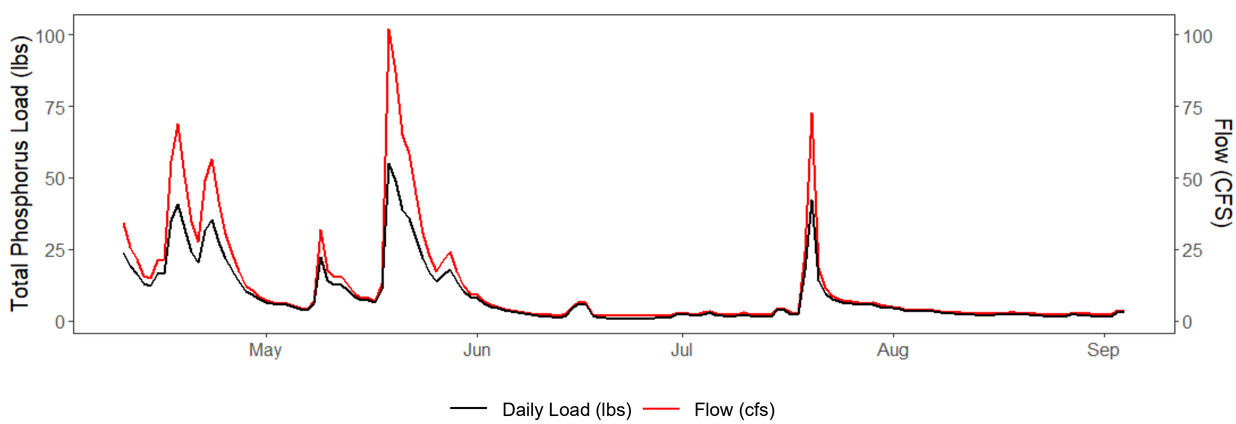
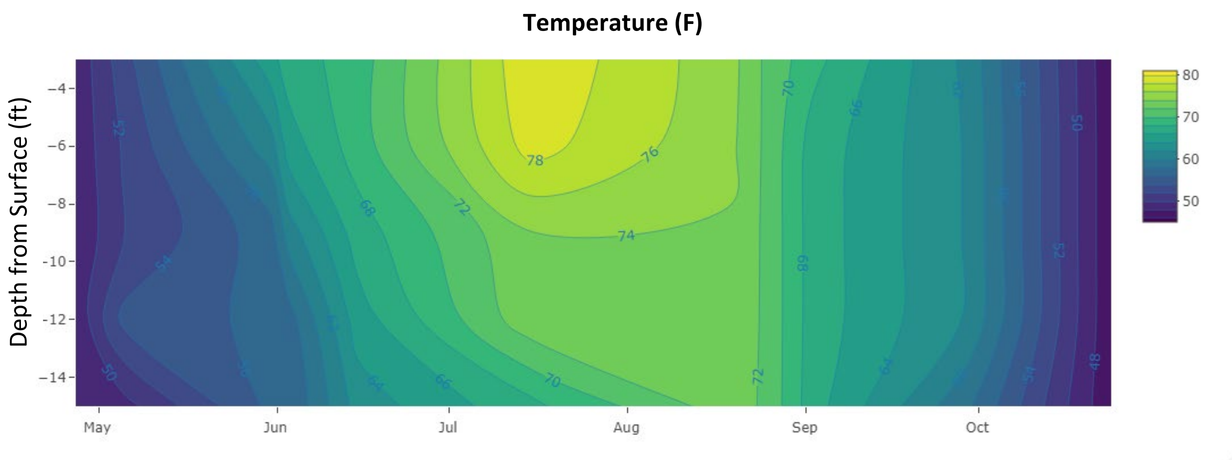


Figure 6: Combined daily total phosphorus load (lbs) and flow (cfs) of both inlets

Based on the monitoring results, the average total phosphorus concentration for the Staples Creek Inlet was 242 ug/L, over three times the Wisconsin phosphorus water quality standard of 75 ug/L for streams. However, the average total phosphorus concentration for the Long Lake Outlet was only 42 ug/L. This trend continues when looking at the annual load of each inlet. In total, Staples Lake received an estimated annual external phosphorus load of 3,052 lbs, with 96% of the load coming from Staples Creek and the remaining 4 % of the load from Long Lake. Even though total phosphorus concentrations were lower for Staples Creek in April and May, loading was still highest during this time when heavier flows from rainfall were recorded. These heavier flows can cause a dilution of total phosphorus concentration in the waterbody resulting in lower total phosphorus concentrations as seen in Staples Creek.

Staples Lake

Staples Lake was stratified from July through August, reaching anoxic conditions in the hypolimnion during this time (Figure 7). The average Secchi depth was 3.3 ft. The lake had a total phosphorus spring average of 111 ug/L, and a summer growing season average of 94 ug/L, both measurements well above the Wisconsin phosphorus water quality standard of 40 ug/L for shallow drainage lakes (Figure 8).



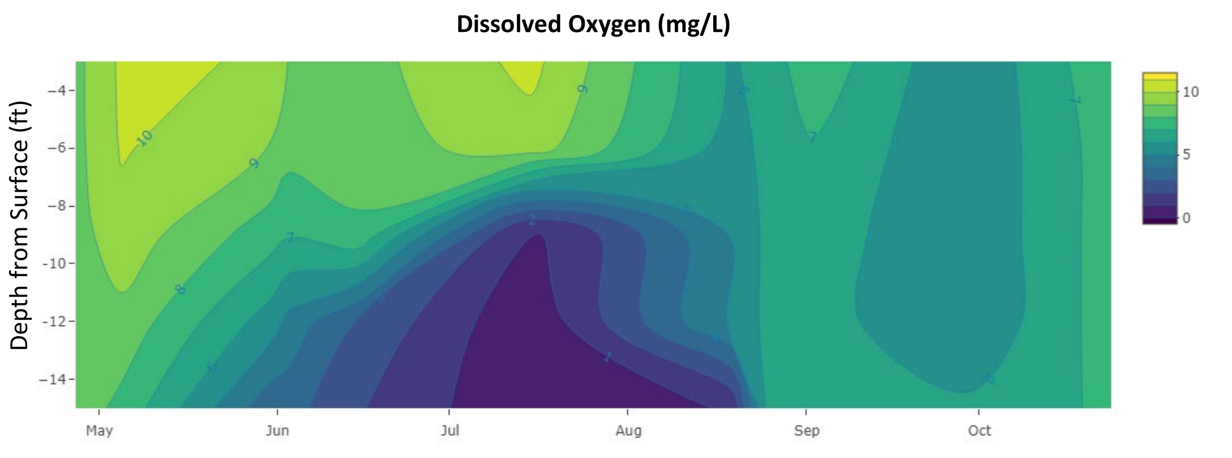


Figure 7: Staples Lake temperature (F) and dissolved oxygen (mg/L) over time

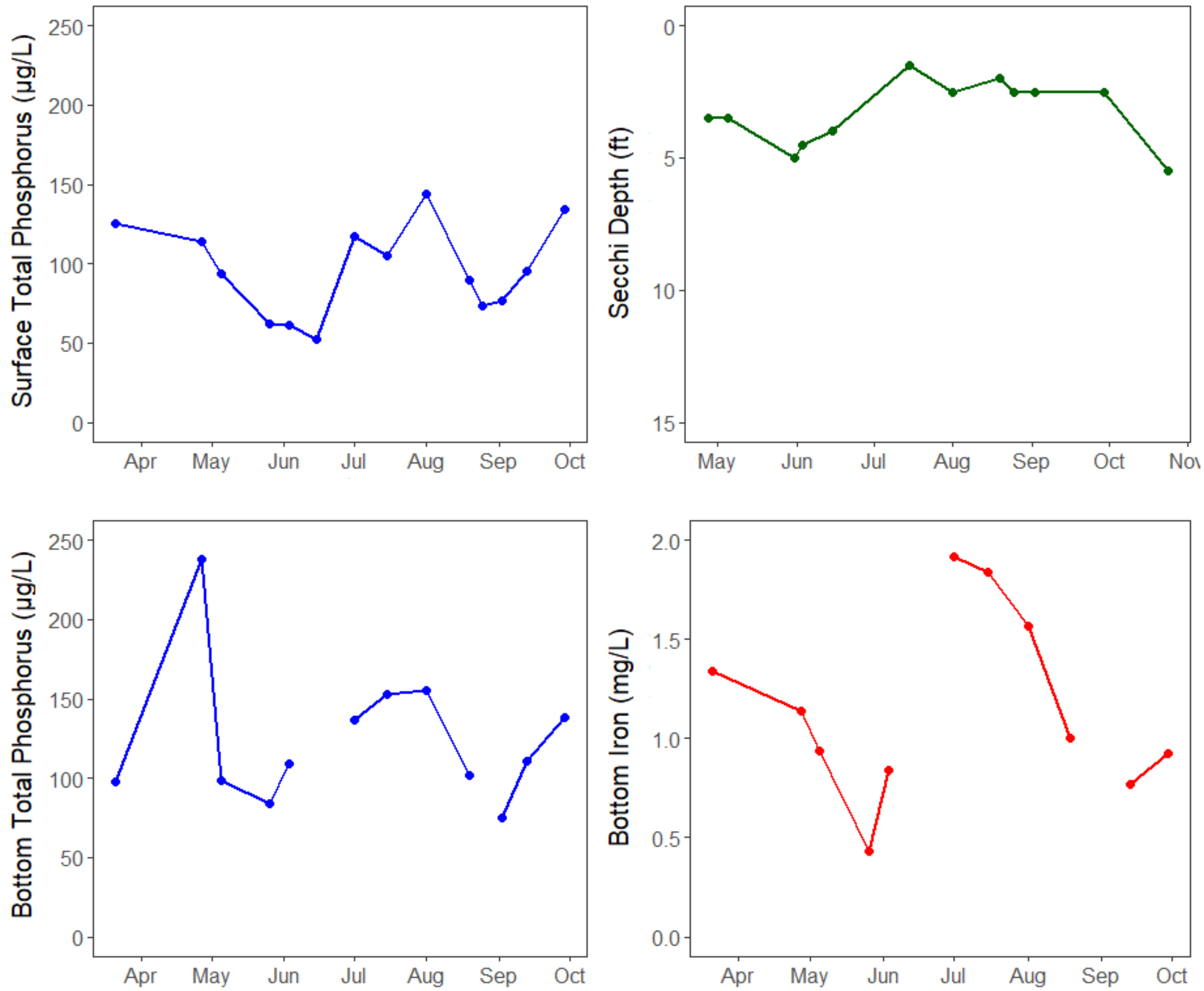


Figure 8: Staples Lake monitoring results

Internal loading for Staples Lake was estimated using the Jensen Shallow Lake Model (Jensen 2006). The model relates a series of parameters to the calculated daily flow and load, the measured in-lake total phosphorus concentration, and estimated daily water temperature to determine the sedimentation and release of phosphorus in the water column. To calibrate the model, an initial sediment phosphorus content was calculated to the lowest possible error (Figure 9).

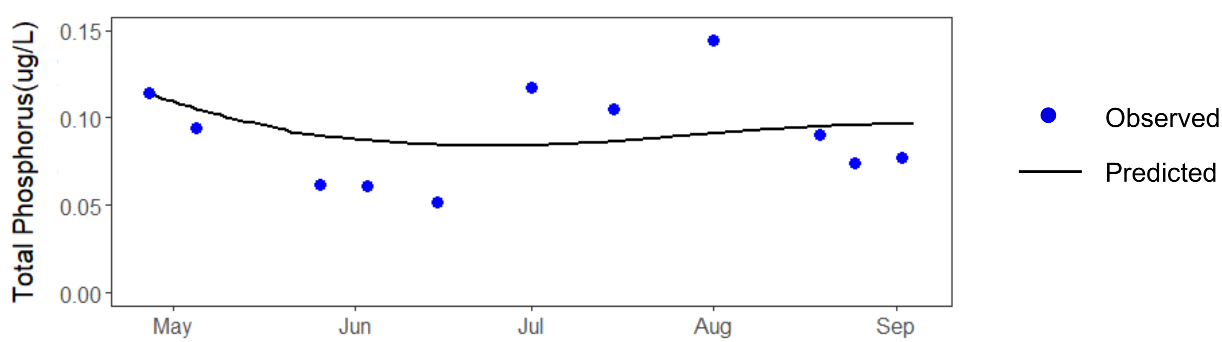


Figure 9: Calibrated Jensen Shallow Lake Model for Staples Lake

Rates of internal loading are usually greatest during the summer months due to anoxic sediment in the hypolimnion. As a result, this study will only look at internal loading from June through September. From the model, total phosphorus sedimentation, sediment release, and outflow can be estimated during the summer growing season. Using these estimations, a mass balance can then be applied to the system where: (TP Inflow + TP Sediment Release) - (TP Outflow + TP Sedimentation) = Net TP Internal Load.

According to the model, over the course of the summer growing season, an estimated net 225 lbs. of total phosphorus was released from the lake sediment into the water column (Figure 10). This indicates that internal loading from sediment is contributing to the high phosphorus concentration in Staples Lake, though currently not as much as external loading.

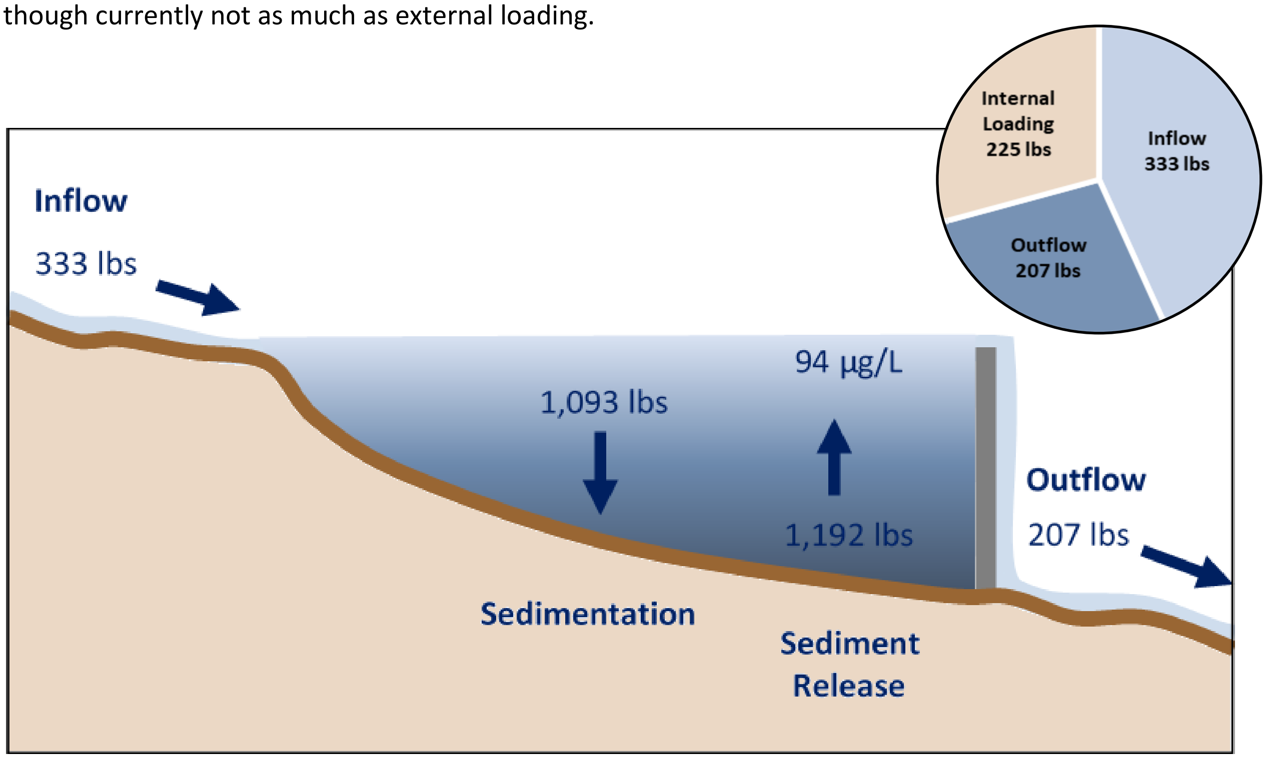


Figure 10: Results of Staples Lake Jensen Shallow Lake model June - September

One component to consider when analyzing the internal load of a lake is the iron concentration near the sediment. Under aerobic conditions, iron will bind with phosphorus at a mass ratio of 5:1. This means that if a lake has sufficient iron in its system, adsorption and redeposition of phosphorus will occur during fall turnover, thereby decreasing the availability of phosphorus in the water column. If a system does not have enough iron, treatments such as Alum can be used to replicate this process. Throughout the sampling season, Staples Lake consistently had an iron:phosphorus ratio at or above 5:1, suggesting that there currently is enough iron in the system (Table 1).

Table 1: Iron : Phosphorus Ratio

Date	Fe : P Ratio
3/21/2019	13.7
4/27/2019	4.8
5/5/2019	9.5
5/26/2019	5.1
6/3/2019	7.7
7/1/2019	14.0
7/15/2019	12.0
8/1/2019	10.1
8/19/2019	9.8
9/13/2019	6.9
9/29/2019	6.7

The Jensen Shallow Lake Model was also used to simulate in-lake responses to three different reduction scenarios (Figure 11). The scenarios were chosen to represent a typical timeline for restoration efforts and included a 25% reduction in external load, a 50% reduction in external load, and a 50% reduction in external load with an 80% reduction in internal loading. Internal loading is often reduced by the use of Alum application to lake sediment, although management activities such as aeration may also be effective. While this method takes a broad approach, it does demonstrate that water quality goals can be achieved for Staples Lake, though it will take a large effort. The growing season mean total phosphorus concentration estimated in the final scenario is 41 ug/L. The Wisconsin phosphorus water quality standard for shallow drainage lakes is 40 ug/L.

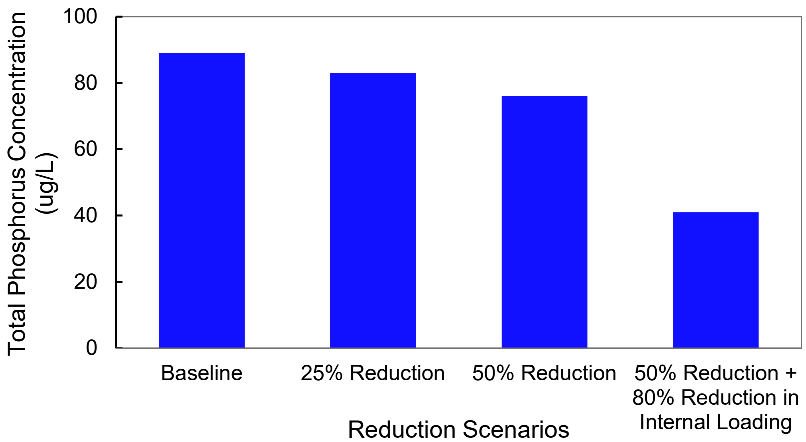


Figure 11: Growing season mean total phosphorus concentration (ug/L) for Staples Lake according modeled reduction scenarios

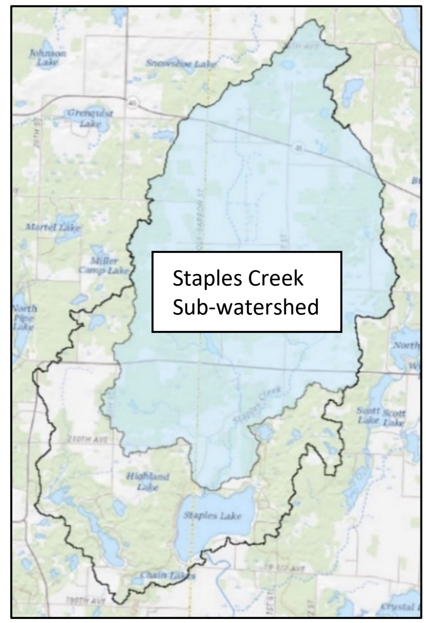


Figure 12: Staples Creek Sub-Watershed

CONCLUSIONS

The high total phosphorus concentration found in Staples Lake is a result of both external and internal loading. Therefore, in order to improve water quality in Staples Lake, steps first need to be taken to reduce the external load. In order to do so, best management practices (BMPs) need to be implemented across the watershed to prevent erosion and runoff, especially during storm events when external loading is highest. BMP implementation efforts should first target the Staples Creek sub-watershed, since according to the monitoring data, this is the region that contributed 96% of the estimated external load (Figure 12). Land use models can also be used to help further narrow in on locations where the implementation of BMPs would have the most impact on nutrient runoff.

It is important to remember that restoration takes time. Decades of runoff from the watershed has resulted in the buildup of phosphorus in the lake sediment. Simply reducing the external load from the watershed will not be enough to reverse impaired water quality. Even though internal loading is derived from the watershed, it can take years to decades to flush phosphorus in the sediment out of the system after watershed BMP implementation, resulting in delayed recovery and continued impairment (James 2016). However, this should not be a deterrent from beginning restoration efforts. Ultimately, successful water quality restoration is a long-term collaborative effort that will need effective partnerships using an integrated strategy to achieve water quality goals.

REFERENCES

James, W. 2016. Internal Loading: A persistent Management Problem in Lake Recovery

Jensen et al. 2006. An empirical model describing the seasonal dynamics of phosphorus in 16 shallow eutrophic lakes after external loading reduction

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