

Description of the Lake and Water Quality Issues

Little Wall Lake is a glacial kettle lake, formed by a melting ice sheet left behind by the retreating glacier. The lake has a surface area of 100.8 hectares and a maximum depth of 4.02 meters. It has a polymictic mixing regime meaning that it is sometimes stratified and sometimes fully mixed. The bottom waters are not hypoxic. The dominant phytoplankton group of Little Wall Lake is cyanophyte and the most dominant zooplankton group is daphnia. The most common fish species found in the lake are the black bullhead, bluegill, walleye, and the common carp.

Little Wall Lake in Hamilton, Iowa is located 2.4 km south of Jewell in north central Iowa. The land use in the watershed around Little Wall Lake is primarily agricultural. Recreational activities at Little Wall Lake include boating, fishing, a beach, and camping areas. Ecosystem services the lake provides are regulating water flow by collecting runoff (agricultural) and helping handle heavy rainfall or flooding events. It also allows habitat for aquatic and terrestrial species contributing to the area's biodiversity. The mean household visits to Little Wall Lake have decreased from 2002 to 2014. Going from 57,288 in 2002 to 45,429 in 2014.

The average Secchi depth (SD), chlorophyll (Chl), and total phosphorus (TP) values for the most recent 3 years of data in your data set were: 0.29 m (SD), 25.75 ug/L (Chl), and 67.68 ug/L (TP).

The trophic state index (TSI) for each variable are as follows:

- $TSI(SD) = 77.8378$
- $TSI(Chl) = 62.467$
- $TSI(TP) = 64.927$
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The average of the three trophic state index values from above [$TSI(SD)$, $TSI(Chl)$, $TSI(TP)$]= 68.4106.

The trophic state of Little Wall Lake is eutrophic. The expected effects on the fishery and recreation given the trophic state of the lake are that there are warm-water fisheries only and bass may dominate. Macrophytes, algal scums, and low transparency may discourage swimming and boating. However, there are no contaminants of concern in my lake. It is extremely infrequent that the dissolved oxygen concentration is less than 5mg/L as it only occurred once over the 20 years of study by the Iowa DNR.

Due to the blue-green algae dominance, algal scums, and macrophyte problems, the lake habitat and ecosystems will be affected. It will also deter recreational activity on the lake including fishing, boating and swimming. Often caused by agricultural runoff from excessive nitrogen and phosphorus, blue-green algae reduces the lake's ability to filter and purify water. The amount of oxygen in the water is also affected, creating dead zones where aquatic life cannot survive.

Identifying the Source of Water Quality Issues

Temporal patterns in water quality problems

The trophic state of Little Wall Lake is eutrophic. Eutrophic lake represents a high biomass high nutrient lake that is green. This indicates that important variables related to water quality problems for Little Wall Lake are phosphorus and nitrogen concentrations. These nutrients are directly linked to the eutrophic state and the resulting blue-green algae (cyanobacteria) dominance, which leads to algal blooms and scums that degrade the lake's water quality and disrupt its ecosystems.

Phosphorus and nitrogen are essential nutrients that fuel algal growth. Sources of these nutrients might include agricultural runoff, lawn fertilizers, and wastewater discharge from the water shed. Blue-green algae blooms are especially problematic because they can reduce water clarity, limit sunlight penetration, and deplete dissolved oxygen through both respiration and decomposition. This oxygen depletion, particularly in the hypolimnion, can create dead zones where aquatic life cannot survive.

Although the major concern and effect of phosphorus on the water quality in Little Wall Lake, total Phosphorus concentrations peaked around 2015 but have been rather consistent and have even slightly decreased throughout the past 20 years (Figure 1). Total nitrogen concentrations also peaked around 2015 and have been increasing the past 20 years (Figure 2).

Data was only taken for the phosphorus and nitrogen concentrations over the summer months, so it is difficult to compare seasonal trends with this data. It is shown that phosphorus concentrations peak in early summer months and relatively stay consistent or decrease slightly throughout the summer (Figure 3). Nitrogen concentrations peak mid-summer and overall, steadily increase throughout the summer months (Figure 4).

External sources/drivers of the water quality problem(s)

Given the agricultural land use in the watershed around Little Wall Lake, agricultural runoff is likely a significant external driver of nutrient loading in the lake, specifically contributing to high phosphorus and nitrogen levels. These nutrients, often originating from fertilizers applied to nearby crop fields, promote eutrophic conditions in the lake, as seen in its high trophic state index (TSI). This hypothesis is supported by the observed seasonal peaks in phosphorus and nitrogen concentrations within the lake, which coincide with typical agricultural cycles and seasonal runoff events. The high levels of these nutrients are likely linked to seasonal patterns such as, early summer runoff from spring rains, carrying soil and fertilizers into the lake. These nutrients fuel algal blooms and limits water clarity, with Secchi depth measurements averaging just 0.29 meters. Little Wall Lake's role in collecting and filtering runoff, as well as its shallower depth and polymictic mixing regime, make it particularly susceptible to nutrient enrichment from agricultural sources.

Based on typical agricultural land use impacts there is likely a lack of an adequate riparian buffer zone around the lake could exacerbate these issues. Without a sufficient buffer of vegetation to absorb nutrients and slow runoff, the lake directly receives high loads of phosphorus and nitrogen. This influx of nutrients contributes to the blue-green algal growth and the growth of macrophytes, both of which reduce water quality and limit recreational activities, such as swimming and boating, due to low transparency and algal scums.

Internal sources/drivers of the water quality problem(s)

There is a positive correlation between total phosphorus (TP) and chlorophyll indicating that TP is related to algal biomass (Figure 5). This suggests that higher phosphorus concentrations support increased algal growth. The phosphorus contributing to algal biomass is a significant factor in the overall water quality issue. The analysis of soluble reactive phosphorus (SRP) against inorganic suspended solids (ISS) shows no correlation between these two variables. This lack of correlation suggests that phosphorus is not primarily supplied by suspended particulate matter in the water column.

Polymictic stratification facilitates internal phosphorus loading by allowing frequent mixing of the water column, which resuspends nutrients from the sediments into the water. The lack of correlation between soluble reactive phosphorus (SRP) and inorganic suspended solids (ISS) suggests that phosphorus is not primarily derived from suspended particles. This reinforces the idea that internal loading from sediments is a significant source of phosphorus in the lake. The positive correlation between total phosphorus (TP) and chlorophyll concentrations indicates that elevated phosphorus levels support increased algal biomass, leading to water quality issues such as harmful algal blooms.

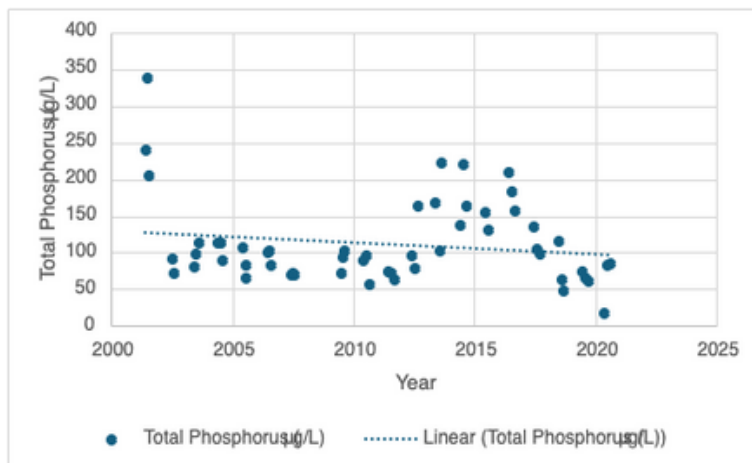


Figure 1: A time series of total phosphorus concentrations in Little Wall Lake.

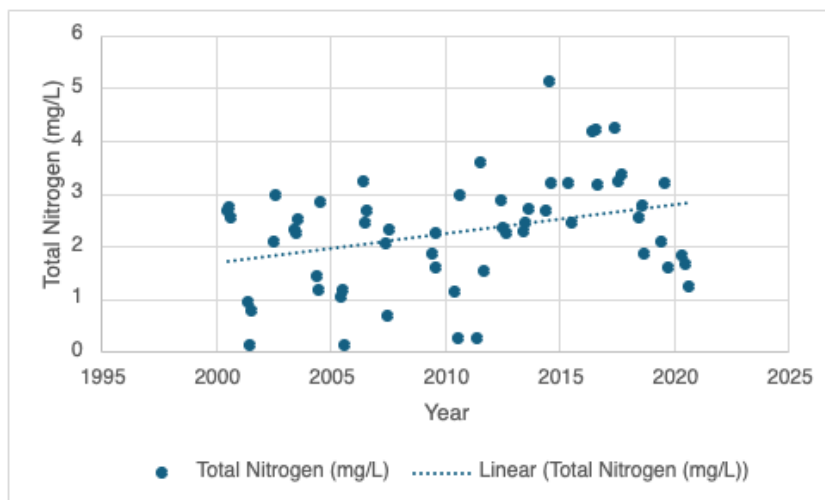


Figure 2: A time series of total nitrogen concentrations in Little Wall Lake.

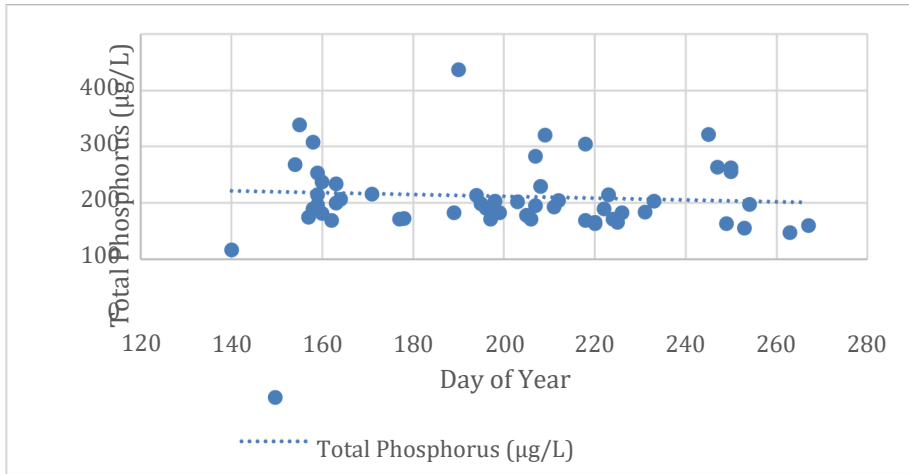


Figure 3: A time series of total phosphorus concentrations over seasons in Little Wall Lake.

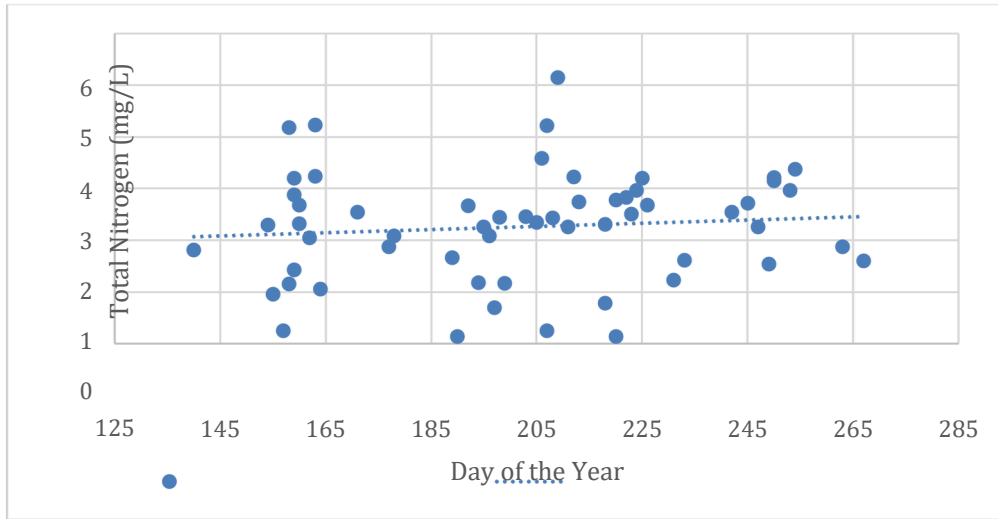


Figure 4: A time series of total nitrogen concentrations over the seasons in Little Wall Lake.

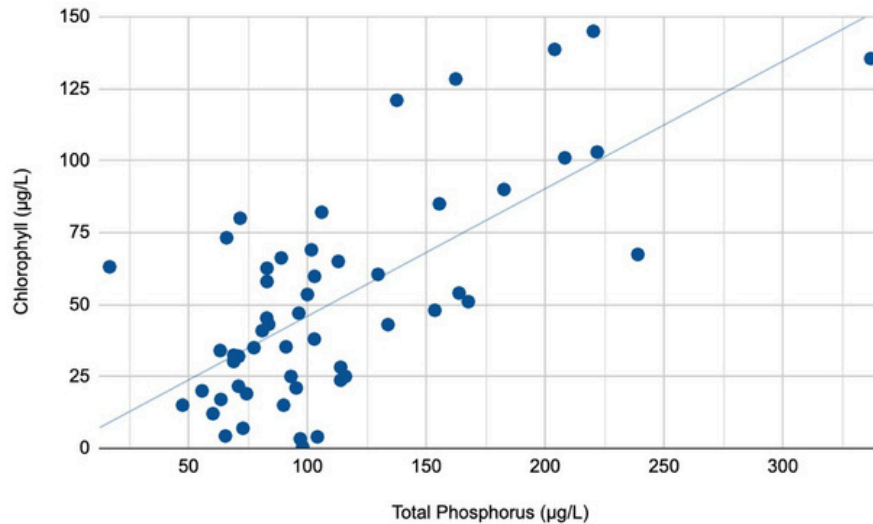


Figure 5: Total phosphorus concentrations plotted with the total chlorophyll concentrations.

Management Recommendations

Watershed Strategies

Riparian restoration for the inlet stream to Little Wall Lake, costing \$150,000, addresses external nutrient loading from agricultural runoff. Vegetated buffer strips act as natural filters, intercepting runoff and trapping sediments and nutrients before they reach the water body. (Schindler, 2006) By reducing the transport of phosphorus, nitrogen, and sediment into the lake, these buffer zones will limit algal growth and chlorophyll-a production. This will reduce blue-green algal blooms, improving water clarity, and enhancing ecosystem health. With lower sediment and algal biomass, Secchi depth will increase, benefiting recreational activities and aquatic habitats. Additionally, riparian vegetation will stabilize stream banks, reducing erosion and preventing further nutrient loading. (Schindler, 2006). Similarly, wetland restoration within the watershed, also costing \$150,000, enhances nutrient retention and reduces agricultural runoff. Wetlands serve as natural filters by facilitating denitrification and phosphorus retention, significantly lowering nitrogen and phosphorus concentrations before they reach the lake. (Zedler, 2003) This process mitigates eutrophication by decreasing algal biomass and improving water clarity. Wetland restoration offers ecological benefits such as flood control, benefits to biodiversity, and improvements to wildlife habitat by stabilizing water flow and reducing sedimentation. (Zedler, 2003) Together, these strategies will stabilize Little Wall Lake's ecosystem, mitigate eutrophication, and support a healthier, more sustainable aquatic environment.

In-Lake Strategies

Alum addition to Little Wall Lake, for \$2,490,000, will address internal nutrient loading, specifically the release of phosphorus from lake sediments during anoxic conditions. This internal phosphorus source is a key contributor to eutrophication, as it fuels algal growth and reduces water quality. Alum binds with phosphorus in the sediments and water column, preventing phosphorus from being released back into the water, particularly under low-oxygen (anoxic) conditions typical in eutrophic lakes such as Little Wall Lake (Cooke et al., 2005). The addition of alum will lead to a significant decrease in phosphorus concentrations in the water column. This reduction will limit the growth of algae and decrease chlorophyll-a concentrations, which will decrease algal biomass. Water clarity will improve, helping aquatic vegetation and stabilizing the ecosystem by providing habitat for aquatic organisms. Reducing phosphorus will limit nitrogen cycling processes, such as ammonium regeneration, which often contributes to sustained algal blooms (Cooke et al., 2005). By the addition of alum, there will be a sharp decline in algal biomass and an increase in dissolved oxygen levels, especially in the hypolimnion, where oxygen depletion is often a concern in eutrophic lakes. By targeting internal nutrient loading, alum treatments will improve overall water quality and support a healthier lake ecosystem.

References

- Schindler, D. W. (2006). Recent advances in the understanding and management of eutrophication. *Limnology and Oceanography*, 51(1), 356-363.
- Zedler, J. B. (2003). Wetlands at your service: reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and the Environment*, 1(2), 65-72.
- Cooke, G. D., Welch, E. B., Peterson, S. A., & Nichols, S. A. (2005). *Restoration and Management of Lakes and Reservoirs* (3rd ed.). CRC Press.

Strategy		Unit Cost	Units	Total Cost
Alum	Additions	\$10,000/acre	249acres	\$2,490,000
Wetland	Restoration	\$150,000/site	1 site	\$150,000
Riparian	Restoration	\$150,000/site	1 site	\$150,000
Total				\$2,790,000