Nutrient Analysis: Sediment release, internal loading, and other sources into Big Lake.

Big Lake, Polk County WI

WBIC: 2615900

2021

Sponsored by: Churchpine, Round and Big Lake Protection and Rehabilitation District, and Wisconsin Dept of Natural Resources

Data collection and analysis conducted by: Ecological Integrity Service, Polk County Land, and Water Resources Dept., and UW-Stout Center for Limnological Research

Analysis summary

This analysis involved the collection of data to more closely evaluate the sediment release of phosphorus, determine if entrainment (*entrainment is the movement of one fluid into another through an interface; in this case bottom layer water into upper layer water where algae can grow*) of that phosphorus occurs into the upper layer of water where algae can grow, and compare that to external sources of phosphorus in Big Lake, Polk County Wisconsin. This analysis is the result of a recommendation from an internal load study conducted by the Polk County Land and Water Resources Dept that occurred from 2016-2018. In-lake total phosphorus concentrations, as well as soluble reactive phosphorus, were collected at one-meter intervals from surface to near bottom in Big Lake. Water was sampled and analyzed from a tributary inlet that flows into Big Lake on the north shore of the lake. The flow was also monitored as was the flow of the outlet that flows out of Big Lake on the northwest shore. Chlorophyll-a and Secchi depth data were collected by Citizen Lake Monitors from Big Lake. The watershed delineation was updated as well as the land cover types. Elevation and flow analysis were used to determine internally drained areas of the Big Lake watershed, to better estimate the over-land runoff nutrient contributions.

A mass balance model (Canfield-Bachman lake phosphorus sedimentation model) was used to predict the most likely phosphorus load into Big Lake. The model was calibrated to observed, in-lake data to allow for predictions of outcomes from decreases and increases in phosphorus loading.

The sediment release portion of the study was conducted by the UW-Stout Center for Limnological Research, using sediment cores that were incubated in the laboratory and the release of phosphorus from the sediment was determined.

The data revealed that the release rate from the sediment is 5.65 mg/m2-d. Considering the period of anoxic conditions and the area in which they occurred, the estimated sediment release from May-Sept in Big Lake in 2020 was 190.2 kg. However, in-lake phosphorus concentrations suggest that entrainment likely occurred in early September and approximately 30 kg of phosphorus was released into the epilimnion. This accounted for about 9% of the total estimated load. This small amount as compared to the potential 190 kg is likely due to the lake remaining stratified enough throughout most of the growing season to cause the phosphorus to remain in the hypolimnion. The entrainment was likely due to degradation of the thermocline leading to limited mixing in Sept. Full mixing (fall turnover) occurred in October, which is considered beyond the growing season.

In comparing the internal load to the other sources, it was determined that the north inlet, which drains the northern sub-watershed was the largest contributor of phosphorus into Big Lake in 2020 (70.6% of the total load). Due to limited historical data from the inlet, comparison from past years was not possible. The phosphorus load from the north inlet is not consistent with loading estimated using export coefficients from the land cover types in the North sub-watershed (prediction is lower than the field data from the tributary). The phosphorus concentration was still high in the tributary during low flow periods. The sources of high phosphorus concentration are unknown and it is recommended this be evaluated to allow for the determination of any possible management practices to reduce phosphorus.

A load analysis using the empirical Bathtub showed that reductions in phosphorus load in both the entire watershed as a whole and in just the northern sub-watershed would result in reduced phosphorus concentration and reduced chlorophyll-a concentration. Eliminating the internal load of 30 kg showed very little change in the phosphorus concentration in the lake. It is recommended that the focus is on the north sub-watershed/north inlet loading.

Summary:

- The sediment release rate of phosphorus is 5.65 g/m^2-d.
- This equates to 190 kg released in summer 2020.
- Only 30 kg of this phosphorus mixed into the upper layer where algae can grow.
- The north inlet (which drains the largest watershed area) is by far the biggest contributor of phosphorus into Big Lake (70.6% of load).
- The source of the high phosphorus concentration in the north inlet is unknown.
- A 20% reduction in external source phosphorus loading is predicted to decrease lake phosphorus concentration from 24.5 ug/L to 22.0 ug/L and chlorophyll-a concentration from 7.7 ug/L to 6.5 ug/L.
- Eliminating the 30 kg internal load is predicted to lower phosphorus concentration by about 1.4 ug/L and chlorphyll-a by 0.5 ug/L
- Further knowledge of these sources would be necessary to develop management recommendations.

Introduction

Big Lake (WBIC: 2615900) is a 252-acre lake (Polk County Land and Water Conservation Dept, 2020) in Polk County, Wisconsin. It is located at the end of a three-lake chain segment, with the other two lakes flowing into Big Lake (Church Pine Lake and Round Lake). Both of these lakes have better water quality than Big Lake. Big Lake is classified as mesotrophic (Wisconsin DNR) from historical data which includes total phosphorus, chlorophyll-a, and Secchi depth. Some years the lake has TSI values in the eutrophic level. In recent years, Big Lake was listed as impaired water due to excessive algae growth. The impaired water listing is the rationale for evaluating the nutrient loading into Big Lake that can contribute to algae growth.

During a period from 2016 to 2018, the Polk County Land and Water Resources Dept. analyzed the internal loading in Big Lake. Internal loading can occur when sediment in the lake bottom becomes anoxic (oxygen-less than 1 mg/L) and releases phosphorus into the lake water. The study analyzed the accumulation of phosphorus in the hypolimnion (dense bottom layer in a stratified lake) to determine the sediment release. However, the phosphorus concentrations in the hypolimnion were sporadic and inconsistent each year, with large spikes and suddenly lower readings. As a result, the report recommended conducting sediment core analysis where lake sediment cores are collected and made anoxic in a lab setting. The release rate is then determined from these cores in the lab, allowing for more precise potential phosphorus release. The focus of this analysis is to better evaluate the sediment phosphorus release using incubated sediment cores, and compare this release to other phosphorus sources using historical nutrient data and data collected in the growing season (May-September) of 2020. The nutrient of concern is phosphorus since it was determined in 2012 that phosphorus is the limiting nutrient. In 2012, Big Lake nutrient data showed a Total N: Total P to be consistently greater than 15:1 (most values were above 20:1). A ratio above 15:1 indicates that phosphorus is the limiting nutrient compared to nitrogen (Shaw, 2004).

The UW-Stout Center for Limnological Research conducted a sediment core analysis to update the potential phosphorus release from Big Lake sediment (separate analysis in a separate report[1]). In-lake phosphorus data was collected to determine if any phosphorus from the hypolimnion mobilized into the upper layers where algae can grow. Even if sediment releases phosphorus, it may not lead to algae growth during the growing season if the lake remains stratified and the high phosphorus hypolimnetic water remains on the bottom where light is limited.

In addition, the external phosphorus loading was evaluated to account for phosphorus entering Big Lake from the watershed. The Polk County internal load analysis report had limited information about the external load determination methods and data. Big Lake has a tributary that enters from the north and drains the largest portion of the Big Lake watershed. The flow and phosphorus concentration from this inlet was analyzed. The land cover in the Big Lake watershed was updated to better evaluate the potential for nutrient loading from the various watershed areas. The Big Lake watershed was delineated into four sub-watersheds. They were the North sub-watershed, Direct sub-watershed, South sub-watershed, and the Southeast sub-watershed. The tributary flow and phosphorus concentration were

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[1] James, William. 2020. Internal phosphorus loading and sediment characteristics in Big Lake, Wisconsin. UW-Stout Center for Limnological Research and Rehabilitation.

used for the North sub-watershed load. Lastly, a flow analysis using elevation (LiDAR) data was also conducted to better understand the runoff potential into Big Lake, internally drained areas, and the entry points into the lake.

This analysis combines the results of the sediment core data, the updated land cover data, inlet flow, and phosphorus data, and the in-lake phosphorus concentrations to evaluate the phosphorus load into Big Lake for 2020. The model was then adjusted to reflect an average precipitation season. The empirical lake model Bathtub was utilized to predict the results of reducing phosphorus loading into Big Lake in terms of chlorophyll-a and Secchi depth.

Methods

The sediment core methods are addressed in the UW Stout sediment core analysis and only the resulting data is used in this analysis. The anoxic factor (area and time duration of anoxic sediment) was determined using data from a profile thermistor string and dissolved oxygen meter. This anoxic factor value was then used to calculate the potential sediment phosphorus release. Anoxic factor (AF) was calculated using the following equation (Nurnberg, 2004):

$$AF = \frac{\sum(T_i)(a_i)}{A_{oi}},$$

where T_i is the time (days of anoxia), a_i is the area of anoxia during that period, and Aoi is the total surface area of the lake during a period. The AF is a time that is area weighted for anoxic conditions in the lake. The AF is used to determine the time to multiply the release rate to calculate the phosphorus released by the sediment based upon the laboratory data.

The land cover update, watershed delineation, and flow analysis were conducted by the Polk County Land and Water Resources Department utilizing the most up-to-date digital aerial photos for Polk County and LiDAR data. Internally drained areas within the sub-watershed were also delineated. Their findings are integrated into this analysis, but they provided a separate report (Sorenson and Anderson), 2020). Export coefficients were used to estimate the phosphorus load from sub-watersheds other than the north sub-watershed, which was determined using the north inlet tributary data (Panuska, 1995). The runoff amounts were estimated through a mass balance of the water budget, whereby the inflow of water from all sources equals the all outflows. Since no groundwater data was available, the net recharge minus discharge was considered zero. The inlet baseflow suggests there is a considerable amount of groundwater discharge into this stream, very full wetlands (during high precipitation years) were discharging water into the inlet, or both occur.

The inlet loading was determined by placing a pressure transducer level logger (to measure water depth) in the inlet with periodic flow readings collected (including low and high flow measurements). The depth from the transducer was correlated with the flow to construct a gage depth and flow. Monthly water samples measuring total phosphorus and dissolved reactive phosphorus were collected and analyzed at the Wisconsin State Lab of Hygiene. The outlet was also monitored at the spillway with a pressure transducer level logger (placed above the spillway to also measure the lake stage). A flow curve was created from this data as well and used to estimate outflow during the monitoring period.

Monthly vertical profiles at each meter from surface to near bottom were collected and analyzed for total phosphorus and dissolved reactive phosphorus from June through September. A precipitation logger was installed on the north shore of Big Lake to monitor on-site rainfall amounts.

The in-lake phosphorus profiles, as well as precipitation amounts, inlet flow and nutrient concentrations along with outlet flow, were used to determine the total phosphorus loading into Big Lake. This data was then input into Canfield/Bachman lake model regression (a steady-state, mass balance model that predicts the growing season mean (GSM) phosphorus concentration) (Canfield, 1981).

$$\textbf{P conc.} = \mathbf{0.114\ (Wp/v)^{0.589}}$$

where, P conc. is the growing season mean phosphorus concentration in the lake, Wp is total phosphorus load into the lake, and v is total volume. This equation is based upon a set sedimentation rate for lakes and fit fairly well. However, the sedimentation rate (decay rate) had to be increased to have the model better predict the in-lake observed phosphorus concentration.

The North-sub-watershed load was determined using field data, the other sub-watershed loads were estimated using published export coefficients and adjusted for precipitation amounts during the monitoring period. The atmospheric deposition was estimated using published values from other studies (which range from 7 ug/L to 16ug/L) (Rose, 1989)(Robertson, 2009) (10ug/L was used for this analysis). The septic system load was based upon previous estimates conducted by the Polk County Land and Water Conservation Dept in 2016-2018.

The internally loaded phosphorus (sediment release) that mobilized into the epilimnion was determined through mass-balance by accounting for all sources of phosphorus and the increase that occurred based upon volume-weighted concentrations above the hypolimnion. This did not appear until the September in-lake phosphorus samples and corresponded to a degradation of the stratification in early September.

The various sources of phosphorus were input into the empirical model Bathtub (Walker, 2004) (from the US Army Corp of Engineers-Canfield Bachman model) to predict load change outcomes such as phosphorus concentration, chlorophyll-a concentration, and Secchi depth. The Bathtub model was calibrated to make the observed 2020 in-lake data match the predicted values from the model. Differences between observed and predicted values are due to estimation errors such as precipitation concentration, export coefficients, and sedimentation rates of phosphorus.

Results

In-lake nutrient data

Phosphorus data collected in the monthly vertical profile samples are shown in Table 1. One concerning observation is that in numerous samples, the soluble reactive phosphorus (SRP) is higher than the total phosphorus. Since total phosphorus includes soluble reactive phosphorus, this should not occur. This has been observed with very low phosphorus concentrations in past studies, but these phosphorus concentrations are within the LOQ listed by the Wisconsin State Lab of Hygiene. According to the State Lab of Hygiene, the soluble reactive phosphorus test is more precise with a lower LOQ. For this reason, the SRP was used in the lake mean phosphorus values for modeling purposes (since the total phosphorus would have to be at least this concentration).

Total Phosphorus (ug/L)					
	9-Jun	6-Jul	11-Aug	16-Sep	Mean
0-2m	15.5	19	18.1	28.8	20.35
3m	22.1	21.1	17.9	26.8	21.98
4m	19.6	24	19	25.7	22.08
5m	17.1	25.4	20.7	41.3	26.13
6m	23.4	28.2	19.3	38.4	27.33
7m	30.7	46	150	64.4	72.78

Table 1: In-lake total phosphorus data, June through Sept.

The in-lake phosphorus data shows a large percentage of the phosphorus is soluble reactive. This form of phosphorus is available for uptake and use to grow algae. This percentage could be misleading as the total phosphorus values may be inaccurate. Using various phosphorus values, the GSM for phosphorus was 24.5 ug/L in the epilimnion (volume weighted).

Soluble reactive phosphorus (ug/L)					
	9-Jun	6-Jul	11-Aug	16-Sep	Mean
0-2m	15.2	14.7	21.3	38.3	22.38
3m	13.6	16.3	21	37.8	22.18
4m	14.3	16.3	22.7	38.4	22.93
5m	14.3	17.8	25.4	43.2	25.18
6m	16.2	17.7	24.3	45.5	25.93
7m	20.9	26.4	37.2	47	32.88

Table 2: In-lake soluble reactive phosphorus data, June through Sept. 2020.

The phosphorus concentrations support an accumulation of phosphorus at the water/sediment interface, which indicates sediment release of phosphorus. Note the higher total phosphorus values at 7 meters as compared to shallower depths. Figure 2 shows the phosphorus concentration each month in the hypolimnion (6-7 meters).

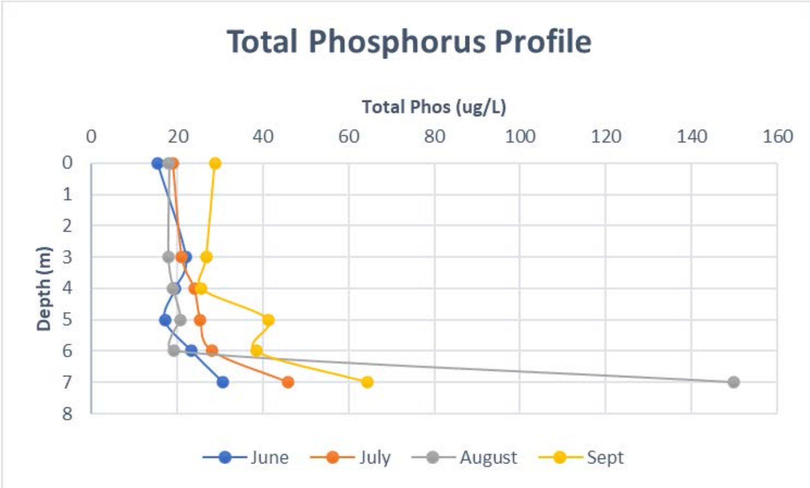


Figure 1: Phosphorus profile for Big Lake; surface to near bottom from June through Sept.

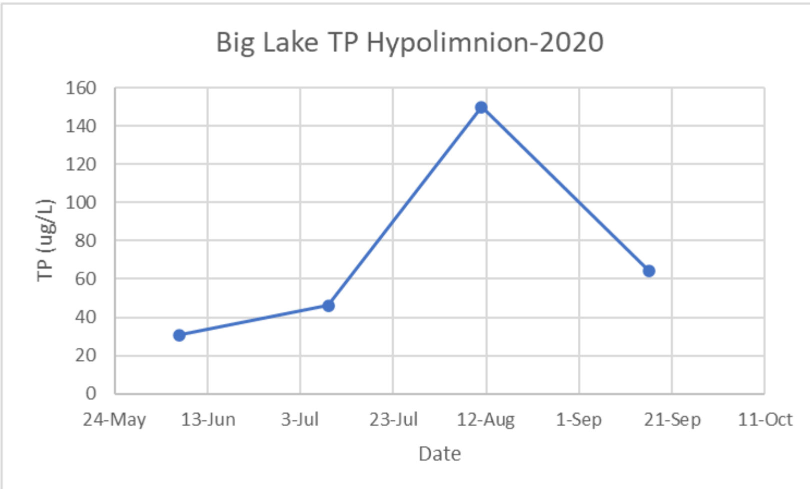


Figure 2: Graph showing the hypolimnion phosphorus concentration June-Sept.

Chlorophyll-a

The Citizen Lake Monitors for Big Lake collected water samples that were analyzed for chlorophyll-a concentration. As the data shows, the concentration was low, indicating limited algae growth until Sept.

Date	Concentration of chlorophyll-a (ug/L)
7/6/20	4.82
7/28/20	7.83
8/11/20	5.47
9/14/20	14.2
GSM Mean	8.0

Table 3: Chlorophyll-a concentration data, July through Sept. 2020.

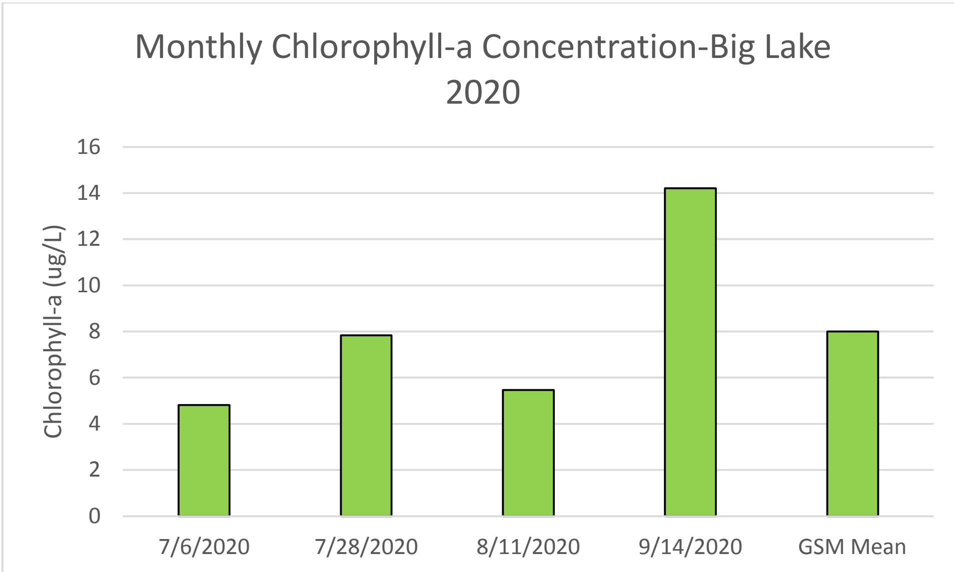
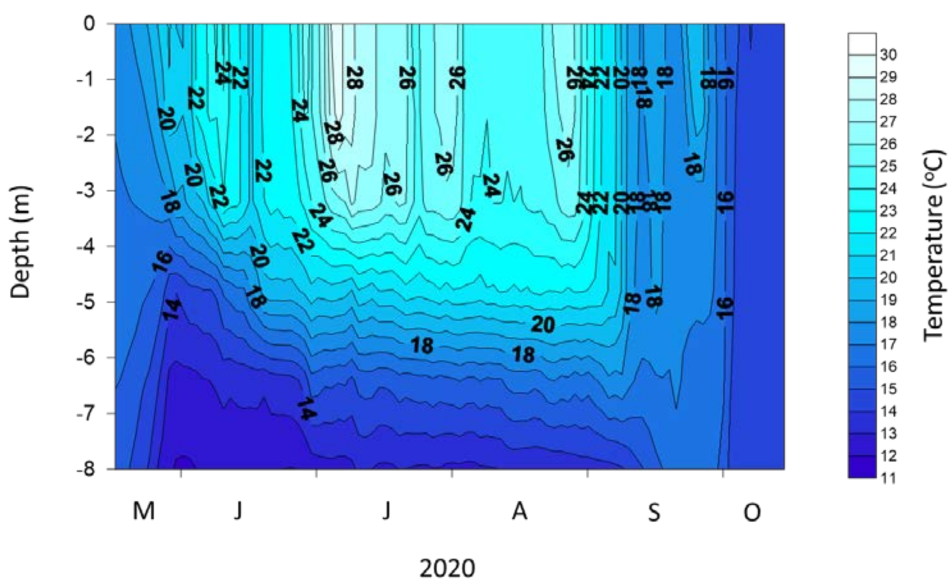


Figure 3: Graph showing the monthly (July-Sept) chlorophyll-a concentration in epilimnion water in Big Lake.

Stratification data

Big Lake vertical temperature profile data shows that Big Lake became stratified in early June and remained stratified until early Sept. (see Figure 4) at which time the stratification seems to degrade. The temperature difference appears substantial enough during stratification to form a thermocline and a thin hypolimnion. The temperature difference appears to keep the lake from mixing during the



stratification period.

Figure 4: Temperature isopleth graph showing stratification profile, 2020[2].

Stratification and anoxia[3]

Overall, Big Lake exhibited strong stratification between late May and late August (Fig. 2). The epilimnion was located between the lake surface and ~ 2 m. Periods of cooling mid-June, mid-July, and early August resulted in an expansion of the epilimnion down to 4 m (Fig. 2 and 3). The metalimnion (i.e., region of greatest temperature change with increasing depth) was expansive, ranging between the 4- and 6-m depths. The hypolimnion was located at depths > 6 m. Periods of cooling and epilimnion expansion did not appear to result in mixing and entrainment of hypolimnetic water. The hypolimnetic bottom temperature gradually increased from ~ 12 C in May to 17.5 C in late September. Autumnal mixing and turnover began in early October.

Sediment release (internal load) from laboratory incubated sediment cores (from UW-Stout Center for Limnological Research-2020 report)

- Sediment release from core incubation**= 5.65 mg/m^2-d**
- Anoxic factor = **34 d** (based upon the area of anoxia and the days of anoxia[4])
- Estimated phosphorus release from sediment core data = **190.2 kg** during the June-Sept period.
- In-situ sediment release from hypolimnion accumulation = **74 kg** (from vertical profile data).

External phosphorus sources

The watershed of Big Lake was delineated and land cover was updated by the Polk County Land and Water Conservation Dept. The watershed was also separated into sub-watersheds, to allow for better determination of phosphorus sources from runoff of the watershed. Figure 5 shows the sub-watershed delineations. Table 4 summarizes the area of land cover types within each sub-watershed. Figure 6 is a map showing the land cover types within the Big Lake watershed.

By area, the North sub-watershed is the largest sub-watershed, followed by the South sub-watershed, SE sub-watershed and the Direct sub-watershed respectively. The North sub-watershed is drained by the inlet that flows in to Big Lake. As the tables show, both the North sub-watershed and the SE sub-watershed have a large percentage of row crop for land cover. Row cropland covers typically have higher runoff amounts along with higher phosphorus concentrations (based upon export coefficients used for Wisconsin land cover) than forested areas. The Direct sub-watershed has a higher percentage of medium residential which also has higher runoff and phosphorus concentrations (as compared to forested areas) largely due to more impervious surfaces associated with roofs, sidewalks, and driveways along with manicured lawns.

The Southeast-sub-watershed and the South sub-watershed are somewhat complicated in terms their contributions of water and nutrient loads. Polk County reports that the Southeast sub-watershed was

[2] Graph provided by the UW-Stout Center for Limnological Research, Bill James Director.

[3] Bill James of UW-Stout. 2020. *Internal phosphorus loading and sediment characteristics in Big Lake, Wisconsin* from results of the thermistor string deployed in 2020.

[4] Days of anoxia as reported by Bill James from thermistor string/DO logger deployed from May-Oct, 2020.

not included in a 2012 watershed delineation. However, with the updated elevation/LiDAR data, it was determined that this portion of land does contribute to runoff into Big Lake but only during higher rain events (reported as 10 yr events). To accommodate this, the flow was reduced from what export coefficients for the land cover estimates.

The South sub-watershed was also adjusted based upon flow information. Although the area of this sub-watershed is large (only the North sub-watershed has a larger area), the flow map shows the water flows into a large wetland adjacent to Big Lake, and then flows directly into Big Lake. This wetland likely slows the water and retains it for a period time after rain events, thus lowering flow and nutrient concentrations. Limited data from the flow from this wetland into Big Lake showed a lower total phosphorus concentration than the export coefficients would predict.

To identify the source(s) of phosphorus into the north inlet, more data will need to be collected. Prior to this analysis, it was assumed there was a more extensive data set for the north inlet. However, that data is limited to one growing season set (2012) and one sample in Feb. (also 2012). Chemical data which includes total phosphorus, soluble reactive phosphorus and chloride sampled and analyzed monthly for the entire calendar year (several years would be best) would help indicate what this tributary consistently contributes year-round.

In 2019, a beaver dam failed and resulted in substantial flow and sediment into Big Lake. The increase in water into Big Lake caused the water to back into Round Lake and Church Pine Lake, which normally flow into Big Lake. It may be that when the beaver dam was in place, the flow was slowed and allowed for settling of sediment behind the dam. This could have led to reduced concentration of total phosphorus into Big Lake. Assuming the dam has not been rebuilt, the water is no longer retained behind a dam so runoff can flow more freely in the tributary into Big Lake, potentially increasing the total phosphorus concentration. During large storm events, it is also possible that stream bed sediment/organic matter that had built up behind the dam over several years, gets released along with more nutrients.

Winter months, could help reflect the baseflow concentration, which may be occurring from groundwater that is high in phosphorus concentration. Quantifying flow would also be necessary to calculate the phosphorus load. Groundwater analysis would also be helpful to determine if this groundwater recharging the inlet (and Big Lake) is high in phosphorus. Polk County has indicated that the groundwater associated with the Horse Creek watershed (of which Big Lake is contained) is high in phosphorus from other studies.

There may be land-use practices that are occurring in the North sub-watershed that is not being represented by standard export coefficients. A more in-depth evaluation of specific land-use activity would help identify (or rule out) any potential significant phosphorus sources. The land cover has been updated, but his update is not specific enough to identify individual, significant phosphorus sources.

The SE sub-watershed, South sub-watershed and the Big Lake Direct sub-watersheds contribute phosphorus into Big Lake. Management practices in these areas would reduce phosphorus. However, the impact would not be as profound compared to reductions in the North sub-watershed. The SE and Direct sub-watersheds could be evaluated with load analysis to determine if it would be worthwhile to put efforts into phosphorus reduction in these areas.

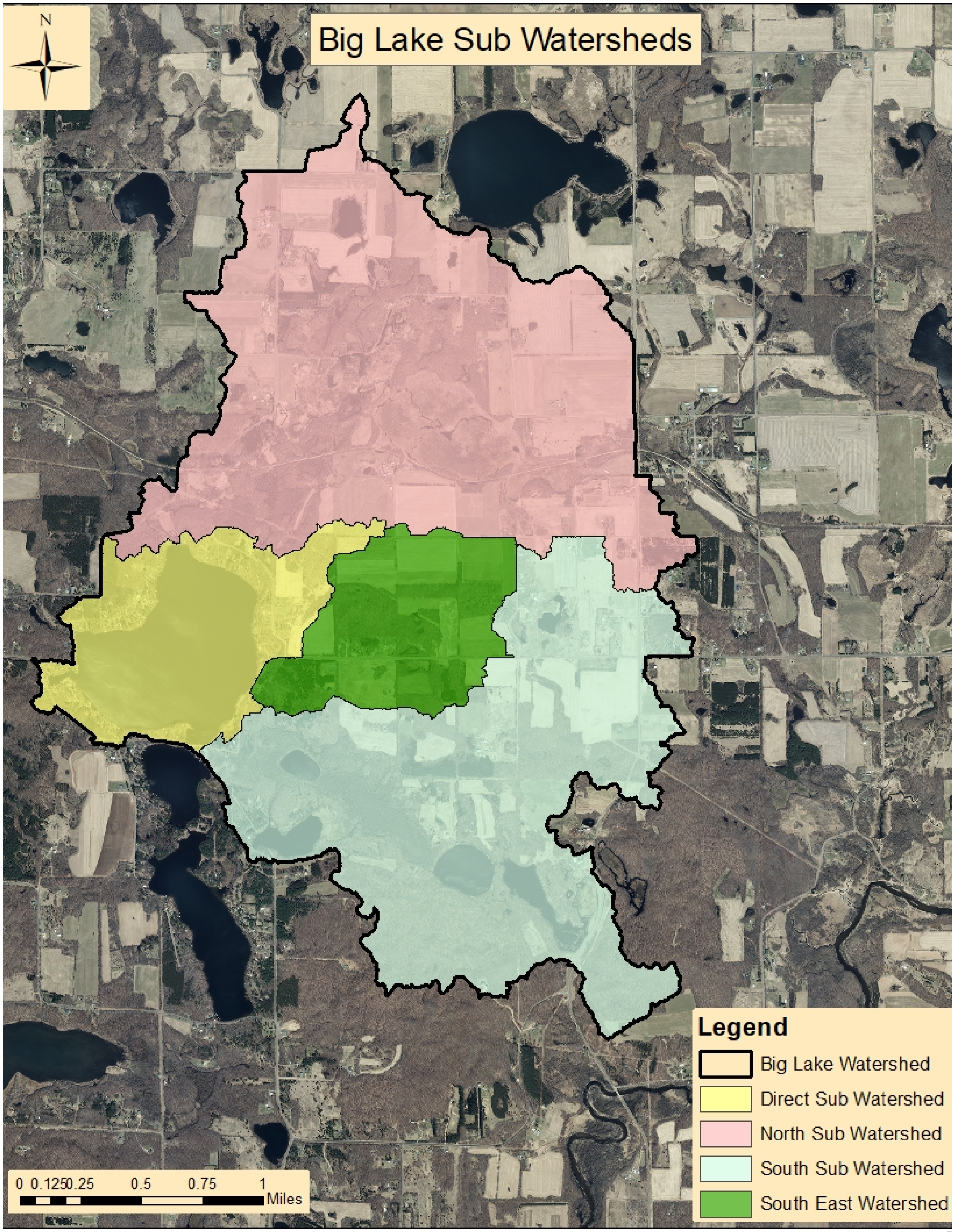


Figure 5: Big Lake watershed delineation with separation of sub-watersheds and internally drained areas.[5]

[5] Provided by Colton Sorenson, Polk County Land and Water Resources Dept., Polk County Wisconsin.

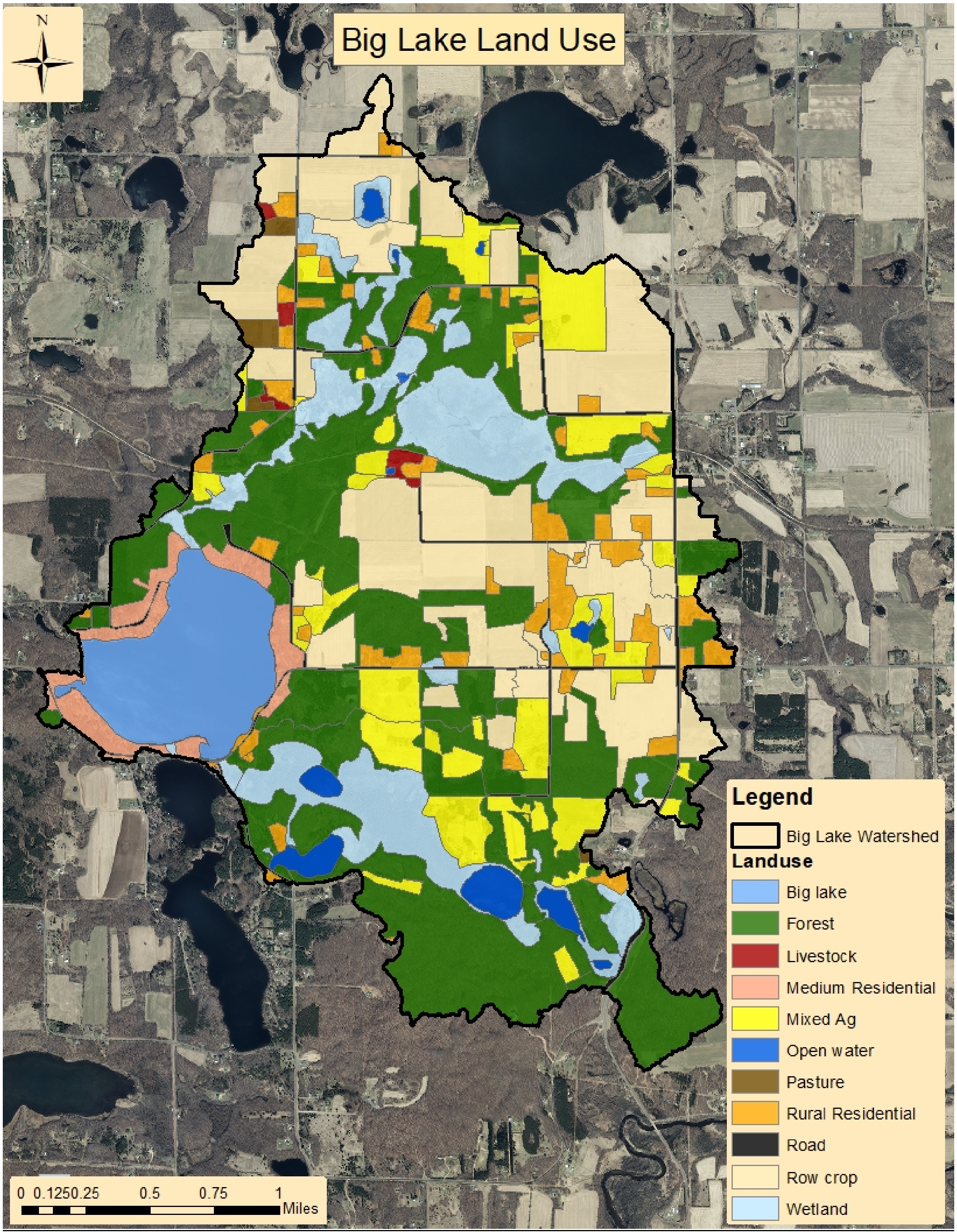


Figure 6: Map of the land cover type within the Big Lake watershed[6].

[6] Map provided by Colton Sorenson, Polk County Land and Water Resources Dept.

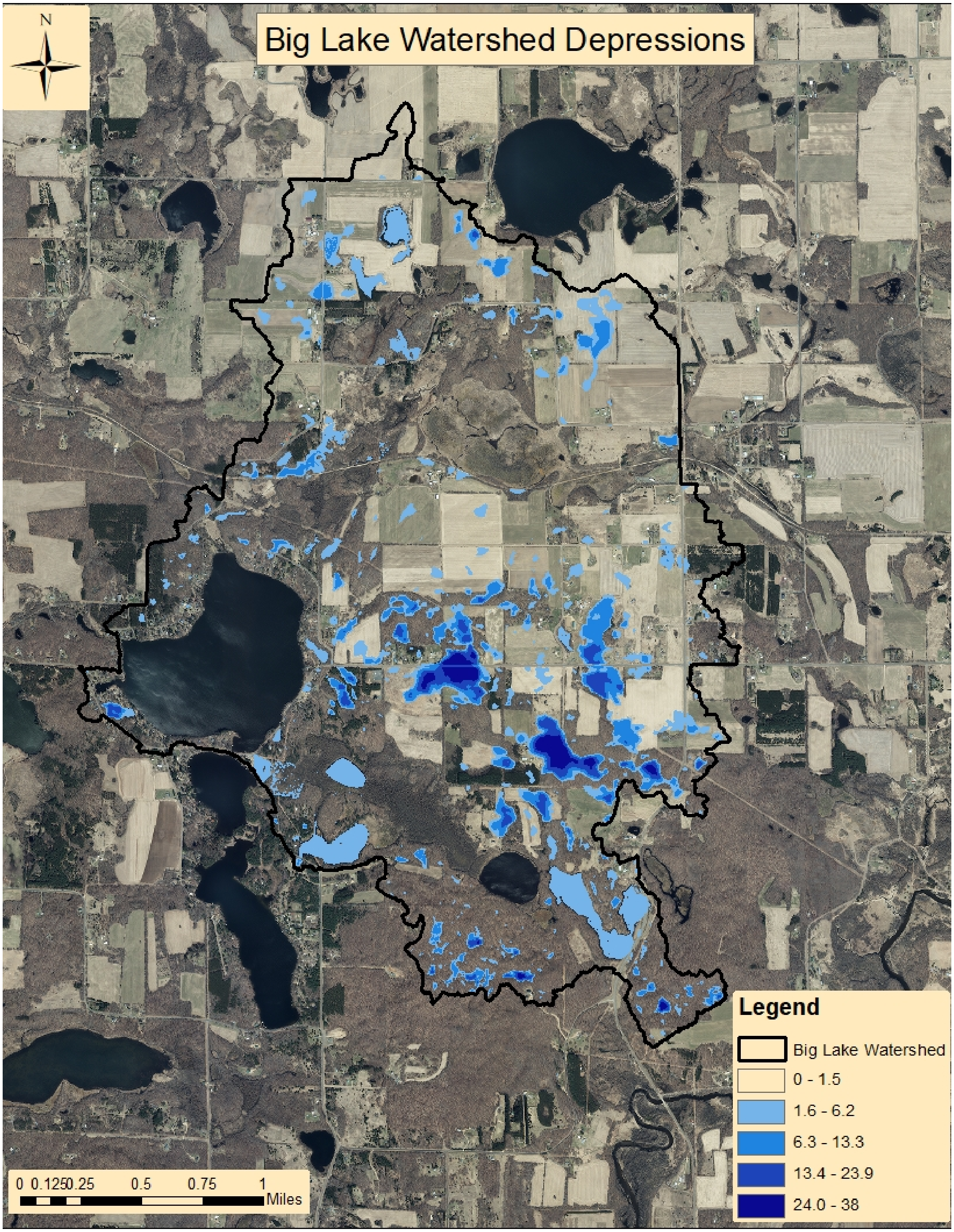


Figure 7: Map showing degrees of depressions within the watershed. The more substantial the depression, the less likely the water will flow into Big Lake from that portion of the watershed.

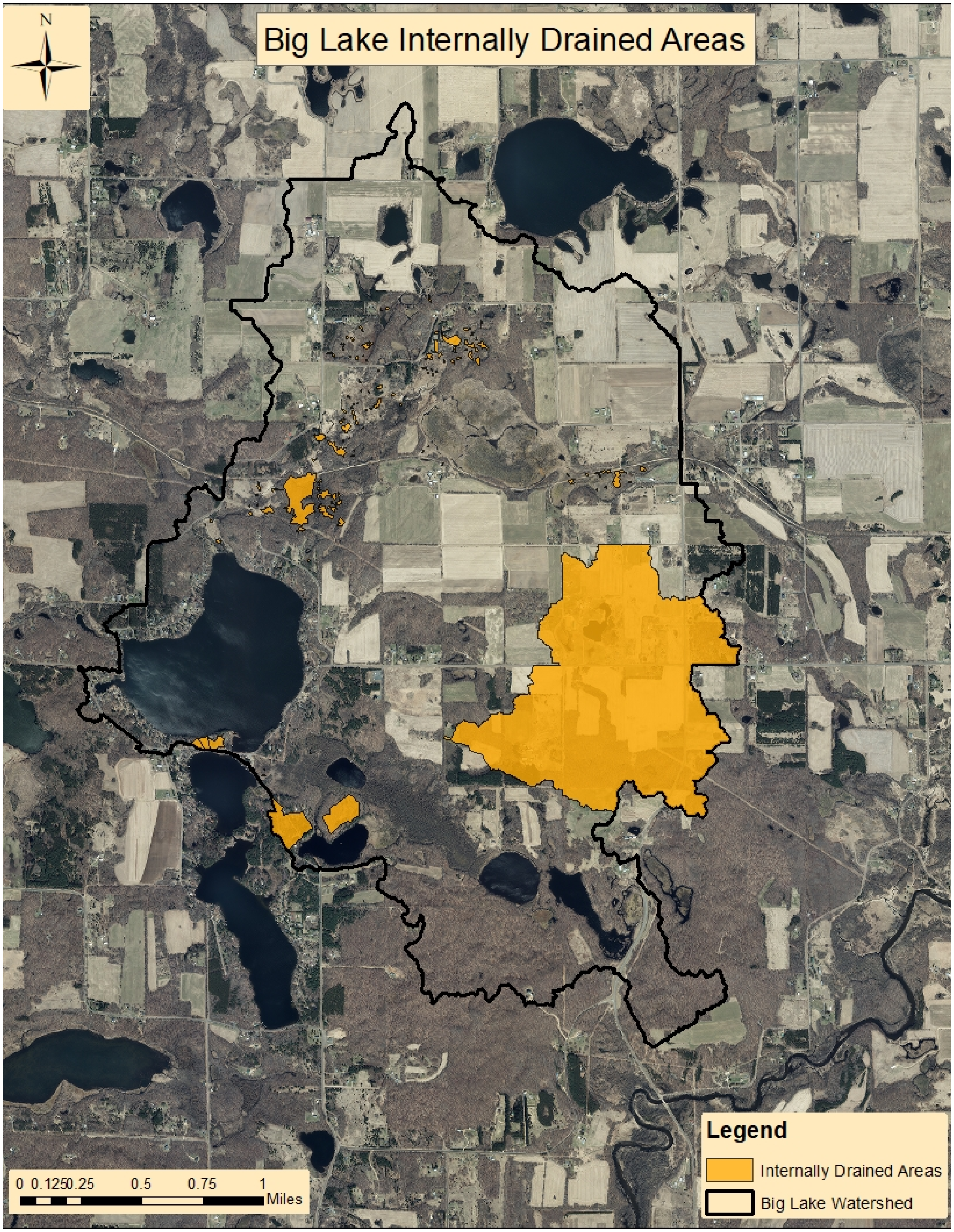


Figure 8: Map showing likely internally drained areas in the Big Lake watershed. These are areas where the over land runoff does not flow into the lake directly. Note the large area which is contained in the South-sub-watershed.

North sub-watershed (inlet drained)		
Landcover type	**Area (acres)**	**% of total**
Row crop	510.8	33.5
Forest	418.3	27.4
Mixed agriculture	165.3	17.4
Wetland	266.2	10.8
Rural residential	91.1	6.0
Medium residential	2.6	0.2
Road	29.1	1.9
Pasture	18.8	1.2
Livestock	15.8	1.0
Open water	8.5	0.6
Total	1526.4	100
Southeast sub-watershed		
Landcover type	**Area (acres)**	**% of total**
Row crop	149.8	41.4
Forest	148.2	41.0
Mixed agriculture	30.22	8.4
Wetland	6.2	1.7
Rural residential	17.1	4.7
Medium residential	3.75	1.0
Road	6.2	1.7
Total	361.45	100
South sub-watershed		
Landcover type	**Area (acres)**	**% of total**
Forest	429.8	54.8
Mixed agriculture	107.75	13.7
Wetland	167.9	21.4
Rural residential	8.8	1.1
Open water	61.6	7.9
Road	6	0.8
Pasture	2.35	0.3
Total	784.2	100
Big Lake Direct sub-watershed		
Landcover type	**Area (acres)**	**% of total**
Row crop	30.2	12.9
Forest	70.9	30.4
Wetland	0.5	0.2
Mixed agriculture	14.6	6.3
Rural residential	13.4	5.7
Medium residential	94.6	40.5
Road	9.4	4.9
Total	233.6	100

Table 4: Sub-watershed land cover areas and % of the total.

North tributary (inlet)

The North sub-watershed is drained by the inlet into Big Lake. The flow and phosphorus concentration were monitored throughout summer 2020. The total loading amounts are summarized in Table 5.

North inlet 2020 data parameter	Amount
Total flow into Big Lake (May-Sept)	2.4 hm^3
Mean Total Phosphorus concentration (adjusted for decrease due to settling in wetland before the lake)	100 mg/m^3 (ppb or ug/L)
Mean soluble reactive phosphorus concentration (not adjusted)	42.6 mg/m^3
Total load from the inlet (May-June) (kg)	240.0
Total load per area (kg/km^2)	38.8

Table 5: North inlet flow and nutrient load data.

The north inlet loading data was used to determine the total load for the North sub-watershed. The other two sub-watershed loads were estimated using export coefficients. The septic load was estimated using the septic system phosphorus model in WILMS, with the per capita septic use data from Polk County Land and Water Conservation Dept data. The internal load was determined using volume-weighted phosphorus increase from August to September and mass balancing with other sources during that period. Round Lake was estimated through the water budget balance and the mean phosphorus concentration of Round Lake during the monitoring period in 2020.

Septic systems

The septic data was obtained from the 2018 (Polk County Land and Water Resources Dept) study where WILMS was used to estimate the load. It was estimated to be **8 kg/yr**. It was not clear as to if this was for the entire year or just the growing season. The use of septic systems is likely most intense in the summer, so the 8 kg was used for the model.

Phosphorus budget-all sources

Estimated phosphorus sources for average precipitation year-May to Sept (based upon 2020 and historical data). This is the data that was used for the load analysis later in this document. The modeled results are based upon **GSM for total phosphorus of 24.5 ug/L and chlorophyll-a of 8 ug/L.**

Source	Kg of Phosphorus/ May-Sept	% of total
North inlet/North sub-watershed	240.0	70.6
Atmospheric deposition	14.1	4.2
SE sub-watershed	11.3	3.3
Big Lake Direct sub-watershed	22	6.5
South-sub-watershed	10.0	2.9
Septic systems	8	2.4
Internal	30.8	9.1
Round Lake	3.6	1.1
Total	**339.8**	100

Table 6: Nutrient loading source summary for Big Lake, adjusted for average year precipitation and 2020 internal load.

The growing season load data were graphed in a pie chart to show the breakdown of phosphorus sources by percent.

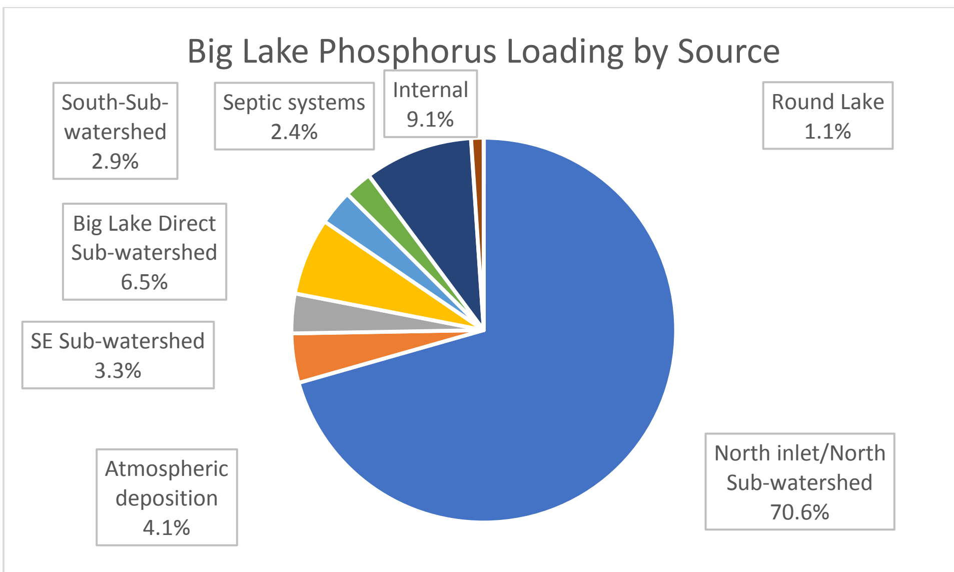


Figure 9: Phosphorus load sources by percent of total load during the growing season, Big Lake.

As the data shows, the main source by a large amount is the north inlet. This is followed by the internal load from the hypolimnion release and the Big Lake Direct sub-watershed runoff. The internal load is based upon the degradation of stratification and can vary from year to year. This is based upon 2020 data only, but historical data suggests mixing happened in September in past years. Full mixing/turnover of the lake occurred in October, which is typically too late to grow algae that affect lake use/aesthetics.

Historical Data

A study to evaluate internal loading in Big Lake was conducted by the Polk County Land and Water Conservation Dept. Data were collected in this study and some are shown to support conclusions/data from the 2020 study. Figure 8 shows the total phosphorus concentration in the hypolimnion in 2017 and 2018. Data shows the concentration varied immensely. In 2017, a major drop in concentration occurred in mid-July and again in early August. However, there was not a corresponding spike in the epilimnion. This shows that the phosphorus did not mix into the upper layer. Similarly, in 2018 a significant decrease occurred in May, but there is no evidence the phosphorus moved out of the lake bottom layer. This suggests that the hypolimnion may be very thin and any deviation in sampling depth could account for the difference rather than the entrainment of phosphorus. Remember the sediment release of phosphorus can be significant in Big Lake, but if it doesn't leave the bottom layer, it will not contribute to algae growth as it is not available.

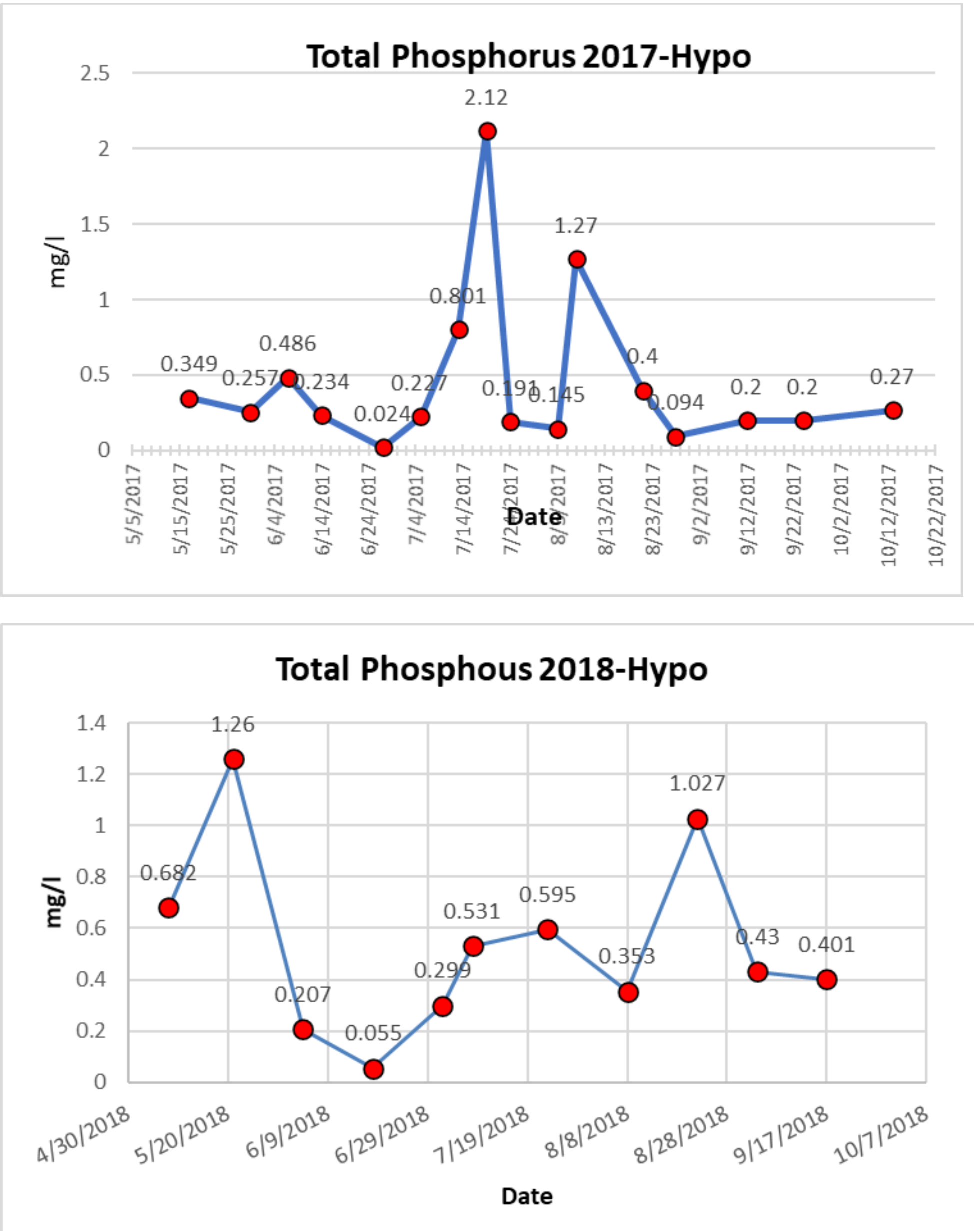


Figure 10: Graphs depicting hypolimnion phosphorus concentration in 2017 and 2018. Note the substantial increases and decreases.

The north inlet data from 2020 shows very high phosphorus concentrations. The only other data that was available was from the summer of 2012, and one sample in Feb. 2014. The summer data in 2012 shows high phosphorus concentration as well and the winter data (obviously limited) shows that the concentration remaining high during a time runoff is likely limited.

North Inlet Sample Date	Total Phos. (mg/m^3)	Soluble reactive phos.
Mean (May-Sept) 2012	87	73.2
2/18/2014 (one sample analyzed)	63	32

Table 7: Historical inlet data (from 2012).

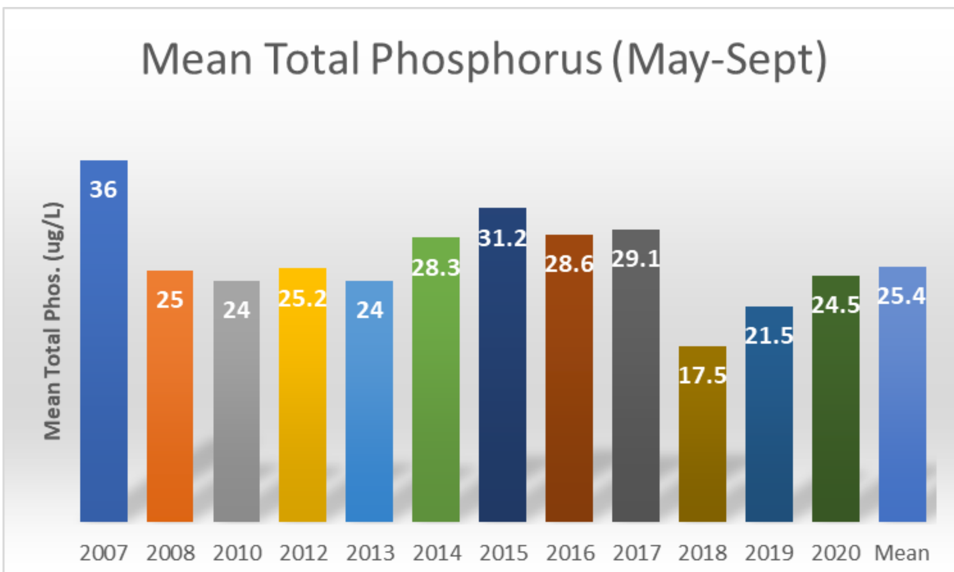


Figure 11: Mean growing season total phosphorus concentration by year (ug/L in the epilimnion).

The figure shows the mean total phosphorus for the growing seasons over various years data is available. As shown, the lake phosphorus concentration mean is about 25 ug/L. It ranges from a low of 17.5 ug/L (2018) to a high of 36 ug/L (2007). The 2020 mean (24.5 ug/L) is nearly identical to the historical mean of 25.4 ug/L.

Figure 11 shows the historical chlorophyll-a concentration (which reflects the amount of algae growth in the water) for years data was available. The mean is about 12 ug/L but varies widely from a high of 31 ug/L (2007) to a low of less than 5 ug/L in 2017. It should be noted that sample collection and analysis were not consistent, with different years having different numbers of samples analyzed, which would create variation in data. 2020 mean chlorophyll concentration was below the mean, as were 6 of the years graphed vs only three above the mean. 2007 likely skewed the mean to be higher than if that data were omitted. The reason for the high value in 2007 is unknown, but it may be that the lake mixed early in the growing season and the accumulated phosphorous mixed into the epilimnion raising the concentration. The profile data available from 2007 suggests that stratification may have degraded enough to lead to the mixing. It is known there is an accumulation of phosphorus in the hypolimnion in Big Lake, therefore if mixing occurs early in the season, higher phosphorus concentrations could be expected.

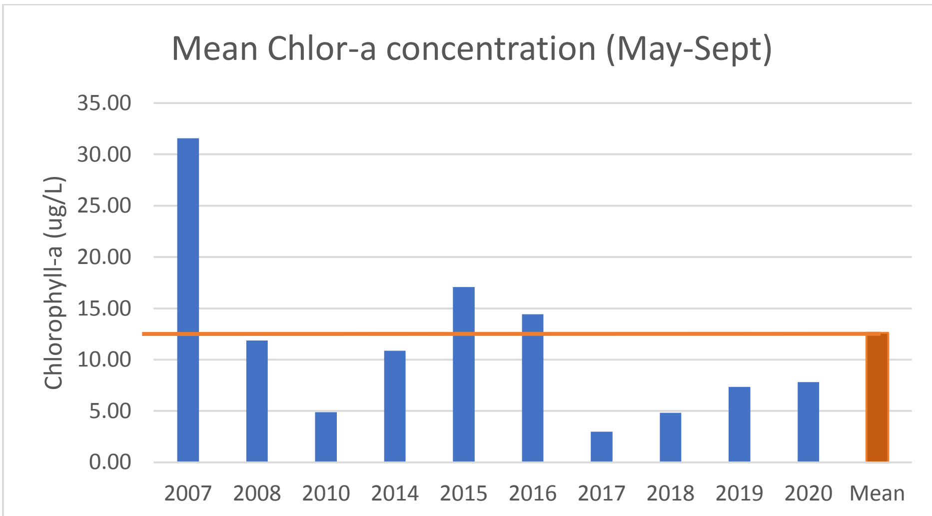


Figure 12: Graph showing historical chlorophyll-a concentrations in the epilimnion of Big Lake. The orange bar (and line) represents the mean value for all years on the graph.

Correlation of parameters associated with water quality

To evaluate how the amount of precipitation may affect the nutrient concentration, historical precipitation amounts were plotted against total phosphorus (growing season mean). The assumption is that if the lake phosphorus is mainly impacted by runoff from overland, then higher precipitation amounts may lead to higher phosphorus concentrations. It must be noted that total precipitation may not adequately reflect potential runoff due to the varying intensity of storm events. For example, one short-duration, 2-inch rain event will have different runoff values (higher) than several small rain events totaling 2 inches.

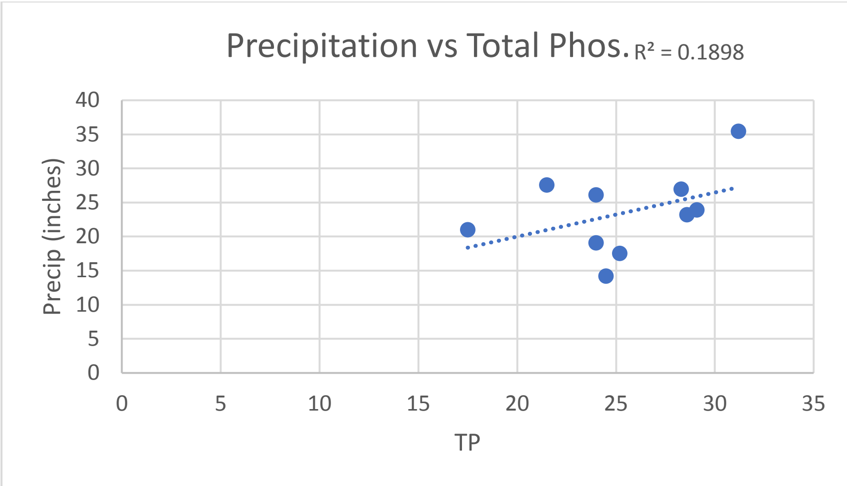


Figure 13: Scatter plot to determine a correlation between precipitation amount and total phosphorus concentration in Big Lake.

Figure 13 shows the scatter plot of precipitation vs total phosphorus concentration in Big Lake (precipitation amounts were not available for all years depicted on the total phosphorus graph). The trendline indicates a weak correlation with an R^2 of 0.19. This could be due to several factors. First, the rain intensity variation is mentioned. It may also be an indication that the north inlet phosphorus concentration is high, even during low precipitation years. It could also be due to internal loading that can occur in late summer/early fall resulting in a phosphorus spike, increasing the mean. Since mixing (or lack of) in late August/early-Sept can be variable, it could account for the variability in the data.

Since chlorophyll-a concentrations represent the algae growth and this is largely dictated by available soluble phosphorus, then there could be a correlation between precipitation and chlorophyll-a. A scatter plot of precipitation and chlorophyll-a showed a weak correlation, which would be consistent with weak precipitation/total phosphorus concentration correlation.

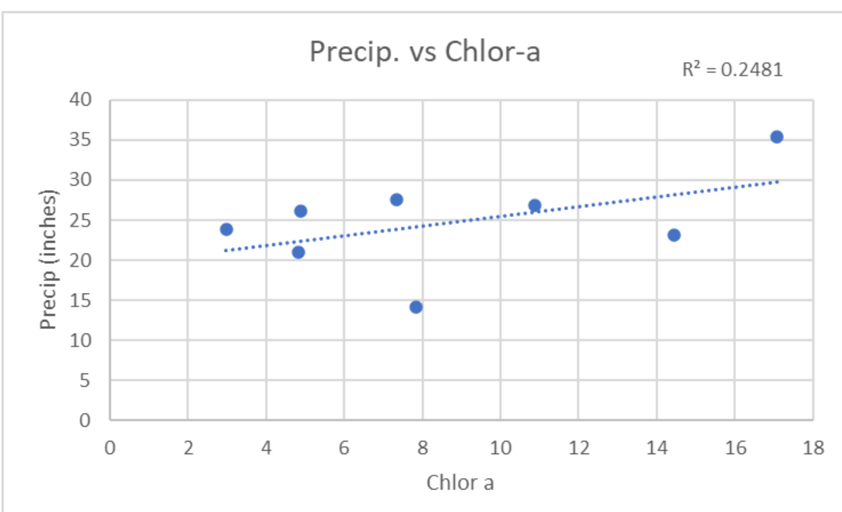


Figure 14: Scatter plot of precipitation vs chlorophyll-a concentration to determine correlation.

Since the issue of concern in Big Lake is excessive algae growth, the mean concentration of chlorophyll-a by month over several years was plotted. This supports that there is an increase in algae growth during the growing season, which is typically due to increases in available phosphorus and warming of the lake water. However, there is a large increase from August to Sept, which would support the potential entrainment of hypolimnetic phosphorus into the epilimnion, which can lead to more algae growth.

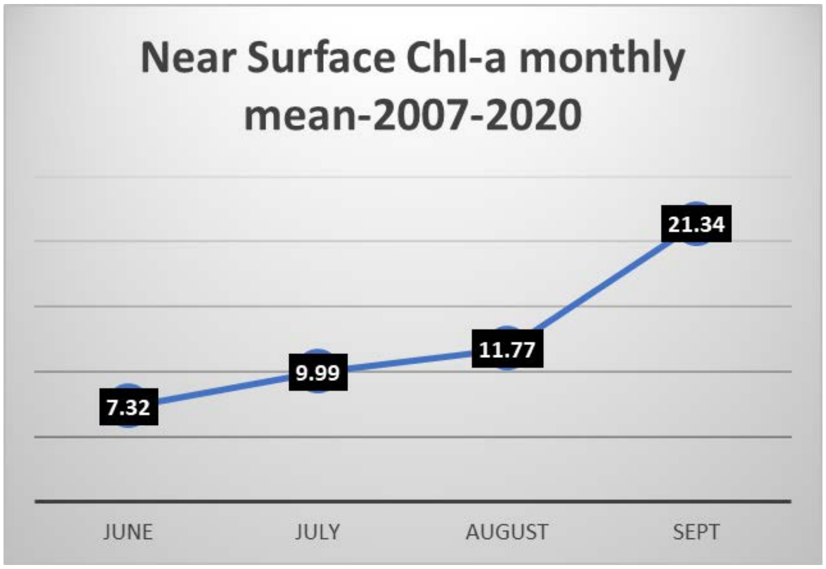


Figure 15: Graph depicting the monthly mean of chlorophyll-a concentration. Note the increase from August to Sept.

Trophic state

The trophic state index indicates the trophic state of the lake based upon three parameters. The Carlson trophic state index (TSI) indicates if the lake is oligotrophic, mesotrophic, or eutrophic using total phosphorus concentration, chlorophyll-a concentration, and Secchi depth (water clarity) to indicate what the state of the lake is regarding these parameters. The higher the TSI the more productive the lake.

Parameter	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean
Total phos.	50.7	50.0*	52.4	53.8	52.5	52.8	45.4	48.4	50.3	50.7
Chlor-a	n/a	n/a	54	58.4	56.8	41.4	46.0	50.2	50.8	51.1
Secchi depth	42.4	38.7*	51.5	49.3	45.7	42.8	46.2	46.2	45.7	45.4

30-40	**Oligotrophic**
40-50	**Mesotrophic**
50-60	**Mild Eutrophic**
60-70	**Eutrophic**
70-80	**Hyper Eutrophic**

Table 8: Summary of Trophic State Index (TSI) data over several years in Big Lake. *Limited data available

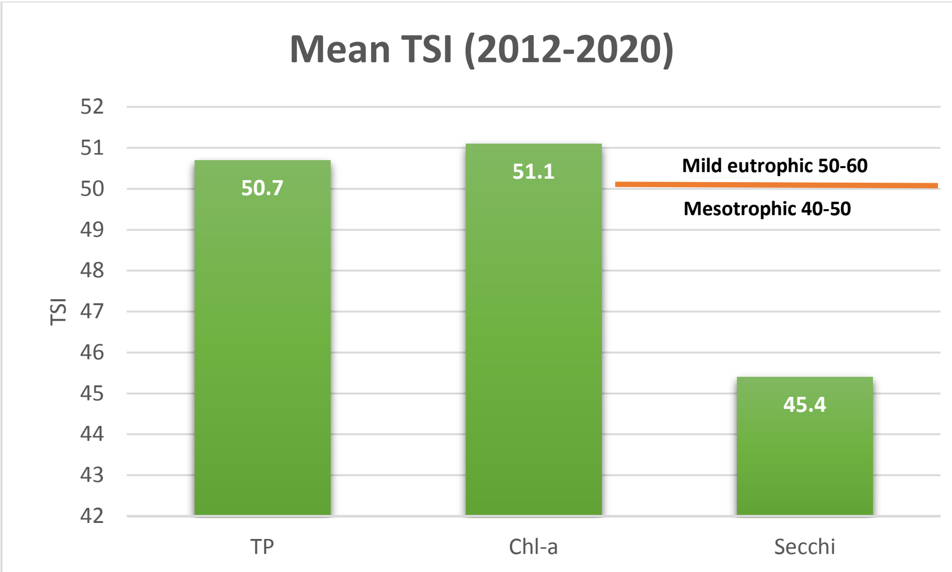


Figure 16: Graph showing mean TSI values for each parameter used in the TSI. Note the cutoff between mesotrophic and mild-eutrophic.

Figure 16 shows that the TSI values for both total phosphorus and chlorophyll-a vary just above and below the threshold between mesotrophic and mild-eutrophic. The Secchi depth is consistently in the mesotrophic category. The better TSI for Secchi depth may be because of larger algae cells or clumped species that produce higher chlorophyll concentrations but allow for more light penetration due to bigger spaces between algae.

Discussion

The Canfield/Bachman lake phosphorus sedimentation model predicted a higher mean phosphorus concentration than the observed data in Big Lake. This may be due to the high flux of phosphorus from the north inlet. However, the confidence value (70%) suggests that the lowest predicted phosphorus concentration is equal to the GSM mean in Big Lake in 2020 (falls within the predicted range 70% of the time). This means that the model is a good enough fit to use. The decay rate of phosphorus in the lake had to be increased to calibrate the model to fit the observed lake data more accurately.

Internal load

The lab incubated sediment cores that were analyzed indicate the release rate that was not reflected in the 2020 hypolimnetic data. This may be due to inaccurate water sampling from a thin hypolimnion layer. Minor changes in depth for water sampling could skew the phosphorus concentration lower than what is actually in the hypolimnion. This is supported by the erratic data collected in past years from the hypolimnion. This is why obtaining data from incubated sediment cores is helpful. The reported release rate along with the area and duration of anoxic conditions in Big Lake should allow for an accurate estimate of the mass of phosphorus released from the sediments.

As mentioned in the results section, the epilimnion phosphorus concentration increased to a degree in September that could not be accounted for in other sources. It was estimated that 30 kg of phosphorus was entrained from the hypolimnion into the epilimnion. Historical data shows similar phosphorus (and chlorophyll-a) increase in September. This may not always be due to sediment release phosphorus as intense rain events could also cause this spike. Furthermore, if Big Lake mixes earlier (i.e., August), then a spike in phosphorus (and likely chlorophyll) would occur earlier. Most years, the total phosphorus increases in September which likely has internal load as a contributor. However, most years, this phosphorus source would be a small percentage of the overall budget.

The data shows that Big Lake has sediment release of phosphorus that likely occurs most years. The rate of release is high enough that with anoxic conditions in Big Lake sediments, the total mass is high. However, this release is significant only if the phosphorus reaches the upper layer of the lake where light is intense enough to grow algae. The 2020 data (as well as historical data) shows that the entrainment of phosphorus into the epilimnion (upper layer) may occur in September. This historically has led to consistent spikes in chlorophyll-a in September. This timing is at the end of the growing season, which means that Big Lake has lower chlorophyll-a throughout much of the growing season, with the very end of the growing season showing higher chlorophyll-a.

Big Lake North Inlet

The largest source of phosphorus appears to be the north inlet. The 2020 model showed it contributed more than 70% of the phosphorus entering Big Lake. The inlet phosphorus concentration is higher than is predicted from typical export coefficients of land cover. This suggests that there is a source of phosphorus that is not being accounted for in the model (the field data allows for an accurate account of this source). Only one other year of tributary data was available from 2012 and that data also showed high concentrations of phosphorus in this tributary. The 2020 data showed most of the phosphorus was not soluble reactive phosphorus, which may indicate much of the phosphorus is sediment. In 2020, the concentration of phosphorus was 21% lower at the mouth of the inlet vs where the water collected just upstream. This was done to determine the effect of the water pooling in a wetland area just upstream from Big Lake. It is likely sediment settled and with it a reduction in phosphorus. However, in 2012 the majority of the phosphorus in the inlet water was soluble reactive phosphorus. This contradiction makes the speculation of phosphorus sources into the inlet more difficult. Interestingly, the concentration ranged from 92 ug/L to 152 ug/L, but the flow was the same in all cases. This indicates that more data is needed to evaluate potential sources of phosphorus. This modeling is based upon one season data therefore may not represent the loading from this tributary over long periods.

These sources could be some or a combination of the following: 1. Groundwater phosphorus concentration is high in this watershed, which could be natural and/or due to human activity; 2. There has been an accumulation of organics in wetlands that are discharging phosphorus; 3. There is land cover/use that is fluxing more phosphorus than would be predicted such as concentrated manure that is leaching into the tributary as an example. Depending on the source of phosphorus in this inlet, it may or may not be manageable. Further study could answer the question of the source(s) of this phosphorus and would be warranted since it appears to be the main issue with Big Lake nutrients. Depending on the source(s), mitigation may be possible to reduce the phosphorus concentration in this tributary.

Other sources

The modeling of the other sources showed that the SE-sub-watershed is the largest contributor of the other sources (and higher than the internal load as well). This is based upon the relatively high amount of row crop land cover. The Direct-sub-watershed had less total phosphorus contribution, but this sub-watershed is smaller than the SE-sub-watershed, so the kg/area is not substantially different (29 kg/km^2 for the SE vs 23 kg/km^2 for the Direct sub-watersheds). The land cover in the Direct-sub-watershed that contributes the most phosphorus is the medium density residential near the lake. Mitigation of phosphorus is likely possible through best management practices in these sub-watersheds.

Septic systems also likely contribute some phosphorus into Big Lake. Since no information was available as to the age or functionality of the various systems, an estimate was determined using WILMS and the data used in a previous Big Lake study. Based upon this estimate, septic systems would not be considered a major source compared to other sources.

The water budget was used to estimate the water flowing into Big Lake from Round Lake (which also receives water from Church Pine Lake). This flow of water into Big Lake via the connected lake system was balanced using the evaporation and the outlet in Big Lake. Since there was no data collected on Church Pine or Round Lake, the water from Round Lake is estimated based on making the mass of water balance, therefore is a rather rough estimate. However, the concentration of phosphorus in Round Lake in 2020 was lower than in Big Lake. This provides predicted load from Round Lake, which may be somewhat misleading as during most of the summer the water flowing into Big Lake from Round Lake is lower in phosphorus concentration.

Atmospheric deposition of phosphorus is based on literature values from studies completed to provide an estimate. These studies show a wide range of values ranging from 7 ug/L to 16+ ug/L. We used 10 ug/L and it should be understood this could be higher or lower. Regardless, mitigation of atmospheric phosphorus is not viable.

Load Analysis

The Bathtub model was used to change the phosphorus load by 20% interval increases and decreases to predict the estimated total phosphorus concentration and chlorophyll-a concentration that would likely result. The load analysis was used to evaluate the entire watershed, only the north tributary, and internal loading.

Change in entire load (from external sources, not internal load)

Load change	**Estimated mean GSM TP (ug/L)**	**Low of range value of TP**	**High of range value of TP**	**Estimated Chlor-a GSM (ug/L)**	**Low of range value chl-a**	**High of range value chl-a**
0.60 **(40% reduction)**	19.3	14.5	25.6	5.3	3.4	8.3
0.80 **(20% reduction)**	22.0	16.4	29.5	6.5	4.2	10.2
1.00 **(present load)**	24.5	18.2	32.9	7.7	4.8	12.0
1.20 **(20% increase)**	26.7	19.7	36.1	8.7	5.5	13.7
1.40 **(40% increase)**	28.8	21.2	39.1	9.7	6.1	15.4

Table 9: Load analysis of changing phosphorus loading from entire watershed and the predicted total phosphorus and chlorophyll-a concentrations.

Change in north inlet load only

Load change	**Estimated mean GSM TP (ug/L)**	**Low of range value of TP**	**High of range value of TP**	**Estimated Chlor-a GSM (ug/L)**	**Low of range value chl-a**	**High of range value chl-a**
0.60 (40% reduction)	20.3	15.2	27.1	5.8	3.7	9.0
0.80 (20% reduction)	22.5	16.8	30.1	6.7	4.3	10.5
1.00 (present load)	24.5	18.2	32.9	7.7	4.8	12.0
1.20 (20% increase)	26.3	19.5	35.6	8.5	5.4	13.4
1.40 (40% increase)	28.0	20.7	38.0	9.3	5.9	14.8

Table 10: Load analysis of changing phosphorus loading from North sub-watershed and the predicted total phosphorus and chlorophyll-a concentrations.

Table 9 shows that a 20% reduction in phosphorus loading into Big Lake would result in fairly significant reductions in predicted total phosphorus and chlorophyll-a concentrations. A 20% reduction in the loading from the north inlet alone also shows fairly robust reductions in total phosphorus and chlorophyll-a in Big Lake. The likely predicted values of 22.5 ug/L (range of 16.8 to 30.1 ug/L) for phosphorus and 6.7 ug/L (range of 4.3 to 10.5 ug/L) for chlorophyll-a with a 20% reduction in the north inlet (Table 10), would put the TSI values for both parameters just below the mild-eutrophic threshold.

No internal load (assuming 30 kg/growing season which implies release is before Oct.1)

Parameter	Estimated concentrations with internal load	Estimated concentration from model without internal load
Total phosphorus	24.5	23.1
Chlorophyll-a	7.7	7.1

Table 11: Predicted total phosphorus concentration and chlorophyll-a concentration with no internal load.

Table 10 shows a slight decrease in chlorophyll-a with no internal loading. The mean chlorophyll-a concentration from July to August in 2020 was 6.04 ug/L. It jumped to 14.2 ug/L in September, which corresponds with the estimated internal load in early September. The predicted 7.1 ug/L without internal loading (from the load analysis) appears to be fairly accurate.

Recommendations

Big Lake was listed as impaired water based upon excess algae growth. The data from 2012-2020, shows that the algae growth (as represented by chlorophyll-a concentrations) is just above the mesotrophic status in the mild eutrophic status. Therefore, it would be prudent to explore this designation further. Was this based on one year of data when there was a spike? Assuming that this designation is proper, then mitigation of phosphorus should result in a reduction of algae growth in Big Lake. The load analysis conducted for the Big Lake phosphorus budget shows that reduction in phosphorus loading would result in lower phosphorus concentrations and lower chlorophyll-a concentrations (indicating fewer algae growth).

The focus of this analysis was to better understand the internal load based upon a recommendation from Polk County in 2018. The sediment release was determined and based upon a period of anoxic condition in the lake bottom sediment, a large amount of phosphorus can be released in any given year. However, the entrainment of this phosphorus was limited to 30 kg in September 2020. Historical data (previous to 2020) suggests that there is not large entrainment of phosphorus into the upper layer (where algae grow) in most years. Therefore, mitigating internal load may not be warranted as it may not make a major impact on algae growth most years (there are some historical data that have high phosphorus growing season mean that could be from internal loading, but it seems to only occur on rare occasion). Monitoring of phosphorus and chlorophyll-a, as well as DO/Temperature profiles, should continue to determine if trends should change. Evaluation of mitigation efforts could occur with the release rate data now available if trends should change.

To reduce phosphorus in Big Lake, the first focus should be on the North inlet sub-watershed. This contributed 70% of the phosphorus into Big Lake from May to Sept of 2020. The concentration of phosphorus in this tributary is not accounted for by the land cover that surrounds it. Therefore, to mitigate phosphorus in this inlet, from the north watershed, the sources of phosphorus need to be identified. It should also be noted that this high loading was from only one season of data and could not necessarily be representative the loading mean over a long periods. Once identified, management practices that can reduce phosphorus can be evaluated and eventually implemented.

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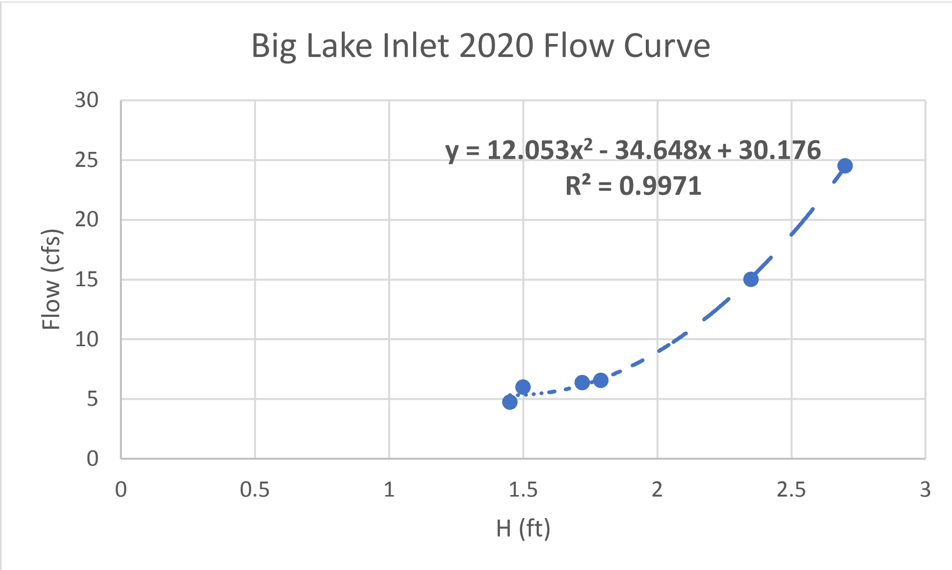
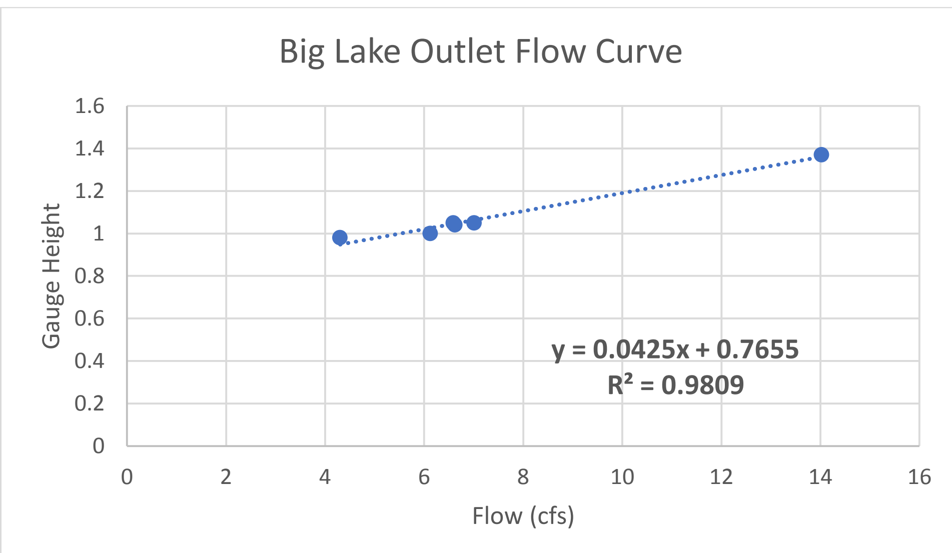
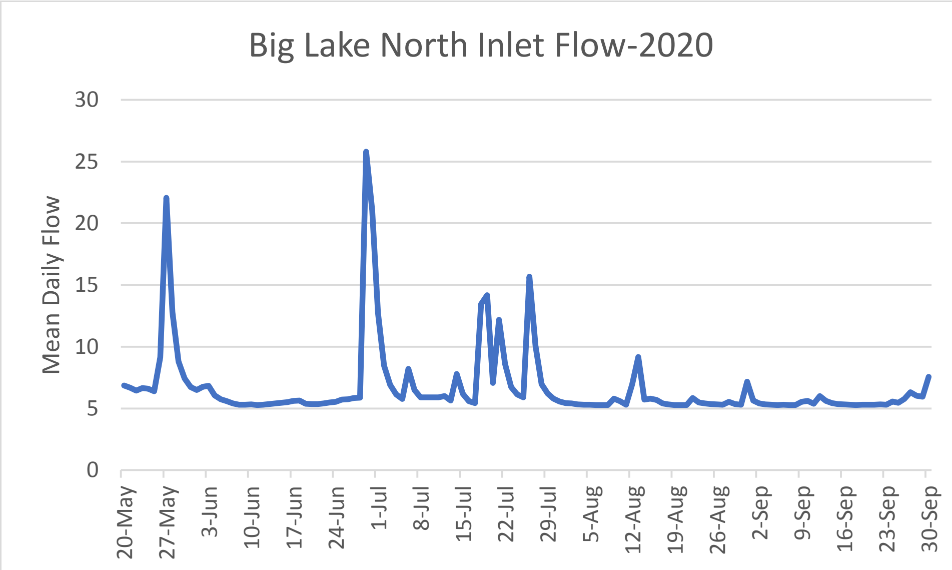
Data

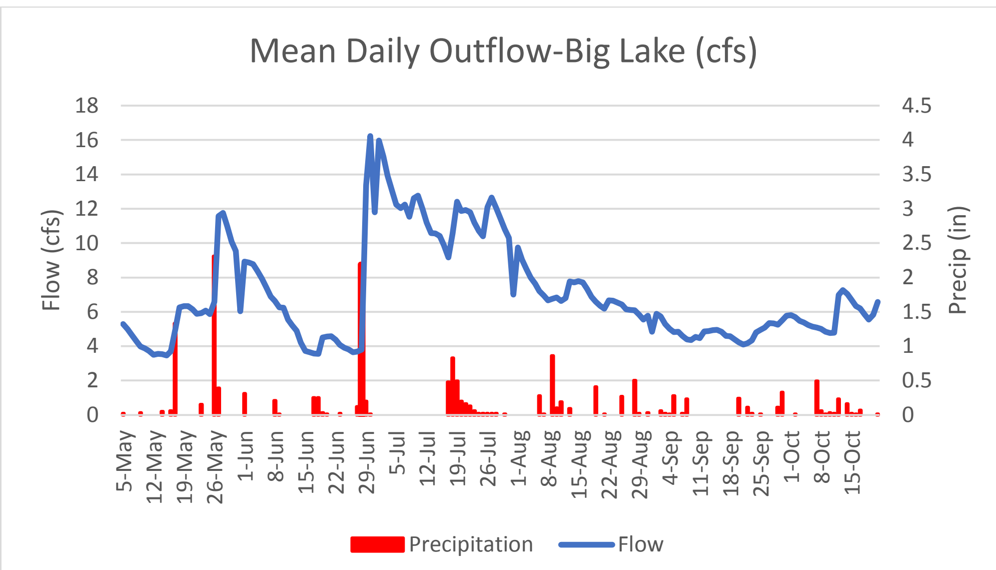
Flow curves for inlet and outlet





Inlet and outlet hydrographs using flow curves





Precipitation Data:

Period	Total Precipitation (in) for period	Largest 24 hr event (in)
May 1 – May 30	3.30	1.7
June 1 – June 30	5.48	2.95
July 1- July 31	7.86	2.7
August 1 – August 31	3.21	1.04
Sept. 1 – Sept 30	1.63	0.3
Total	21.48	2.95 (June 29)

Bathtub input/output Needs to be changed….

Overall Water & Nutrient Balances

Overall Water Balance | **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km²	Flow hm³/season	Variance (hm3/season)²	CV -	Runoff m/season
1	1	1	Inlet creek-North Sub-watershed	6.2	2.4	0.00E+00	0.00	0.39
2	2	1	Big Lake Direct Watershed	0.9	0.1	0.00E+00	0.00	0.11
3	1	1	Round Lake		0.2	0.00E+00	0.00	
4	1	1	SE Sub-watershed	1.5	0.0	0.00E+00	0.00	0.03
5	1	1	Septic		0.0	0.00E+00	0.00	
6	4	1	Outlet		2.8	0.00E+00	0.00	
7	1	1	South Sub-watershed	3.2	0.1	0.00E+00	0.00	0.03
PRECIPITATION				1.4	0.8	0.00E+00	0.00	0.54
TRIBUTARY INFLOW				10.8	2.7	0.00E+00	0.00	0.25
NONPOINT INFLOW				0.9	0.1	0.00E+00	0.00	0.11
***TOTAL INFLOW				13.2	3.6	0.00E+00	0.00	0.27
GAUGED OUTFLOW					2.8	0.00E+00	0.00	
ADVECTIVE OUTFLOW				13.2	0.0	0.00E+00	0.00	
***TOTAL OUTFLOW				13.2	2.8	0.00E+00	0.00	0.21
***EVAPORATION					0.8	0.00E+00	0.00	

Overall Mass Balance Based Upon | **Predicted** | **Outflow & Reservoir Concentrations**

Component: | **TOTAL P**

Trb	Type	Seg	Name	Load kg/seas	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/seas
1	1	1	Inlet creek-North Sub-watershed	240.0	70.6%	0.00E+00		0.00	100.0	38.8
2	2	1	Big Lake Direct Watershed	21.5	6.5%	0.00E+00		0.00	204.6	22.7
3	1	1	Round Lake	3.6	1.1%	0.00E+00		0.00	18.0	
4	1	1	SE Sub-watershed	11.3	3.3%	0.00E+00		0.00	283.0	7.8
5	1	1	Septic	8.0	2.4%	0.00E+00		0.00	80000.0	
6	4	1	Outlet	69.3		5.91E+02		0.35	24.4	
7	1	1	South Sub-watershed	10.0	3.0%	0.00E+00		0.00	100.0	3.1
PRECIPITATION				14.1	4.1%	0.00E+00		0.00	18.5	10.0
INTERNAL LOAD				30.3	9.0%	0.00E+00		0.00		
TRIBUTARY INFLOW				272.9	80.5%	0.00E+00		0.00	99.6	25.2
NONPOINT INFLOW				21.5	6.4%	0.00E+00		0.00	204.6	22.7
***TOTAL INFLOW				338.9	100.0%	0.00E+00		0.00	94.0	25.7
GAUGED OUTFLOW				69.3	20.5%	5.91E+02		0.35	24.4	
ADVECTIVE OUTFLOW				-0.9		9.93E-02		0.35	24.4	
***TOTAL OUTFLOW				68.4	20.2%	5.76E+02		0.35	24.4	5.2
***RETENTION				270.5	79.8%	5.76E+02		0.09		

Overflow Rate (m/yr)	2.0	Nutrient Resid. Time (yrs)	0.5268
Hydraulic Resid. Time (yrs)	2.6100	Turnover Ratio	1.9
Reservoir Conc (mg/m3)	24	Retention Coef.	0.798

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.540000021	0.0
Evaporation (m)	0.569999993	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	10	0.50
Total N	1000	0.50
Ortho P	5	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	5	P, JONES & BACHMAN
Secchi Depth	4	VS. TP, CARLSON TSI
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	2	MODEL ONLY
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	
1	1	0	1.429999948	0	1	0	0.899999976	0	1.399999976	

Tributary Non-Point Source Drainage Areas (km^2)

Trib	Trib Name	1	2	3	4	5	6	7	8
		Land Use Category--->							
1	Inlet creek-North Sub-watershed	2.130000114	1.690000057	1.080000043	0.66900003	0.368999988	0.01	0.118000001	0.075999998
2	Big Lake Direct Watershed	0.122000001	0.287	0.0019	0.059	0.054000001	0.382999986	0.037999999	0
3	Round Lake	0	0	0	0	0	0	0	0
4	SE Sub-watershed	0.606999993	0.600000024	0.025	0.122000001	0.068999998	0.015	0.025	0
5	Septic	0	0	0	0	0	0	0	0
6	Outlet	0	0	0	0	0	0	0	0
7	South Sub-watershed	0	1.74000001	0.680000007	0.439999998	0.039999999	0	0.02	0.009

Non-Point Source Export Coefficients

Categ	Land Use Name	Runoff (m/yr) Mean	CV	Conserv. Subs. Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Ortho P (ppb Mean
1	Row crop	0.140000001	0	0	0	400	0	0	0	0
2	Forest	0.059999999	0	0	0	80	0	0	0	0
3	Wetland	0.059999999	0	0	0	80	0	0	0	0
4	mixed ag	0.108999997	0	0	0	250	0	0	0	0
5	rural residential	0.059999999	0	0	0	120	0	0	0	0
6	medium residential	0.136000007	0	0	0	200	0	0	0	0
7	Road	0.239999995	0	0	0	100	0	0	0	0
8	Pasture	0.059999999	0	0	0	300	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0