Bone Lake Internal Load Studies and Alum Recommendations

Newly available estimates greatly increase the percentage of the phosphorus budget coming from internal load from lake sediments when compared with previous studies. Prior to the 2017 results, the most recent estimates of internal load were completed in 2009. These estimates were used to prepare the 2010 pie chart of the phosphorus budget which helped to target Bone Lake management efforts in recent years.

The 2009 internal load study noted a substantial internal load from lake sediments. The accuracy of the methods used to estimate internal loading was reported as limited in 2009 because the lake did not stay stratified throughout the summer. With temperature stratification in lakes, the bottom layer stays cold and oxygen levels decline. When there is low oxygen at the bottom of the lake, phosphorus is released from lake sediments. If stratification remains in place, the released phosphorus doesn't come to the surface until the top layer of the lake cools and the lake mixes. In Bone Lake, low oxygen levels occur and phosphorus is released, but the lake periodically mixes bringing high phosphorus water to the surface. High phosphorus concentrations lead to algae blooms. This characteristic of Bone Lake made estimates of the internal load with the methods used in 2009 (and the phosphorus budget available at that time) imprecise.

The Bone Lake Management District embarked on more detailed and accurate ways to measure internal loading with two studies initiated from 2015-2017. These studies were supported by Wisconsin DNR grants.

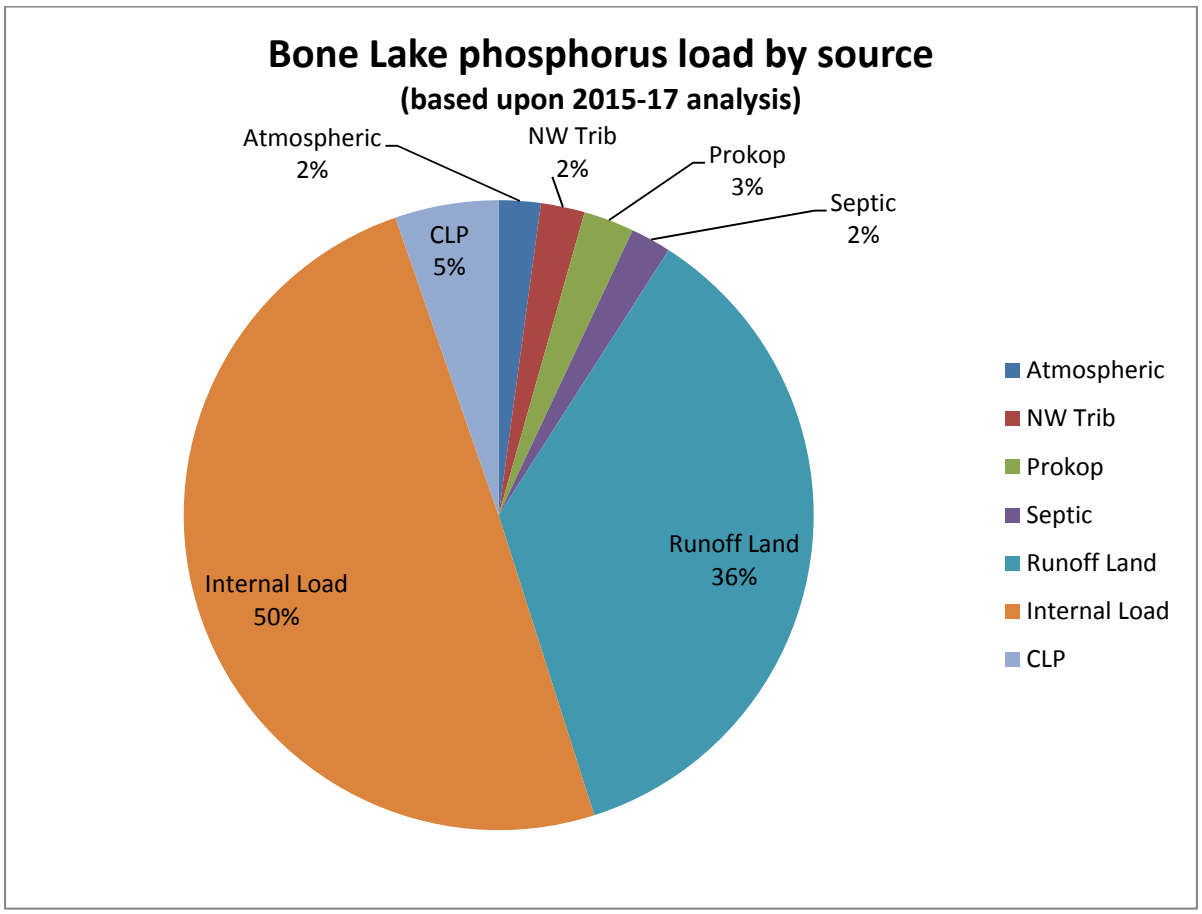
Analysis of in situ internal phosphorus load: Bone Lake, Polk County, Wisconsin 2015-2017. Ecological Integrity Service.

Volunteers and scientists measured temperature stratification and phosphorus levels in situ (in the lake) for this study. They took temperature and oxygen profiles (measurements at various depths) at 24 locations in deep areas of the lake from mid-May to the end of September in 2015, 2016, and 2017. These measurements told us how long bottom waters of each basin were anoxic (very low in oxygen) and therefore released phosphorus. They also told us the time period each basin stratifies (and when it mixes). In-lake phosphorus concentration was measured every other week in each of the three basins in Bone Lake (North, Central, and South). Measurements of phosphorus concentration throughout the water column before and after mixing told us how much phosphorus was released from lake sediments. Phosphorus measurements in the water near the lake bottom also provided a means to measure phosphorus release from sediments.

Results show that the lake was anoxic for 58 to 69 days in each year over the 3 year period. The lake was weakly stratified over the study period, suggesting partial mixing of lake layers throughout the summer. In each year there was a full lake mixing event in early to mid-August resulting in substantial phosphorus release and algae blooms.

Internal phosphorus load estimate

Two methods were used to calculate the internal load from lake sediments. The estimate for annual internal phosphorus loading over the three-year period was 51 percent of the total lake phosphorus budget.



Removing internal load – predicted results

A lake model (Bathtub) was used to test the calculated internal and external phosphorus loads and to estimate the impact of removing the external load. The estimated in-lake total phosphorus for 2015 to 2017 averaged 54 ppb (ug/L), which predicts a secchi depth of 1.8 m or 5.9 feet. (The actual secchi depth averaged 1.8 m). If the internal load from sediment release of phosphorus is eliminated, the model predicts a total phosphorus concentration of 34 ppb, a secchi depth of 2.6 m or 8.5 feet, and a chlorophyll-a concentration of 12 ppb. This is a 37% decrease in total phosphorus, a 44% increase in secchi depth, and a 45% decrease in chlorphyll-a.[1] Chlorophyll-a is a measure of algae growth.

[1] Bone Lake is listed as an impaired water for total phosphorus (NR 102 4 (b). It is considered a deep lowland lake. As such, the total phosphorus standard Bone Lake must attain to be removed from the Wisconsin Impaired Waters List is 30 ug/L.

*Model Predicts**	2015-17 mean	No sediment release	No internal (remove sediment & CLP)
Total Phosphorus(ppb)	54	34	31
Chlorophyll-*a* (ppb)	22	12	10
Secchi (m)	1.8	2.6	2.7
Secchi (ft)	5.9	8.5	8.9

*These are "growing season means", so total P and chl-*a* will likely be lower in early summer and higher later in summer/fall, and secchi will likely be higher in early summer and lower in later summer.

Examination of sediment phosphorus fluxes and aluminum sulfate dosage considerations for Bone Lake, WI. University of Wisconsin Stout Sustainability Sciences Institute - Center for Limnological Research and Rehabilitation. December 2017.

This study estimated sediment phosphorus release rate from sediment cores incubated in the laboratory. The internal load is calculated using the release rate and the duration of anoxia. The lake-wide sediment phosphorus release rate was 6.42 mg/m^2/day. This rate (along with duration and area of anoxia) estimates an internal load of 1505 kg in 2017. This is close to the results from the Ecological Integrity study and validates each result.

The study also looked at the types of phosphorus contained in Bone Lake sediments and characteristics of the sediment. This information can be used to design an alum treatment for Bone Lake and predict the result of an alum treatment.

Alum (aluminum sulfate) is used to bind phosphorus and prevent its release from lake sediments. Alum application was recommended where anoxia occurs (at least 30 feet and deeper according to Ecological Integrity study). A dose of 90 to 100 g/m2 split over several years each in early June is recommended. Such a dose is estimated to cost about $1.4 to $1.8 million. Since the per gallon cost of alum could increase the future, this cost estimate should be considered conservative. Extensive monitoring of lake sediment and water quality response is recommended to adjust doses made following an initial application of 60% of the recommended total amount. Application of multiple alum doses likely leads to more effective binding of phosphorus and longer control of internal load.