Estimation of Ground Water Inflow and Phosphorus Load

Bone Lake, Winter 2018/19

Background

The nutrient budget of Bone Lake was updated in 2018, with more detailed information about internal loading. One potential source of water and nutrients that has not been evaluated previously is groundwater. Typically, groundwater is low in phosphorus and is not a large contributor to the phosphorus budget. However, springs that flow into Bone Lake were recently monitored for phosphorus and some of the readings at half the sites were quite high. For this reason, an estimate of phosphorus loading from groundwater was warranted.

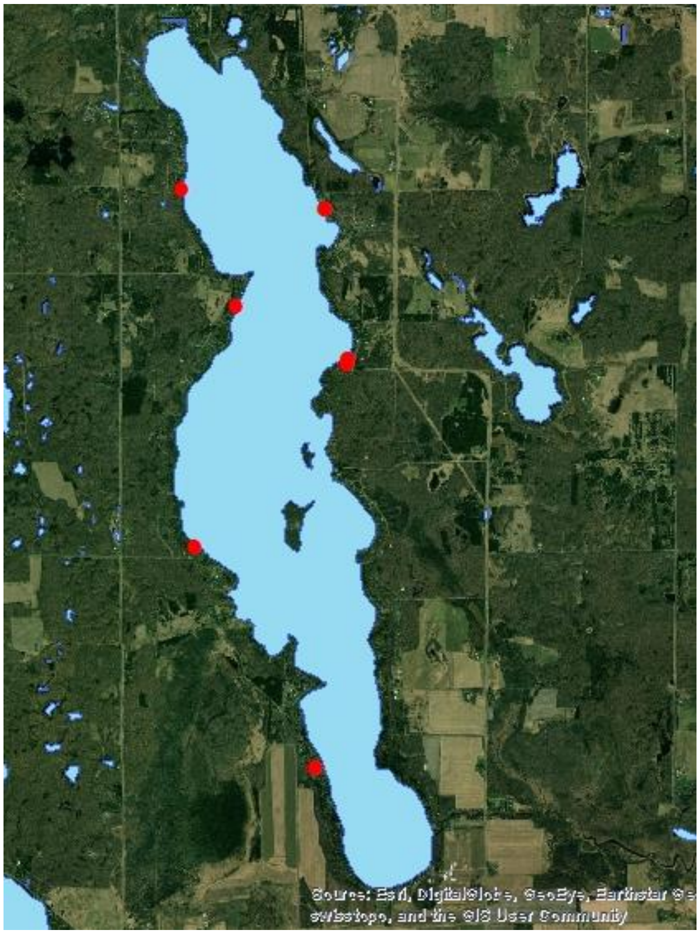
To model a lake's phosphorus sources, a water budget is needed. The water budget simply considers all sources of water entering the lake, and all water leaving the lake. Water entering the lake includes precipitation, surface runoff and groundwater. And, water leaving the lake includes outflow from Fox Creek, evaporation, and groundwater flowing out. The change in lake volume is the difference between water entering and water leaving. It is measured by change in lake level. A groundwater flow map of Bone Lake shows groundwater flows only into the lake and does not predict ground water flow out of the lake.

Estimating groundwater flow into a lake can be very difficult. However, the water budget is simplified in the winter because there is little or no liquid precipitation (rain) or surface runoff, and with ice, there is little to no evaporation. Therefore, with measurements of change in lake volume and Fox Creek outflow in the winter, groundwater inflow volume can be estimated. The phosphorus load is estimated by using the groundwater flow multiplied by the average concentration of phosphorus in groundwater samples to determine a mass of phosphorus flowing into the lake via groundwater.

Methods

Flow was determined from late December, 2018 until March 1, 2019. There was little to no liquid precipitation during this period, and there was never a melt that led to runoff into the lake. The lake was frozen over during this entire time period. The two main tributaries that flow into the lake were monitored for volume and the Fox Creek outflow was monitored for volume. The lake depth was also monitored with a data logger to determine changes in lake volume over the monitoring period. As described above, this provided an estimate of ground water flowing into Bone Lake.

To determine the concentration of phosphorus in groundwater, seven springs/shallow wells were monitored for total phosphorus, orthophosphate and chloride. The chloride measurement was to assess if septic contamination was present which may occur in the shallow wells. Septic contamination can increase phosphorus concentration above the natural groundwater levels. The volume of groundwater estimated from the water budget, along with the average concentration of phosphorus in spring and well samples, was used to estimate the total mass of phosphorus coming in during the monitoring period.



Groundwater collection sites (red dots)

Results

The volume of water coming into Bone Lake during the 69 days monitored was estimated to be: **2.2 hm^3**

(hm^3 is cubic hectometers or 1×10^9 liters)

This can be adjusted to match the time period during the growing season for the internal loading study. The volume adjusted during the growing season is: **5.83 hm^3**.

The mean total phosphorus in the groundwater samples was **32.3 ug/L**

The mean orthophosphate concentration in the groundwater samples was **21.7 ug/L.** This concentration indicates that a large portion of the total phosphorus is in reactive form, available to immediate absorption and assimilation by algae and plants.

This gives a total load of ***188.5 kg*** of total phosphorus and ***126.5 kg*** of orthophosphate from groundwater during the growing season.

Discussion

The base flow used to determine groundwater flow into Bone Lake should be considered a "rough" estimate. We can use this data in the nutrient model to gain a basic understanding of the contributions due to groundwater. However, assumptions made can reduce the accuracy of these estimates. First, we will assume that the estimated groundwater volume flowing into lake is similar to the volume flowing in during the 2015-2017 study period. Second, we will assume that the mean concentration of phosphorus in spring and well samples is reflecting the actual phosphorus in groundwater. Neither of these are likely true. Groundwater flow can vary seasonally. Also, the range in phosphorus concentration from one site to another was five-fold. As a result, if the higher or lower phosphorus concentration at particular a spring has higher flow volumes, then the phosphorus contributions would increase or decrease significantly. A weighted mean (considering volume and concentration from each particular spring) would be much better, but that data is not available.

Modeling

The mean Bathtub model from the 2015-2017 study period was adjusted using the groundwater data from winter 2018/19. The water budget was adjusted to account for increased volume inflow due to groundwater. This was done by lowering the surface runoff from the watershed (land) since that was predicted based upon runoff coefficients. Since this watershed runoff volume was reduced, so was the estimate of phosphorus loading from these areas. It is possible that hypolimnetic (lake bottom) accumulation of phosphorus could be affected by groundwater entering in the hypolimnion. However, these data are not available and, therefore, the surface loading was the only source adjusted. Modeling with existing data provides an estimate only, and many factors were unknown, thus allowing an estimate for some sources.

The following graph is the updated estimated percentage of phosphorus from various sources including groundwater:

Source	Kg of P
Atmosphere	69
Runoff	938
Anoxic sediment	1596
CLP	171
Septic systems	67
Groundwater	189
Total load	3030