Phosphorus Budget Analysis

Bone Lake, Polk County Wisconsin
2008

Sponsored by: Bond Lake Protection and Rehabilitation District and
Wisconsin Dept of Natural Resources

Prepared by: Ecological Integrity Service, LLC

Introduction

The most recent analysis for nutrient loading on Bone Lake was in 1996. In that analysis two tributaries were monitored with somewhat limited data and the remainder of the watershed was modeled using WILMS (as best can be determined from the report) to estimate the phosphorus loading into Bone Lake. In addition, sediment release rates were conducted in the lab and used to estimate internal loading.

In response to a Comprehensive Lake Management Plan developed by the Bone Lake Protection District, an updated nutrient analysis was requested to identify areas that could be managed to reduce nutrient inputs.

The external phosphorus budget was analyzed during the growing season from April 2008 until October 2008. To calculate the loading of phosphorus two tributaries (Prokop Creek and an un-named tributary on the northwest portion of the lake) were measured for flow and water samples were analyzed for phosphorus and suspended solids. In addition, the land-use was updated for 2008 and WILMS was used to model (estimate) the remaining phosphorus loading. No internal loading calculations were done in this model, but the predicted WILMS internal calculator was used to calibrate the model.

Methods

The loading of the two tributaries was determined by installing two gage data loggers. The data loggers measured the water level to the nearest 0.001 feet every hour of every day they were installed. The flow was determined on 8 different dates by measuring the stream cross section and measuring the rate of flow with a flow rate meter. These flow values were then correlated to the gage height reading and a flow curve rating was calculated. In addition, two samples were obtained each month and during 4 different rainfall events that were in excess of 1 inch in 24 hours. Each sample was analyzed for total phosphorus (TP), soluble reactive phosphorus (SRP) and for total suspended solids (TSS) These measurements were then used to determine the nutrient loading through either averaging or flow weighted loading, depending on the nutrient results (averaging was done for Prokop Creek while the flow weighted method was used for the un-named tributary since the nutrient values correlated well will flow levels). In the averaging method, the average value for each test was used for each flow period (one hour). These values were then totaled to get a total load for that component. In the case of the flow weighted, the flows above the base flow threshold were weighted using the average for a particular nutrient test at high flow levels. Those at or below the base flow measurement used the average for the particular nutrient test at base flow levels. These weighted values were then totaled to get a total load for each nutrient test.

To estimate the phosphorus loads from the remaining portion of the watersheds, the WILMS lake-modeling suite was utilized. The land-use categories were imputed into WILMS from the updated land-use analysis provided by the Polk County Land and Water Resources Department. Export coefficients recommended for this region were utilized. These coefficients were adjusted to better fit the model based upon the field data from the tributaries, recommendations for the Polk County Land and Water Department, and soil types. In addition, the septic loading was estimated using estimated capita data provided by the Polk County Land and Water Resources Dept.

Results

Tributaries

The following table summarizes the tributary loading results.

Table 1: Tributary loading of Total Phosphorus, Soluble Reactive Phosphorus and TSS.

Tributary	Volume (m^3/yr)	TP Load (kg/yr)	SRP loading (kg/yr)	TSS loading (kg/yr)
Prokop Creek	1,126,670	85.6	20.4	2145
Northwest Tributary	590,129	71.4	16.7	2793

The WILMS model predicted about 50% less loading for the un-named north tributary and about twice as much loading from Prokop Creek (100% more). The large amount of wetland that occurs in the headwaters of Prokop Creek may cause a reduction in phosphorus concentration in the creek and could account for the difference. The difference for the un-named tributary is interesting as the main landuse is forest and would not tend to contribute higher phosphorus input into the lake.

The SRP made up only 23-24% of the total phosphorus in both tributaries. This indicates that the source of phosphorus is not likely in highly soluble forms such as fertilizers, manure, sewage, etc. The TSS was much higher in the un-named tributary and will contribute more sedimentation into Bone Lake. Neither tributary had huge TSS values but did increase (especially with the un-named tributary) with increased flow, which would be expected.

It should be mentioned that the growing season of 2008 was rather dry in the latter half of the summer, reducing flow in both tributaries. Prokop creek went dry during several weeks in August and September. The un-named tributary had flow the entire sampling period. In both tributaries the flow and gage height correlation was very good (r^2=0.92 and 0.98) which makes the field data valid and a good reflection of the hydrologic load.

Land-use

The land-use was determined through an analysis of satellite imagery and some field checks of the topography and culvert locations. In addition, the entire watershed was divide into sub-watersheds. The following is a synopsis of those land-use determinations and a map of the land-use in the watershed as well as the sub-watershed boundaries.

Figure 1: Map of sub-waterhsheds of Bone Lake

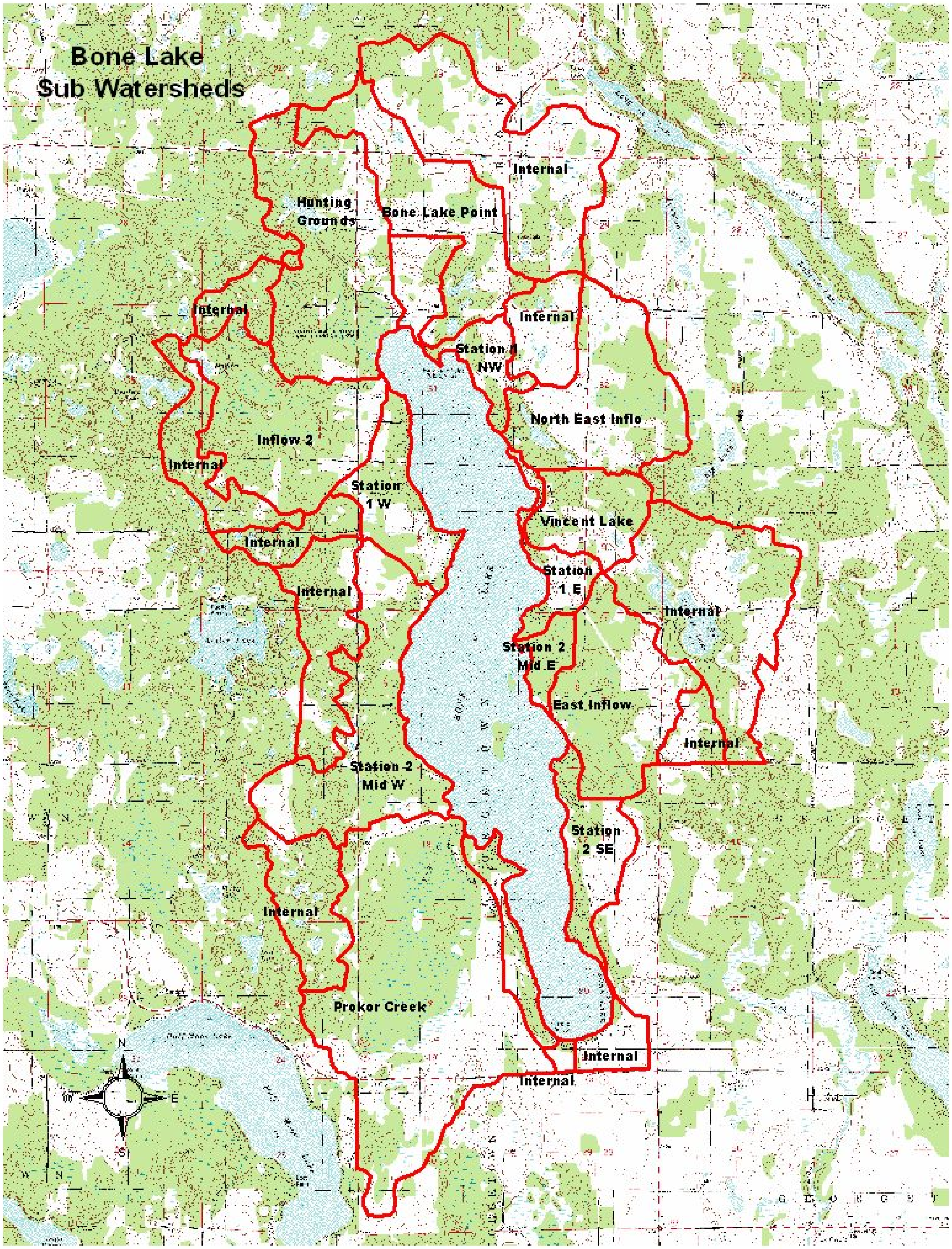


Table 2: Total acres and % of watershed for each sub-watershed.

Total acres by Sub-watershed		
Sub-watershed	%	Acres
Bone Lake Point	4.83	526
East Inflow	4.61	501
Hunting Grounds	6.86	746
Inflow 2	5.57	606
Internal	26.15	2847
North East Inflo	5.15	560
Prokop Creek	12.96	1411
Station 1	5.95	647
Station 2	10.06	1095
Vincent Lake	2.22	241
Lake	15.66	1704
Total	100.0	10887

These were not used in modeling as not directly drained into lake.

Setting up sub-watersheds allows for the designation of high impact areas and makes for easier management determinations.

Figure 2: Landuse map of Bone Lake watershed.

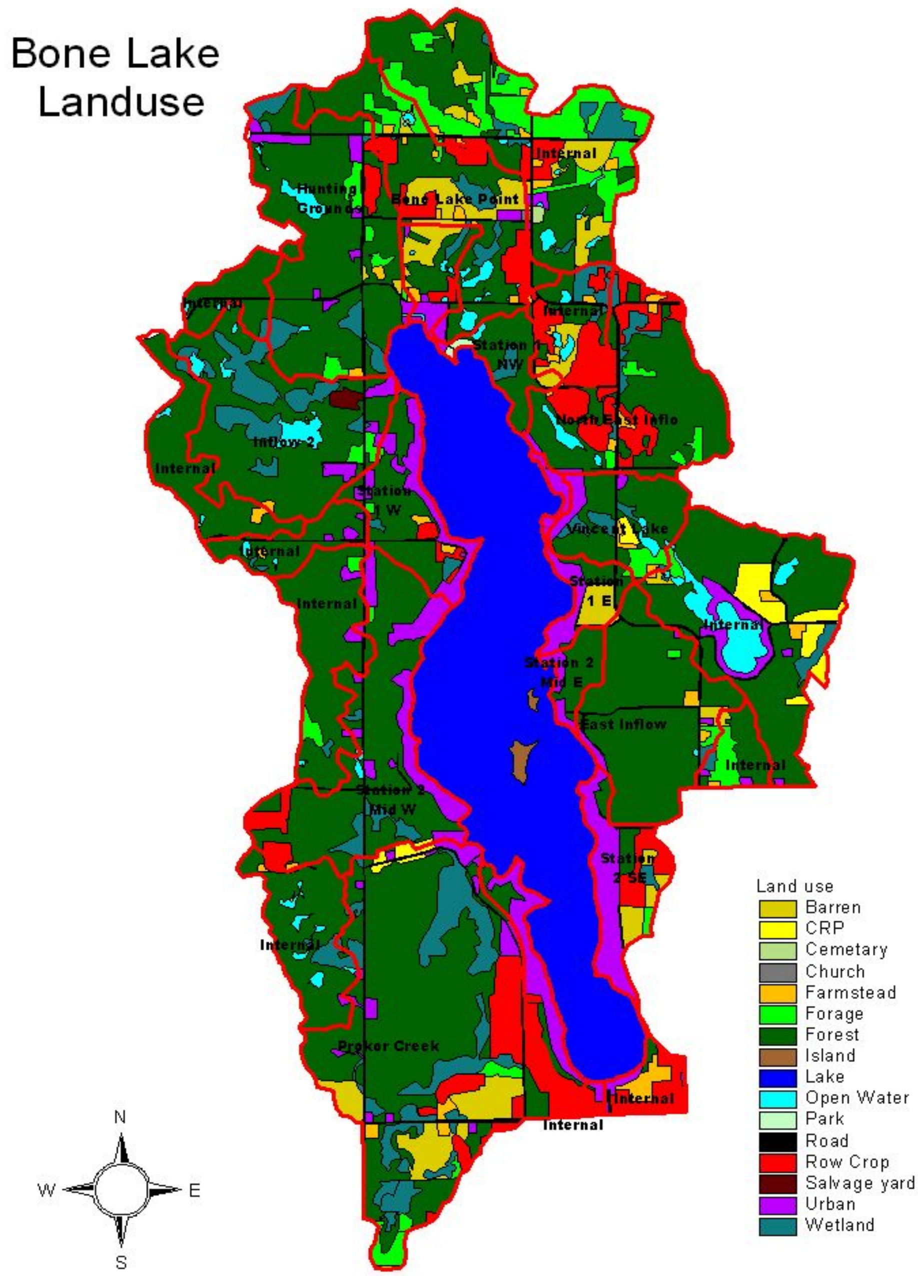


Table 3: Land-use by acres and % of total watershed.

Land-use	%	Acres
Barren	3.79	413
CRP	0.98	106
Cemetary	0.04	4
Church	0.02	2
Farmstead	1.32	143
Forage	4.25	463
Forest	50.50	5498
Island	0.15	16
Lake	15.66	1704
Open Water	2.20	239
Park	0.06	6
Road	1.55	169
Row Crop	6.33	689
Salvage yard	0.11	12
Urban	6.97	759
Wetland	6.28	684

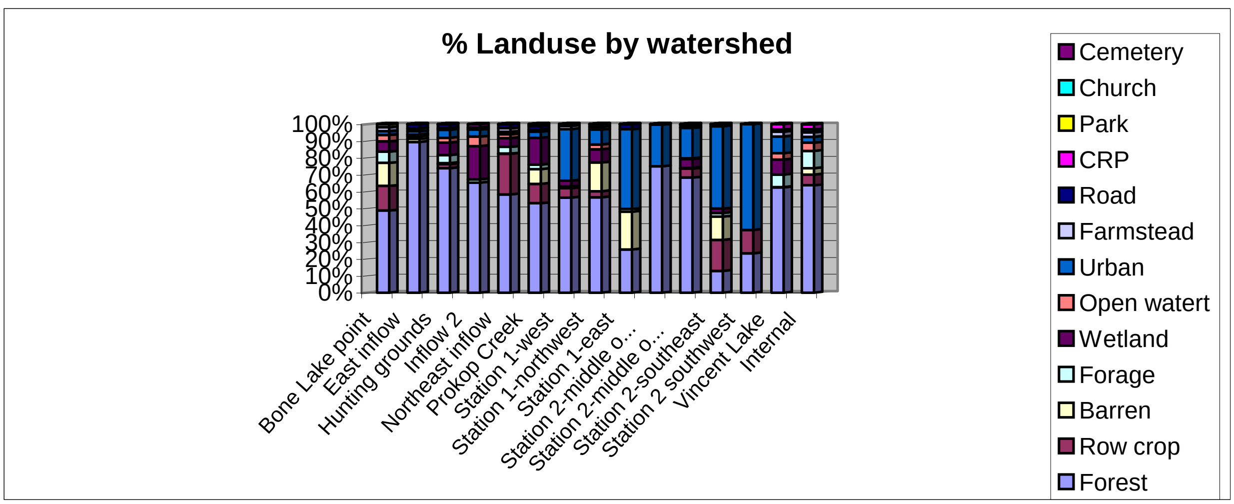
As can be observed, forest makes up just over half of the land-use types. This is a good thing as this land-use has a very low export coefficient (a number used to calculate phosphorus loading), which means very little phosphorus comes from this land into the lake as compared to the other landuses. Although row crops and urban make up only 6.33% and 6.97% respectively, they have high export coefficients which would indicate high phosphorus loading into the lake from these areas. Therefore, management of these landuses can have a large impact on phosphorus loading reductions.

Table 4 lists each sub-watershed by land-use. This is helpful to see those sub-watersheds that have low loading land-use such as forest and grassland as well as high loading landuses such as urban. Figure 3 shows a graphic to compare the landuse within each sub-watershed.

Table 4: Land-use list for each sub-watershed.

Sub-watershed acreage	Forest	Row crop	Barren	Forage	Wetland	Open watert	Urban	Farmstead	Road	CRP	Park	Church	Cemetery
Bone Lake point	256	77	72	35	32	20	12	12	0	0	9	1	0
East inflow	449	0	9	8	4	1	10	8	13	0	0	0	0
Hunting grounds	552	18	4	36	55	21	36	7	18	0	0	0	0
Inflow 2	396	0	0	12	120	34	25	3	5	0	0	0	12
Northeast inflow	327	135	0.4	22	29	13	8	12	14	0	0	0	0
Prokop Creek	749	163	122	38	225	0	51	16	32	16	0	0	0
Station 1-west	151	15	0	3	9	0	82	5	3	0	0	0	0
Station 1-northwest	139	9	42	0.3	19	7	22	4	4	0	0	0	0
Station 1-east	33	0	29	2	0	0	61	0	4	0	0	0	0
Station 2-middle on east	61	0	0	0	0	0	20	0	0.3	0	0	0	0
Station 2-middle on west	447	35	0	3	34	3	118	2	10	3	0	0	0
Station 2-southeast	30	43	32	5	6	0	114	0	3	0	0	0	0
Station 2 southwest	30	18	0	0	0	0	81	0	0	0	0	0	0
Vincent Lake	152	0	0.2	18	22	9	24	7	3	8	0	0	0
Internal	1727	174	103	278	0	131	97	69	50	79	0	1	4
Not used as not direct drained into lake.													

Figure 3: Percent landuse type for each sub-watershed.



Watershed loading

The land-use listed was used as input data for WILMS. In WILMS the export coefficients were adjusted to meet the field data, based upon soil types and finally to calibrate the model. The WILMS predictions need to be conducive with the growing season mean (GSM) for the total phosphorus measured in the lake. The export coefficients used are in Table 5.

Table 5: Land-use export coefficients used in WILMS

Land-use	Export coefficient (kg/ha/yr)
Barren	0.3
Cemetary	0.3
Church	0.3
CRP	0.3
Farmstead	0.8
Forage	0.3
Forest	0.09
Island	0.09
Open water	0.3
Park	0.3
Road	1.0
Row crop	1.0
Salvage yard	0.3
Urban	1.0
Wetland	0.1

In addition to the land-use, the septic loading was estimated in WILMS. The septic capita-year was estimated at 676 based upon some rather limited information provided by Polk County.

The results of the most likely phosphorus loading predicted by WILMS are listed below.

Loading from watershed directly drained into lake estimate =**557.1 kg/yr**
Septic system loading estimate= **67.6 kg/yr**[1] **(6.8% of total load)**
Loading from monitored tributaries (field data not estimated)=**157 kg/yr**
Estimated total load (including lake surface)=988.6 kg/yr

Various sub-watersheds have a wide range of nutrient loading impacts. For management purposes, it is convenient to compare the contribution each sub-watershed has based upon the area and loading, expressed in kg/acre. Table 6 shows the loading per acre for each sub-watershed.

[1] This is based upon rather incomplete capita-year data. An attempt for more precise data is being made which could result in a more valid calculation.

Table 6: Area, load and loading per acre for each sub-watershed.

Sub-watershed	Acres	Load (kg)	Kg/acre
Station 2 Southwest	129	41.13	0.319
Station 2 Southeast	234	70.73	0.302
Station 1 East	128	31.13	0.243
Station 1 West	269	48.53	0.18
Northeast Inflow	561	84.63	0.151
Station 2 Middle on West	655	85.24	0.13
Station 2 Middle on East	82	10.46	0.128
Bone Lake Point	526	66.94	0.127
Inflow 2 (NW)	606	71.4	0.118
Station 1 Northwest	244	26.72	0.11
Hunting Grounds	746	60.96	0.082
East inflow	501	30.51	0.061
Prokop Creek	1411	85.6	0.061

Figure 4: Graph of percent load by sub-waterhsed.

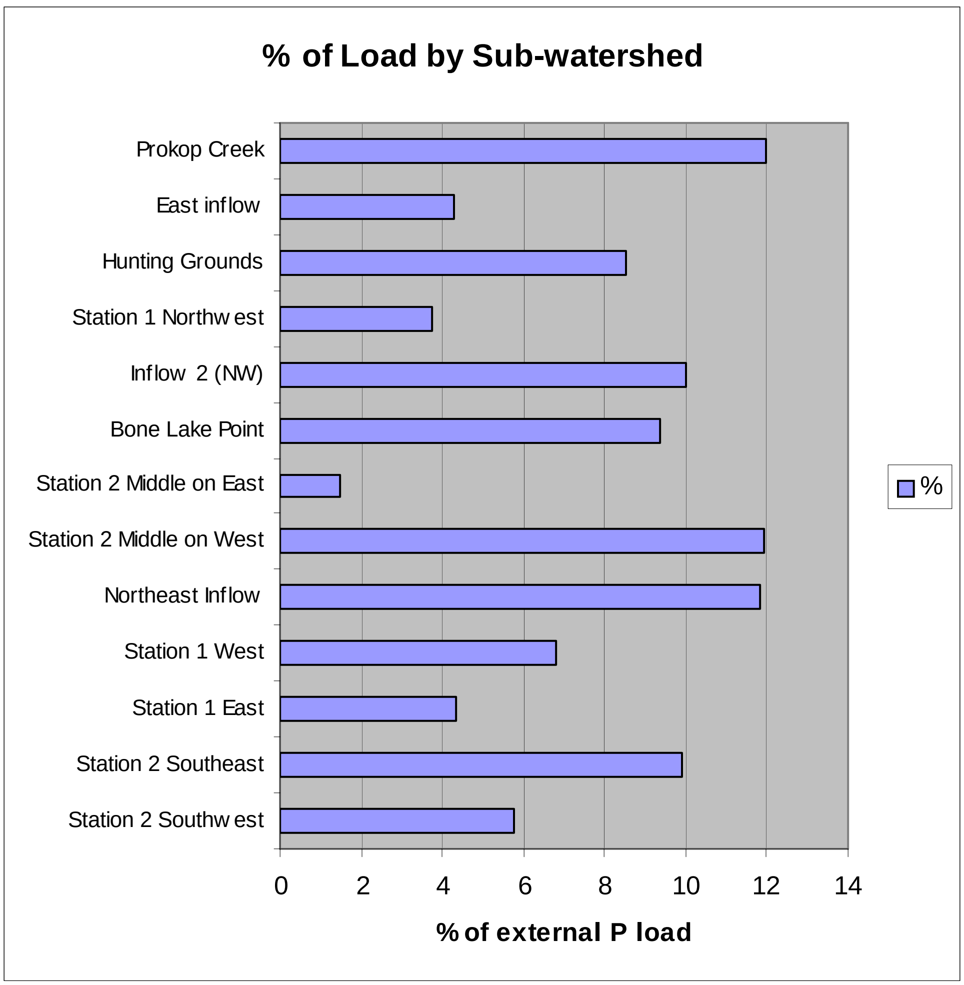
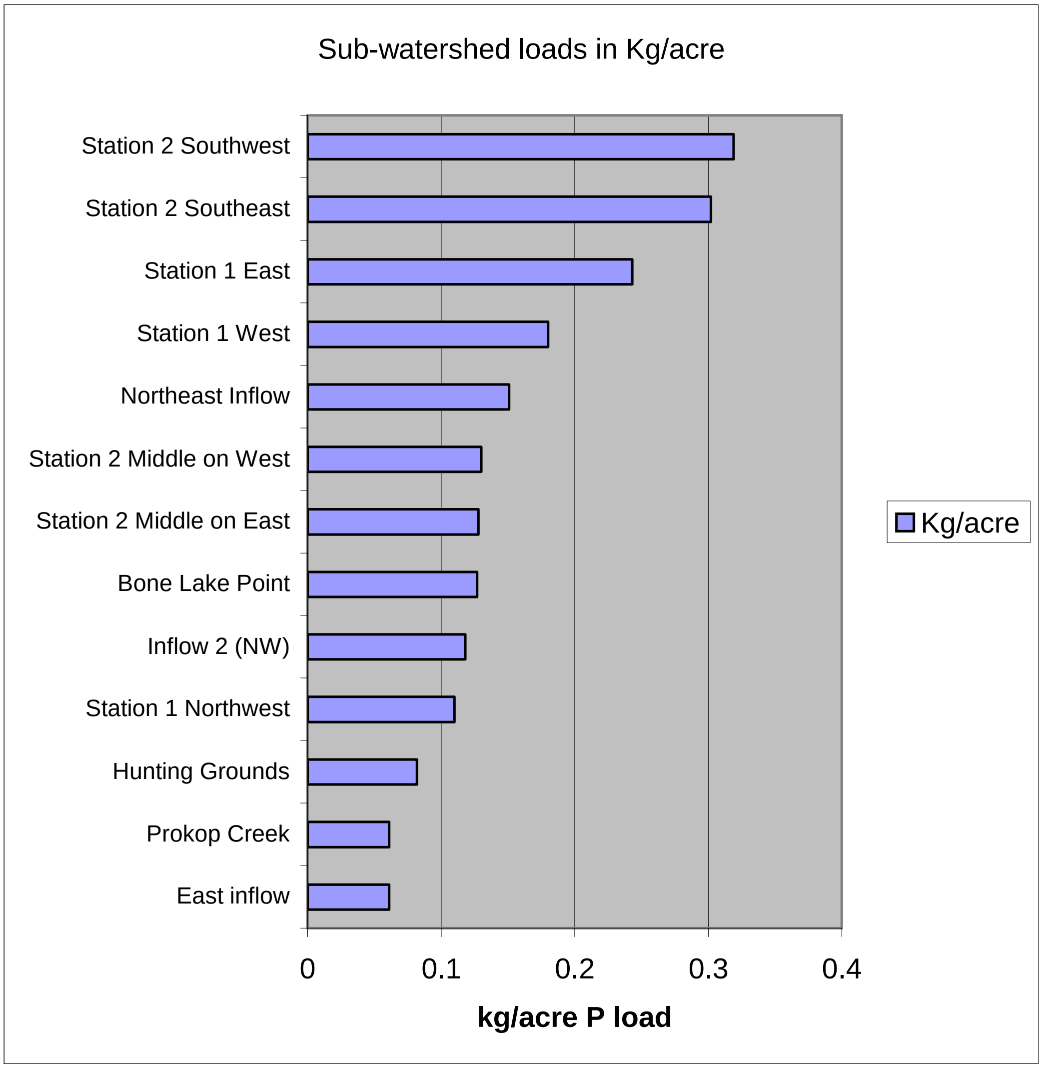
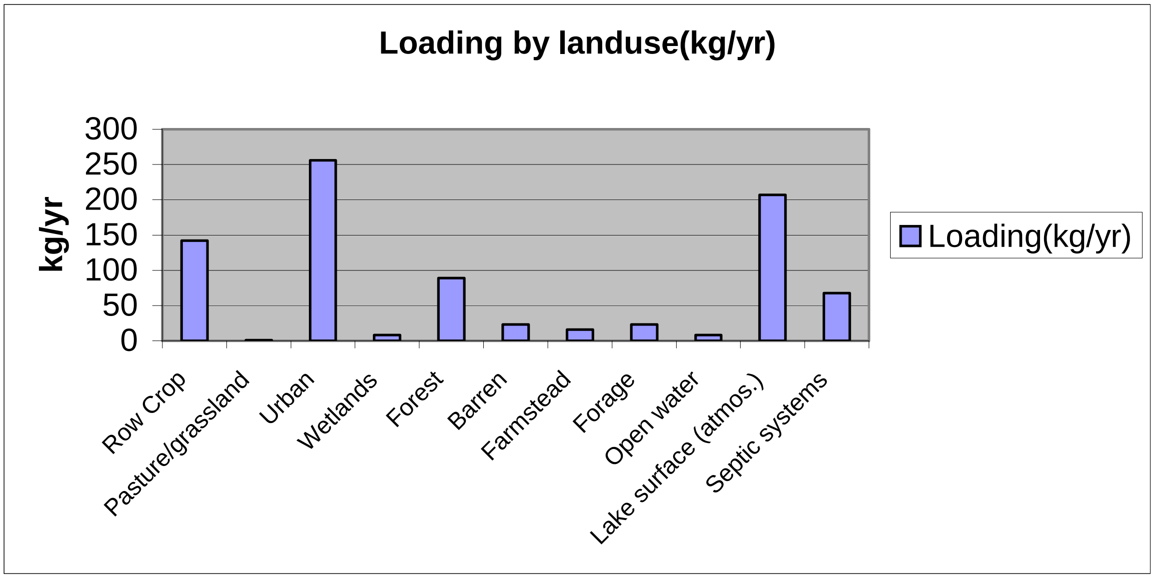


Figure 5: Graph of load of each sub-watershed in kg/acre.



The type of landuse can determine the amount of loading into the lake. As can be observed, row crops and urban development make up a large portion of the total external load in Bone Lake. Both of these landuses can have their impact reduced through management practices, which could result in a reduction in whole-lake phosphorus concentration.

Figure 6: Graph of loading of each landuse in Bone Lake watershed in kg/yr.



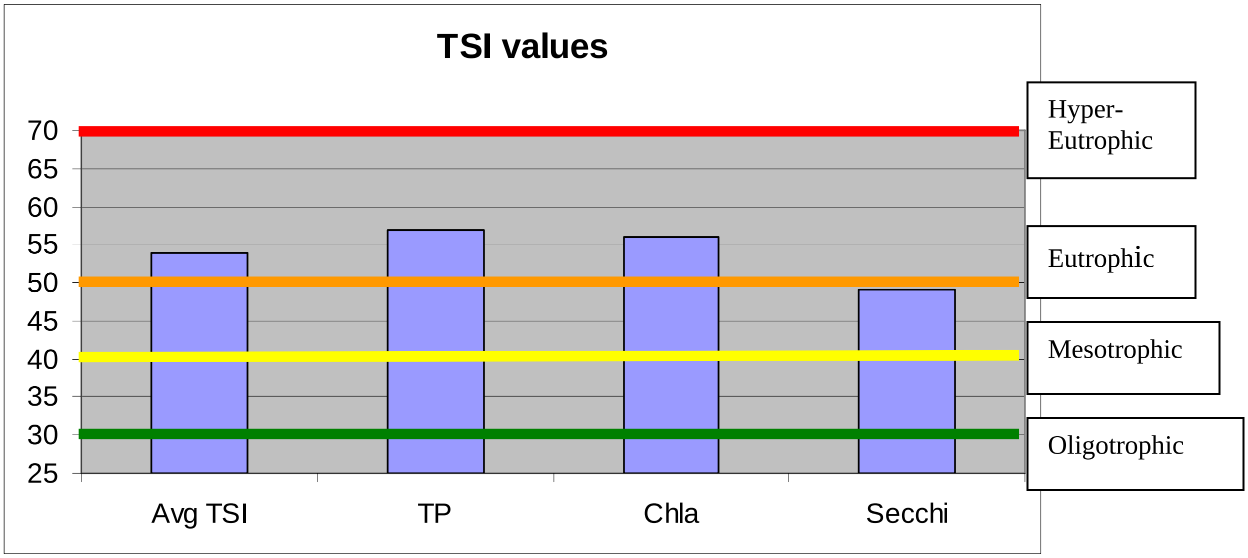
<u>Internal loading</u>

Internal loading was not analyzed in this study. Barr Engineering did an analysis of internal loading in 1996. In this study, it was determined that the internal loading of Bond Lake was 201 kg/yr. This calculation was based upon laboratory studies of sediment release rates of phosphorus. This is a valid way to determine internal loading. However, recent data from the Self-Help Monitoring program does not suggest the lake is undergoing anoxic conditions for any length of time. The Barr report shows anoxic conditions but the actual data and the area that is anoxic in the lake is not contained (or at least located) in the report. For this reason, a more recent determination of internal loading should be conducted. If the Barr calculation were accurate, then the internal load would be very significant as compared to the external loading.

<u>Trophic status</u>

The Carlson Trophic Status Index uses chlorophyll a, total phosphorus and Secchi depth to calculate a value that represents the degree of production in the lake. As can be observed, Bone Lake fell within the eutrophic (lower values for eutrophic) in all parameters.

Figure 7: Trophic status of Bone Lake in 2008[2]



The average TSI for Bone Lake in 2008 was just below 55, which is above the eutrophic level, but not by very much. The Secchi depth shows tha the water clarity remained quiet good (just up to eutrophic level) even though all other values were in the eutrophic level.

Discussion

The watershed around Bone Lake is quite diverse, ranging from forested areas to agriculture and numerous urban or residential areas. Just over half of the watershed is forested, which can help reduce phosphorus loading. However, some key areas have large amounts of row crop agriculture lands and urban areas. As a result, these areas contribute large amounts of phosphorus as compared to other sub-watersheds.

The highest contributing watersheds are Station 2 southwest, Station2 southeast, Station 1 east and Station 1 west. This is due to the landuse within the boundaries of these watersheds. Through management practices it may be possible to reduce the impacts these areas have on Bone Lake by reducing urban runoff and/or changing agriculture lands from row crop to forage or even native grasses. A modest reduction in runoff and therefore phosphorus in these areas could reduce whole-lake phosphorus significantly. Very small reductions in whole lake phosphorus can result in very large changes in water clarity and the aesthetic nature of the lake.

The field data on the two monitored tributaries reflect interesting results. The Prokop Creek watershed is a very large sub-wathershed, yet contributes very low amounts of phosphorus per acre. The wetland area that the creek flow originates may be holding much of that nutrients. In a high water year, it is possible this wetland could flush, resulting in a much higher load. The un-named tributary is flowing from the Inflow 2 subwatershed. The field

[2] Data from Self Help data set provided by the Wisconsin DNR.

data reflected a much higher phosphorus load compared to what the model predicted based upon landuse. There are a few high export landuses, but very little in the total acreage. There is a salvage yard, but it is not known if anything that is present in the salvage yard to warrant high phosphorus loads. There is also a possibility that this salvage yard could release other chemicals (petroleum based) into the tributary and therefore the lake. No monitoring of such chemicals was conducted and is therefore not known

The septic loading in Bone Lake is estimated at just under 7%. This is similar to the report from a previous study. At this level, the biggest improvement would be to try and reduce the number of old, failing systems and have them replaced with holding tanks or good functioning systems. The number of old and failing systems were not known for this estimate calculation and therefore the impact of newer systems is unknown.

Barr Engineering reported a rather high internal load in 1996. In order for a large internal load to occur, the sediment must go anoxic for a length of time and over a rather wide area. The data that is available from self-help monitoring over recent years does not reflect periods of anoxic conditions and therefore the internal load wouldn't be large. This issue should be resolved with an updated internal load calculator. If it is significant, it would reduce the impact the external budget has on the lake by comparison. If the internal load isn't significant, then the external load reduction is much more signficant.

The growing season mean for total phosphorus in Bone Lake was 38.1 micrograms per liter (ppb). This is in the eutrophic zone for trophic status. The WILMS model watershed outputs predicted this same GSM, showing the model may have a good estimate of the loading that occurs from the watershed. Reducing non-point phosphorus loads through best management practices could reduce the GSM by several micrograms per liter. Even small GSM changes can result in large improvements in water clarity.

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