An Estimation of the Annual Loading of Phosphorus and Sediment - Hillsdale Lake, 2002

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Introduction

Hillsdale Lake and its watershed lie in the Lower Marais des Cygnes Basin in eastern Kansas. The Hillsdale Watershed is 144 square miles and spans four counties. The lake is used primarily for flood protection, fish and wildlife, recreation and as a public water supply. More than 30,000 residents in Johnson and Miami County are supplied drinking water from the lake. The use of Hillsdale Lake as a public water supply is expected to proportionately increase with the areas rapid growth and urbanization. About 6.6 million gallons of water per day is currently allocated for public consumption and about 8.2 million gallons per day remains available.

In recent years, there has arisen a concern that the water quality in Hillsdale Lake and its tributaries has diminished. Currently, the Kansas Department of Health and Environment lists Hillsdale Lake as eutrophication impaired. Therefore, a eutrophication TMDL (Total Maximum Daily Load) has been implemented for Hillsdale Lake. Phosphorus and sediment are contributing factors to eutrophication. The geology and soil characteristics in the area naturally allow large quantities of sediment and nutrients into local streams the lake. However, agriculture, urban development and other land uses have exacerbated this phenomenon. Phosphorous and sediment levels have particularly become a source of concern. Phosphorus in Hillsdale Lake's Watershed is limiting concerning algal and plant requirements, meaning it is the nutrient that limits biological growth. An excessive amount of phosphorus in the water column can lead to high aquatic production of biomass. This can affect the clarity, taste and odor of the water and inflicts stress on aquatic organisms. Excessive sediment deposition can dramatically decrease the design life of the reservoir by taking up floodwater storage space. Sediment can also bury fish spawning areas and benthic organisms in lakes and streams. Harmful chemicals can also attach to sediment and become deposited with it affecting water quality.

The Hillsdale Water Quality Project resolved to improve the quality of water entering Hillsdale Lake. In early 1998 specific water quality goals were established that included a reduction of the annual phosphorus load to the lake by 30 percent or 21,000 kg/year (based on USGS Sediment Study Estimate of 70,000 kg/year entering the lake from 1981 - 1996) and a reduction of the annual sediment load by 30 percent or 39,750 tons/year (based on USGS Sediment Study Estimate of 132,500 tons/year entering the lake from 1981 - 1996).

The purpose of this study is to monitor the status of phosphorus and sediment loading into Hillsdale Lake by estimating the input of total phosphorus and sediment in 2002. This may identify a general trend in phosphorus and sediment loading as monitoring continues. The estimations were derived using total phosphorus and total suspended solids concentration data from the lake's major tributaries. This data was obtained through the analysis of samples taken by HWQP using established methods at these sites. A map detailing the sampling locations within the watershed is provided in the supplemental information section (p. 16). A general trend in total phosphorus and sediment loading will allow progress made by the project's efforts to be assessed. The project and its volunteers should not expect to see significant trends in total phosphorus and sediment reduction in a short period of time, as noted by Ed Carney with the Kansas Department of Health and Environment. However, the Hillsdale Water Quality Project believes if this process continues to be carried out in future years it can be assumed that trends will continue. It may also place the size of the problems that need to be faced into greater perspective.

Methods of Estimation

Prior to 1999, loading estimates were calculated using a method that was developed by Michael D. Franano with the help of board members and technical advisers. It was used in his study, Hillsdale Lake Water Quality Assessment and Phosphorus Load Estimate. This method involved calculating the average yearly concentration in the monitored streams – Big Bull Creek, Little Bull Creek, Rock Creek and Wade Creek – and multiplying these concentrations by the total annual water flow into Hillsdale Lake. This initial calculation method was ideal to obtain rough estimations with minimal resources, but there was understandably likelihood for error.

The only stream flows in the watershed currently monitored by the U.S. Geological Survey gauging stations are at the Big Bull and Little Bull sampling sites. Using Franano's method, the annual flow for these streams was multiplied by the average total phosphorus concentration of grab samples and storm runoff samples at these sites to obtain the estimated annual load from these two tributaries. When these calculations were completed, the annual flow from these two sites was subtracted from the lake's total annual inflow (estimated by USACE) and the remaining flow was used in the "other" calculation. The concentration for all other tributaries in the watershed was determined by averaging the yearly average concentrations from all sampled tributaries. This average concentration was then multiplied by the remaining flow to estimate the load from the watershed's unmonitored tributaries. The "other" total was then added to the Big Bull and Little Bull loading estimates to derive a total loading estimate.

Members of the Hillsdale Water Quality Project staff refined this method in 2000, largely based on Anthony A. Holt's study, Estimation of 1994 Point Source And Non-Point Source Phosphorus Loading to Hillsdale Lake, for calculating yearly total phosphorus loading. The board approved this plan on March 16, 2000. This refined method provides estimates that should be more accurate and will be used until otherwise noted.

First, direct precipitation is determined using rainfall data obtained from the National Weather Service (collected by the U.S. Army Corps of Engineers) and the total phosphorous concentration in rainfall suggested by Dr. John R. Jones in his 1998 study, Evaluation of the Limnology of Hillsdale Lake, Kansas. Next, composite sampling data collected from the Big Bull and Little Bull creeks is used to estimate the amount of total phosphorous and sediment that flows into the lake during storms from these two streams. Then, a low flow estimate is made for these two tributaries using an average of the mean daily flows for the sampling year and the average concentrations of total phosphorous and sediment found in the grab samples. The next step finds an estimate of the total phosphorus and sediment loads for all events that do not fall under low flow or storm flow. Finally, an estimate of the total phosphorous and sediment load from all other tributaries in the watershed is made. The combined totals of the preceding steps are used to calculate the estimated total phosphorus and sediment load input to Hillsdale Lake.

Loading from Direct Precipitation – Phosphorus Loading Only

The contribution of phosphorus from direct precipitation is found by multiplying the volume of direct precipitation (liters) into the lake by 0.05 mg/L (Jones) and dividing the result by 1,000,000 to obtain the mass of phosphorus in kilograms (there are 1,000,000 milligrams in 1 kilogram). During the year 2002, 33.72 inches of precipitation fell on Hillsdale Lake (National Weather Service) or 15,870,000 liters. Using the multiplication described above,

$$\frac{\mathbf{(0.05\ mg/L)\ X\ (15{,}870{,}000{,}000\ L)}}{\mathbf{1{,}000{,}000\ mg/Kg}}$$

It is found that **794 Kg** of the phosphorus input to Hillsdale Lake came from precipitation.

Loading from Storm Runoff

The total phosphorus and sediment loading resulting from storm flow in Big Bull Creek and Little Bull Creek is found by multiplying the concentrations of the nutrients from each composite sample collected by the volume of water passing the sample site during that time.

Flow data in cubic feet per second, taken every 15 minutes, is multiplied by 60 seconds and then by 15 minutes to obtain the storm flow volume in cubic feet for that particular 15-minute period. These flow volumes are each multiplied by the total phosphorous or sediment concentration of the event and then by 28.32 liters per cubic foot. The 28.32 multiplier is used to remove the liters and cubic feet from the equation so as to be left with milligrams of total phosphorus. This total is then divided by 1,000,000 to yield the amount of phosphorous in kilograms passing the site for that 15-minute period. The calculation is shown below:

$$\frac{\mathbf{(flow\ in\ cubic\ feet\ [ft^3])(28.32\ L/ft^3)(nutrient\ concentration\ in\ mg/L)}}{\mathbf{1{,}000{,}000\ mg/Kg}}$$

The amounts for each 15-minute period were then summed to obtain the amount of phosphorus loading during the entire event. This loading data from each event was summed, yielding the total amount of phosphorous input into the lake from that specific tributary during storm flow periods.

Using the preceding formula, total phosphorus loading from storm events in Big Bull and Little Bull Creeks in 2002 were:

Big Bull Creek: 7,601 Kg
Little Bull Creek: 1,433 Kg

Using the preceding formula, total sediment loading from storm events in Big Bull and Little Bull creeks in 2002 were:

Big Bull Creek: 6.430 X 10^6 Kg
Little Bull Creek: 1.670 X 10^6 Kg

Loading from Low Flow Periods

The equation used to calculate the yearly low flow contribution of phosphorus from Big Bull Creek and Little Bull Creek is similar to the equation used in the storm runoff calculation, except that the flow was calculated for an entire year instead of a 15-minute interval. The average low flow was calculated by averaging the mean daily flows, less than 15 ft^3/s in Big Bull and 13 ft^3/s for Little Bull. The average low flow concentration for each year was obtained by averaging grab samples of that year taken during low flow. Grab samples taken when the creeks exceeded these limits were not used. The equation is as follows:

$$\frac{(\text{flow in cubic feet } [ft^3])(28.32\ L/ft^3)(\text{nutrient concentration in mg/L})}{1{,}000{,}000\ \text{mg/Kg}}$$

The total low flow phosphorus load contributed by Big Bull and Little Bull Creeks in 2002 was:

Big Bull Creek: **2,770 Kg**
Little Bull Creek: **259 Kg**

The total low flow sediment load contributed by Big Bull and Little Bull Creeks in 2002 was:

Big Bull Creek: **0.080 X 10^6 Kg**
Little Bull Creek: **0.050 X 10^6 Kg**

Loading from Low-Storm Flow Events

Loading from low-storm flow events includes all flow resulting from a rain event that does not exceed daily flow values of 50 ft^3/s at Little Bull Creek, and 100 ft^3/s at Big Bull Creek, does not fall below 13 ft^3/s and 15 ft^3/s respectively, and does not trigger a sampling event. The daily flow for these events is totaled for the entire year. An average concentration is figured from composite samples collected during small storm events, and from grab samples collected during low flow and multiplied by the total flow. This result is then multiplied by 28.32 L / ft^3 and then divided by 1,000,000 mg / Kg to get the answer in kilograms.

$$\frac{(\text{flow in cubic feet } [ft^3])(28.32\ L/ft^3)(\text{avg. nutrient concentration in mg/L})}{1{,}000{,}000\ mg/Kg}$$

The total low-storm flow phosphorus load contributed by Big Bull and Little Bull Creeks in 2002 was:

Big Bull Creek: **2,855 Kg**
Little Bull Creek: **285 Kg**

The total low-storm flow sediment load contributed by Big Bull and Little Bull Creeks in 2002 was:

Big Bull Creek: **0.170 X 10^6 Kg**
Little Bull Creek: **0.310 X 10^6 Kg**

Loading from Other Tributaries

The most difficult part of the load to determine is the contribution from portions of the watershed not including the Big Bull and Little Bull Subwatersheds. Estimating loading from Rock Creek and Wade Creek is also difficult because of the lack of gauging equipment at these sites to calculate flow. The Big Bull Creek and Little Bull Creek sites are the only sites with flow measuring equipment and automatic samplers designed to sample storm runoff. During the 2002 sampling year, about 59 percent of the flow from Big Bull Creek and Little Bull Creek moved past the gauging stations during storm flow. It is estimated that another 17 percent of the flow was at a height that would be considered low-storm flow. Therefore, 24 percent can be used as an amount of total flow from Big Bull Creek and Little Bull Creek that could be considered low flow and represented by grab sample results. Samples may not have been collected due to operator error, mechanical error, staff decision or the beginning or end of an event being below the sampler activation level.

Storm Flow Contribution:
To calculate the contribution of stormwater runoff from the unmonitored portion of the watershed, the amount of water contributed to the lake by direct precipitation and the amount of inflow from Big Bull Creek and Little Bull Creek is subtracted from the total inflow to the lake. The result is the remaining inflow from the rest of the Hillsdale Lake Watershed. Then, an average of all composite sample concentrations collected at the Big Bull Creek and Little Bull Creek sites during the year and 59 percent of the remaining inflow to the lake, are multiplied.

Unmonitored Total Storm Flow =
(0.59) X [(Total Lake inflow) – (Big Bull inflow + Little Bull inflow) – (Direct Precip. volume)]

Unmonitored Storm Flow Nutrient Load =
(Unmonitored Total Storm Flow) X (Average Storm Flow Concentration)

In 2002, the unmonitored storm flow phosphorus load was **11,500 Kg**.

In 2002, the unmonitored storm flow sediment load was **11.0 X 10^6 Kg**.

Low-Storm Flow Contribution:
To calculate the contribution of low-stormwater runoff from all other parts of the watershed, nutrient concentrations of all composite samples collected during low-storm flow events and grab samples (including Big Bull, Little Bull, Rock and Wade Creek sites) collected during low flow are averaged, and multiplied by 17 percent of the remaining inflow to the lake.

Unmonitored Total Low-Storm Flow =
(0.17) X [(total lake inflow) – (Big Bull inflow + Little Bull inflow) – (direct precip. volume)]

Unmonitored Low-Storm Flow Nutrient Load =
(unmonitored total low-storm flow) X (average low-storm flow & low flow concentration)

In 2002, the unmonitored low-storm flow phosphorus load was **3,910 Kg**.

In 2002, the unmonitored low-storm flow sediment load was **2.01 X 10^6 Kg**.

Low Flow Contribution:
The remaining 24 percent of flow from the unmonitored part of the watershed are attributed to low flow conditions and events too small to be monitored.

Unmonitored Total Low Flow =
(0.24) X [(total lake inflow) – (big bull inflow + little bull inflow) – (direct precip. volume)]

Unmonitored Low Flow Phosphorus Load =
(unmonitored total low flow) X (average low flow concentration)

Therefore, an average of grab samples collected from Big Bull, Little Bull, Rock, and Wade creeks is calculated and multiplied by the remaining flow.

In 2002, the unmonitored low flow phosphorus load was **6,370 Kg**.

In 2002, the unmonitored low flow sediment load was **0.160 X 10^6 Kg**.

The <u>total</u> unmonitored phosphorus load was **38,137 Kg**.

The <u>total</u> unmonitored sediment load was **21.9 X 10^6 Kg.**

Summary

Now the estimates for each of the following can be summed to obtain total phosphorous and sediment loads for 2002.

Total phosphorus load due to direct precipitation	794 Kg
Total phosphorus load from storm events in Big Bull Creek	7,601 Kg
Total phosphorus load from storm events in Little Bull Creek	1,433 Kg
Total phosphorus load from low-storm flow events in Big Bull Creek	2,855 Kg
Total phosphorus load from low-storm flow events in Little Bull Creek	285 Kg
Total phosphorus load during low flow in Big Bull Creek	2,770 Kg
Total phosphorus load during low flow in Little Bull Creek	259 Kg
Total phosphorus load from unmonitored flow	22,140 Kg
Total phosphorus load for Hillsdale Lake - 2002 =	**38,140 Kg**

Total sediment load due to direct precipitation	0 Kg
Total sediment load from storm events in Big Bull Creek	6.43×10^6 Kg
Total sediment load from storm events in Little Bull Creek	1.67×10^6 Kg
Total sediment load from low-storm flow events in Big Bull Creek	0.17×10^6 Kg
Total sediment load from low-storm flow events in Little Bull Creek	0.31×10^6 Kg
Total sediment load during low flow in Big Bull Creek	0.08×10^6 Kg
Total sediment load during low flow in Little Bull Creek	0.05×10^6 Kg
Total sediment load from unmonitored flow	13.2×10^6 Kg
Total sediment load for Hillsdale Lake - 2002 =	**21.9×10^6 Kg**

Conclusion

Phosphorus and Sediment Load - 2002

The estimated phosphorus load for 2002 equaled 38,140 Kg. The sediment load totaled 24,100 tons. These were the second lowest amounts since the inception of the project (**fig. 1**). An increase of best management practices within the watershed since the early 1990s may have played a roll. However, phosphorus and sediment loading show a strong correlation with the amount of inflow that occurs (**fig. 2**). In 2002, the lake inflow was 45,453 acre-ft, the second lowest amount recorded since 1994. The yearly lake inflow is a direct result of precipitation. The precipitation total for 2002 was below average.

Year	Yearly Lake Inflow (acre-ft)	Estimated Phosphorus Load (Kg)	Estimated Sediment Load (Short Tons)
1994	90,733	63,290	99,400
1995	112,747	71,410	127,000
1996	75,922	57,770	133,000
1997	110,870	80,440	108,000
1998	133,521	80,070	156,000
1999	96,357	73,310	98,700
2000	31,690	25,970	19,300
2001	58,261	54,090	58,800
2002	45,453	38,140	24,100

fig. 1. Inflow data provided by the U.S. Army Corps of Engineers.

Data acquired from the National Weather Service indicated total precipitation in 2002 of 33.72 inches. This is short of the average yearly total precipitation amount of 42.31 inches (based on U.S. Army Corps of Engineers data 1982 – 1999). The low precipitation amount resulted in less inflow from the tributaries of Hillsdale Lake. In turn, less phosphorus loading occurred in Hillsdale Lake. Obvious conclusions can be made by reviewing **fig. 1 and fig. 2** that phosphorus and sediment loading is directly affected by lake inflow.

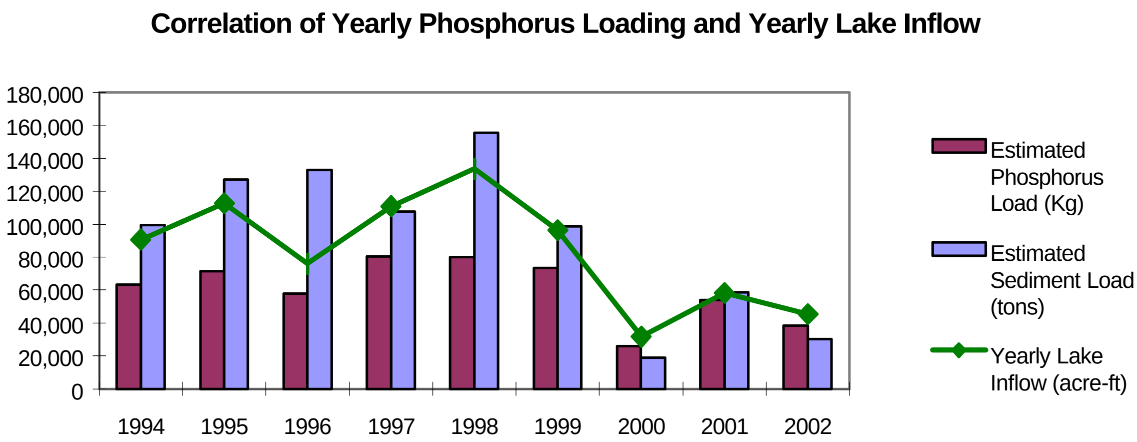


fig. 2. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

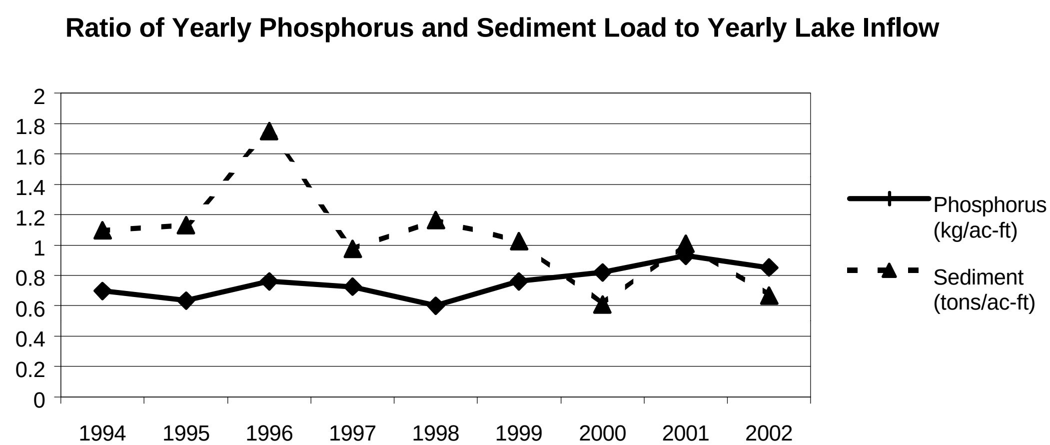
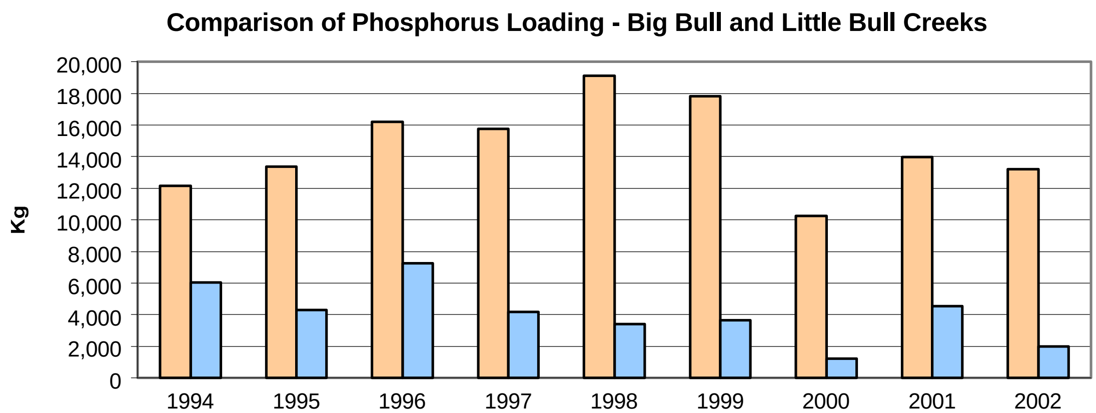


fig. 3. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

Figure 3 shows concentration levels of phosphorus and sediment. The values are derived by dividing the mass of phosphorus and sediment by the yearly lake inflow. While sediment concentrations are trending down, phosphorus concentrations are trending slightly upwards. The past three years produced the highest concentration levels of phosphorus. It is possible that this was due to the sporadic precipitation events, or "gully washers," that are experienced during dry years. Stream waters become more highly concentrated in phosphorus during a dry year because more phosphorus can be absorbed into bottom sediments and assimilated into plant materials, before being flushed into the lake. This process is known as phosphorus banking (Holt). It can be demonstrated that phosphorus concentrations deplete towards the tail end of a series of closely spaced runoff events because phosphorus banking is not occurring.

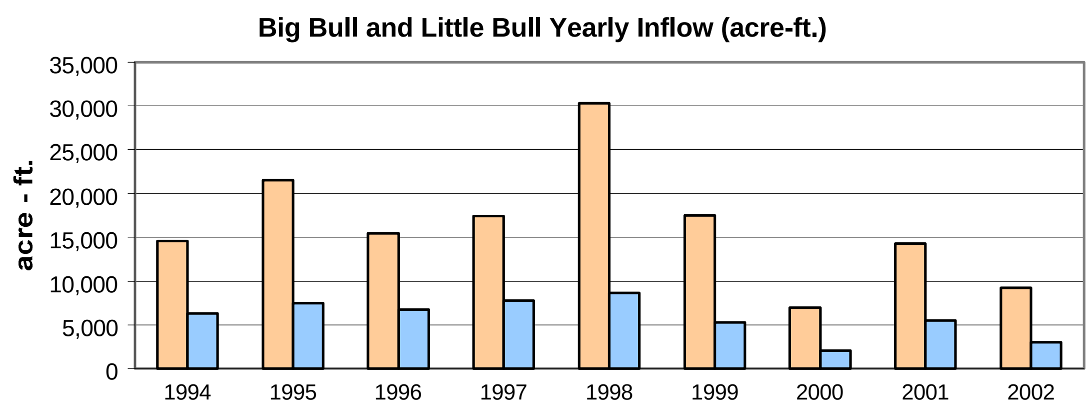
Priority Subwatershed

Each year, the Hillsdale Water Quality Project determines a subwatershed that requires the project's special attention. Efforts are made to contact landowners within the area to help spread the implementation of Best Management Practices within the subwatershed. In the past, two subwatersheds were isolated as the largest point and non-point source pollution contributors to Hillsdale Lake. They include the Big Bull and Little Bull subwatersheds. These two subwatersheds have flow gauging equipment and therefore, produce more accurate loading results. Of these two subwatersheds, Big Bull Creek consistently had the highest phosphorus load (**fig. 4**). In 2002, Big Bull Creek contributed about three times the total phosphorus load of Little Bull Creek. The main reason for this is the large difference of inflow into Hillsdale Lake (**fig. 5**).



	1994	1995	1996	1997	1998	1999	2000	2001	2002
Big Bull	12,149	13,358	16,211	15,749	19,125	17,843	10,266	13,989	13,226
Little Bull	6,057	4,291	7,237	4,166	3,394	3,657	1,205	4,558	1,977

fig. 4. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.



	1994	1995	1996	1997	1998	1999	2000	2001	2002
Big Bull	14,559	21,540	15,457	17,409	30,266	17,475	6,991	14,275	9,249
Little Bull	6,319	7,515	6,764	7,785	8,626	5,313	2,061	5,480	3,047

fig. 5. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

In an effort to compare the two subwatersheds equally, the phosphorus load per acre-foot of water was analyzed. The results are now independent of the total amount of water that flows through each subwatershed (**fig. 6**). In 2002, Big Bull Creek produced a concentration of 1.43 Kg / AF, or 0.78 Kg / AF higher than Little Bull Creek. This disparity is the second largest since 2000. In terms of inflow and precipitation, year 2000 and 2002 were very similar.

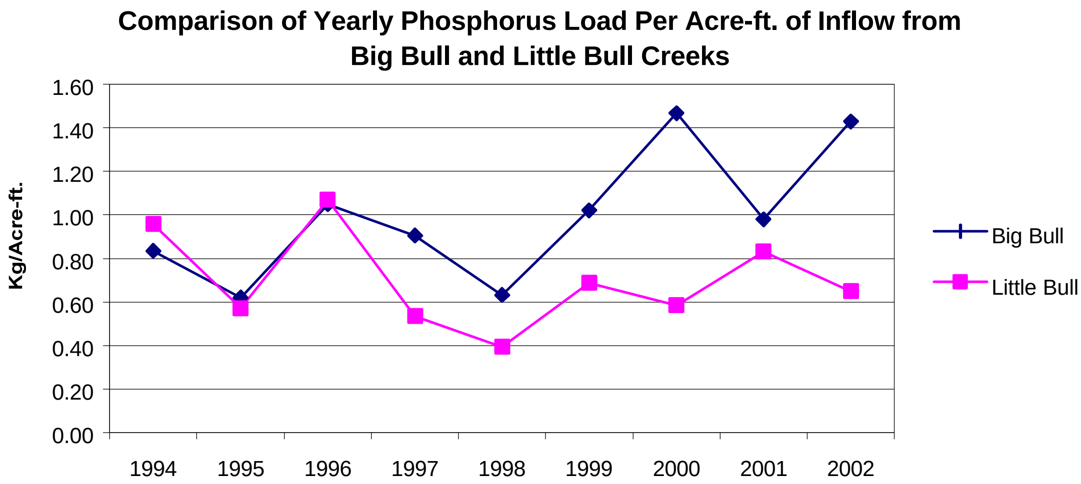


fig. 6. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

Similarly, the phosphorus load per acre of land within each subwatershed was analyzed. The Big Bull Subwatershed is 25 percent larger than the Little Bull Subwatershed (Big Bull Subwatershed = 23,628 acres, Little Bull Subwatershed = 17,770 acres). Dividing the acreage of each subwatershed by the amount of phosphorus load contributed by each subwatershed results in the amount of phosphorus that is washed from the surface per acre of each subwatershed. This results in data that is independent of inflow. Big Bull Subwatershed contributed 0.56 kg of phosphorus per acre and Little Bull Subwatershed contributed about 0.11 kg of phosphorus per acre (**fig. 7**).

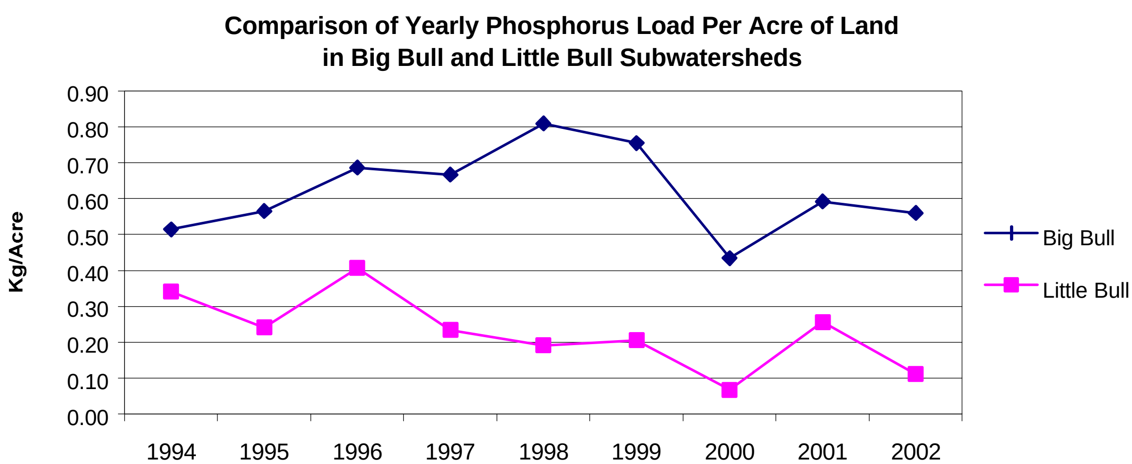


fig. 7. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

The Big Bull Subwatershed has more than 36 percent of all cropland in the Hillsdale Watershed. The subwatershed also contributed the greatest load of phosphorus and sediment (**figs. 8 and 9**). This is in contrast to 2001 as it was estimated that Little Bull Subwatershed contributed over one thousand tons more sediment than Big Bull during that year.

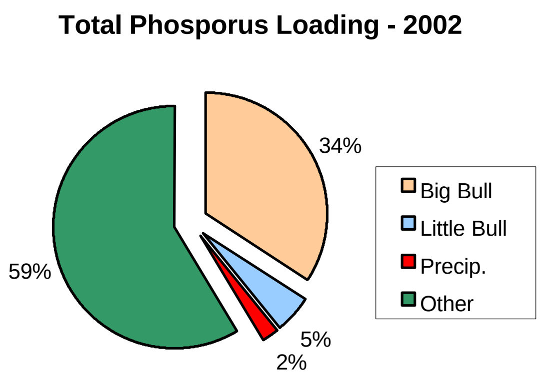


fig. 8. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

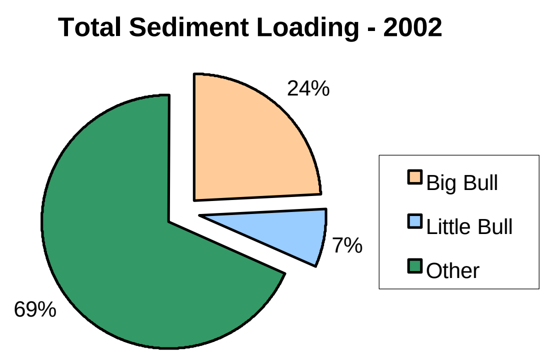


fig. 9. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

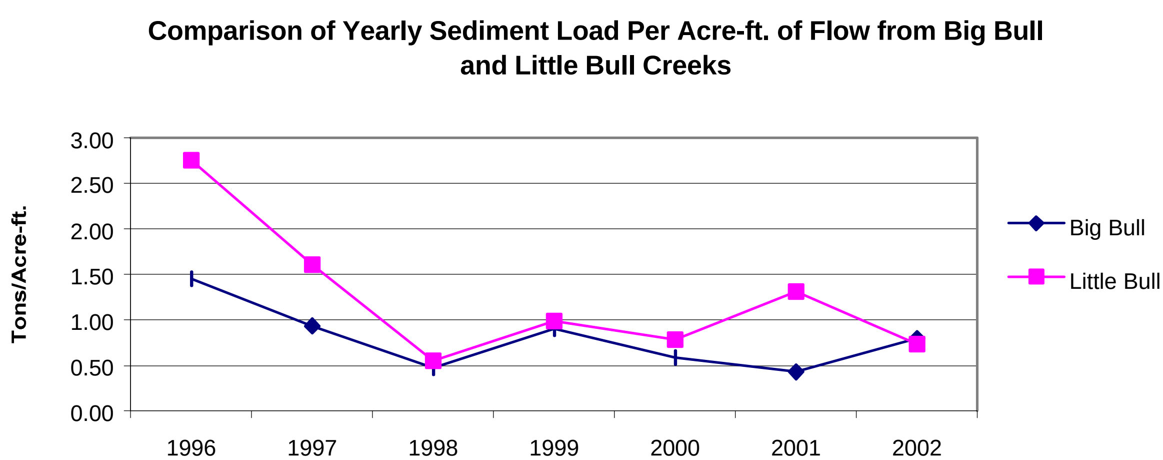


fig. 10. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

Sediment concentration in Little Bull Creek fell below Big Bull Creek for the first time in 2002. Prior to 2002, sediment concentrations were consistently higher in Little Bull Creek (**fig. 10**). The Little Bull subwatershed became the priority subwatershed for the first time in 2002. The 2001 analysis of Little Bull Creek illustrates increased phosphorus and sediment concentration and loading when compared to Big Bull Creek. In 2002, estimated phosphorus and sediment concentrations and loading were highest in Big Bull Creek. However, 2002 was an unusually dry year and estimations may revert back in favor of Little Bull Creek during a more normal year. Also, the Little Bull Creek Subwatershed has become more urbanized. For these reasons, the project designates the Little Bull Subwatershed as the project's priority subwatershed.

<u>Project Goals</u>
Estimates of phosphorus and sediment load reductions, attributed to BMPs implemented between January 1, 1997 and December 31, 2001, indicate that the sediment goal has been met. According to NRCS, those best management practices save 54,294.95 tons of sediment annually. While estimations provided by the NRCS are positive, this loading report provides more accurate estimates of phosphorus and sediment loads as it is based on actual flow and sampling data.

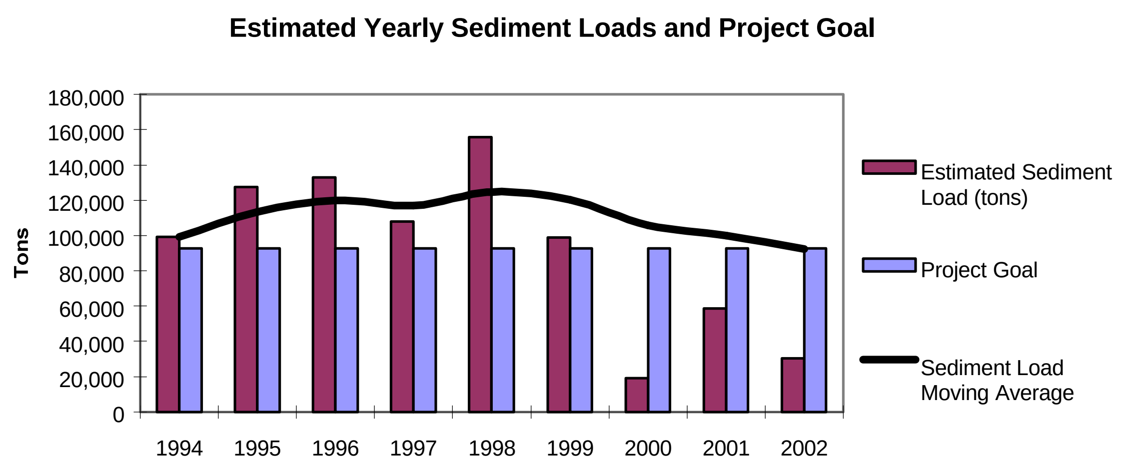


fig. 11. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

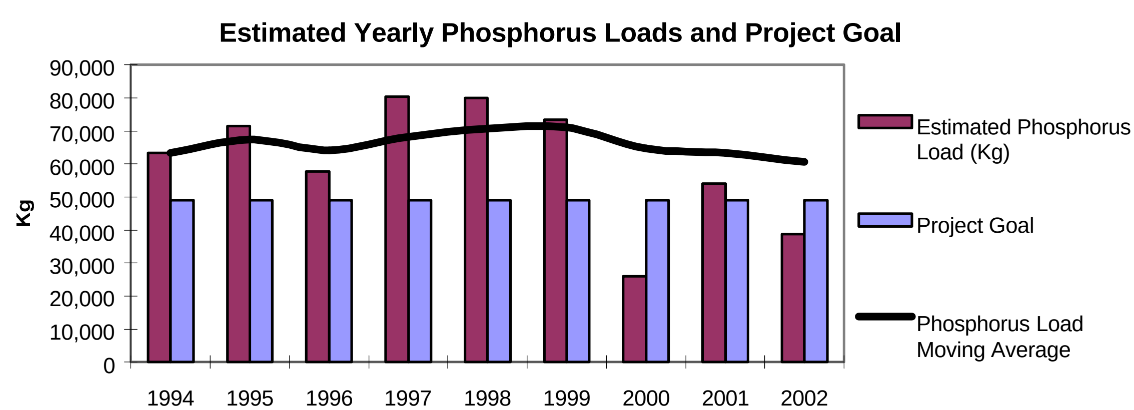


fig. 12. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

Efforts made by those associated with the Hillsdale Water Quality Project have likely been good for water quality. Loading estimates in recent years show sediment and phosphorus levels below or near the project's established goals. However, lake inflow has also dropped during this timeframe (**figs. 11 and 12**). Therefore, further implementation of best management practices is required to insure accomplishment of the project's goals especially during years of higher inflow.

References

-Franano, Michael D. 1997, "Hillsdale Lake Water Quality Assessment and Phosphorus Load Estimate": 1993-1996.

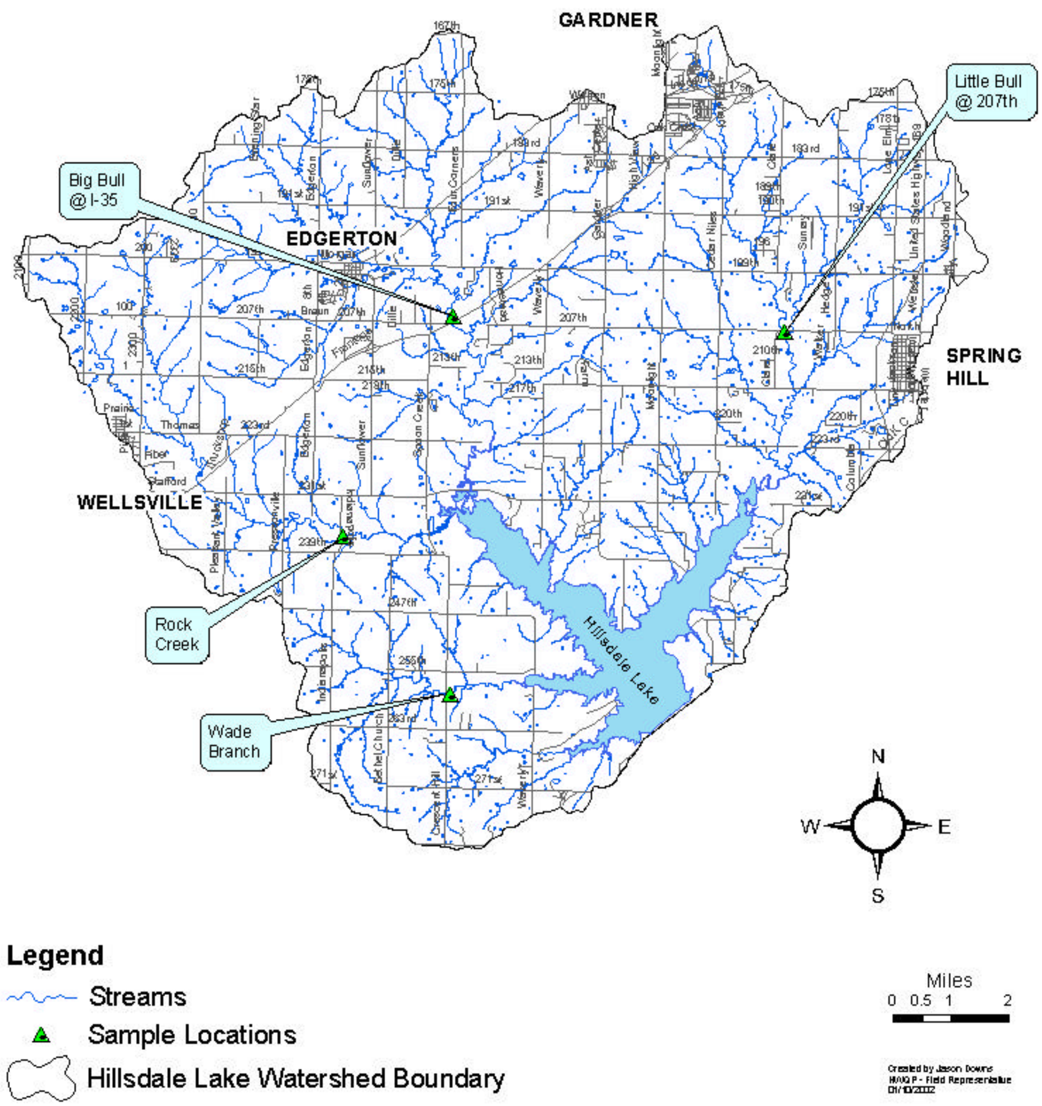
-Holt, Anthony A. 1996, "Estimation of 1994 Point Source and Non-Point Source Phosphorus Loading to Hillsdale Lake": Shawnee Mission, Kansas, Johnson County Environmental Department, various pagination.

-Jones, John R. Ph.D. 1998, "Evaluation of the Limnology of Hillsdale Lake, Kansas", Columbia, Mo., various pagination.

-Juracek, Kyle E. 1997, "Analysis of Bottom Sediment to Estimate Non-point Source Phosphorus Loads for 1981-96 in Hillsdale Lake, Northeast Kansas", Lawrence, Kansas, U.S. Geological Survey, Report 97-4235,Pg 1-55.

Supplemental Section

2002 Hillsdale Lake Watershed Sample Locations



CALCULATIONS AND NOTES:

I. Precip. Contribution

A. Precip Total for 2002 @ Hillsdale Lake = 33.72” = 2.81 ‘

B. Phos. concentration in precip. = 0.05 mg / L

C. Precip. volume

1. Surface Area of Lake = 4580 acres = 199.504,300 ft^2
2. Volume = (199,504,800 ft^2) * (2.81 ft)
3. Volume = 560,608,488 ft^3
4. Volume = 15,874,664,553 Liters

D. Mass of Phos. = <u>0.05 mg / L (15,874,664,553 L)</u>
1,000,000 mg / kg
= **<u>794 Kg</u>**

II. Monitored Portion

A. Low Flow – Big Bull

1. Avg. of 2002 Daily Mean Flow (DMF > 15 cfs) = 2.23 cfs
2. Yearly Total Low Flow Volume (amt. of water that passed USGS station during low flow)

= 2.23 ft^3 / s (60 s / min) (60 min / hr) (24 hr / day) (365 days / yr)
= **70,325,280 ft^3**

3. Total Low Flow Phos. (average grab concentration = 1.39 mg / L)

= <u>70,325,280 ft^3 (28.32 L / ft^3) (1.39 mg / L)</u>
1,000,000 mg / Kg
= **<u>2,770 Kg</u>**

4. Total low flow sed. (average grab concentration = 26 mg / L)

= <u>70,325,280 ft^3 (28.32 L / ft^3) (26 mg / L)</u>
1,000,000 mg / Kg
= **<u>52,000 Kg</u>**

B. Low Flow – Little Bull

1. Avg. of 2002 Daily Mean Flow (DMF > 13 cfs) = 1.81 cfs
2. Yearly Total Low Flow Volume (amt. of water that passed USGS station during low flow)

= 1.81 ft^3 / s (60 s / min) (60 min / hr) (24 hr / day) (365 days / yr)
= **57,180,461 ft^3**

3. Total Low Flow Phos. (average grab concentration = 0.16 mg / L)

= <u>57,180,461 ft^3 (28.32 L / ft^3) (0.16 mg / L)</u>
1,000,000 mg / Kg
= **<u>260 Kg</u>**

4. Total low flow sed. (average grab concentration = 33 mg/L)

   = $\frac{57{,}180{,}461\ ft^3\ (28.32\ L/ft^3)\ (33\ mg/L)}{1{,}000{,}000\ mg/Kg}$

   = **53,000 Kg**

C. Storm Events – Big Bull

See file: D:\Field Rep\loading report\Storm\Storm Load BB 2002

1. Total Amt. of Phos. produced from storm events
   = **7,601 Kg**
2. Total Amt. of Sed. produced from storm events
   = **6.431×10^6 Kg**

D. Storm Events – Little Bull

See file: D:\Field Rep\loading report\Storm\Storm Load LB 2002

1. Total Amt. of Phos. produced from storm events
   = **1,433 Kg**
2. Total Amt. of Sed. produced from storm events
   = **1.668×10^6 Kg**

E. Low Storm Flow - Big Bull

1. Phosphorus
   1. Avg. low and low-storm flow Phos. = 1.32 mg/L
   2. Total low-storm flow = **76,377,600 ft^3**
   3. Phos. load for low storm flow

      = $\frac{76{,}377{,}600\ ft^3\ (28.32\ L/ft^3)\ (1.32\ mg/L)}{1{,}000{,}000\ mg/Kg}$

      = **2,855 Kg**
2. Sediment.
   1. Avg. low and low-storm flow Sed. = 80 mg/L
   2. Total low-storm flow = **76,377,600 ft^3**
   3. Sed. load for low storm flow

      = $\frac{76{,}377{,}600\ ft^3\ (28.32\ L/ft^3)\ (80\ mg/L)}{1{,}000{,}000\ mg/Kg}$

      = **1.730×10^6 Kg**

F. Low Storm Flow - Little Bull

1. Phosphorus
   1. Avg. low and low-storm flow Phos. = 0.64 mg/L
   2. Total low-storm flow = **15,724,800 ft^3**
   3. Phos. load for low storm flow

      = $\frac{15{,}724{,}800\ ft^3\ (28.32\ L/ft^3)\ (0.64\ mg/L)}{1{,}000{,}000\ mg/Kg}$

      = **285 Kg**
2. Sediment

1. Avg. low and low-storm flow Sed. = 687 mg/L
2. Total low-storm flow = **15,724,800 ft^3**
3. Phos. load for low storm flow
   $= \frac{15{,}724{,}800\ ft^3\ (28.32\ L/ft^3)\ (687\ mg/L)}{1{,}000{,}000\ mg/Kg}$
   = **0.3059×10^6 kg**

III. Unmonitored Portion

A. Unmonitored Flow

1. Percent of unmonitored flow
   1. Total BB + LB Inflow = 12,296 af
   2. Storm:
      a. BB + LB Stormflow/12,296 af X 100
      b. 7256 af/12,296 X 100 = 59
      c. **59%**
   3. Low-Storm flow:
      a. BB + LB Low-Stormflow/12,296 X 100
      b. 2114 af/12,296 af X 100 = 17
      c. 17%
   4. Low flow:
      a. 100% - 59% - 17%
      b. 24%
2. Unmonitored flow totals:
   1. Storm Flow:
      a. 59%[(Total Lake Inflow) – (BB + LB Inflow)] = 11,969 af = 521,369,640 cf
   2. Low-storm flow:
      a. 17%[(Total Lake Inflow) – (BB + LB Inflow)] = 3,449 af = 150,238,440 cf
   3. Low flow:
      a. 24%[(Total Lake Inflow) – (BB + LB Inflow)] = 4,869 af = 212,093,640 cf

B. Unmonitored loading - Phosphorus

1. Storm Loading:
   1. $\frac{\text{unmon. stormflow (28.32 L/cf)(2002 Avg. storm conc.)}}{\text{1,000,000 mg/Kg}}$
   = **11,500 Kg**
2. Low-storm flow Loading:
   1. $\frac{\text{unmon. low-storm (28.32 L/cf)(2002 Avg low-storm conc.)}}{\text{1,000,000 mg/Kg}}$
   = 3,910 Kg
3. Low Flow Loading:
   1. $\frac{\text{unmon. low flow (28.32 L/cf)(2002 Avg. conc.)}}{\text{1,000,000 mg/Kg}}$
   = 6,370 Kg

C. Unmonitored loading – Sediment

1. Storm Loading:
   1. $\frac{\text{unmon. storm flow (28.32 L/cf)(2002 Avg. storm conc.)}}{\text{1,000,000 mg/Kg}}$

      = **11.0 X 10^6 Kg**
2. Low Storm Flow Loading:
   1. $\frac{\text{unmon. low-storm (28.32 L/cf)(2002 Avg low-storm conc.)}}{\text{1,000,000 mg/Kg}}$

      = **2.01 X 10^6 Kg**
3. Low Flow Loading:
   1. $\frac{\text{unmon. low flow (28.32 L/cf)(2002 Avg. conc.)}}{\text{1,000,000 mg/Kg}}$

      = **0.16 X 10^6 Kg**

D. Unmonitored – Load Totals

1. Phosphorus:

Storm Load =	11,500 Kg
Low Flow Load =	3,910 Kg
Low Storm Flow Load =	+ 6,370 Kg
	21,780 Kg

2. Sediment:

Storm Load =	**11.0 X 10^6 Kg**
Low Flow Load =	**2.01 X 10^6 Kg**
Low Storm Flow Load =	**+ 0.16 X 10^6 Kg**
	13.17 X 10^6 Kg

IV. Total Phos. Load for Hillsdale Lake 2002 =

1. Total Phos. – Precip =	794 Kg
2. Total Phos. – Storm BB =	7,601 Kg
3. Total Phos. – Low Storm BB =	2,855 Kg
4. Total Phos. – Low Flow BB =	2,770 Kg
5. Total Phos. – Storm LB =	1,433 Kg
6. Total Phos. – Low Storm LB =	285 Kg
7. Total Phos. – Low Flow LB =	259 Kg
8. Total Phos. – Unmonitored =	+22,140 Kg
	38,137 Kg

V. Total Sed. Load for Hillsdale Lake 2002 =

1. Total Sed. – Precip =	0 Kg
2. Total Sed. – Storm BB =	6.431 X 10^6 Kg
3. Total Sed. – Low Storm BB =	1.730 X 10^6 Kg
4. Total Sed. – Low Flow BB =	0.052 X 10^6 Kg
5. Total Sed. – Storm LB =	1.668 X 10^6 Kg
6. Total Sed. – Low Storm LB =	0.305 X 10^6 Kg
7. Total Sed. – Low Flow LB =	0.052 X 10^6 Kg
8. Total Sed. – Unmonitored =	+ 13.17 X 10^6 Kg
	21.88 X 10^6 Kg