Arkansas Water Resources Center

ILLINOIS RIVER 2003 POLLUTANT LOADS AT ARKANSAS HIGHWAY 59 BRIDGE

Submitted to the
Arkansas Soil and Water Conservation Commission
and the
Arkansas-Oklahoma Arkansas River Compact Commission

By
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SUMMARY

Results for Illinois River at AR59 for calendar year **2003**.

Pollutant	Total Discharge (m^3/yr)	Total Load (kg/yr)	Average Discharge (m^3/s)	Mean Concentrations (mg/l)
	289,188,131		9.1	
N03-N		590,943		2.04
TKN		144,041		0.50
TP		64,854		0.22
TSS		11,845,136		41

- Comparison between the loads and discharge calculated for 2003 to previous years indicate a decline in all parameters.

Comparison between 1997, 1998, 1999, 2000,2001,2002 and 2003 **loads**

Para meter	**1997** Loads	**1998** Loads	**1999** Loads	**2000** Loads	**2001** Loads	**2002** Loads	**2003** Loads
Discharge (m^3)	458,460, 000	588,000, 000	635,000, 000	536,000, 000	532,000, 000	531,000, 000	289,188, 131
N03-N (kg/yr)	1,020, 000	1,390, 000	1,560, 000	1,100, 000	1,520, 000	1,340, 000	590, 943
TKN (kg/yr)	301,000	481,000	514,000	462,000	447,000	294,000	144,041
TP (kg/yr)	127,000	232,000	267,000	283,000	256,000	218,000	64,854
TSS (kg/yr)	18,400, 000	72,600, 000	77,100, 000	63,600, 000	70,800, 000	39,000, 000	11,845, 136

- The total phosphorus load significantly decreased in 2003 as compared to 2002 (70%). This decrease can be attributed to two primary factors. Storm loads were reduced by 82%, which is probably the result of the reduction in storm flows by 80%. Base-flow loads were reduced by 51% which can be attributed to the reduction is WTTP phosphorus discharges by over 70%.

INTRODUCTION

Automatic water samplers and a U. S. Geological Survey gauging station were established in 1995 on the main stem of the Illinois River at the Arkansas Highway 59 Bridge. Since that time, continuous stage and discharge measurements and water quality sampling have been used to determine pollutant concentrations and loads in the Arkansas portion of the Illinois River. This report represents the results from the measurement and sampling by the Arkansas Water Resources Center -Water Quality Lab for January 1, 2003 to December 31, 2003.

PREVIOUS RESULTS

In the fall of 1995, a gauge was installed at the Highway 59 Bridge by the USGS and automatic sampling equipment was installed by the Arkansas Water Resource Center. In September 1995, sampling was begun on the Illinois River. Grab samples were taken every week and storms were sampled using an automatic sampler set to take samples every 4 hours. During the period from September 13, 1995 to September 15, 1996 one hundred thirty seven grab samples and discrete storm samples were collected and analyzed. Table 1 summarizes the results from that study (Parker et al, 1997).

Table 1. Results from **1996** study period (Parker et al, 1997)

Nutrients	Total Discharge (m^3/yr) 300,775,680	Total Load (kg/yr)	Average Discharge (m^3/s) 9.5	Average Flow Weighted Concentrations (mg/l)
N03-N		550,000		2.0
NH3-N		8,530		0.031
TKN		201,000		0.74
TP		89,900		0.29
TSS		27,000,000		89
TOC		1,130,000		4.2

Sampling was discontinued on September 15, 1996 and no water quality samples were taken between September 15, 1996 and November 1, 1996. Stage and discharge was still recorded for this period, however, no loads were calculated. Water quality sampling was resumed on November 1, 1996. The sampling protocol was changed to collection of grab samples every two weeks and flow-weighted storm composite samples. Between November 1, 1996 and December 31, 1996 a total of four grab samples and one storm composite sample were collected and analyzed. Stage and discharge were recorded.

During the period from January 1, 1997 to October 15, 1997, there were twenty-six grab samples and twenty-five storm composite samples collected and analyzed using the same protocol. During the period from October 15, 1997 to December 31, 1997, the sampling protocol was changed to taking grab samples every two or three days and taking discrete storm samples every thirty or sixty minutes. In this period, there were twenty-four grab samples and one hundred and forty storm discrete samples collected and analyzed. The loads and mean concentrations for 1997 calculated using these samples are summarized in Table 2.

Table 2. Results from **1997**-study period (Nelson and Soerens, 1998).

Pollutant	Total Discharge (m^3/yr) 458,460,000	Total Load (kg/yr)	Average Discharge (m^3/s) 14.5	Mean Concentrations (mg/l)
N03-N		1,020,000		2.24
TKN		301,000		0.66
TP		127,000		0.28
TSS		18,400,000		40.2

In the periods from January 1, 1998 to May 15, 1998 and November 1, 1998 to December 31, 1998, the Illinois River sampling was supplemented by sampling from another research project. That project, sponsored by the USGS Water Resource Institute Program, was titled "Investigation of Optimum Sample Interval for Determining Storm Water Pollutant Loads" by Marc Nelson, Thomas Soerens and Jean Spooner. The sampling protocol for that project consisted of taking grab samples every two days and discrete storm water samples at thirty-minute intervals on the rising limb and sixty-minute intervals on the falling limb of storm hydrographs. Storm water sampling was begun at a variable trigger level set to the current stage plus ten percent and adjusted every two days. After the first thirty-six hours of each storm, sample times were increased to from four to twenty-four hours until the stage fell below the initial trigger. All samples were collected within twenty-four hours. All samples were analyzed for nitrate nitrogen (NO3-N), ammonia nitrogen (NH4-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP), ortho phosphate (O-P) and total suspended solids (TSS). AWRC Field Services personnel collected all samples and all samples were analyzed by the AWRC Water Quality Lab using standard field and laboratory QA/QC procedures.

In the period from May 16, 1998 to October 31, 1998, the sampling protocol was changed back to the collection of grab samples every two weeks and flow-weighted composite samples during storms. Storms were defined as all flows above a five-foot trigger level. Once stage had risen above the trigger, a USGS programmable data logger began summing the volume of water discharged. Once a determined amount of water had been discharged, the data logger sent a signal to an automatic water sampler that filled one of twenty-four one-liter bottles. The total was then reset to zero and discharge was again summed for the next sample. In this fashion up to twenty-four samples, each representing an equal volume of storm water was collected. The volume of water represented by each individual sample was eight million cubic feet. These samples were retrieved before all twenty-four bottles were filled, or within 48 hours after being taken. The individual samples were composited into a flow-weighted composite storm sample by combining equal volumes of each. Samples were taken as long as the stage remained above the trigger level. All samples were analyzed for nitrate nitrogen (NO3-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP) and total suspended solids (TSS). AWRC Field Services personnel collected all samples and all samples were analyzed by the AWRC Water Quality Lab using standard field and laboratory QA/QC procedures.

In the period from January 1, 1998 to December 31, 1998, there were four hundred and forty nine samples collected and analyzed. These results are summarized in Table 3.

Table 3. Results from **1998**-study period (Nelson and Soerens, 1999).

Pollutant	Total Discharge (m^3/yr) 588,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 18.6	Mean Concentrations (mg/l)
N03-N		1,390,000		2.37
TKN		481,000		0.82
TP		232,000		0.39
TSS		72,600,000		123.5

In the period from January 1, 1999 to December 31, 1999, there were three hundred and sixty nine samples collected and analyzed. These results are summarized in Table 4.

Table 4. Results from the **1999** study period (Nelson and Soerens, 2000)

Pollutant	Total Discharge (m^3/yr) 635,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 20.0	Mean Concentrations (mg/l)
N03-N		1,560,000		2.45
TKN		514,000		0.81
TP		267,000		0.42
TSS		77,100,000		121

In the period from January 1, 2000 to December 31, 2000, there were fifty-one samples collected and analyzed. These results are summarized in Table 5.

Table 5. Results for Illinois River at AR59 for calendar year **2000**. (Nelson and Soerens, 2001).

Pollutant	Total Discharge (m^3/yr) 536,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 17	Mean Concentrations (mg/l)
N03-N		1,100,000		2.06
TKN		462,000		0.86
TP		283,000		0.53
TSS		63,600,000		118

In the period from January 1, 2001 to December 31, 2001, there were forty-nine samples collected and analyzed. These results are summarized in Table 6.

Table 6. Results for Illinois River at AR59 for calendar year **2001**. (Nelson and Soerens, 2002).

Pollutant	Total Discharge (m^3/yr) 532,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 16.9	Mean Concentrations (mg/l)
N03-N		1,520,000		2.86
TKN		447,000		0.84
TP		256,000		0.48
TSS		70,800,000		133

In the period from January 1, 2002 to December 31, 2002, there were Fifty-six samples collected and analyzed. These results are summarized in Table 7.

Table 7.Results for Illinois River at AR59 for calendar year **2002**. (Nelson and Cash, 2003).

Pollutant	Total Discharge (m^3/yr) 531,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 16.8	Mean Concentrations (mg/l)
N03-N		1,340,000		2.52
TKN		294,000		0.55
TP		218,000		0.41
TSS		38,900,000		73

METHODS

In the period from January 1, 2003 to December 31, 2003, the Illinois River sampling followed the following protocol. Base flow grab samples were taken every two weeks using the automatic sampler. Storm flow-weighted composite samples were taken during all storm events. Sampling was initiated when the river stage exceeded the trigger level of 5 feet. Flow-weighted composite samples were taken by causing the sampler to collect a single discrete sample for every four million cubic feet of water that passed the bridge. These discrete samples were collected once per day and composited by taking equal volumes from each discrete and combining them to form a single sample. Flow-weighted composite samples were taken from trigger level to trigger level of all storm events where the river stage was above the trigger for at least twelve hours. All samples were collected within twenty-four hours of being taken. All samples were analyzed for nitrate nitrogen (NO3-N), ammonia nitrogen (NH4-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP), ortho-phosphate (O-P) and total suspended solids (TSS). AWRC Field Services personnel collected all samples and all samples were analyzed by the AWRC Water Quality Lab using standard field and laboratory QA/QC procedures.

Calendar year pollutants loads and mean concentrations were calculated from the collected data. USGS stage and discharge data in thirty-minute intervals was used to calculate thirty-minute total volumes. Each volume was assigned a pollutant concentration. The pollutant concentrations were assigned by applying the results of grab samples between storm trigger levels and the results of storm water samples above trigger levels. All concentration data were assigned to the time periods from half way to the previous sample to half way to the subsequent sample except the first and last of a storm or base flow period which were assigned to the start or end of the period. Thirty-minute loads were calculated by multiplying thirty-minute volumes by their assigned concentrations. The yearly loads were calculated by summing the thirty-minute loads during the calendar year. Yearly mean concentrations were calculated by dividing the yearly load by the yearly volume.

In addition to the above sampling for load determination, the AWRC in conjunction with the USGS conducted cross-section sampling to determine the relationship between auto-sampler concentrations and cross-section concentrations. The USGS collected evenly weighted integrated (EWI) cross section samples at the same time AWRC collected discrete auto-samples. All samples were transported and analyzed by the AWRC Water Quality Lab. Five storm-flow paired samples were taken and compared during the year.

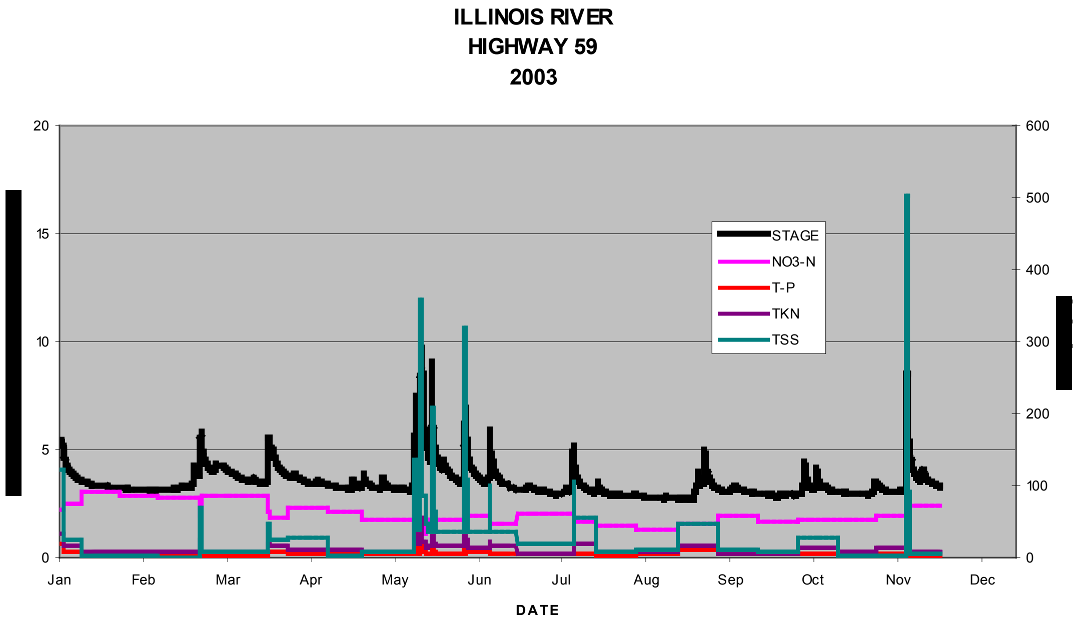
RESULTS

In the period from January 1, 2003 to December 31, 2003, there were twenty-five composite storm samples and twenty-six base-flow grab samples collected, analyzed and used to calculate loads. These results are summarized in Table 8 and Figure 1.

Table 8. Results for Illinois River at AR59 for calendar year **2003**.

Pollutant	Total Discharge (m^3/yr)	Total Load (kg/yr)	Average Discharge (m^3/s)	Mean Concentrations (mg/l)
	289,188,131		9.1	
N03-N		590,943		2.04
TKN		144,041		0.50
TP		64,854		0.22
TSS		11,845,136		41

Figure 1. Recorded stage and measured concentration for 2003.



DISCUSSION

The loads that were calculated for the year 2003 should be considered a very reliable estimate of the actual loads in the Illinois River in Arkansas. There were no gaps in the discharge data and all storm events were sampled adequately.

A source of error in the use of automatic samplers to collect samples is that the sampler may take samples that are not representative of the cross-section. In an effort to determine the possible error, beginning in 1998, the USGS began taking samples that represent the entire cross-section (EWI samples) at the same time the auto sampler was taking samples. Results from those samples indicate that the auto samples may be underestimating TSS by 6% and overestimating concentrations of total phosphorus by 9% (see Figure 2 and 3) compared to the USGS EWI samples.

Figure 2. Regression of log TSS concentrations AWRC vs. USGS.

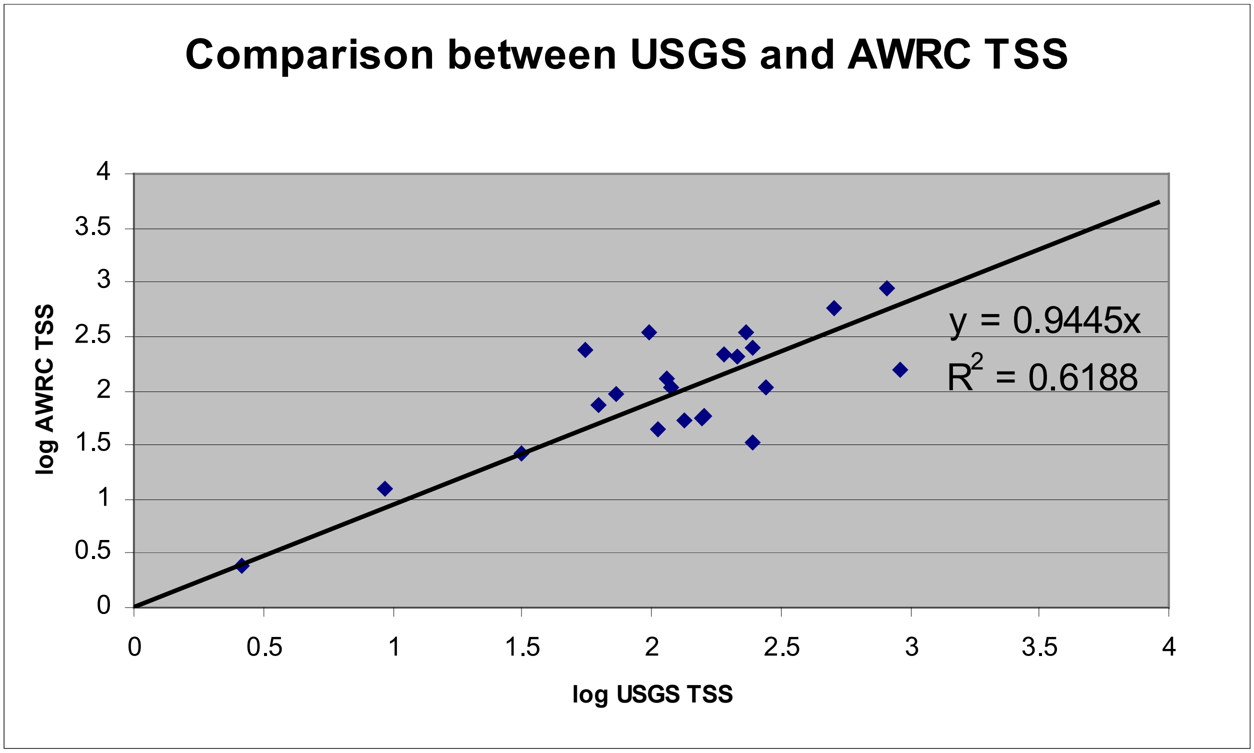
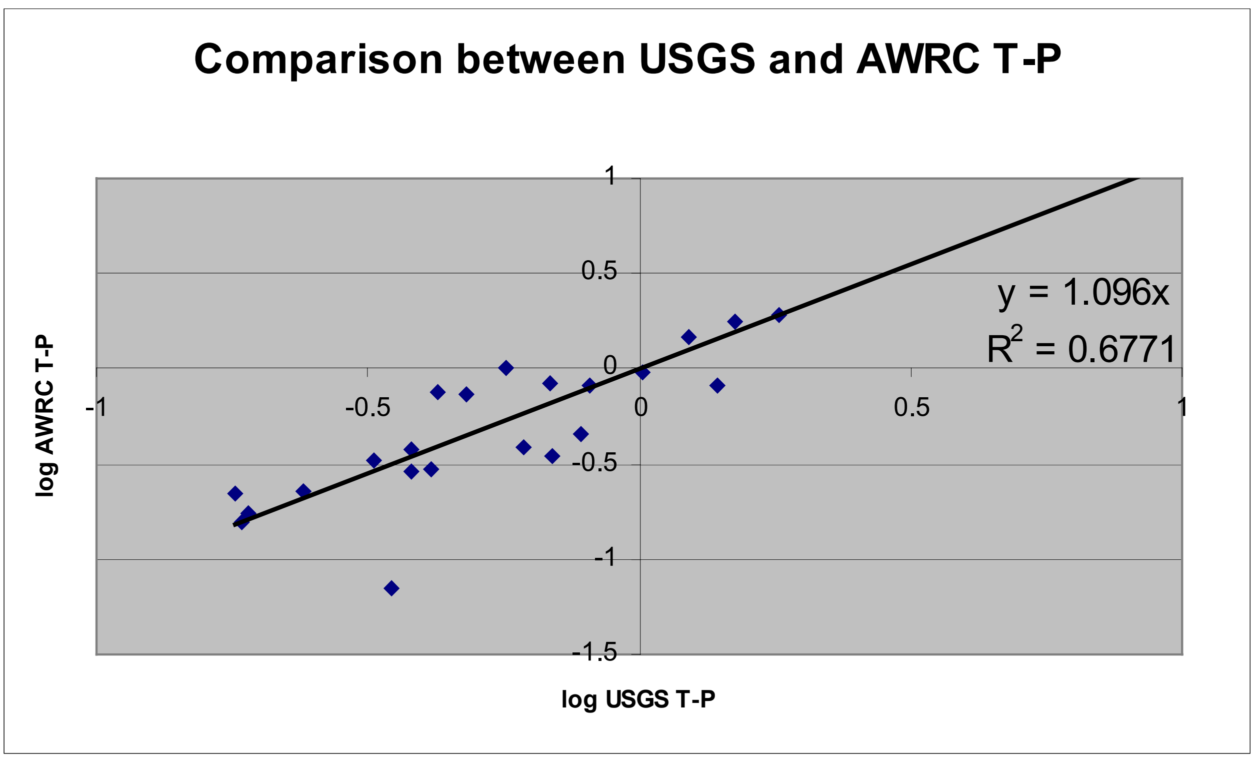


Figure 3. Regression of log T-P concentrations AWRC vs. USGS.



Results from seven years water quality monitoring for total phosphorus are summarized in Figures 4 to 7. The mean concentrations were determined by dividing the annual load by the annual discharge. Shown in figure 4 are the base flows, storm flows and combined concentrations. Base flow concentrations represent the phosphorus load determined when the river stage was below five feet divided by the total discharge that occurred when the river stage was below five feet. Storm flow concentrations are loads divided by discharge above five feet. The combined flow concentration is the total load divided by the total discharge. These results show a decreasing trend in base-flow concentrations in the last two years. Figure 5 shows that the T-P base-flow load measured at the 59 Bridge correlates well with the T-P discharged by the municipal WWTPs in the watershed.

Figure 4 trends in discharge and T-P concentrations.

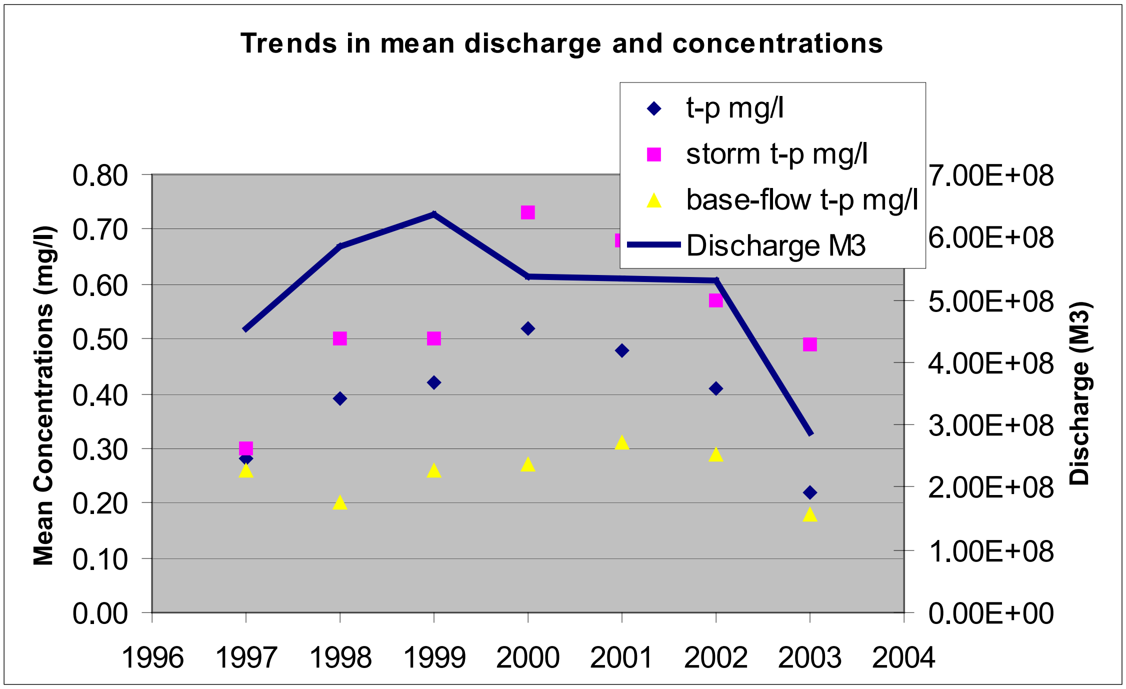
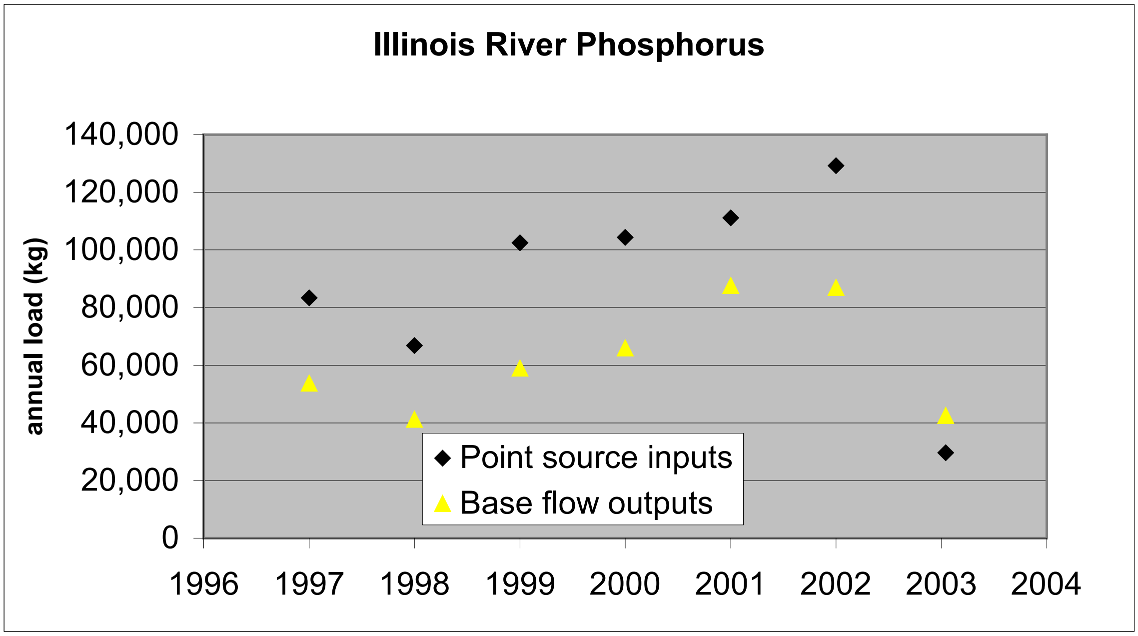


Figure 5 Comparison of measured base-flow T-P load to WWTP T-P discharge.



Storm-flow loads tend to be related to discharge, with higher loads associated with higher discharges. This relationship was observed throughout the study period. The decreasing trend in storm-flow loads in the last three years can probably be attributed to the decreasing storm-flow discharges in the last four years of the study period.

Short-term trends in total phosphorus loads show the impacts of changing storm-flow loads as shown in figures 6 and 7. For the first 3 years of the study, the annual loads were increasing at a rate of approximately 70,000 kg per year. The loads decreased at a rate of approximately 30,000 kg per year for the next three years. The trend for the seven-year period as a whole is decreasing at a rate of 8000 kg per year.

Figure 6. Short-term trends in T-P loads.

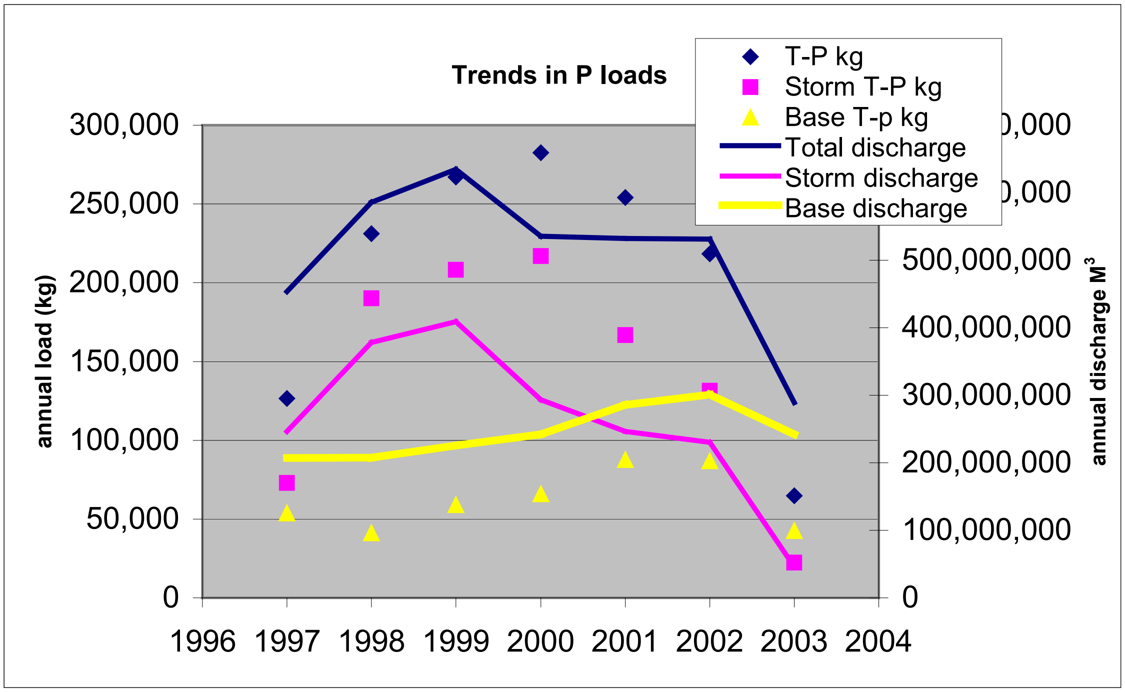
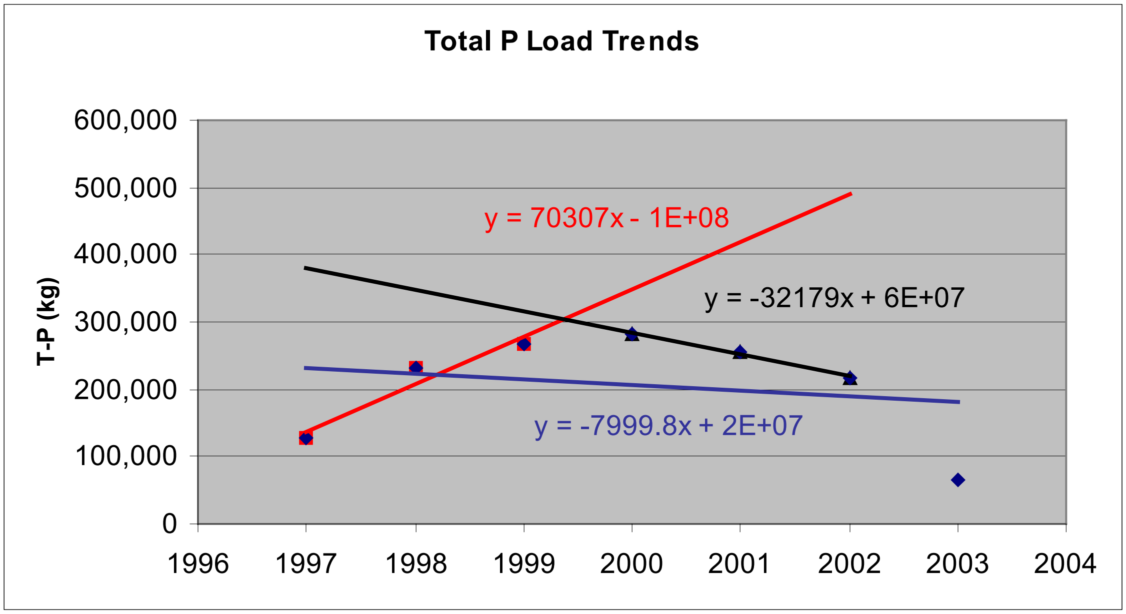


Figure 7 Total Phosphorus load trends



The total phosphorus load significantly decreased in 2003 as compared to 2002 (70%). This decrease can be attributed to two primary factors. Storm-flow loads were reduced by 82%, which is probably the result of the reduction in storm flows by 80%. Base-flow loads were reduced by 51%, which can be attributed to the reduction is WTTP phosphorus discharges by over 70%. This implies that the base-flow loads may continue to decrease as the WTTPs continue to improve their phosphorus removal. Also implied is that the storm-flow phosphorus loads may return to higher levels with increased discharge.

The loads and concentrations developed for the Illinois River can be compared to loads and concentrations developed in other watersheds in Northwest Arkansas. Five other watersheds have been monitored using the same monitoring and load calculation protocols. The only differences between the protocols are that trigger levels and storm composite sample volumes are different for each site. This means that the distinction between storm and base flows (defined here as the trigger level) may be relatively different at each site.

The results for the six watersheds are summarized in Table 8 and Figure 8. The table and figure show TSS and phosphorus as total annual loads per watershed acre, as storm loads per watershed acre and as base-flow concentrations. Normalizing total and storm loads to a per acre basis allows easy comparison between watersheds of differing sizes. The total loads indicate the mass of TSS or P that are being transported to a receiving water body. Storm loads per acre may be used to represent relative impacts from non-point sources. In Figure 8, a red line represents the total loads and blue diamonds represents the storm loads.

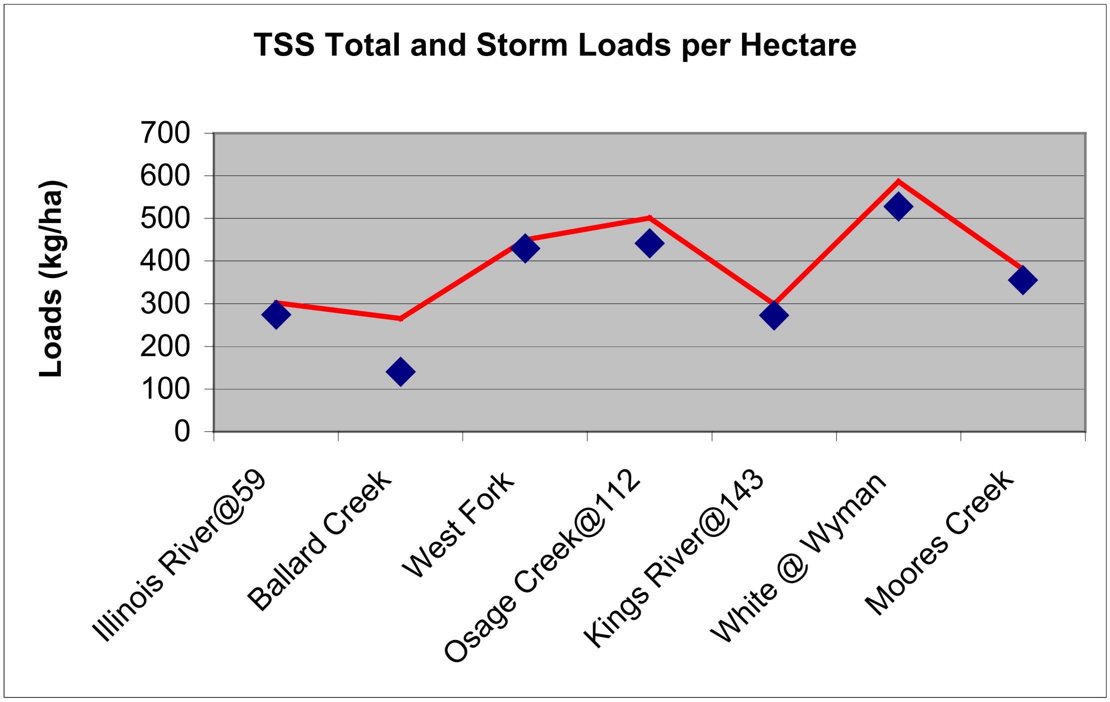
The Illinois River watershed has relatively low total TSS compared to the others (except Ballard Creek) and most of the TSS is transported during storm events. The P load for the Illinois is fairly consistent with the other watersheds with the White at Wyman and Moores Creek (a primarily agricultural sub-watershed of the Illinois) and showing higher levels of P per acre especially during storm events. The Kings River and West Fork showed lower values.

The base-flow concentrations show relative levels of TSS and P that are impacting in-stream biological activity during most of the year. These are the values that are of greatest interest for determining impacts to in-stream macro invertebrate habitat and nuisance algae production. The Illinois River has average concentrations of TSS compared to the others. It is low compared to the White The base-flow P concentrations for all of the watersheds except the West Fork are similar.

Table 8 Comparison of six watersheds

	Illinois River@59	Ballard Creek	West Fork	Osage Creek@112	Kings River@143	White @ Wyman	Moores Creek
Hectares	167,273	6,742	29,964	10,095	153,309	116,364	1,000
YEARS of data	7	1	2	2	5	2	4
tss load (kg/ha)	302	265	450	501	299	586	381
tss load storm (kg/ha)	274	141	430	442	273	528	355
tss conc. base (mg/l)	20	28.03	18	39	19	40	18
p load (kg/ha)	1.24	1.50	0.94	1.16	0.76	1.66	1.27
p storm load (kg/ha)	0.86	0.58	0.92	0.70	0.53	1.26	1.01
p base conc. (mg/l)	0.25	0.21	0.02	0.21	0.18	0.27	0.17
DISCHARGE (m^3)	545,516,682	36,251,012	106,081,072	38,827,312	378,398,602	243,428,688	3,011,285
DISCHARGE/AC (m^3/ha)	3,261	5,377	3,540	3,846	2,468	3,540	3,011

Figure 8 Comparison of seven watersheds



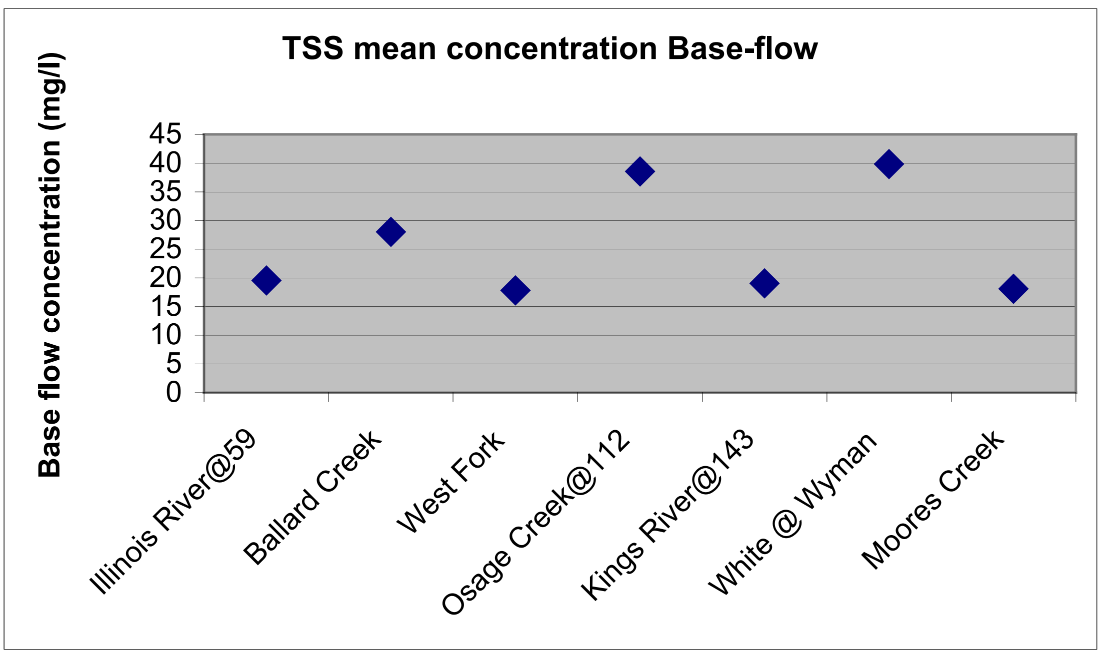
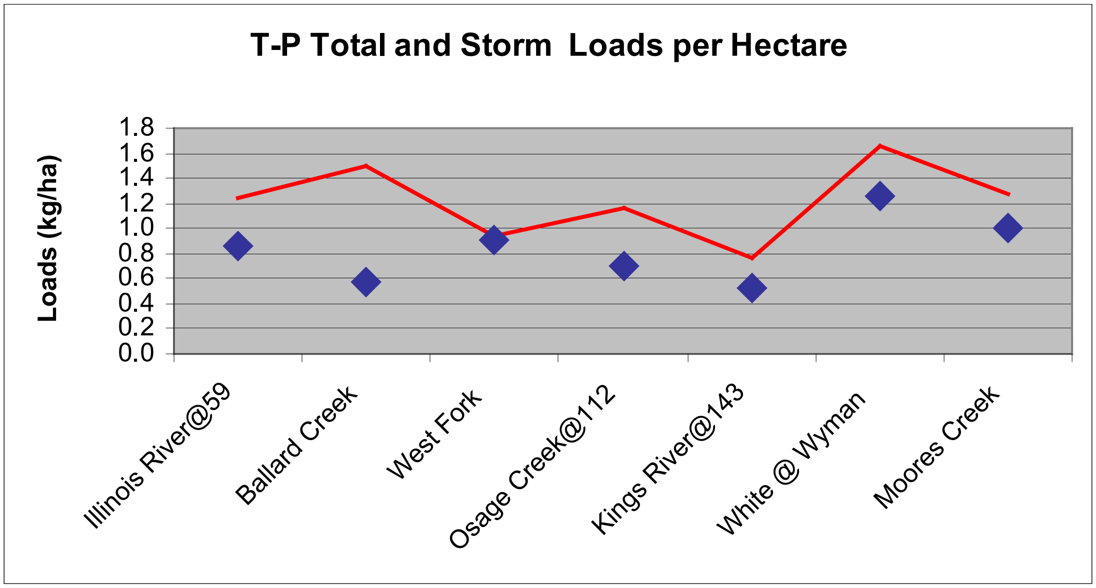
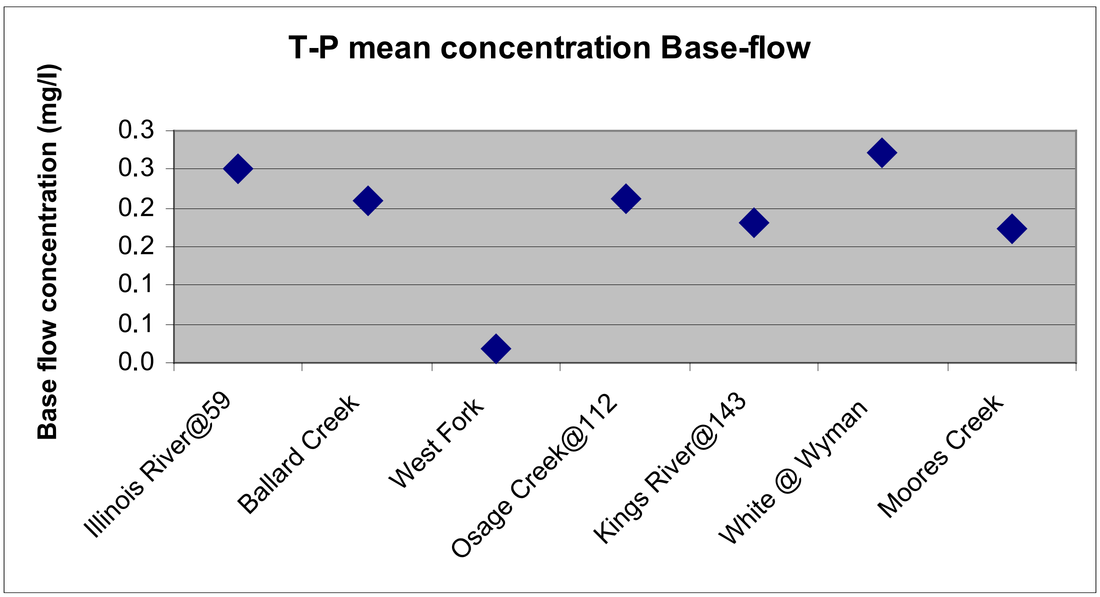


Figure 7 (continued).





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