Arkansas Water Resources Center

ILLINOIS RIVER
2006
WATER QUALITY ASSESSMENT
At ARKANSAS HIGHWAY 59 BRIDGE

Submitted to the
Arkansas Natural Resources Commission

Prepared by:

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June 2007

ARKANSAS WATER RESOURCES CENTER
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And
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SUMMARY

Results for Illinois River at AR59 for calendar year **2006**.

Pollutant	Total Discharge (m^3/yr)	Total Load (kg/yr)	Average Discharge (m^3/s)	Mean Concentrations (mg/l)
	256,585,770		8.10	
NO_3-N		513,847		2.00
T-P		96,596		0.38
NH_4-N		29,870		0.12
TN		575,412		2.24
PO_4-P		33,837		0.13
TSS		33,054,951		128

2006 Loads and Concentrations during storm and base-flows.

	Storm Loads (kg)	Base Loads (kg)	Storm Concentrations (mg/l)	Base Concentrations (mg/l)
Discharge (m^3/yr)	107,602,614	148,983,156		
NO_3-N	195,226	318,621	1.81	2.14
T-P	77,314	19,282	0.72	0.13
NH_4-N	21,657	8,214	0.20	0.06
TN	244,722	330,691	2.27	2.22
PO_4-P	20,114	13,723	0.19	0.09
TSS	31,752,053	1,302,898	295	9

INTRODUCTION

Automatic water sampler 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, 2006 to December 31, 2006.

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

Table 8 Results for Illinois River at AR59 for calendar year **2003**(Nelson and Cash, 2004)..

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

Table 9. Results for Illinois River at AR59 for calendar year **2004**. (Nelson, et. al.)

Pollutant	Total Discharge (m^3/yr)	Total Load (kg/yr)	Average Discharge (m^3/s)	Mean Concentrations (mg/l)
	565,760,474		17.8	
N03-N		1,207,335		2.13
TKN		512,358		0.91
TP		281,425		0.5
TSS		92,080,737		163

Table 9. Results for Illinois River at AR59 for calendar year **2005**. (Nelson, et. al.)

Pollutant	Total Discharge (m^3/yr)	Total Load (kg/yr)	Average Discharge (m^3/s)	Mean Concentrations (mg/l)
	390,894,159		12.3	
NO3-N		1,018,744		2.61
T-P		106,979		0.27
NH4		20,602		0.05
TN		1,170,851		3.00
PO4		44,213		0.11
TSS		33,560,475		85.86

Table 10. Summary of previous years load results.

Para meter	**1997** Loads	**1998** Loads	**1999** Loads	**2000** Loads	**2001** Loads	**2002** Loads	**2003** Loads	**2004** Loads	**2005** Loads
Discharge 10^6(m^3)	458	588	635	536	532	531	289	566	391
N03-N 10^3 (kg/yr)	1,020	1,390	1,560	1,100	1,520	1,340	591	1,207	1,018
TkN 10^3 (kg/yr)	301	481	514	462	447	294	144	512	153
TP 10^3 (kg/yr)	127	232	267	283	256	218	64	281	107
TSS 10^3 (kg/yr)	18,400	72,600	77,100	63,600	70,800	39,000	11,845	92,080	33,560

METHODS

In the period from January 1, 2006 to December 31, 2006, the Illinois River sampling followed the following protocol. Base flow grab samples were taken every two weeks using the automatic sampler. Discrete storm samples were collected during all storm events (herein defined as when the stage was above five feet for more than 12 hours). Samples were collected every 30 minutes during the first 12 hours of a storm and every 60 minutes during the rest of the storm. All samples were analyzed for nitrate nitrogen (NO3-N), ammonia nitrogen (NH4-N), total nitrogen (TN), 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.

RESULTS

In the period from January 1, 2006 to December 31, 2006, there were a total of 57 samples consisting of 19 composite storm samples, 26 base-flow grab samples, 4 field blank samples, 4 sampler duplicate samples and 4 bank replicate samples collected, analyzed and used to calculate loads. These results are summarized in Tables 11and 12 and Figure 1.

Table 11. Results for Illinois River at AR59 for calendar year **2006**.

Pollutant	Total Discharge (m^3/yr)	Total Load (kg/yr)	Average Discharge (m^3/s)	Mean Concentrations (mg/l)
	256,585,770		8.10	
NO_3-N		513,847		2.00
T-P		96,596		0.38
NH_4-N		29,870		0.12
TN		575,412		2.24
PO_4-P		33,837		0.13
TSS		33,054,951		128

Figure 1. Recorded stage and measured concentrations for **2006**.

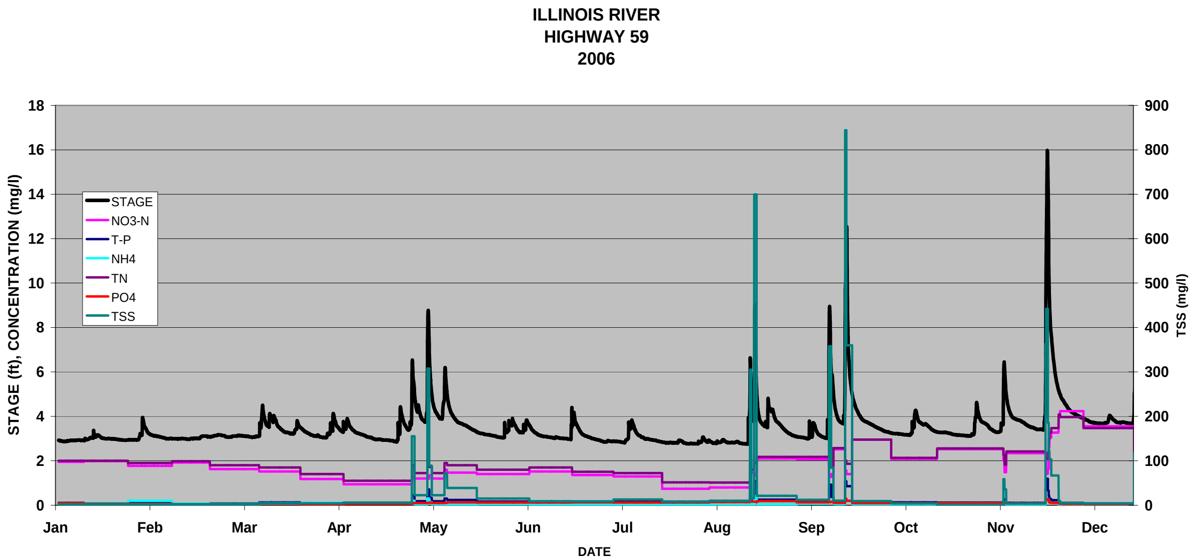


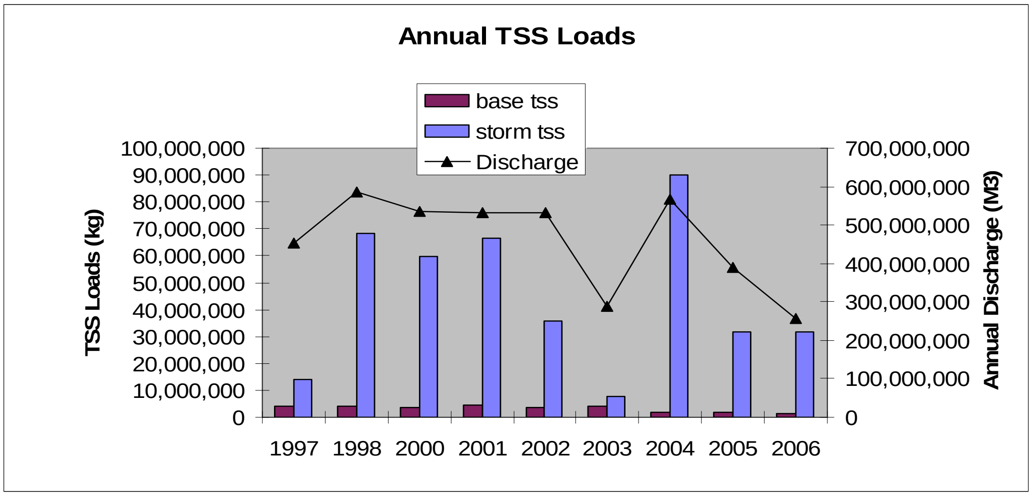
Table 12. **2006** Loads and Concentrations during storm and base-flows.

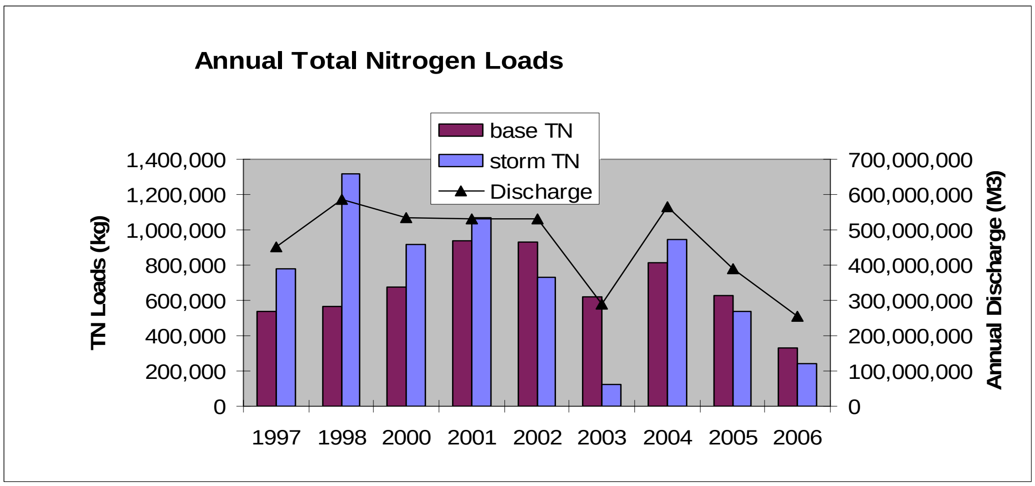
	Storm Loads (kg)	**Base Loads (kg)**	**Storm Concentrations (mg/l)**	**Base Concentrations (mg/l)**
Discharge (m^3/yr)	107,602,614	148,983,156		
NO_3-N	195,226	318,621	1.81	2.14
T-P	77,314	19,282	0.72	0.13
NH_4-N	21,657	8,214	0.20	0.06
TN	244,722	330,691	2.27	2.22
PO_4-P	20,114	13,723	0.19	0.09
TSS	31,752,053	1,302,898	295	9

DISCUSSION

Results from nine years of water quality monitoring for total phosphorus are summarized in Figures 2 to 4. The mean concentrations were determined by dividing the annual load by the annual discharge. The trends in base and storm-flow loads and total discharge are shown in figure 2. Base-flow loads represent the phosphorus load determined when the river stage was below five feet. These results show a decreasing trend in base-flow loads in the last four years. Figure 3 shows that the reduction in T-P base-flow loads measured at the 59 Bridge correlates well with the reduction of T-P discharged by the municipal WWTPs into the river.

Figure 2 trends in discharge and annual loads.





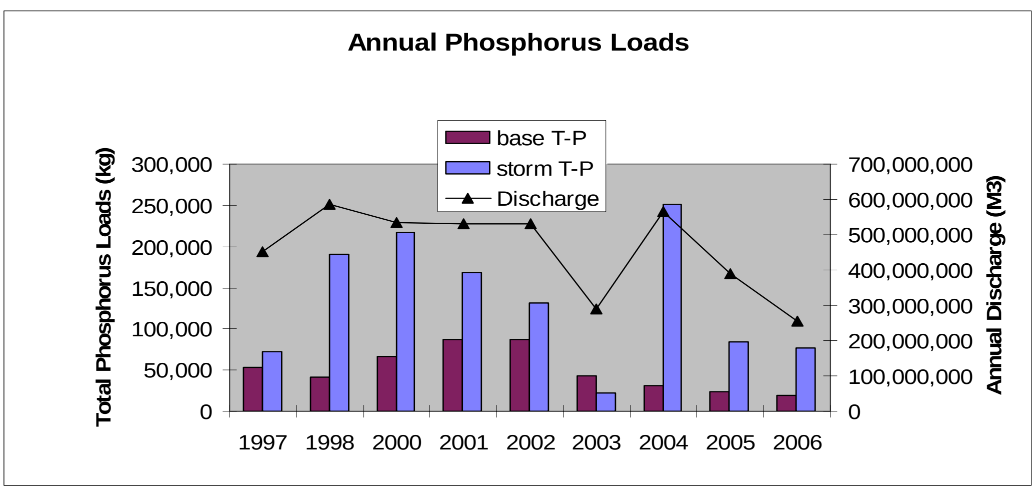
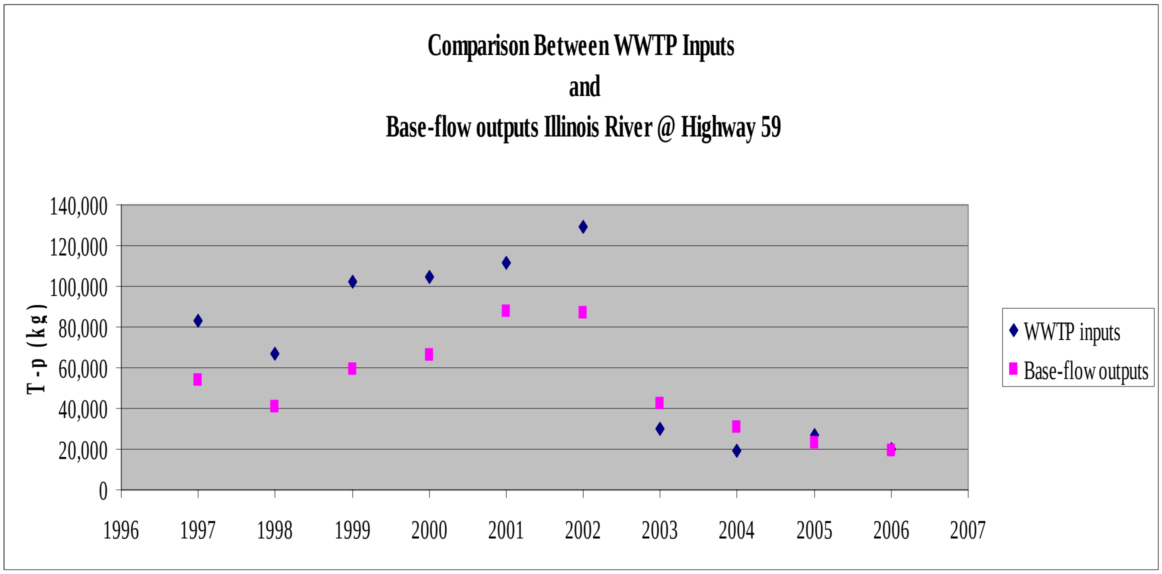
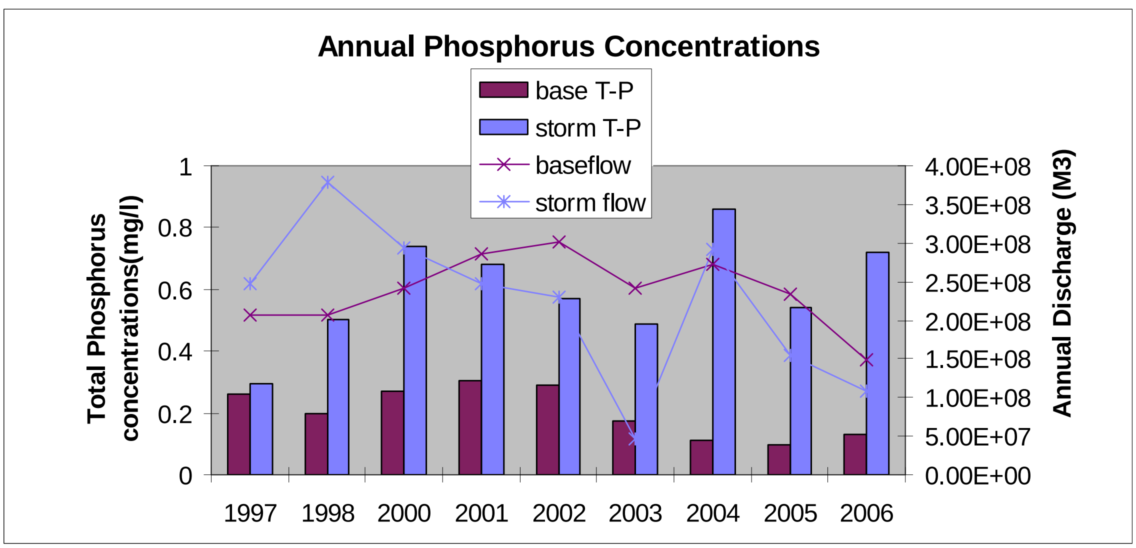


Figure 3 Comparison of measured base-flow T-P load to WWTP T-P discharge.



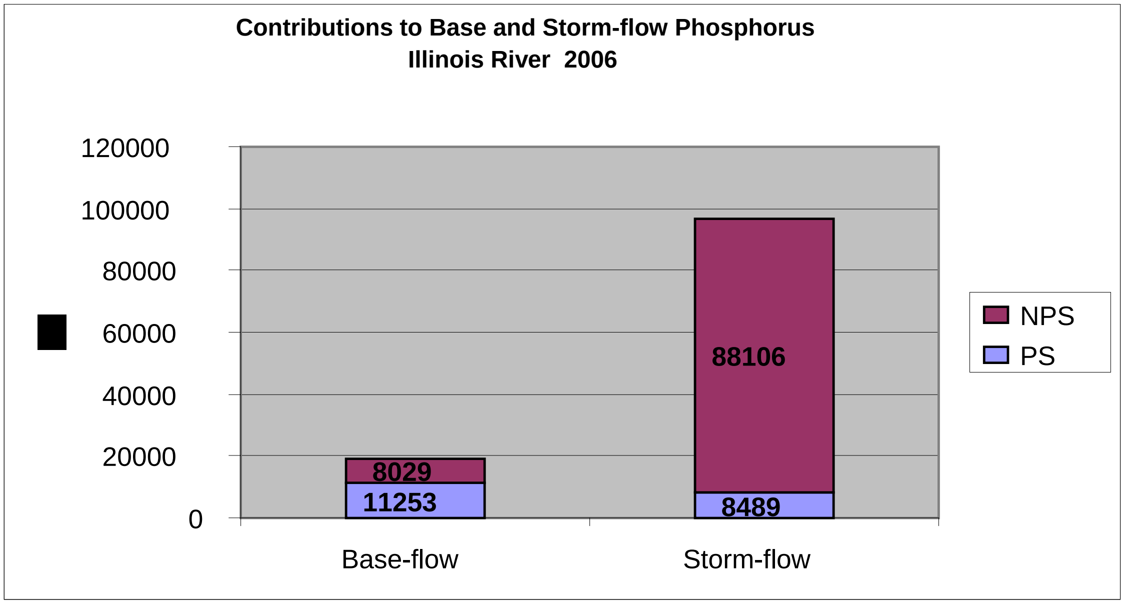
Storm –flow loads are highly correlated to discharge. Storm events usually have higher concentrations and with the higher discharges, have much greater loads. Higher total annual discharge usually implies higher mean storm concentrations and storm loads. Figures 2 and 4 show that the total and storm discharge has declined in the last two years. The total nitrogen storm load has followed this trend. However, the loads for TSS and P have not decreased as much as expected and figure 4 shows that P concentrations during storm events have increased in 2006. This could imply either that the storms that did occur had greater intensity or the watershed had more disturbed soils containing phosphorus to be washed into the rivers during storm events. It is less likely that the increased P was from increased application of P in the watershed since it is listed as a nutrient surplus watershed and P application rates are limited. Figure 4 shows that base-flow P concentrations increased slightly from 0.10 to 0.13 mg/l due to decreased base- flow discharge.

Figure 4 Trends in phosphorus concentrations.



Previous studies for the period from 1997 to 2001 estimated that 57% of the WWTP discharged P was measured in the base-flow and 43% was measured in the storm-flows (Nelson and White, 2002). Using this relationship, Figure 5 shows the contributions of point sources and non-point sources to measured base and storm-flows for 2006.

Figure 5 Point source and non-point source contributions to base and storm-flow phosphorus.



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The Illinois River @ 59 Bridge during 2006 can be compared to loads and concentrations developed in other watersheds in Northwest Arkansas for 2006. 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 13 and Figure 6. The table and figure show TSS, total phosphorus and total nitrogen as total annual storm-flow loads per watershed hectare, as base-flow loads per watershed hectare and as base-flow concentrations. Normalizing storm and base-flow loads to a per hectare basis allows 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 hectare may be used to represent relative impacts from non-point sources. The Illinois River watershed had lower TSS loads per hectare compared to the other watersheds during both base-flows and storm-flows (Kings River had lower base-flow TSS). Most of the TSS was transported during storm events. The P load for the Illinois River was lower compared to the other watersheds (except the Kings) during storm-flows. The P load during base-flow conditions was the lowest in the Illinois River watershed. Most of the phosphorus was transported during storm events. There is a strong correlation between base-flow phosphorus loads and the phosphorus discharged by the 4 WWTPs discharging in the watershed (see figure 3). Total nitrogen loads per hectare were higher than the others except Ballard Creek and in general higher than in the White River Basin.

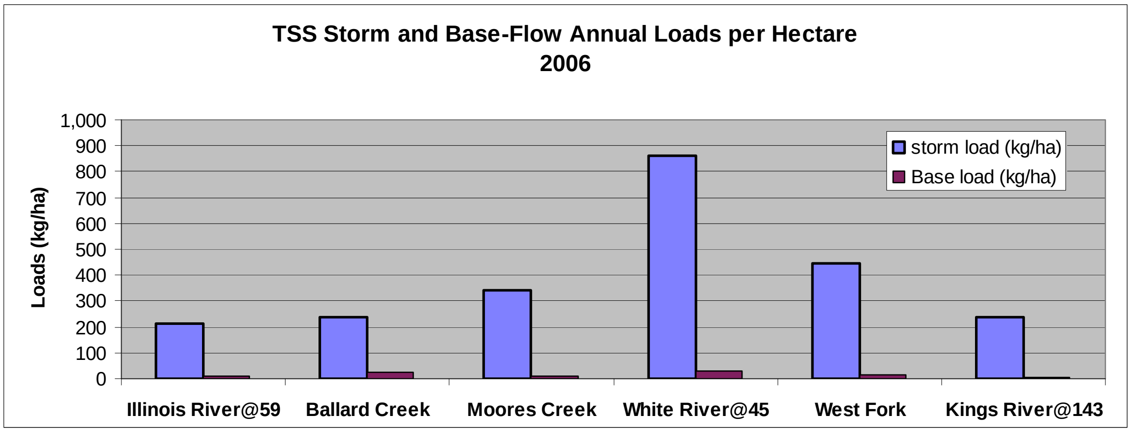
The base-flow concentrations show relative levels of TSS, T-P and TN that are impacting in-stream biological activity during most of the year. These are the values that are of greatest interest for determining impacts to in-stream biological habitat and nuisance algae production. The base-flow concentration of TSS was average. The T-P concentration was 0.13 mg/l which was greatly reduced from the peak of 0.3 mg/l in 2002. However, the concentration was up from 0.1 mg/l in 2005 due to the dry weather. The nitrate concentration of 2.41 mg/l was high compared to the others, but down slightly from 2.57 mg/l in 2005. This is a possible result of the combination of high groundwater levels and discharges by the 4 WWTPs discharging in the watershed.

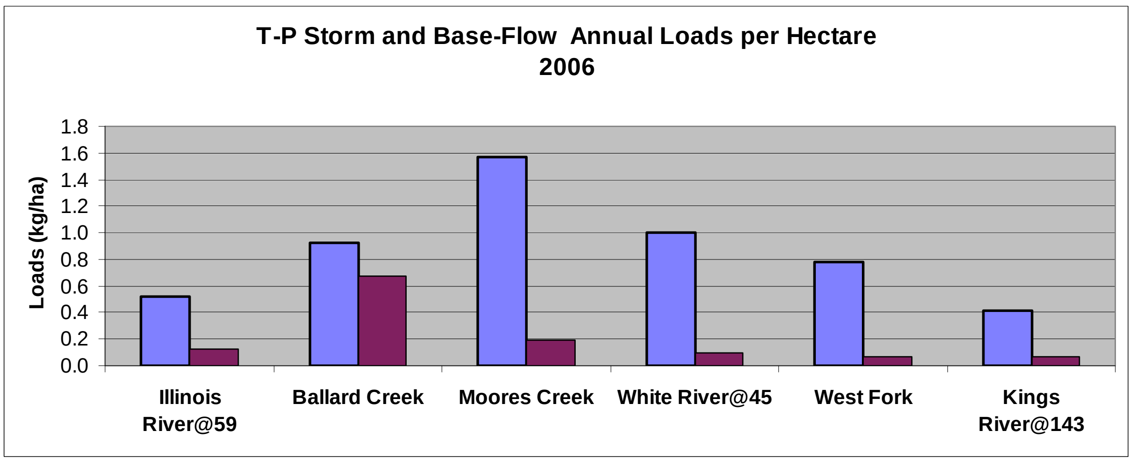
2006 was a very dry year. It was particularly dry in the Illinois River watershed which had an average discharge of 287 cfs compared to a long term average of 594 cfs: less than 50%. The other watersheds showed less of an impact from the dry weather. The dry weather means less stormwater runoff (and loads) and higher concentrations during the base-flows.

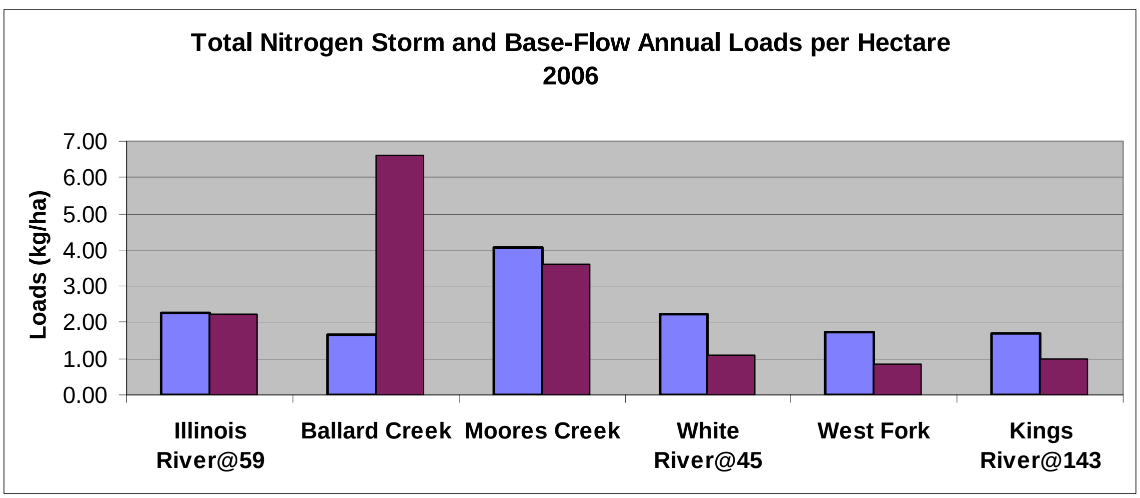
Table 13 Comparison of six watersheds 2006.

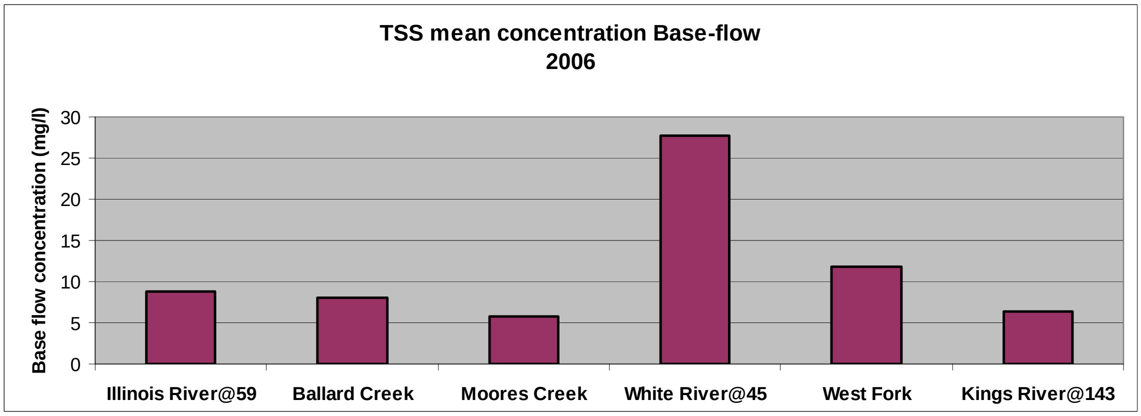
2006	Illinois River@59	Ballard Creek	Moores Creek	White River@45	West Fork	Kings River@143
Hectares	**148,930**	**7,106**	**1,000**	**106,711**	**30,563**	**136,497**
Years of data	**2006**	**2006**	**2006**	**2006**	**2006**	**2006**
TSS yield (kg/ha)	**222**	**261**	**352**	**889**	**460**	**245**
TSS storm yield (kg/ha)	**213**	**235**	**341**	**860**	**444**	**237**
TSS base yield (kg/ha)	**9**	**26**	**11**	**29**	**16**	**7**
TSS conc. base (mg/l)	**9**	**8**	**6**	**28**	**12**	**6**
P yield (kg/ha)	**0.65**	**1.60**	**1.77**	**1.10**	**0.85**	**0.48**
P storm yield (kg/ha)	**0.52**	**0.93**	**1.57**	**1.00**	**0.78**	**0.41**
P base yield (kg/ha)	**0.13**	**0.67**	**0.20**	**0.10**	**0.06**	**0.07**
P base conc. (mg/l)	**0.13**	**0.21**	**0.10**	**0.10**	**0.05**	**0.06**
Total Nitrogen yield (kg/ha)	**3.86**	**8.27**	**5.73**	**3.34**	**2.58**	**2.69**
Total Nitrogen storm yield (kg/ha)	**2.27**	**1.66**	**4.08**	**2.24**	**1.74**	**1.71**
Total Nitrogen base yield (kg/ha)	**2.22**	**6.62**	**3.61**	**1.10**	**0.84**	**0.98**
NO3-N base conc. (mg/l)	**2.14**	**1.68**	**1.58**	**0.90**	**0.43**	**0.73**
Discharge (m^3)	**256,585,770**	**28,532,395**	**3,845,410**	**385,860,012**	**103,028,696**	**310,839,767**
Discharge/area (m^3/ha)	**1,722.87**	**4,015**	**3,845**	**3,616**	**3,371**	**2,047**

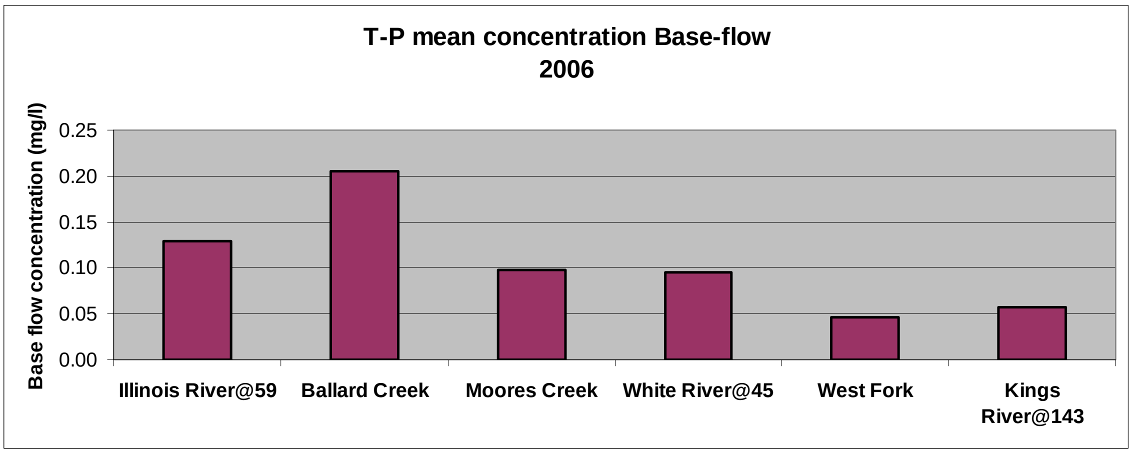
Figure 6 Comparison of six watersheds

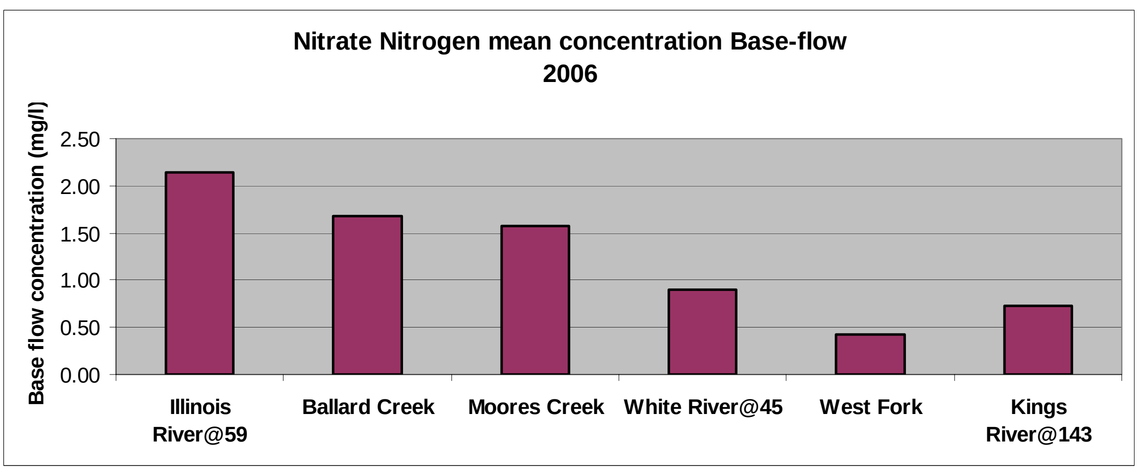







TSS mean concentration Base-flow
2006
Base flow concentration (mg/l)
30
25
20
15
10
5
0
Illinois River@59
Ballard Creek
Moores Creek
White River@45
West Fork
Kings River@143


T-P mean concentration Base-flow
2006
Base flow concentration (mg/l)
0.25
0.20
0.15
0.10
0.05
0.00
Illinois River@59
Ballard Creek
Moores Creek
White River@45
West Fork
Kings River@143


Nitrate Nitrogen mean concentration Base-flow
2006
Base flow concentration (mg/l)
2.50
2.00
1.50
1.00
0.50
0.00
Illinois River@59
Ballard Creek
Moores Creek
White River@45
West Fork
Kings River@143

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