Arkansas Water Resources Center

Continuation of Water Quality Monitoring of the Osage Creek Above the Highway 112 Bridge Near Cave Springs, Arkansas

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MSC-338

May 2007

ARKANSAS WATER RESOURCES CENTER
UNIVERSITY OF ARKANSAS
112 OZARK HALL
FAYETTEVILLE, ARKANSAS 72701

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INTRODUCTION

The City of Rogers is one of the fastest growing communities in Arkansas. Located in Northwest Arkansas, Rogers lies in two primary watersheds; the Illinois River Watershed and Beaver Lake Watershed. The Illinois River Watershed receives municipal wastewater discharge from most of the metropolitan communities in Northwest Arkansas, along with nonpoint source urban and agricultural runoff. The Illinois River originates in Arkansas and flows west into Oklahoma where it is classified as a scenic river. The river has been a source of interstate disputes for a number of years. A federal interstate compact commission was established to mediate these disputes, especially concerning high levels of phosphorus, which is perceived to degrade in-stream water quality as well as to accelerate eutrophication of an Oklahoma reservoir. Recent developments include establishment of in-stream phosphorus limits of 0.037 mg/l for Oklahoma scenic rivers (current base-flow only levels at the state line are around 0.1 mg/l) and an EPA mandate that the Spring Creek and Osage Creek be included on Arkansas' 303d list for impacts by high levels of nutrients.

A growing concern about sediment and phosphorus loading into the Illinois River led the City of Rogers to submit a proposal for and receive EPA 319 Nonpoint Source grant funding. That funding established a water quality monitoring station on Osage Creek in 2001. Osage Creek is the tributary of the Illinois River which originates in and drains most of the City of Rogers. The monitoring station was established at a USGS gauging station on the Osage Creek at Highway112 (USGS# 07194880, watershed area = 34.7 miles^2) located just below the city limits of Rogers and about a mile below the City's wastewater treatment plant (WWTP) and 200 acre sludge application area (figure 1).

Water quality sampling at the Highway 112 Bridge over Osage Creek was initiated on January 1, 2001. A report prepared in 2003 detailed the results for the sampling at this site for the calendar years 2001 and 2002 (Nelson, Diffin, 2003). Also included were sampling results from two additional sampling sites located above the Highway 112 site. One of the monitoring sites is located above the City of Rogers WWTP discharge while the second site is located below the WWTP discharge and sludge application area. These sites are referenced in this report as above outfall and below outfall (figure2). They are located above and below the City of Rogers WWTP discharge and sludge application area (figure 2). This report details the results of continued sampling at the three sites (Highway 112, above outfall, below outfall) for the period of January 2003 to December 2006. Also included for comparison are the results for the Illinois River at the Highway 59 Bridge for the same time period.

Figure 1. Osage creek sampling sites

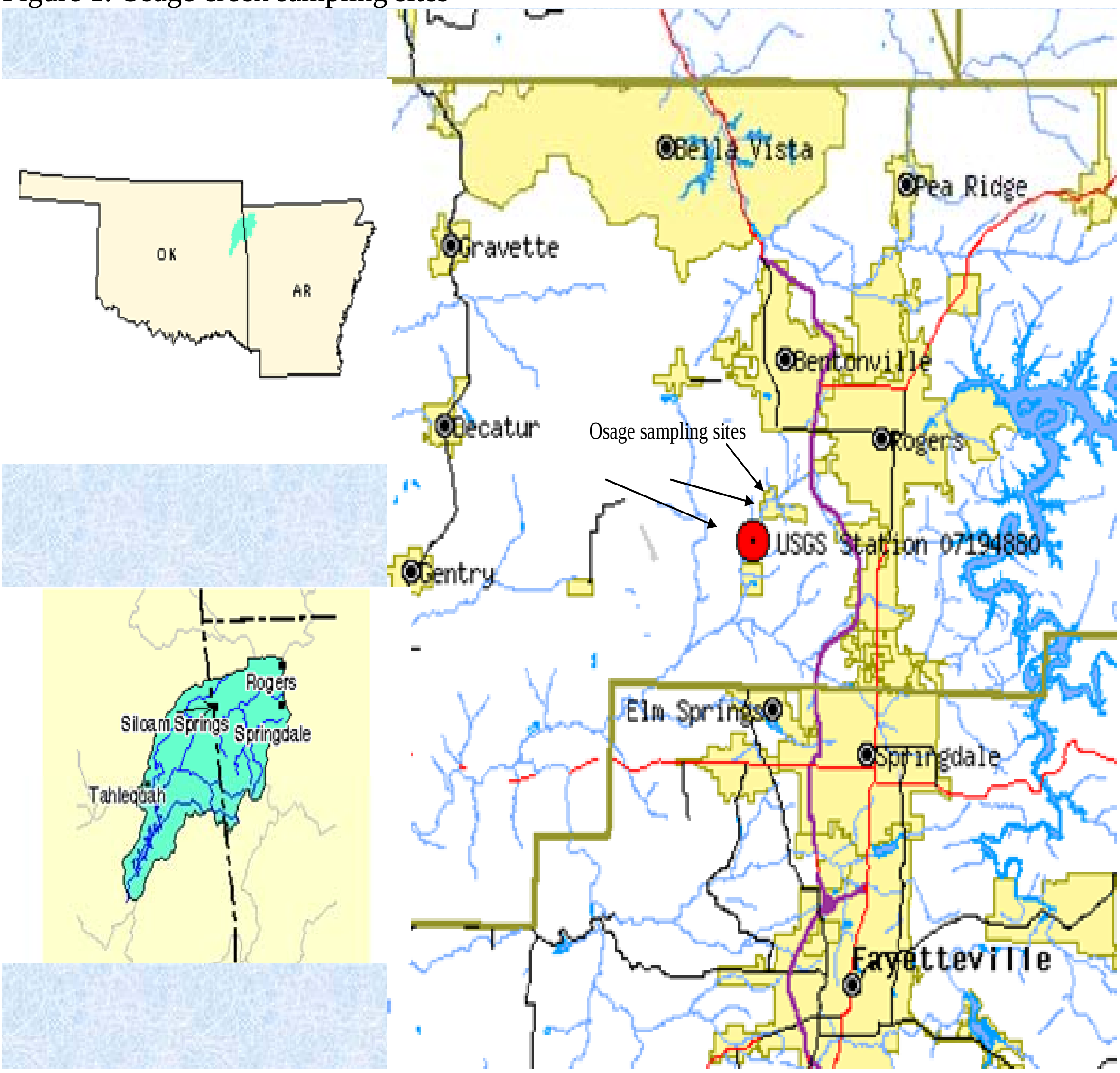
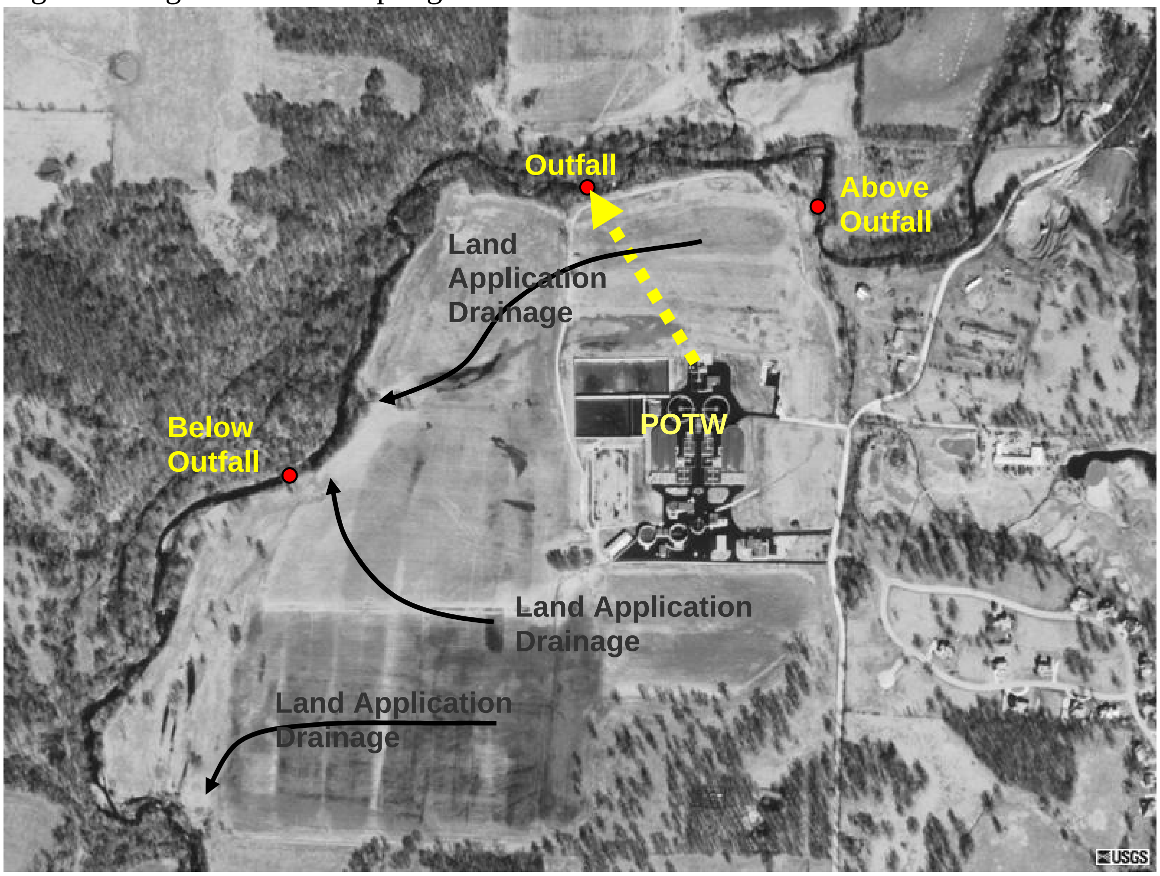


Figure 2. Rogers POTW sampling sites



METHODS

All three sites use ISCO automatic sampling equipment to collect flow-weighted composite samples from all storm events. Each site has stage measuring and recording equipment. Each site has a rating curve developed that relates discharge to stage. The site at the Highway 112 Bridge is a USGS maintained gauging station. The other two sites were installed by Rogers Water Utilities (RWU) personnel. The USGS developed the rating curve for the Highway 112 site. RWU, in conjunction with Nelson Engineering, developed the rating curves for the above outfall and below outfall sites. These curves were developed using HEC-RAS models and validated with field measurements (Figure 3 & 4). The modeled curve was approximated using a best fit power curve for calculations.

Figure 3. Rating cure for Above Outfall

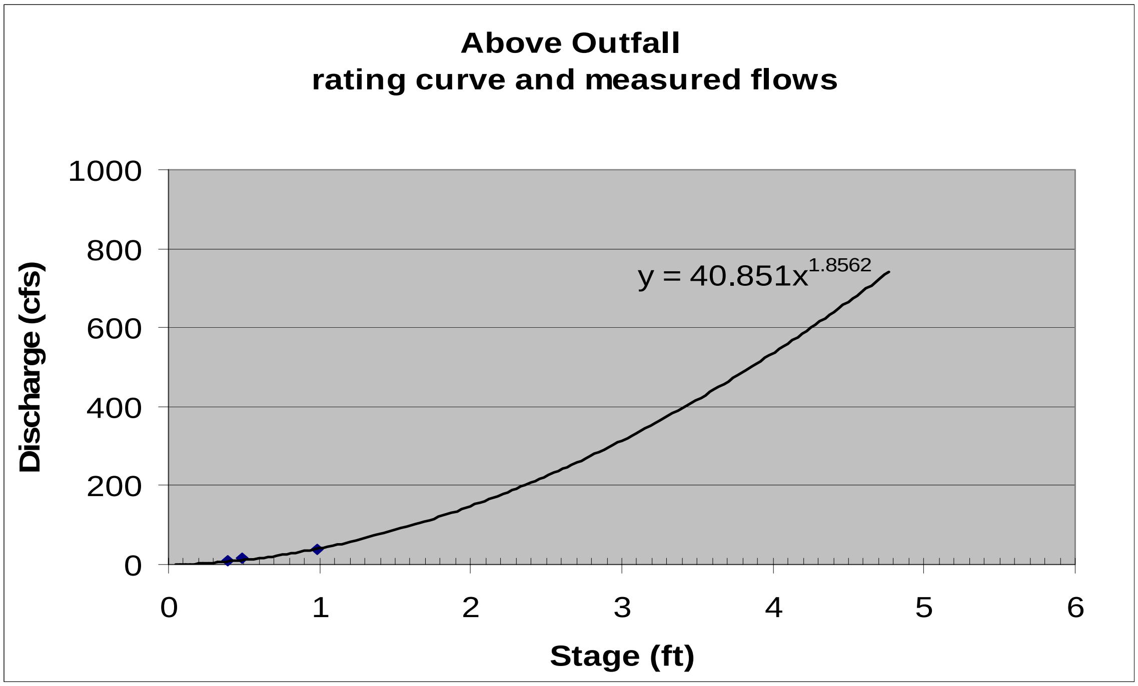
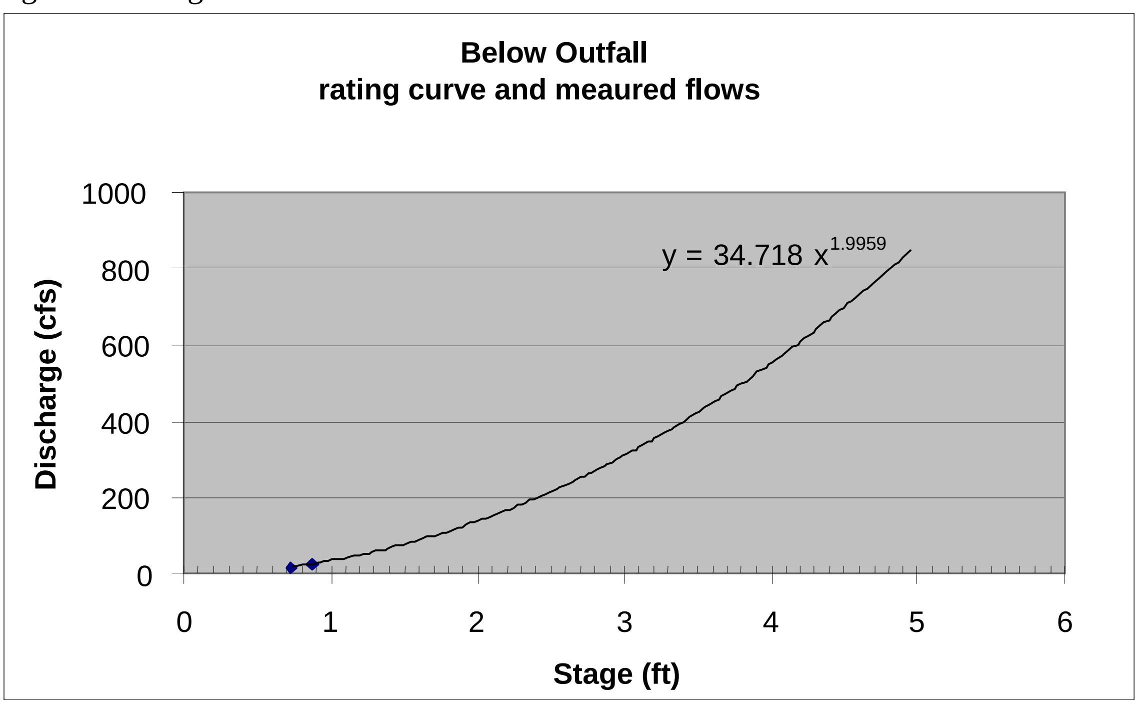


Figure 4. Rating curve for Below Outfall



Samples have been collected at all three sites since 2001. All storm events were sampled (attempted) at each site when the stage was above a fixed trigger level. Trigger levels were set initially so that each sampler triggered at approximately the same level during storm events. During the project as conditions changed the trigger levels and the rating curves were adjusted up or down to compensate for shifts due to such factors as transducer offset changes, relocated transducer or gravel accretion.

Grab samples were collected during base-flow conditions. These grabs were collected intermittently in the first three years of the project and weekly in the last three years of the project. All samples were collected by RWU personnel and transported immediately to the RWU laboratory (certified by ADEQ) for analysis. All samples were analyzed for total phosphorus, soluble reactive phosphate, TKN (or TN), nitrate, ammonia and TSS.

Discharge and analytical results were combined in a spreadsheet to calculate annual discharge, annual parameter loads and annual mean concentrations for each site as total flow, storm-flow only and base-flow only. These loads were calculated by assigning each 15 minute period during the year a discharge and a concentration. The 15 minute loads were then summed for the year. Base-flow sample results (below trigger level) are applied only to base-flows and storm flow samples only to storm flows (above trigger levels). Any time periods that do not have samples collected (example: portion of storm event missed) are assigned the annual mean concentration (either storm or base) determined for the year.

The Rogers WWTP also monitored its effluent during this time period for the same parameters. The results are available in daily average values and are comparable to the Osage monitoring results. The WWTP values were provided as daily average values which were evenly distributed throughout the day. The segregation of the discharges between base and storm-flows was done using the stage measurements from the below outfall monitoring station. When the below-outfall station was above trigger level, the plant discharge was considered a storm discharge.

This sampling and load calculation method is the same method that has been applied to the Illinois River at the Highway 59 Bridge (just before entering Oklahoma) since 1997 by the Arkansas Water Resources Center. It is the most accurate method being used for assessing nutrient and sediment loadings in streams. A QAPP was approved for the Osage sampling in 2001 and was current for the duration of the 319 project that funded the first two years of the project. Although not resubmitted for approval at the project end in 2003, the protocol has remained the same. The Illinois River site at Highway 59 has had an approved QAPP each year.

RESULTS

The results for the four years of water quality sampling at the three sites on Osage Creek below Rogers and the Rogers wastewater treatment facility are summarized by site as annual values. Each site’s summary provides total loads for each measured parameter, total mean concentrations, storm-flow loads, storm-flow concentrations, base-flow loads and base-flow concentrations. Concentrations are all annual flow-weighted mean values calculated by dividing the annual load by the annual discharge. The trigger level set for each site is the dividing line between base-flow and storm-flow. The wastewater treatment plant discharge, loads and concentrations are summarized in the same fashion. These site summaries are in Tables A1 through A4 in the appendix.

The results are also summarized by year. Each year has the values for total loads for each measured parameter, total mean concentrations, storm-flow loads, storm-flow concentrations, base-flow loads and base-flow concentrations. The values are summarized by site in ascending stream order (upper to lower). These summaries are located in the appendix in Tables A5 through A8.

All of these results are summarized for the project time period in Tables 1 and 2 below. They are the average annual values listed for the four sites in ascending stream order averaged for the 4 years. Also included for comparison are the values from the Illinois River measured near the State line at the Highway 59 Bridge (USGS site# 07195430, watershed area = 575 miles ^{2}).

There were a total of 1,085 samples collected, analyzed and used to calculate loadings at the three sampling sites during the four years of the project.

Table 1. Annual Average Loads

2003-2006	Annual Average Loads						
	Total Loads (kg)						
	Volume (m^3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
above outfall	9,582,929	21,006	1,634	450	27,575	1,022	1,252,462
plant discharge	8,181,288	25,458	4,750	0	16,366	3,033	37,406
below outfall	25,790,525	95,716	6,622	1,540	113,299	3,869	1,752,734
highway 112	38,574,911	109,062	11,815	2,104	141,990	6,613	5,368,668
Illinois River @ 59	375,381,909	832,717	137,463	26,374	1,050,234	47,810	42,635,308
	note: plant discharge and loads partitioned using below outfall storm and base flow						
	Storm-flow Loads (kg)						
	Volume (m^3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
above outfall	4,286,980	4,927	1,274	339	10,440	735	1,111,072
plant discharge	1,402,473	3,921	830	0	2,536	505	8,544
below outfall	8,705,988	22,224	2,733	937	31,429	1,596	1,576,022
highway 112	18,905,496	40,847	8,252	1,627	64,295	4,052	4,879,543
Illinois River @ 59	150,036,534	292,928	108,636	19,084	454,310	26,038	40,325,743
	Base-flow Loads (kg)						
	Volume (m^3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
above outfall	5,295,949	16,078	360	110	17,135	287	141,390
plant discharge	6,778,815	21,537	3,920	0	13,829	2,527	28,862
below outfall	17,084,537	73,492	3,890	602	81,870	2,272	176,711
highway 112	19,669,415	68,216	3,563	477	77,696	2,560	489,126
Illinois River @ 59	224,374,590	539,779	28,827	7,291	595,917	21,772	2,309,544

Table 2. Annual Average Mean Concentrations

2003-2006	Annual Average Mean Concentration					
	Total Concentrations (mg/L)					
	NO3-N	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	2.19	0.17	0.05	2.88	0.11	130.70
plant discharge	3.11	0.58		2.00	0.37	4.57
below outfall	3.71	0.26	0.06	4.39	0.15	67.96
highway 112	2.83	0.31	0.05	3.68	0.17	139.18
Illinois River @ 59	2.22	0.37	0.07	2.80	0.13	113.58
	Storm-flow Concentrations (mg/L)					
above outfall	1.15	0.30	0.08	2.44	0.17	259.17
plant discharge	2.80	0.59		1.81	0.36	6.09
below outfall	2.55	0.31	0.11	3.61	0.18	181.03
highway 112	2.16	0.44	0.09	3.40	0.21	258.10
Illinois River @ 59	1.95	0.72	0.13	3.03	0.17	268.77
	Base-flow Concentrations (mg/L)					
above outfall	3.04	0.07	0.02	3.24	0.05	26.70
plant discharge	3.18	0.58		2.04	0.37	4.26
below outfall	4.30	0.23	0.04	4.79	0.13	10.34
Highway 112	3.47	0.18	0.02	3.95	0.13	24.87
Illinois River @ 59	2.41	0.13	0.03	2.66	0.10	10.29

DISCUSSION

This discussion will focus on the results for phosphorus since the focus in the Illinois River watershed has been on the phosphorus levels in the stream reaches and at the state line. It should be noted that nitrogen and sediment values are high and are of increasing concern.

The above outfall values represent the impacts from nonpoint sources (NPS) within the Osage Creek watershed in the City of Rogers. Storm-flow values represent the direct NPS impacts. That is, runoff during storm events carries nutrients and sediment from the surface into the creeks. The high flows also erode stream banks and suspend sediments from the stream bottoms. These are NPS direct impacts. Base-flow values represent the indirect NPS impacts from the City since there are no point sources above this station. The sediments that are deposited in the stream as the velocities drop contain nutrients that form equilibrium with stream base-flows. These are indirect NPS impacts. Groundwater also has an impact especially for nitrogen, but for sediment and phosphorus the impact is minimal. Table 3 summarizes direct and indirect impacts on base and storm-flows.

Table 3.

	Point Source Impact	Nonpoint Source Impact	
	WWTP discharge	Run-off	Groundwater
base-flow conditions	Direct	Indirect	Direct
storm-flow conditions	Indirect	Direct	Direct

The below outfall values represent the NPS impact from Rogers, the point source (PS) impacts from the WWTP discharge as well as the NPS impacts from the Rogers sludge application area surrounding the plant. Most of this area drains to the creek above the below outfall sampling point. However, some drains to the creek below the sampling point. In addition, a small creek joins the Osage from north of the application area between the above outfall and below outfall sampling sites.

The Highway 112 measured values represent the impacts at the below outfall site plus the remaining storm flows from the sludge application area and the NPS impacts from the watershed area between the sites. This area contains a large golf course surrounding the creek that was constructed in 2002.

Using these relationships, the phosphorus impacts from the different sources can be calculated from the average annual values. The total NPS phosphorus impact from the City of Rogers upstream of the above outfall site averaged 1,634 kg. The direct portion was 1,274 kg or 78% and the indirect portion was 360 kg or 22%. The plant discharge was 4,750 kg phosphorus and was 72% of the phosphorus measured at the below outfall site. The plant and above outfall phosphorus constituted 96% of the phosphorus at the below outfall site. The remaining 239 kg was from runoff from the sludge application area and the small creek. The volume of this runoff was 3,016,535 m^3 and the mean concentration was 0.08 mg/l, a lower concentration than the total NPS impacts from the City at the above outfall site (0.17 mg/l). Thus, the sludge application area had a lower impact than the average NPS impacts in the watershed.

The area between the below outfall and the Highway 112 sites contributed a significant portion of the total flow phosphorus in the watershed. 56% of the phosphorus measured at Highway 112 was from this area. This area contains both the golf course and some of the overland flow from a section of the sludge application area and the relative contribution from each are not known. However, since a major portion of the sludge application area contributed only 208 kg, this minor portion of the application area probably contributed less. Thus, the phosphorus impact from the golf course and surrounding area is approximately 5,500 kg, which is similar to the WWTP impact (5,231kg). The relative contributions of PS and NPS to base-flow and storm-flow at the Highway 112 Bridge are summarized in figure 5.

Figure 5.

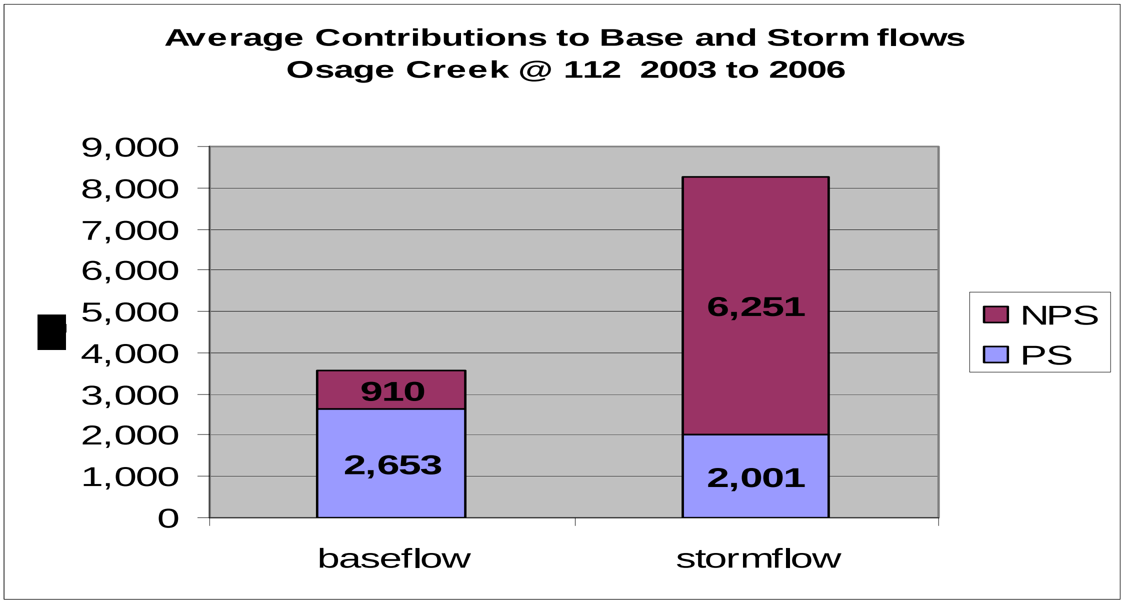
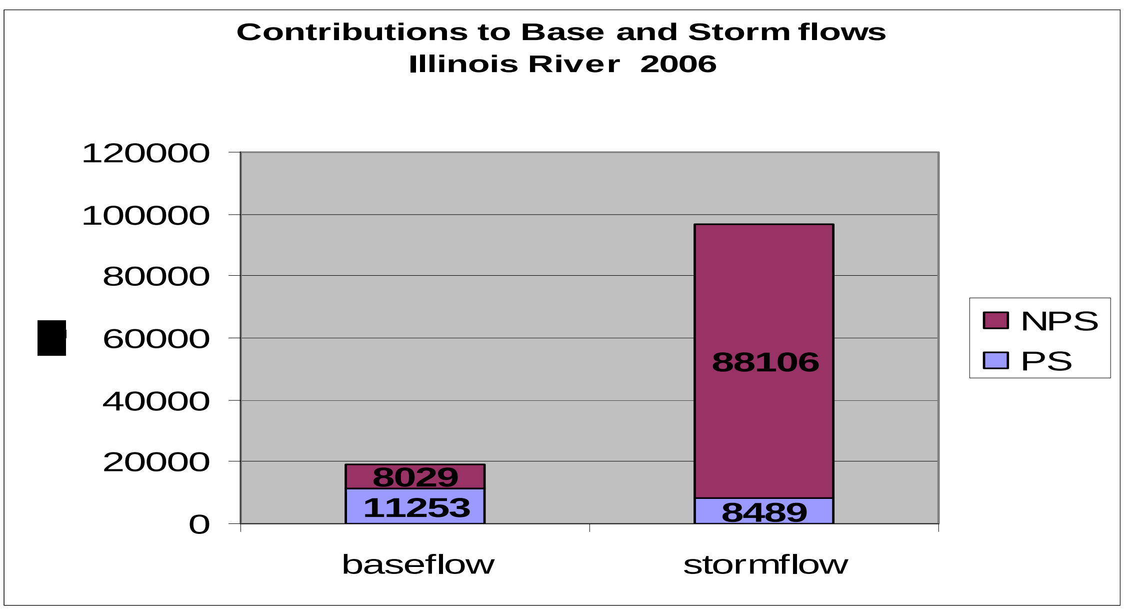


Table 4 lists the percent of the Illinois River at Highway 59 loads measured at each of the sites. The below outfall values represented 7% of the volume at the state line and 5% of the phosphorus. Thus the contribution of Rogers NPS and PS phosphorus was on average approximately the same as the rest of the watershed. This is a slightly larger volume per area than the average for the watershed but two factors must be considered to contribute to this. The plant discharge is water that originated from Beaver Lake and the impervious surface area of the city is greater than the watershed average. Both of these factors contribute to the greater discharge for this area. The exact area is unknown. However, the watershed area at the Highway 59 Bridge is 575 square miles and the area at the Highway 112 Bridge is 34.7 square miles or 6% and the area for below outfall is somewhat less than this. The plant discharge constituted 2% of the volume at the Highway 59 Bridge and 3% of the total flow phosphorus at the bridge. It was 14% of the base-flow phosphorus measured at the Highway 59 Bridge. The relative contributions of PS and NPS to base-flow and storm-flow in the Illinois River at the Highway 59 Bridge for 2006 are summarized in figure 6.

Table 4. Percent of Illinois River Loads Measured at Each Site.

2003-2006	Annual Average						
	Total Loads						
	VOLUME	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
above outfall	3%	3%	1%	2%	3%	2%	3%
plant discharge	2%	3%	3%	0%	2%	6%	0%
below outfall	7%	11%	5%	6%	11%	8%	4%
highway 112	10%	13%	9%	8%	14%	14%	13%
Illinois River @ 59	100%	100%	100%	100%	100%	100%	100%
	Storm Loads						
above outfall	3%	2%	1%	2%	2%	3%	3%
plant discharge	1%	1%	1%	0%	1%	2%	0%
below outfall	6%	8%	3%	5%	7%	6%	4%
highway 112	13%	14%	8%	9%	14%	16%	12%
Illinois River @ 59	100%	100%	100%	100%	100%	100%	100%
	Base Loads						
above outfall	2%	3%	1%	2%	3%	1%	6%
plant discharge	3%	4%	14%	0%	2%	12%	1%
below outfall	8%	14%	13%	8%	14%	10%	8%
highway 112	9%	13%	12%	7%	13%	12%	21%
Illinois River @ 59	100%	100%	100%	100%	100%	100%	100%

Figure 6



Historically the PS contribution of phosphorus in this watershed has been much higher. A study in 2002 determined that 43% of the phosphorus measured at the Highway 59 Bridge was from the four municipal WWTPs in the watershed (Nelson, White 2002, Table A9 in appendix). This percentage has been significantly reduced since that time to 20% in 2006 and the base-flow phosphorus measured at the Highway 59 Bridge has decreased in accordance. In 2003 the municipalities agreed to implement a voluntary 1 mg/L phosphorus WWTP discharge limit. Prior discharges were as high as 7.5 mg/l annual average. Figure 7 shows the correlation between base-flow phosphorus at the Highway 59 Bridge and the WWTP discharges. The phosphorus load inputs and outputs are summarized in Table 5 (Nelson et. al., 2006).

Figure 7. Comparisons between WWTP discharges and Base-flow P

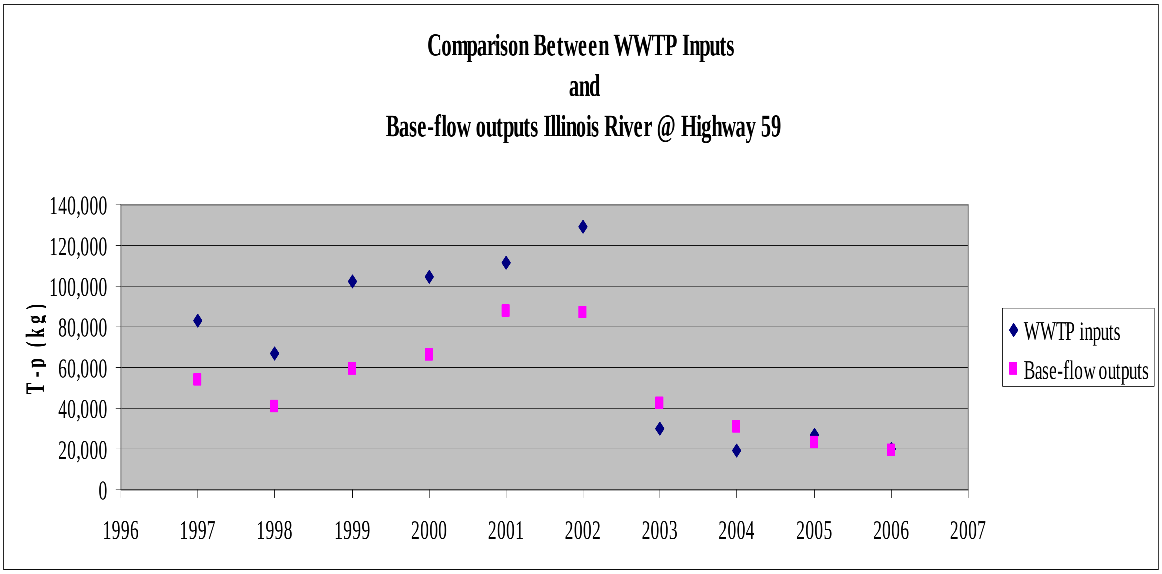


Table 5 Comparison between WWTP phosphorus discharges and P values at Highway 59 Bridge

		Total Phosphorus (kg)								
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Fayetteville	1,863	2,505	1,583	2,366	1,369	1,698	2,073	2,652	2,658	3,187
Prairie Grove	1,816	1,901	1,859	1,099	1,213	1,327	1,420	1,572	1,799	2,225
Rogers	20,068	8,669	18,842	9,627	7,017	3,932	3,401	3,982	5,885	5,351
Springdale	59,646	53,797	80,166	91,320	101,576	122,299	22,754	11,119	16,399	8,951
WWTP Totals	83,394	66,872	102,450	104,411	111,175	129,256	29,648	19,325	26,740	19,714
Base-flow at Hwy 59	53,623	41,119	58,856	65,789	87,444	86,809	42,413	30,633	22,980	19,282
Combined-flow at Hwy 59	126,539	231,239	267,150	282,486	255,691	218,274	64,854	281,425	106,979	96,595

The same study concluded that 57% of the four WWTP's phosphorus was contributing to the base-flow phosphorus at the Highway 59 Bridge (direct PS impact) and the remaining 43% was contributing phosphorus to the storm flows (indirect PS impact). This indirect PS impact occurs because phosphorus is adsorbed by the sediments and taken up by the biological community in the stream during base-flows and then re-suspended and washed downstream during storm-flows. The combined WWTP phosphorus value was estimated to account for 88% of the base-flow phosphorus at the 59 Bridge. The remaining 12% of base-flow phosphorus was indirect NPS impact and that amounted to an average of 8,000 kg per year.

Osage Creek below Rogers has been listed on Arkansas' 303D list and may require a TMDL or watershed management plan that allocates phosphorus loads to PS and NPS sources. In addition, the State of Oklahoma has set a 0.037 mg/l limit for phosphorus in the Illinois River. The following tables illustrate some scenarios for calculating WWTP discharge limits. Tables 6 to 8 show the discharge concentration by each of the 4 WWTPs in the watershed that would be required to meet the 0.037 mg/l phosphorus concentration limit at the state line during base-flows only. These calculations are made by dividing the total allowable PS discharge by 4 to approximate the value that any one of the four could discharge. This is only an approximation because all 4 WWTPs do not discharge the same volumes. A method to equitably divide the totals among the 4 (or 5 in the future) would need to be used in the actual allocation process. Table 6 uses the average base-flow discharge at the Highway 59 Bridge of 7.8 m^3/s and the average discharge from Rogers WWTP as measured in this project (0.29 m^3/s). The flow multiplied by the target concentration of 0.037 yields the base-flow P value of 9,101 kg. The amount of indirect NPS impacts at the Highway 59 Bridge is varied above and below the 8,000 kg/ year estimated from 1997 to 2001. The 9,101 kg of base-flow minus the NPS contribution leaves the PS contribution to base-flow. The PS contribution to base-flow was calculated to be 57% of the total PS discharge in the Illinois River study. That percentage has been applied to these tables to calculate the total point source contribution. Table 6 shows that with a 50% reduction in NPS impacts at the Highway 59 Bridge, the 0.037 mg/l limit could be met by reducing the Rogers WWTP discharge to 0.25 mg/l (The other WWTPs would need to make an equivalent load reduction). Without a NPS reduction the Rogers WWTP discharge would need to be 0.05 mg/l.

Table 6. Target 0.037 @ State line: Current conditions, variable NPS contribution

base-flow (m^3/s)	7.8	7.8	7.8	7.8	7.8
target concentration (mg/l)	0.037	0.037	0.037	0.037	0.037
base-flow P (kg)	9,101	9,101	9,101	9,101	9,101
non-point source P (kg)	4,000	6,000	7,000	8,000	9,000
point source contribution to Base (kg)	5,101	3,101	2,101	1,101	101
total point source (kg)	8,950	5,441	3,686	1,932	178
point source / 4 (kg)	2,237	1,360	922	483	44
Rogers discharge (m^3/s)	0.29	0.29	0.29	0.29	0.29
discharge concentration (mg/l)	**0.25**	**0.15**	**0.10**	**0.05**	**0.00**

Table 7 uses the 50% NPS reduction and varies the base-flow discharge at the Highway 59 Bridge (as in wet and dry years) and using a 50% reduction in indirect NPS impacts calculates the required WWTP discharge concentration. It shows that the limits required are a function of base-flow discharges. Using the average value for the base-flow discharge at the Highway 59 Bridge to allocate loads would allow consistent WWTP discharge requirements that are not a function of weather changes.

Table 7. Target 0.037 @ State line: NPS @ 50%, Variable base-flow

base-flow (m^3/s)	12.0	10.0	8.0	6.0	4.0
target concentration (mg/l)	0.037	0.037	0.037	0.037	0.037
base-flow P (kg)	14,002	11,668	9,335	7,001	4,667
non-point source P (kg)	4,000	4,000	4,000	4,000	4,000
point source contribution to Base (kg)	10,002	7,668	5,335	3001	667
total point source (kg)	17,547	13,453	9,359	5,265	1,171
point source / 4 (kg)	4,387	3,363	2,340	1,316	293
Rogers discharge (m^3/s)	0.29	0.29	0.29	0.29	0.29
discharge concentration (mg/l)	**0.49**	**0.37**	**0.26**	**0.15**	**0.03**

Table 8 uses the same values as Table 6 but increases the WWTP discharge by 50% as might occur in future plant expansions. These scenarios point out that if the average base-flow discharge remains at 7.8 m^3/s, the plant discharge remains constant and a 50% reduction in indirect NPS impacts were achieved, the required WWTP discharge would be 0.25 mg/l. Further, it would need to be 0.17 mg/l with a 50% increase in WWTP discharge volume. It should be noted that the 2002 study determined that only 4% of the phosphorus applied to the watershed each year reached the river at the state line, less than 1% was estimated as indirect impact to the base-flow and the indirect impacts include both phosphorus applied during the year and phosphorus accumulated in the watershed. These facts point to the potential difficulty in reducing the indirect NPS impacts by 50%.

Table 8. Target 0.037 @ State line: NPS @ 50%, Variable base-flow, 50% increase WWTP discharge

base-flow (m^3/s)	12.0	10.0	8.0	6.0	4.0
target concentration (mg/l)	0.037	0.037	0.037	0.037	0.037
base-flow P (kg)	14,002	11,668	9,335	7,001	4,667
non-point source P (kg)	4,000	4,000	4,000	4,000	4,000
point source contribution to Base (kg)	10,002	7,668	5,335	3001	667
total point source (kg)	17,547	13,453	9,359	5,265	1,171
point source / 4 (kg)	4,387	3,363	2,340	1,316	293
Rogers discharge (m^3/s)	0.43	0.43	0.43	0.43	0.43
discharge concentration (mg/l)	**0.32**	**0.25**	**0.17**	**0.10**	**0.02**

Tables 9 through 11 calculate the Rogers WWTP discharge concentration required to meet different proposed in-stream base-flow water quality standards for the Osage Creek stream reach ending at the Highway 112 Bridge. The tables use the average base-flow at the Highway 112 Bridge measured during the project (0.6 m^3/s). They also use the ratio determined in the 2002 study that found that the direct PS impact to base-flow was 57% of the total PS discharge (Table A9 in appendix). Table 9 uses the estimated indirect NPS contribution to base-flow of 910 kg/yr (base-flow load – 57% PS load). The target concentrations used to estimate discharge concentrations range from 0.1 mg/l (the current Arkansas suggested value) to 0.02 mg/l. Table 9 shows the discharge concentration required to meet a target phosphorus concentration at current conditions varies from 0.19 mg/l to meet a 0.1 mg/l target to 0.01 mg/l to meet a 0.037 mg/l target. The 0.037 and 0.02 mg/l phosphorus targets are not achievable at current conditions.

Table 9. Variable in-stream target concentration in Osage @112 Bridge, Current conditions

base-flow (m^3/s)	0.6	0.6	0.6	0.6
target concentration (mg/l)	0.1	0.05	0.037	0.02
base-flow P (kg)	1,892	946	700	378
non-point source P (kg)	910	910	910	910
point source contribution to Base (kg)	982	36	-210	-532
total point source (kg)	1,723	63	-368	-933
Rogers discharge (m^3/s)	0.29	0.29	0.29	0.29
discharge concentration (mg/l)	**0.19**	**0.01**	**-0.04**	**-0.10**

Table 10 varies the phosphorus target concentration with a reduction of indirect NPS loads by 50%. Table 10 shows that if indirect NPS impacts are reduced by 50% the range of discharge phosphorus concentrations rise to from 0.28 to -0.01 mg/l.

Table 10. Variable in-stream target concentration in Osage @112 Bridge, NPS @50%

base-flow (m^3/s)	0.6	0.6	0.6	0.6
target concentration (mg/l)	0.1	0.05	0.037	0.02
base-flow P (kg)	1,892	946	700	378
non-point source P (kg)	450	450	450	450
point source contribution to Base (kg)	1,442	496	250	-72
total point source (kg)	2,530	870	439	-126
Rogers discharge (m^3/s)	0.29	0.29	0.29	0.29
discharge concentration (mg/l)	**0.28**	**0.10**	**0.05**	**-0.01**

Table 11 varies the target concentration with a reduction of indirect NPS loads and an increase in WWTP discharge by 50%. Table 11 shows that if WWTP discharge volumes are increased by 50% the required discharge concentrations fall to from 0.19 to -0.01 mg/l.

Table 11 Variable in-stream target concentration in Osage @112 Bridge, NPS @50%, 50% increase WWTP discharge

base-flow (m^3/s)	0.6	0.6	0.6	0.6
target concentration (mg/l)	0.1	0.05	0.037	0.02
base-flow P (kg)	1,892	946	700	378
non-point source P (kg)	450	450	450	450
point source contribution to Base (kg)	1,442	496	250	-72
total point source (kg)	2,530	870	439	-126
Rogers discharge (m^3/s)	0.43	0.43	0.43	0.43
discharge concentration (mg/l)	**0.19**	**0.06**	**0.03**	**-0.01**

SUMMARY

Rogers Water Utilities has performed extensive and accurate monitoring of the Osage Creek near the WWTP for six years. These results can be used to identify the sources of nutrient and sediment impacts to the creek. The results show that the average WWTP discharge from 2003 to 2006 of the project accounts for 44% of the total phosphorus in the Osage Creek watershed above Highway 112 and 4% of the total phosphorus in the Illinois River Watershed at the Highway 59 Bridge. The sludge application area surrounding the WWTP had less impact on the creek total phosphorus levels than the average land surface in the City of Rogers.

Accurate partitioning of the sources of phosphorus in the watershed allows the calculation of the required discharge concentrations to meet a State-line concentration of 0.037mg/l. If NPS contributions to base-flows could be reduced by 50%, the discharge would need to be 0.25 mg/l. Future plant expansion or additional point source discharges in the watershed would require a lower effluent concentration.

In-stream total phosphorus level requirements to meet designated uses for the Osage Creek have not been determined. Potential target values range from 0.1 mg/l phosphorus to 0.006 mg/l. At 0.1 mg/l, a 50% reduction of NPS impacts to base-flows and a 50% increase in plant discharge volume the required concentration would be 0.19 mg/l.

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APPENDIX

Table A1. **Above Outfall** Results Summary

Above outfall			Total loads		kg		
	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003	8,460,368	19,142	1,048	191	24,405	1,056	864,076
2004	14,590,139	32,210	3,428	941	47,103	1,210	2,720,330
2005	7,677,055	18,743	1,011	336	21,376	1,146	694,447
2006	7,604,155	13,928	1,048	330	17,416	677	730,996
above outfall			Mean concentrations		mg/l		
		NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003		2.26	0.12	0.02	2.88	0.12	102.13
2004		2.21	0.23	0.06	3.23	0.08	186.45
2005		2.44	0.13	0.04	2.78	0.15	90.46
2006		1.83	0.14	0.04	2.29	0.09	96.13
			storm loads		kg		
above outfall	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003	2,627,718	2,380	772	146	6,916	644	754,746
2004	7,949,454	9,649	2,825	797	22,124	942	2,476,120
2005	3,119,837	3,990	746	190	6,459	876	599,135
2006	1,652,140	1,617	329	132	2,944	203	280,513
			storm concentrations		mg/l		
above outfall	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003		0.91	0.29	0.06	2.63	0.24	287.22
2004		1.21	0.36	0.10	2.78	0.12	311.48
2005		1.28	0.24	0.06	2.07	0.28	192.04
2006		0.98	0.20	0.08	1.78	0.12	169.79
			base loads				
above outfall	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003	5,832,446	16,762	276	46	17,488	412	109,329
2004	6,640,634	22,561	603	144	24,979	268	244,210
2005	4,557,172	14,753	265	146	14,917	270	95,312
2006	2,144,133	4,824	157	65	5,367	106	74,200
			base concentrations		mg/l		
above outfall	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003		2.87	0.05	0.01	3.00	0.07	18.74
2004		3.40	0.09	0.02	3.76	0.04	36.78
2005		3.24	0.06	0.03	3.27	0.06	20.91
2006		2.25	0.07	0.03	2.50	0.05	34.61

Table A2. **Plant Discharge** Results Summary

Plant Discharge		**Total loads**		**kg**		
	VOLUME (m3)	**Eff. P04-P**	**Eff. TP-P**	**Eff. TSS**	**EFF N03 + N02**	**TN-N**
2003	7,934,555	1,347	3,154	39,239	33,030	
2004	8,917,944	1,905	3,774	42,304	25,974	
2005	8,029,696	4,529	6,240	34,740	14,359	25,933
2006	7,842,958	4,351	5,833	33,340	28,467	39,529
Plant Discharge		**mean concentrations**		**mg/l**		
	VOLUME (m3)	**Eff. P04-P**	**Eff. TP-P**	**Eff. TSS**	**EFF N03 + N02**	**TN-N**
2003		0.17	0.40	4.95	4.16	
2004		0.21	0.42	4.74	2.91	
2005		0.56	0.78	4.33	1.79	3.23
2006		0.55	0.74	4.25	3.63	5.04
Plant Discharge		**storm loads**		**kg**		
	VOLUME (m3)	**Eff. P04-P**	**Eff. TP-P**	**Eff. TSS**	**EFF N03 + N02**	**TN-N**
2003	757,414	115	242	3,479	2,376	
2004	2,506,460	566	1,152	14,503	6,702	0
2005	914,143	437	729	8,928	1,914	3,274
2006	1,431,875	904	1,196	7,264	4,692	6,871
Plant Discharge		**storm concentrations**		**mg/l**		
	VOLUME (m3)	**Eff. P04-P**	**Eff. TP-P**	**Eff. TSS**	**EFF N03 + N02**	**TN-N**
2003		0.15	0.32	4.59	3.14	
2004		0.23	0.46	5.79	2.67	
2005		0.48	0.80	9.77	2.09	3.58
2006		0.63	0.84	5.07	3.28	4.80
		base loads		**kg**		
	VOLUME (m3)	**Eff. P04-P**	**Eff. TP-P**	**Eff. TSS**	**EFF N03 + N02**	**TN-N**
2003	7,177,141	1,232	2,913	35,760	30,654	
2004	6,411,484	1,339	2,622	27,800	19,272	0
2005	7,115,552	4,092	5,511	25,812	12,445	22,659
2006	6,411,083	3,447	4,637	26,076	23,776	32,659
Plant Discharge		**base concentrations**		**mg/l**		
	VOLUME (m3)	**Eff. P04-P**	**Eff. TP-P**	**Eff. TSS**	**EFF N03 + N02**	**TN-N**
2003		0.17	0.41	4.98	4.27	
2004		0.21	0.41	4.34	3.01	
2005		0.58	0.77	3.63	1.75	3.18
2006		0.54	0.72	4.07	3.71	5.09

Table A3. **Below Outfall** Results Summary

Below outfall			Total loads		kg		
	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003	21,060,577	90,850	5,304	1,201	108,470	1,903	723,863
2004	32,297,138	128,905	8,669	2,786	157,263	3,879	4,266,748
2005	23,598,777	80,072	6,016	1,289	89,957	4,943	788,306
2006	26,205,607	83,038	6,501	883	97,505	4,749	1,232,017
Below outfall			Mean concentrations		mg/l		
		NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003		4.31	0.25	0.06	5.15	0.09	34.37
2004		3.99	0.27	0.09	4.87	0.12	132.11
2005		3.39	0.25	0.05	3.81	0.21	33.40
2006		3.17	0.25	0.03	3.72	0.18	47.01
			storm loads		kg		
Below outfall	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003	4,098,975	9,388	934	279	14,999	1,071	569,792
2004	16,580,574	45,277	6,190	2,411	21,984	2,426	3,924,772
2005	5,864,413	16,160	1,469	575	19,415	1,366	679,484
2006	8,279,991	18,073	2,339	484	24,041	1,522	1,130,042
			storm concentrations		mg/l		
Below outfall	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003		2.29	0.23	0.07	3.66	0.26	139.01
2004		2.73	0.37	0.15	1.33	0.15	236.71
2005		2.76	0.25	0.10	3.31	0.23	115.87
2006		2.18	0.28	0.06	2.90	0.18	136.48
			base loads				
Below outfall	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003	16,961,602	81,462	4,370	921	93,471	832	154,072
2004	15,716,564	83,629	2,479	375	6,374	1,454	341,977
2005	17,734,365	63,912	4,547	714	70,542	3,577	108,822
2006	17,925,616	64,964	4,162	399	73,464	3,228	101,975
			base concentrations		mg/l		
Below outfall	VOLUME (m3)	NO3-N	T-P	NH4-N	TN-N	PO4-P	TSS
2003		4.80	0.26	0.05	5.51	0.05	9.08
2004		5.32	0.16	0.02	0.41	0.09	21.76
2005		3.60	0.26	0.04	3.98	0.20	6.14
2006		3.62	0.23	0.02	4.10	0.18	5.69

Table A4. **Osage 112** Results Summary

Osage 112			**Total loads**		**kg**		
	VOLUME (m3)	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
2003	27,141,648	86,363	4,340	698	109,277	2,504	2,094,667
2004	60,309,237	159,561	24,611	4,573	229,623	11,862	10,293,208
2005	35,459,107	104,733	8,881	1,783	121,792	5,551	4,680,810
2006	31,389,653	85,592	9,429	1,361	107,269	6,533	4,405,988
Osage 112			**Mean concentrations**		**mg/l**		
		NO3-N	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
2003		3.18	0.16	0.03	4.03	0.09	77.18
2004		2.65	0.41	0.08	3.81	0.20	170.67
2005		2.95	0.25	0.05	3.43	0.16	132.01
2006		2.73	0.30	0.04	3.42	0.21	140.36
			storm loads		**kg**		
Osage 112	**VOLUME (m3)**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
2003	5,404,054	10,063	1,650	455	19,878	788	1,333,164
2004	41,644,043	89,215	21,490	4,012	150,255	9,986	9,921,678
2005	18,251,046	49,421	5,283	1,246	60,088	2,801	4,372,011
2006	10,322,840	14,688	4,586	796	26,959	2,633	3,891,317
			storm concentrations		**mg/l**		
Osage 112	**VOLUME (m3)**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
2003		1.86	0.31	0.08	3.68	0.15	246.70
2004		2.14	0.52	0.10	3.61	0.24	238.25
2005		2.71	0.29	0.07	3.29	0.15	239.55
2006		1.42	0.44	0.08	2.61	0.26	376.96
			base loads				
Osage 112	**VOLUME (m3)**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
2003	21,737,594	76,300	2,690	243	89,398	1,716	761,503
2004	18,665,194	70,346	3,121	562	79,369	1,875	371,530
2005	17,208,061	55,314	3,598	537	61,707	2,750	308,801
2006	21,066,813	70,904	4,843	566	80,310	3,900	514,671
			base concentrations		**mg/l**		
Below outfall	**VOLUME (m3)**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
2003		3.51	0.12	0.01	4.11	0.08	35.03
2004		3.77	0.17	0.03	4.25	0.10	19.90
2005		3.21	0.21	0.03	3.59	0.16	17.95
2006		3.37	0.23	0.03	3.81	0.19	24.43

Table A5. **2006** Results Summary

	m3	total loads		kg			
2006	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	7,604,155	13,928	1,048	330	17,416	677	730,996
plant discharge	7,842,958	28,467	5,833		39,529	4,351	33,340
below outfall	26,205,607	83,038	6,501	883	97,505	4,749	1,232,017
highway 112	31,389,653	85,592	9,429	1,361	107,269	6,533	4,405,988
Illinois @59	256,585,770	513,847	96,596	29,870	575,412	33,837	33,054,951
		mean concentrations			**mg/l**		
2006		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		1.83	0.14	0.04	2.29	0.09	96.13
plant discharge		3.63	0.74		5.04	0.55	4.25
below outfall		3.17	0.25	0.03	3.72	0.18	47.01
highway 112		2.73	0.30	0.04	3.42	0.21	140.36
Illinois @59		2.00	0.38	0.12	2.24	0.13	128.83
	m3	**storm loads**	**kg**				
2006	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	3,450,912	3,691	752	225	6,261	477	614,287
plant discharge	1,431,875	4,692	1,196		6,871	904	7,264
below outfall	8,279,991	18,073	2,339	484	24,041	1,522	1,130,042
highway 112	10,322,840	14,688	4,586	796	26,959	2,633	3,891,317
Illinois @59	107,602,614	195,226	77,314	21,657	244,722	20,114	31,752,053
		storm concentrations			**mg/l**		
2006		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		1.07	0.22	0.07	1.81	0.14	178.01
plant discharge		3.28	0.84		4.80	0.63	5.07
below outfall		2.18	0.28	0.06	2.90	0.18	136.48
highway 112		1.42	0.44	0.08	2.61	0.26	376.96
Illinois @59		1.81	0.72	0.20	2.27	0.19	295.09
			kg	**base loads**			
2006	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	4,153,244	10,237	296	105	11,155	200	116,709
plant discharge	6,411,083	23,776	4,637		32,659	3,447	26,076
below outfall	17,925,616	64,964	4,162	399	73,464	3,228	101,975
highway 112	21,066,813	70,904	4,843	566	80,310	3,900	514,671
Illinois @59	148,983,156	318,621	19,282	8,214	330,691	13,723	1,302,898
		base concentrations			**mg/l**		
2006		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		2.46	0.07	0.03	2.69	0.05	28.10
plant discharge		3.71	0.72		5.09	0.54	4.07
below outfall		3.62	0.23	0.02	4.10	0.18	5.69
highway 112		3.37	0.23	0.03	3.81	0.19	24.43
Illinois @59		2.14	0.13	0.06	2.22	0.09	8.75

Table A6. **2005** Results Summary

	m3	total loads		kg			
2005	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	7,677,055	18,743	1,011	336	21,376	1,146	694,447
plant discharge	8,029,696	14,359	6,240		25,933	4,529	34,740
below outfall	23,598,777	80,072	6,016	1,289	89,957	4,943	788,306
highway 112	35,459,107	104,733	8,881	1,783	121,792	5,551	4,680,810
Illinois @59	390,894,159	1018744	106979	20602	1170851	44213	33560475
		mean concentrations			**mg/l**		
2005		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		2.44	0.13	0.04	2.78	0.15	90.46
plant discharge		1.79	0.78		3.23	0.56	4.33
below outfall		3.39	0.25	0.05	3.81	0.21	33.40
highway 112		2.95	0.25	0.05	3.43	0.16	132.01
Illinois @59		2.61	0.27	0.05	3.00	0.11	85.86
	m3	**storm loads**	**kg**				
2005	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	3,119,837	3,990	746	190	6,459	876	599,135
plant discharge	914,143	1,914	729		3,274	437	8,928
below outfall	5,864,413	16,160	1,469	575	19,415	1,366	679,484
highway 112	18,251,046	49,421	5,283	1,246	60,088	2,801	4,372,011
Illinois River @ 59	155,440,681	417,016	83,998	11,943	541,306	26,859	31,627,581
		storm concentrations			**mg/l**		
2005		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		1.28	0.24	0.06	2.07	0.28	192.04
plant discharge		2.09	0.80		3.58	0.48	9.77
below outfall		2.76	0.25	0.10	3.31	0.23	115.87
highway 112		2.71	0.29	0.07	3.29	0.15	239.55
Illinois @59		2.68	0.54	0.08	3.48	0.17	203.47
			kg	**base loads**			
2005	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	4,557,218	14,753	265	146	14,917	270	95,312
plant discharge	7,115,552	12,445	5,511		22,659	4,092	25,812
below outfall	17,734,365	63,912	4,547	714	70,542	3,577	108,822
highway 112	17,208,061	55,314	3,598	537	61,707	2,750	308,801
Illinois River @ 59	233,952,444	601,703	22,980	8,659	629,539	17,353	1,932,864
		base concentrations			**mg/l**		
2005		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		3.24	0.06	0.03	3.27	0.06	20.91
plant discharge		1.75	0.77		3.18	0.58	3.63
below outfall		3.60	0.26	0.04	3.98	0.20	6.14
highway 112		3.21	0.21	0.03	3.59	0.16	17.95
Illinois @59		2.57	0.10	0.04	2.69	0.07	8.26

Table A7. **2004** Results Summary

	m3	total	loads	kg			
2004	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	14,590,139	32,210	3,428	941	47,103	1,210	2,720,330
plant discharge	8,917,944	25,974	3,774			1,905	42,304
below outfall	32,297,138	128,905	8,669	2,786	157,263	3,879	4,266,748
highway 112	60,309,237	159,561	24,611	4,573	229,623	11,862	10,293,208
Illinois @ 59	565,760,474	1,207,334	281,424	44,795	1,719,690	73,313	92,080,668
		mean	**concentrations**		**mg/l**		
2004		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		2.21	0.23	0.06	3.23	0.08	186.45
plant discharge		2.91	0.42			0.21	4.74
below outfall		3.99	0.27	0.09	4.87	0.12	132.11
highway 112		2.65	0.41	0.08	3.81	0.20	170.67
Illinois @59		2.13	0.50	0.08	3.04	0.13	162.76
	m3	**storm**	**loads**				
2004	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	7,949,454	9,649	2,825	797	22,124	942	2,476,120
plant discharge	2,506,460	6,702	1,152			566	14,503
below outfall	16,580,574	45,277	6,190	2,411	67,261	2,426	3,924,772
highway 112	41,644,043	89,215	21,490	4,012	150,255	9,986	9,921,678
Illinois @ 59	291,021,664	492,470	250,791	39,801	907,561	49,575	90,055,395
		storm	**concentrations**		**mg/l**		
2004		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		1.21	0.36	0.10	2.78	0.12	311.48
plant discharge		2.67	0.46			0.23	5.79
below outfall		2.73	0.37	0.15	4.06	0.15	236.71
highway 112		2.14	0.52	0.10	3.61	0.24	238.25
Illinois @59		1.69	0.86	0.14	3.12	0.17	309.45
		base	**loads**				
2004	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	6,640,684	22,561	603	144	24,979	268	244,210
plant discharge	6,411,484	19,272	2,622			1,339	27,800
below outfall	15,716,564	83,629	2,479	375	90,003	1,454	341,977
highway 112	18,665,194	70,346	3,121	562	79,369	1,875	371,530
Illinois @ 59	272,566,290	714,847	30,633	4,994	812,109	23,737	2,025,223
		base	**concentrations**		**mg/l**		
2004		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		3.40	0.09	0.02	3.76	0.04	36.77
plant discharge		3.01	0.41			0.21	4.34
below outfall		5.32	0.16	0.02	5.73	0.09	21.76
highway 112		3.77	0.17	0.03	4.25	0.10	19.90
Illinois @59		2.62	0.11	0.02	2.98	0.09	7.43

Table A8. **2003** Results Summary

	m3	total loads		kg			
2003	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	8,460,368	19,142	1,048	191	24,405	1,056	864,076
plant discharge	7,934,555	33,030	3,154			1,347	39,239
below outfall	21,060,577	90,850	5,304	1,201	108,470	1,903	723,863
highway 112	27,141,648	86,363	4,340	698	109,277	2,504	2,094,667
Illinois @ 59	288,287,233	590,943	64,854	10,231	734,984	39,879	11,845,136
		mean concentrations			**mg/l**		
2003		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		2.26	0.12	0.02	2.88	0.12	102.13
plant discharge		4.16	0.40			0.17	4.95
below outfall		4.31	0.25	0.06	5.15	0.09	34.37
highway 112		3.18	0.16	0.03	4.03	0.09	77.18
Illinois @59		2.05	0.22	0.04	2.55	0.14	41.09
	m3	**storm loads**	**kg**				
2003	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	2,627,718	2,380	772	146	6,916	644	754,746
plant discharge	757,414	2,376	242	0	0	115	3,479
below outfall	4,098,975	9,388	934	279	14,999	1,071	569,792
highway 112	5,404,054	10,063	1,650	455	19,878	788	1,333,164
Illinois @ 59	46,081,177	66,999	22,440	2,933	123,653	7,604	7,867,944
		storm concentrations			**mg/l**		
2003		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		0.91	0.29	0.06	2.63	0.24	287.22
plant discharge		3.14	0.32			0.15	4.59
below outfall		2.29	0.23	0.07	3.66	0.26	139.01
highway 112		1.86	0.31	0.08	3.68	0.15	246.70
Illinois @59		1.45	0.49	0.06	2.68	0.17	170.74
			kg	base loads			
2003	**VOLUME**	**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall	**5,832,650**	**16,762**	**276**	**46**	**17,489**	**412**	**109,329**
plant discharge	7,177,141	30,654	2,913			1,232	35,760
below outfall	16,961,602	81,462	4,370	921	93,471	832	154,072
highway 112	21,737,594	76,300	2,690	243	89,398	1,716	761,503
Illinois @ 59	241,996,472	523,944	42,414	7,297	611,331	32,275	3,977,192
		base concentrations			**mg/l**		
2003		**NO3-N**	**T-P**	**NH4-N**	**TN-N**	**PO4-P**	**TSS**
above outfall		2.87	0.05	0.01	3.00	0.07	18.74
plant discharge		4.27	0.41			0.17	4.98
below outfall		4.80	0.26	0.05	5.51	0.05	9.08
highway 112		3.51	0.12	0.01	4.11	0.08	35.03
Illinois @59		2.17	0.18	0.03	2.53	0.13	16.43

Table A9. Mass Balance Computations 1997 to 2001 (Nelson, 2002)

Illinois River Watershed Phosphorus Mass Balance

	Outputs	Point Source				Non Point Source			
	59 bridge (lbs)	**watershed inputs** (lbs)	**river outputs** (lbs)	**%** point source	**%** total output	**watershed inputs** (lbs)	**river outputs** (lbs)	**%** non-point source	**%** total output
all T-P	**510,200**	**206,053**	**206,053**	**100%**	**43%**	**7,092,250**	**304,147**	**4%**	**57%**
1997	278,000	183,466	183,466		66%	6,702,611	94,534	1%	34%
1998	502,000	147,119	147,119		29%	6,838,914	354,881	5%	71%
1999	587,000	225,390	225,390		38%	7,107,732	361,610	5%	62%
2000	621,000	229,705	229,705		37%	7,195,455	391,295	5%	63%
2001	563,000	244,584	244,584		43%	7,616,538	318,416	4%	57%
base T-P	**135,006**		**116,668**	**56%**	**88%**		**18,338**	**0%**	**12%**
1997	117,972		103,879		88%		14,092	0%	12%
1998	90,461		83,299		92%		7,162	0%	8%
1999	129,482		127,617		99%		1,866	0%	1%
2000	144,736		130,060		90%		14,676	0%	10%
2001	192,377		138,485		72%		53,892	1%	28%
storm T-P	**376,818**		**89,385**	**44%**	**27%**		**287,433**	**4%**	**73%**
1997	160,403		79,587		50%		80,816	1%	50%
1998	418,252		63,819		15%		354,433	5%	85%
1999	458,242		97,773		21%		360,469	5%	79%
2000	477,055		99,645		21%		377,410	5%	79%
2001	370,137		106,100		29%		264,037	3%	71%

NOTE: output numbers are measured at the Highway 59 bridge
base numbers are contributions below 5 feet stage, storm is above 5 feet stage
NPS watershed inputs are estimates that include WWTP sludge, animal manure and commercial fertilizer T-P
PS inputs are Springdale, Fay, Rogers and Prairie Grove T-P
PS inputs are allocated to base flow as a function of instream k rate ($lbs_{downstream} = lbs_{upstream} \times e^{(-k \times dist.)}$)
remainders are allocated to storm flow assuming 100 % conservation