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Illinois River 1998 Nutrient and Suspended Sediment Loads at Arkansas Highway 59 Bridge

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Arkansas Water
Resources Center

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AT ARKANSAS HIGHWAY 59 BRIDGE

Submitted to the
Arkansas-Oklahoma Arkansas Rvier Compact Commission

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September, 1999

SUMMARY

Results for Illinois River at AR59 for Calendar Year **1998**.

Parameter	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

Comparison between the loads and discharge calculated for 1997 and the loads and discharge calculated for 1998 indicate a significant increase in 1998.

Comparison between 1998 and 1997

Parameter	**1997** Totals	**1998** Totals	Percent Change
Discharge	458,460,000 (m^3)	588,000,000 (m^3)	+ 28
N03-N	1,020,000 (kg/yr)	1,390,000 (kg/yr)	+ 36
TKN	301,000 (kg/yr)	481,000 (kg/yr)	+ 60
TP	127,000 (kg/yr)	232,000 (kg/yr)	+ 83
TSS	18,400,000 (kg/yr)	72,600,000 (kg/yr)	+394

Most of the increase for the year can be attributed to a single storm that began on January 4, 1998. The river was above the trigger level for seventeen days. In that time, the following discharge and loads occurred.

Discharge and loads for January 4, 1998 Storm.

Parameter	Storm Values	Percentage of 1998 Total
Discharge	150,739,967 (m^3)	25.6 %
N03-N	351,920 (kg)	25.3 %
TKN	197,599 (kg)	41.1 %
TP	100,165 (kg)	43.2 %
TSS	37,263,085 (kg)	51.3 %

The results for 1998 show that storms were the largest source of pollutant load during the year and that significant individual storms can be a large percentage of a year's total load. These significant storms may or may not occur in a given year. Such storms can dramatically affect the year's total loads and makes the prediction of trends very difficult, especially over short time periods. These results also reinforce the fact that storm events must be adequately sampled for accurate determination of pollutant loads. In addition, there must be a method to reasonably predict individual storm loads for "missed" storms.

INTRODUCTION

Automatic water samplers and a U. S. Geological Survey (USGS) 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 for January 1, 1998 to December 31, 1998.

PREVIOUS RESULTS

In the fall of 1995, a gauge was installed at the Highway 59 bridge by the USGS and the Arkansas Water Resource Center (AWRC) installed automatic sampling equipment. 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)

Parameter	Total Discharge (m^3/yr) 267,740,640	Total Load (kg/yr)	Average Discharge (m^3/s) 8.5	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		0.33
TSS		27,500,000		101
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).

Parameter	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

METHODS

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. This 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 analyses were performed by the AWRC Water Quality Lab using standard field and laboratory quality assurance and quality control (QA/QC) procedures.

In the period from May 16, 1998 to October 31, 1998, the sampling protocol reverted 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 24 one-liter bottles. The total was then reset to zero and discharge was again summed for the next sample. In this fashion up to 24 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 24 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 analyses performed 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 30-minute intervals was used to calculate 30-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 30-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, 1998 to December 31, 1998, there were 449 samples collected and analyzed. These results are summarized in Table 3 and Figure 1.

Table 3. Results for Illinois River at AR59 for Calendar Year **1998**.

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

DISCUSSION

Comparison between the loads and discharge calculated for 1997 and the loads and discharge calculated for 1998 indicate a significant increase in 1998. The total discharge in 1998 was 28% higher than in 1997. The 1998 loads increased to an even greater extent.

Table 4. Comparison between 1997 and 1998.

Parameter	1997 Total Load (kg/yr)	1998 Total Load (kg/yr)	Percent Change
Discharge	458,460,000 (m^3/yr)	588,000,000 (m^3/yr)	+ 28
N03-N	1,020,000	1,390,000	+ 36
TKN	301,000	481,000	+ 60
TP	127,000	232,000	+ 83
TSS	18,400,000	72,600,000	+394

The differences between the years can largely be attributed to the differences in storm flows and storm flow concentrations. Storm and base flows can be differentiated by defining storm flows as all discharges that occurred when the stage was above the five-foot trigger level. Base flow volumes for the two years are essentially identical, 208 million cubic meters in 1997 and 209 million cubic meters in 1998. Concentrations measured during base flows are also very similar (see figure 2.). Storm flow volumes increased from 55 to 64% of the total volume. Since, with the exception of nitrate-nitrogen, the concentrations of the storm flows increased from 1997 to 1998, the percentages of loads that occurred during storm flows increased substantially. Storm flow total phosphorus load increased from 58 to 82% of the total. Storm flow total Kjeldahl nitrogen load increased from 71 to 84% of the total. Storm flow total suspended solids load increased from 77 to 94% of the total.

Most of the increase for the year can be attributed to a single storm that began on January 4, 1998 (see Figure 3.). The river stage was above the trigger level for seventeen days. In that time, the following discharge and loads occurred.

Table 5. Discharge and loads for January 4, 1998 Storm.

Parameter	Storm Values	Percentage of 1998 Total
Discharge	150,739,967 (m^3)	25.6 %
N03-N	351,920 (kg)	25.3 %
TKN	197,599 (kg)	41.1 %
TP	100,165 (kg)	43.2 %
TSS	37,263,085 (kg)	51.3 %

The stage was above fifteen feet for only twelve hours. In that time, 20% of the total yearly phosphorus load, nineteen percent of the total yearly TKN load and 26% of the total yearly suspended solids load occurred (see Figure 2).

The fact that such a large percentage of the year's total loads resulted from a single storm indicates the need for a means to estimate pollutant loads for storms with missing concentration data. One method used to accomplish this is to develop a concentration / discharge rating curve. Looking at the development of these rating curves for total phosphorus shows that they do not accurately predict the relationship even when segregated into three flow regimes (see Figure 4). Even base flow values are not accurately predicted since they have a greater correlation with time of year than with stage. Another technique being investigated using this data set is to develop a relationship between storm mean concentration and peak stage (see Figure 5). The use of these or other techniques to predict loads for "missed" storms is critical for accurate yearly load calculations

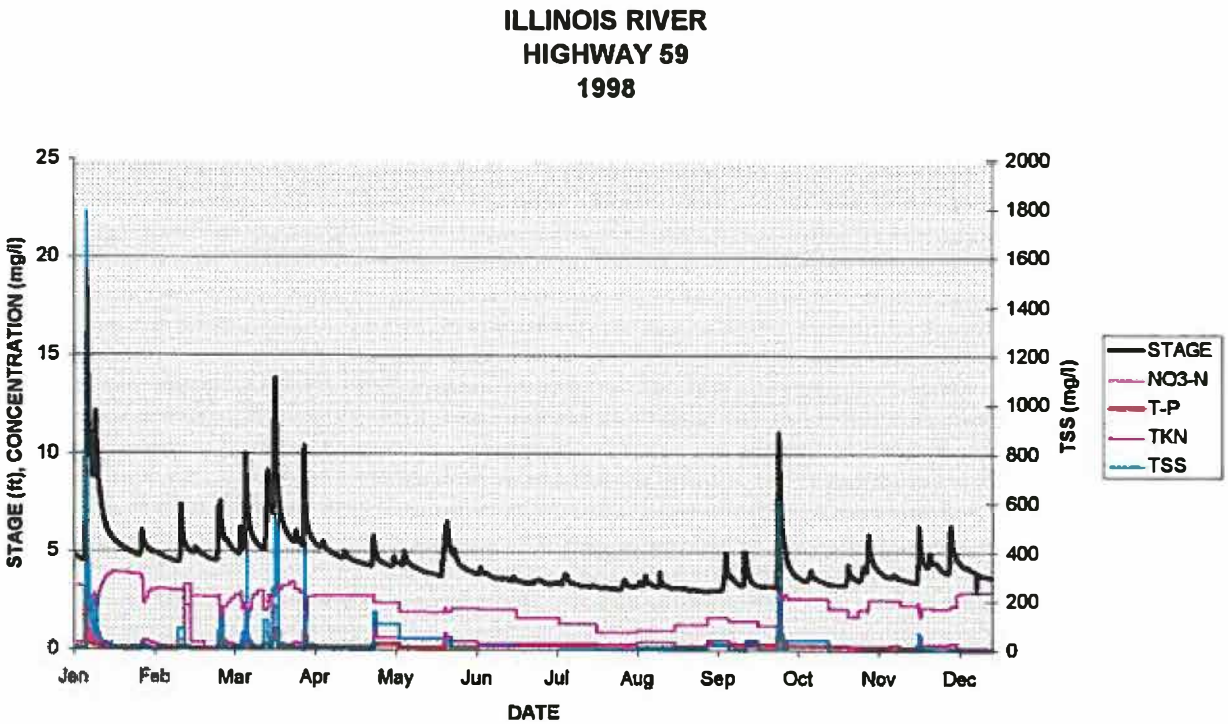
The year 1998 was not a particularly wet year. Looking at the yearly discharges at a site five miles down stream near Watts Oklahoma, for which historic records are available, shows that the total discharge for 1998 was very near the 33-year mean value of 577 million cubic meters (see Figure 6). Also plotted on figure four is the trailing five year moving average discharge that corresponds to the five year moving average loads that the Arkansas-Oklahoma Arkansas River Compact Commission uses to determine trends in phosphorus loads. This shows the cyclical nature of the yearly discharge from the Illinois River. A graph of calculated loads if available would probably exhibit the same cyclical nature with the peaks and valleys accentuated.

The loads calculated for the year 1998 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. Most of the storm events were sampled using discrete samples taken at 30-minute intervals during rising flow and 60-minute intervals during falling flow. The preliminary results of the research conducted during 1997 and 1998 at this site to determine an optimum sample interval indicate that on average, the loads calculated from storms that were sampled at 60-minute intervals or less are within 5% of the actual value.

A potential 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 1999, the USGS began taking samples that represent the entire cross-section at the same time the autosampler was taking samples. Preliminary results from those samples indicate that the auto samples may be underestimating concentrations during low flow and overestimating concentrations during high flow (see Figure 7). More measurements particularly at high flows need to be made to accurately characterize this relationship.

CONCLUSIONS

The results for 1998 show that storm flow carried a large portion of nutrient and total suspended sediment loads during the year and that large individual storms can comprise a significant percentage of a year's total load. These significant storms may or may not occur in a given year and thus can dramatically affect the year's total loads and makes the prediction of trends very difficult, especially over short time periods. These results also reinforce the fact that storm events must be adequately sampled for accurate determination of pollutant loads. In addition, a method must be developed to reasonably predict individual storm loads for "missed" storms.



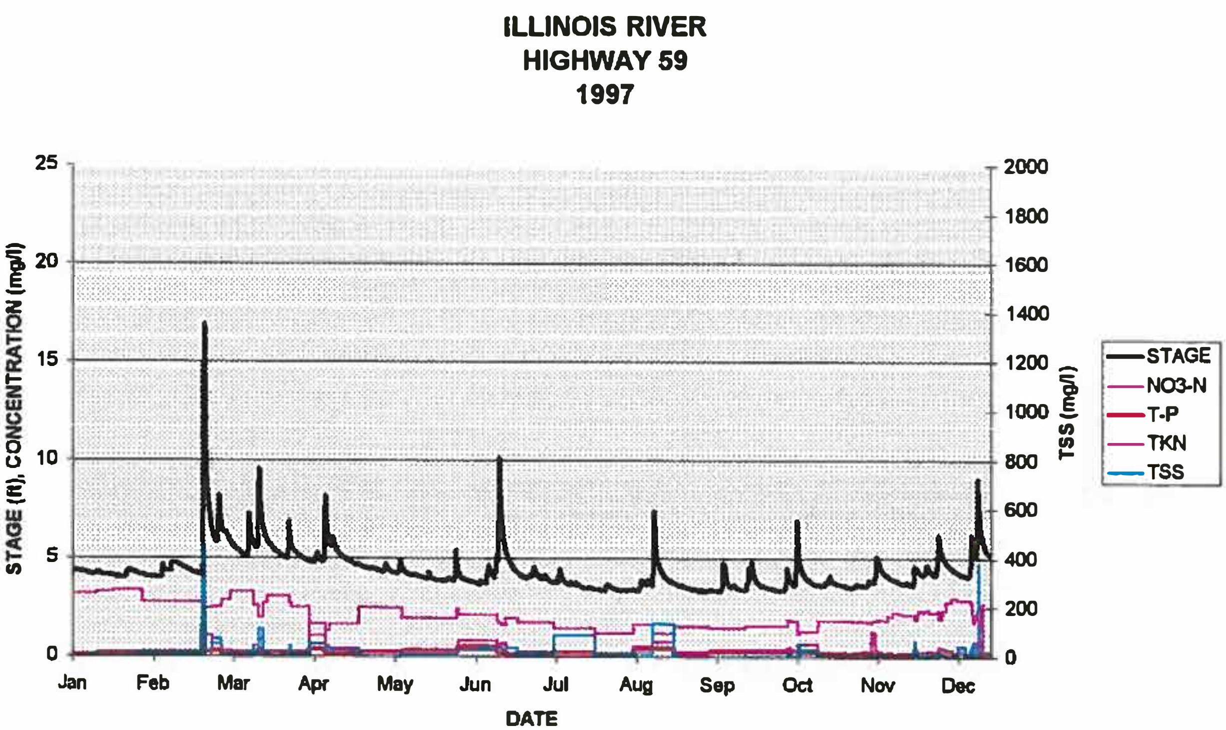


Figure 1. Stage and Measured Concentrations for 1998 and 1997.

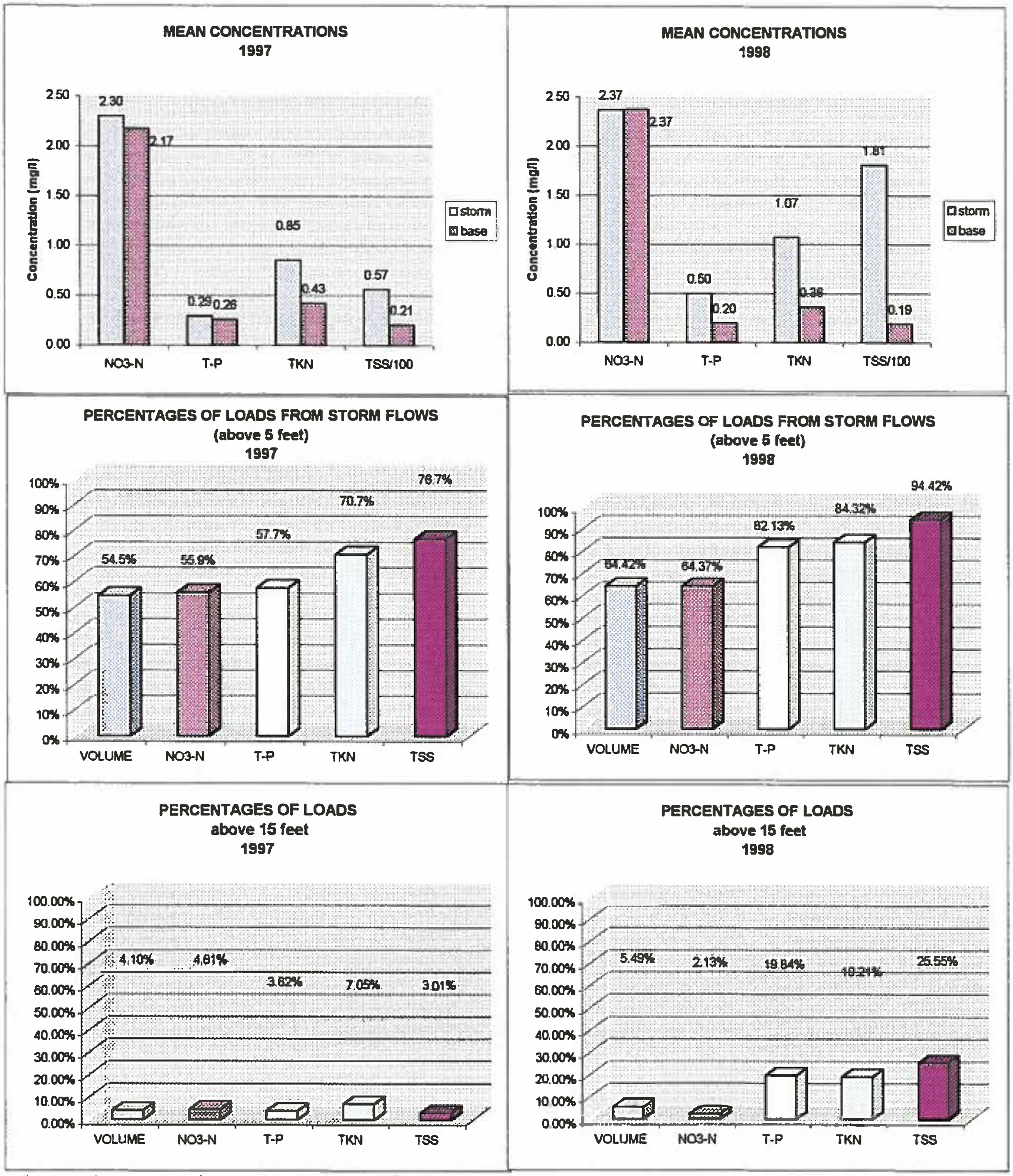


Figure 2. Comparisons between 1997 and 1998

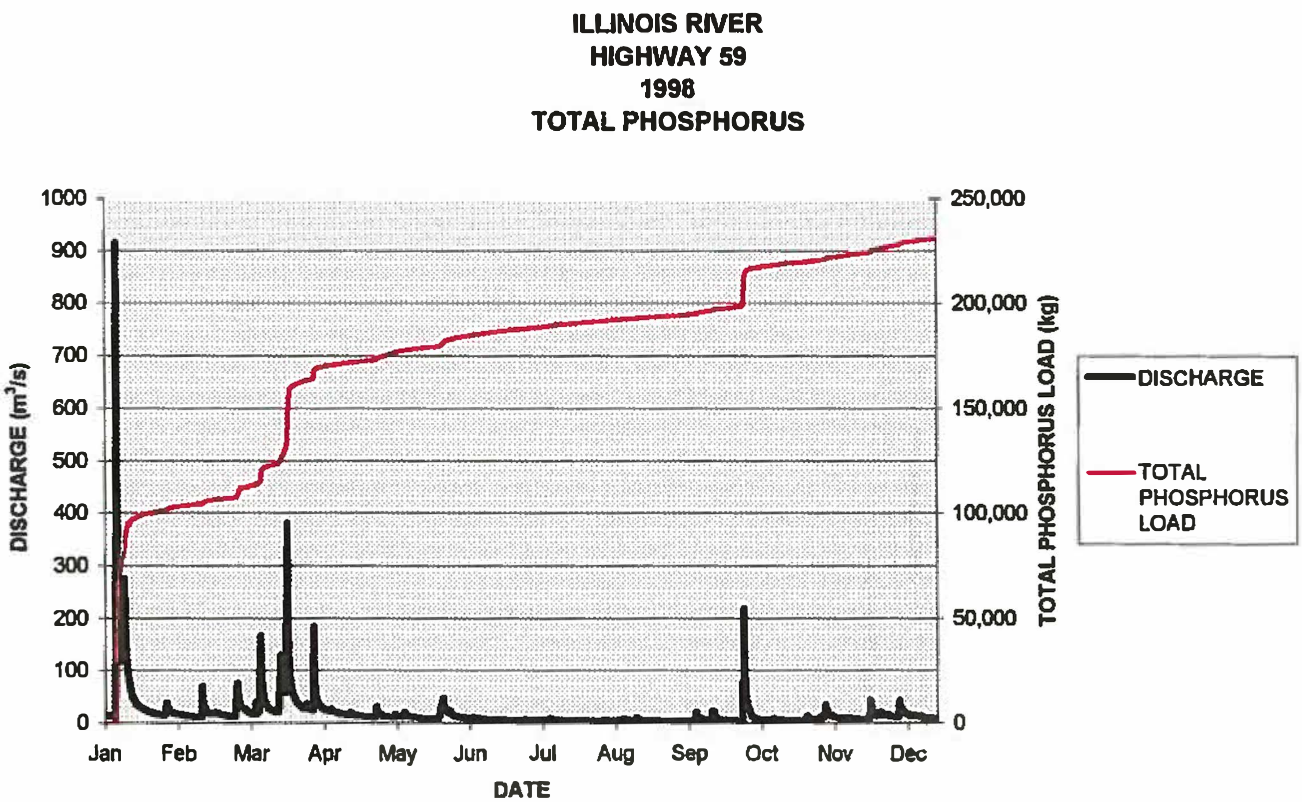


Figure 3. 1998 Discharge and Total Phosphorus load.

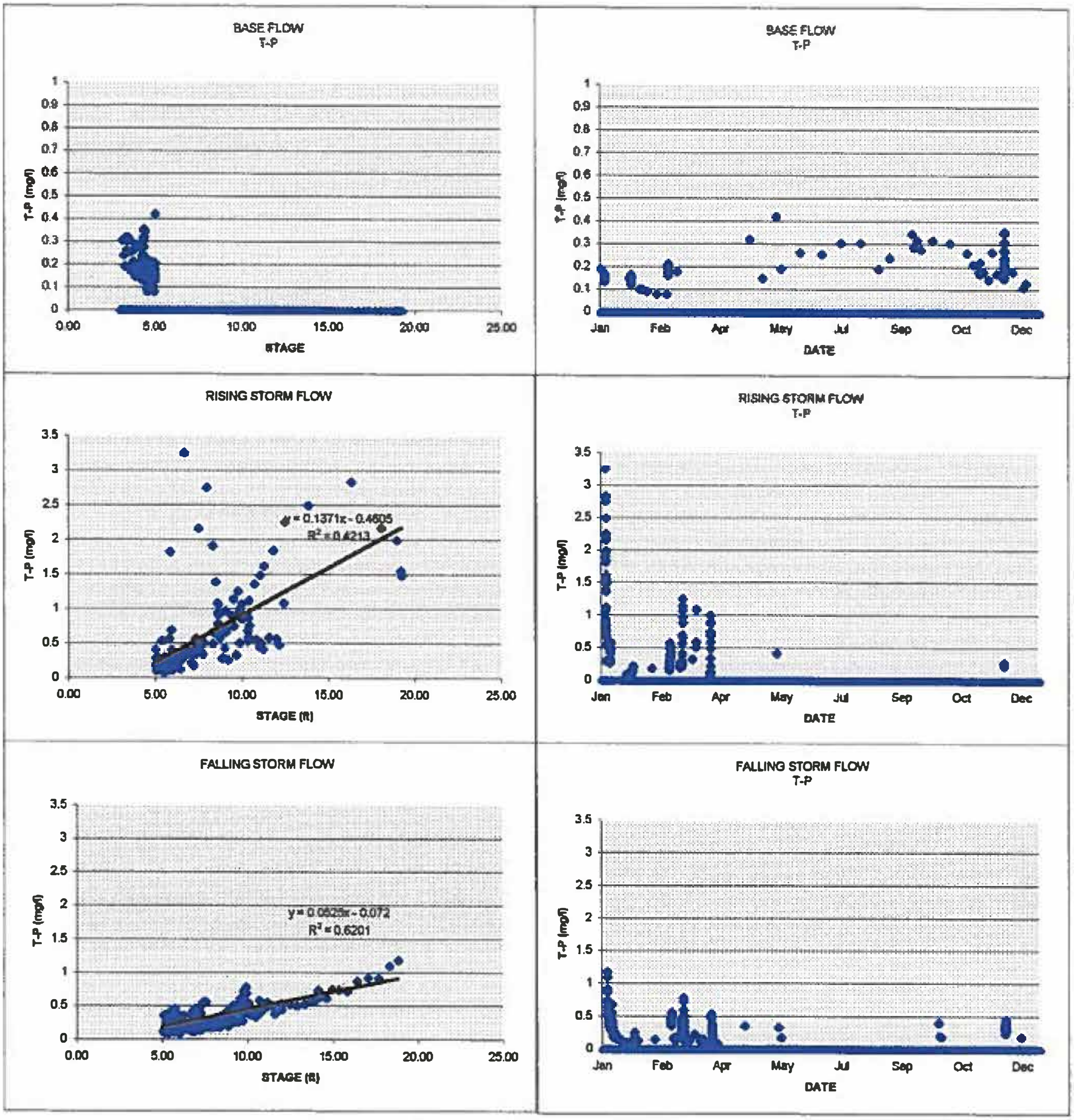


Figure 4 Development of rating curve for total phosphorus.

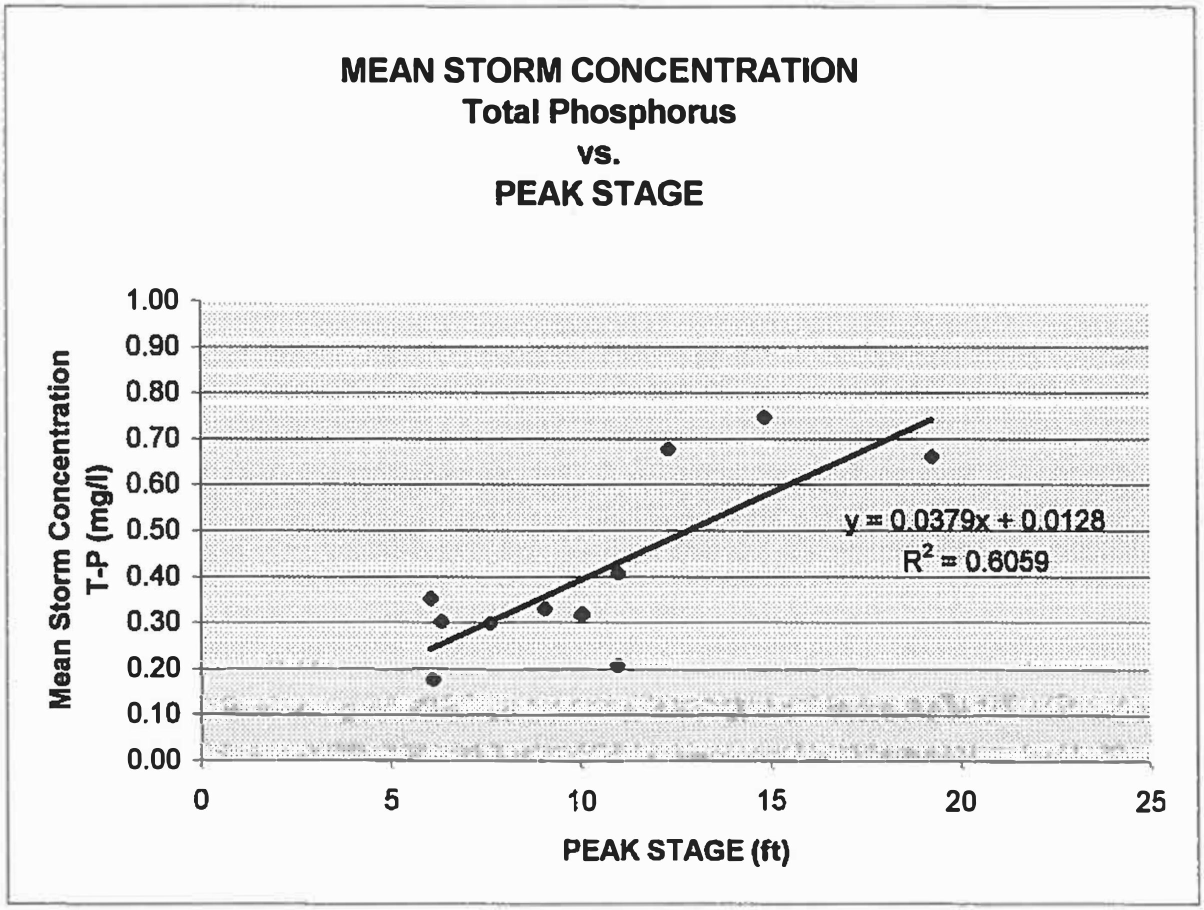


Figure 5 Mean Storm Concentration vs. Peak Stage for Total Phosphorus.

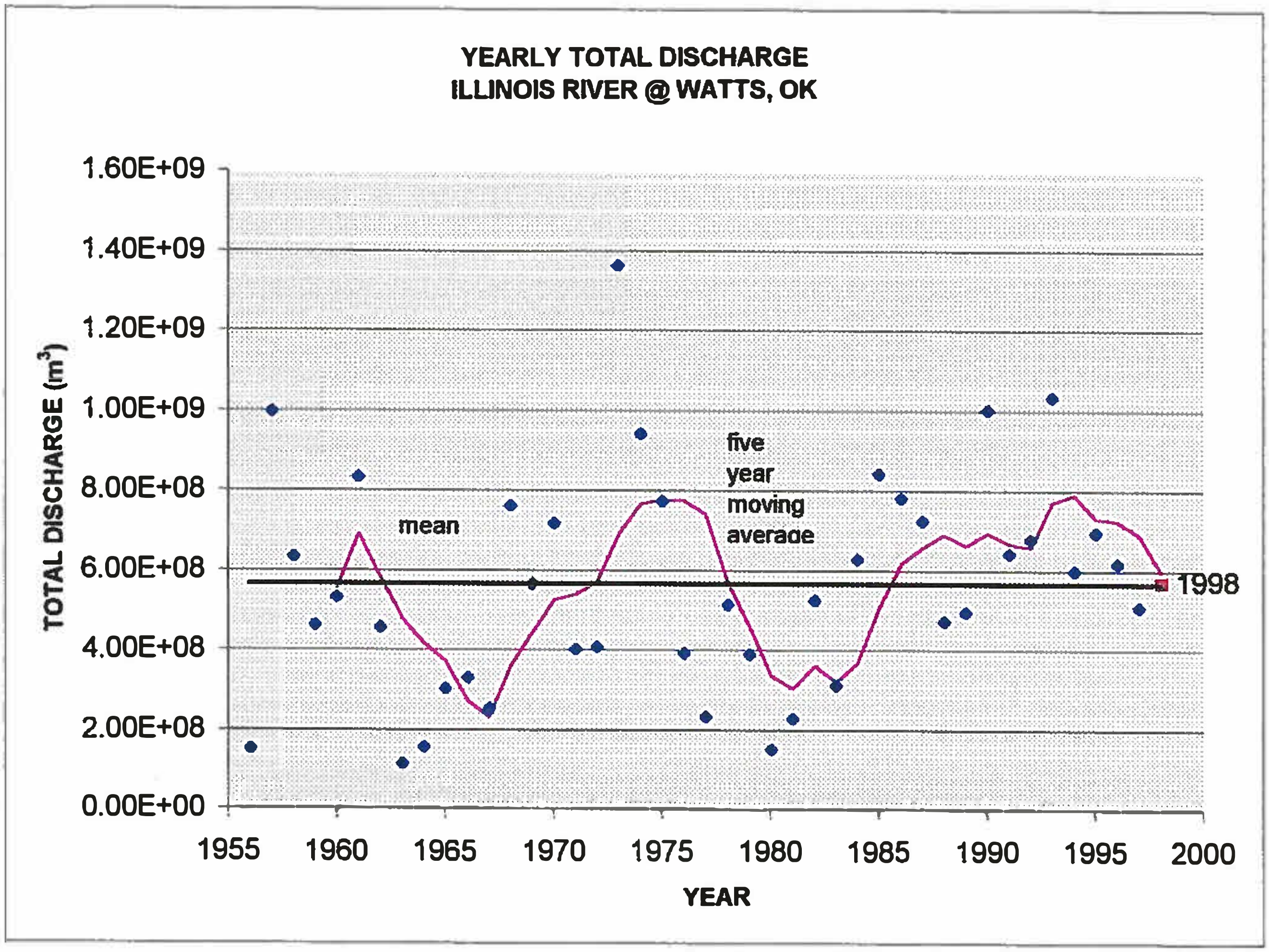


Figure 6. Total discharge at Illinois river near Watts Oklahoma

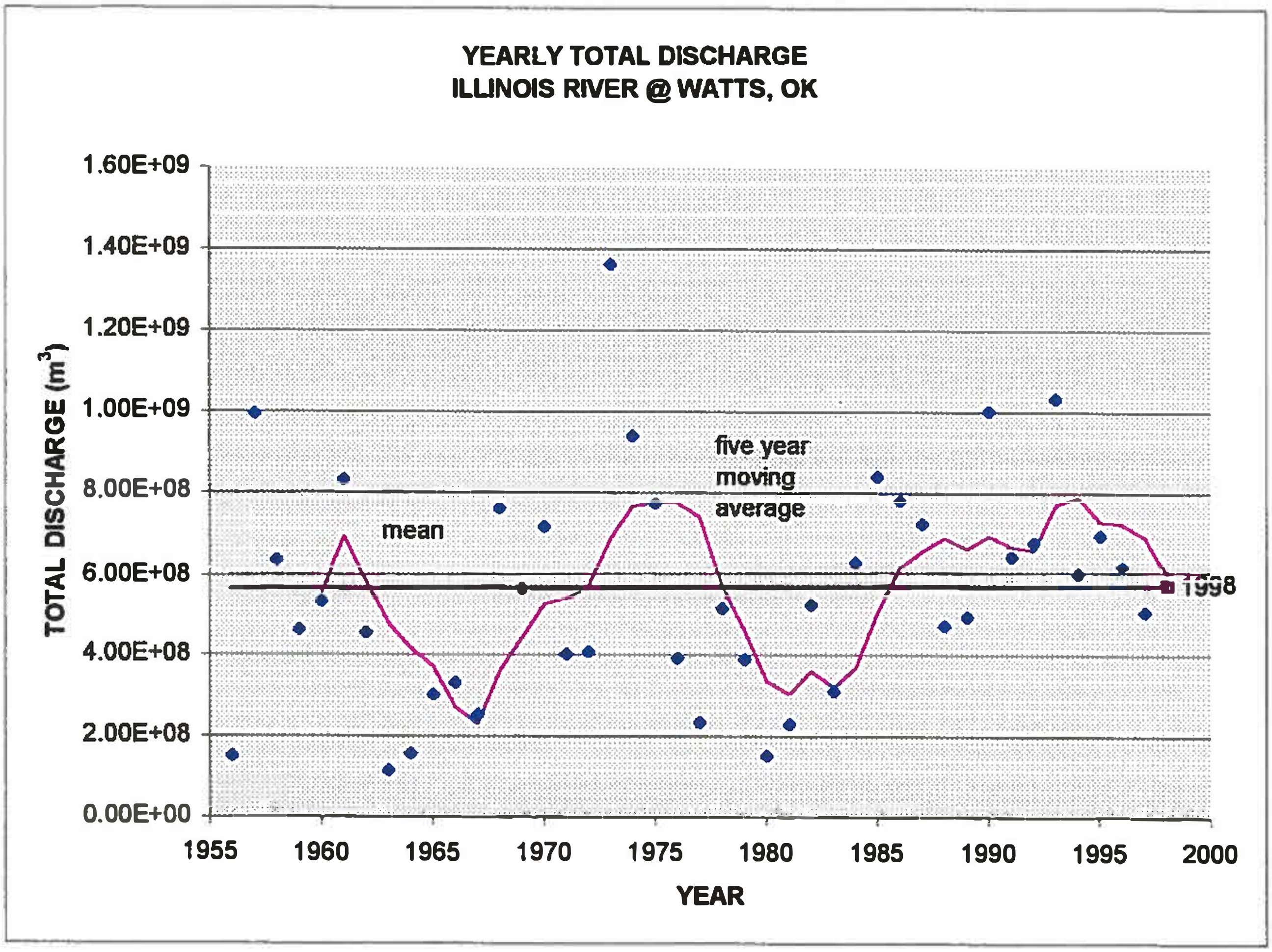
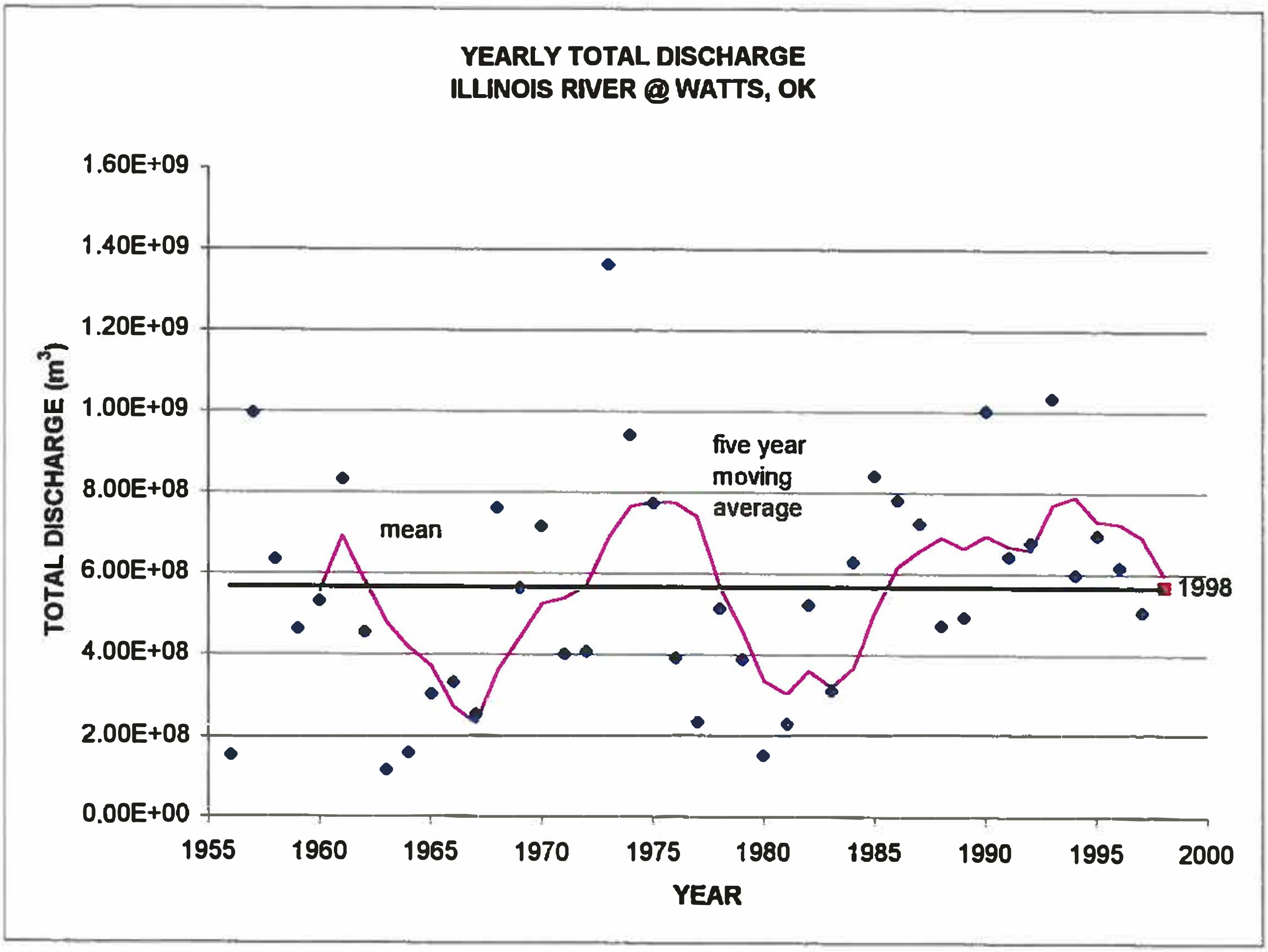


Figure 6. Total discharge at Illinois river near Watts Oklahoma



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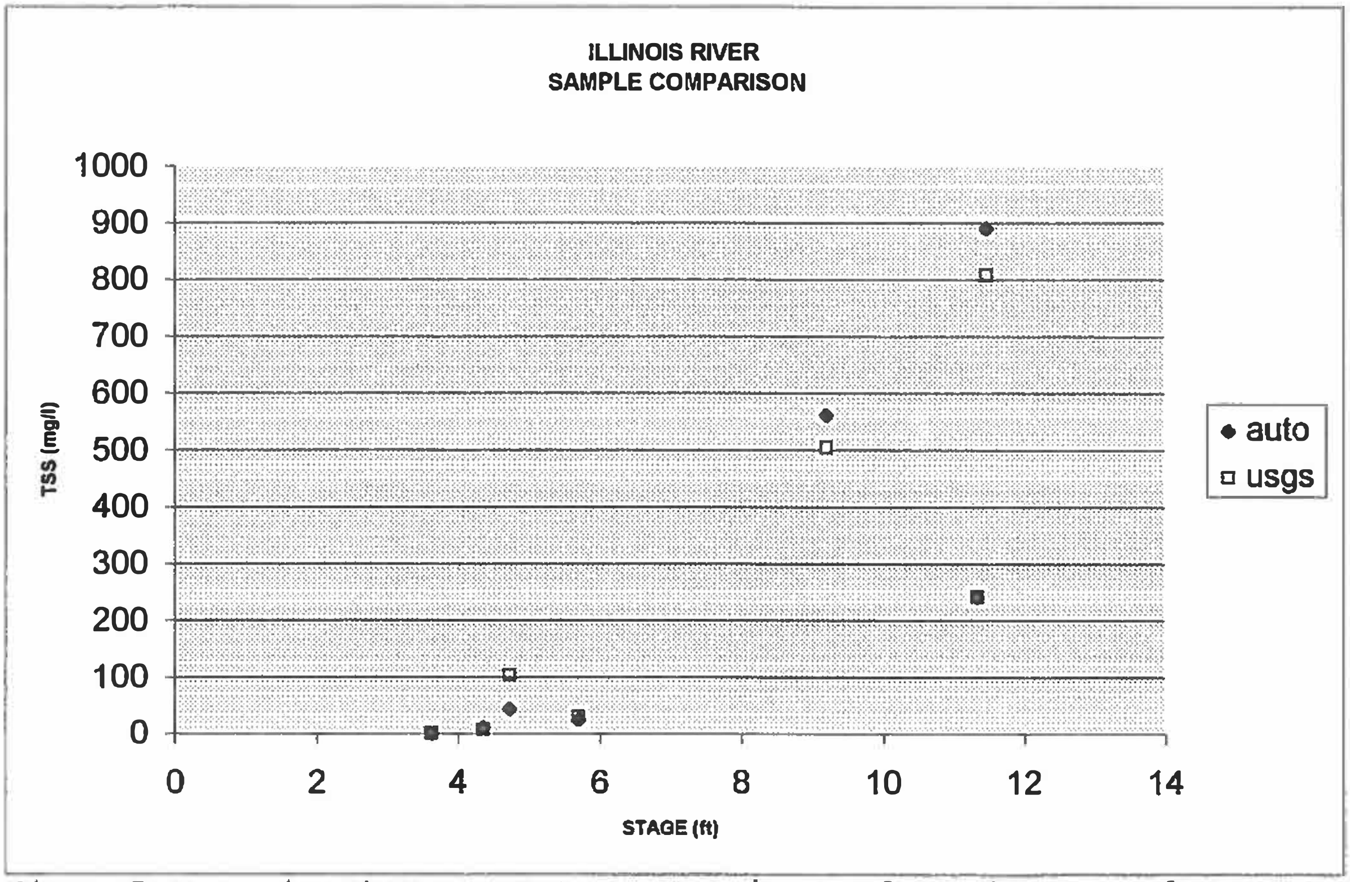

Figure 7. Comparison between USGS cross section samples and auto samples.