WATER QUALITY SURVEY AND BIOLOGICAL ASSESSMENT

OF THE EFFECTS OF WASTEWATER DISCHARGES

FROM THE CITY OF SILOAM SPRINGS

ON SAGER CREEK

ARKANSAS DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY

WATER DIVISION

in cooperation with

OKLAHOMA WATER RESOURCES BOARD

DECEMBER, 1995

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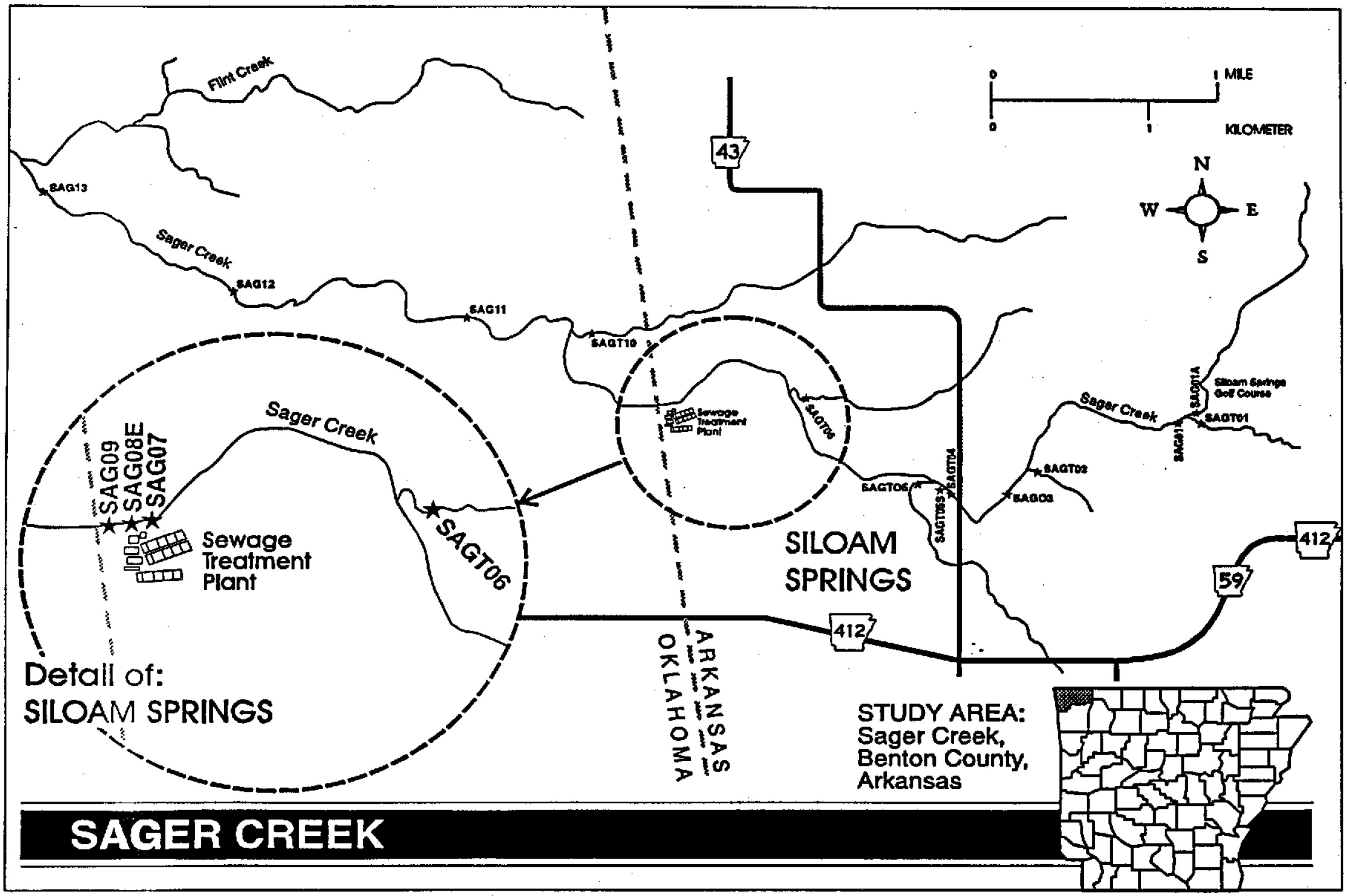
INTRODUCTION

An intensive stream study was conducted on Sager Creek between July 1993 and June 1994. The study included seasonal water quality analyses, measures of periphyton production, macroinvertebrate community sampling and fish community sampling. Monitoring stations were located above and below the major point source discharge to the stream, which is the Siloam Springs sewage treatment plant (STP). Tributary inputs were also monitored to quantify nonpoint source contributions and two reference streams were sampled to compare with the biotic conditions in Sager Creek.

The study was initiated as a result of objections from the State of Oklahoma to a discharge permit modification for the City of Siloam Springs. The city requested an increase in their design discharge flow from the STP from 3 million gallons per day (MGD) to 4.4 MGD. This discharge is into Sager Creek which flows less than one-half mile before entering the State of Oklahoma. A "desktop" wasteload allocation model was used with field verified stream data to establish discharge limits for the STP. Oklahoma claimed the discharge would violate their dissolved oxygen (D.O) standard for Sager Creek. The discharge limits were then modified to levels which would not violate Oklahoma's D.O. standards according to the model. However, Oklahoma claimed that the model was inappropriate and that a calibrated wasteload study must be conducted on Sager Creek and that an intensive stream study, to determine the impacts of nutrient discharges on the aquatic life communities in Sager Creek, must be conducted. A work plan for the intensive stream study was developed by the Arkansas Department of Pollution Control and Ecology and the Oklahoma Water Resource Board. The study was initiated in July 1993. The calibrated wasteload evaluation study was conducted in August 1994, and will be reported in a separate document.

STUDY AREA

Sager Creek originates just northeast of Siloam Springs, Arkansas (Figure 1). Its base flow originates from a spring at the northwest corner of the Siloam Springs golf course, and several other springs contribute flow throughout its length. Much of the surface runoff is from the city and its adjacent rural areas. The creek flows through downtown Siloam Springs where it has been dammed to create pools through the city park. At the western edge of the city the STP discharges into Sager Creek less than one-half mile from the Oklahoma stateline. The creek continues to flow westward in Oklahoma to its confluence with Flint Creek about 4.7 miles below the STP discharge. The City of Siloam Springs has a population of less than 10,000 people; however, a poultry processing plant


Flint Creek
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ARKANSAS
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SAG09
SAG08E
SAG07
Sewage Treatment Plant
SAGT06
Detail of:
SILOAM SPRINGS
STUDY AREA:
Sager Creek,
Benton County,
Arkansas
SAGER CREEK

Figure 1

discharges into the city's STP, thereby substantially increasing the waste load to the plant.

The drainage basin of Sager Creek in Arkansas is about 13 square miles. The reference stream in Arkansas was Flint Creek, which has a drainage basin of approximately 20 square miles above Highway 59, which was the location of the biological sampling site. This station was also used in 1983 as a least-disturbed reference stream in Arkansas' Ecoregion studies. The Oklahoma reference site was on Battle Branch. This site is monitored routinely by the State of Oklahoma as a least-disturbed reference site. It has a drainage basin of 8 to 10 square miles.

STUDY OBJECTIVE AND DESIGN

The objective of the intensive stream survey was to determine nutrient loadings and their impacts on Sager Creek and its biota, and to generally characterize the seasonal water quality of the creek.

Water quality grab samples were collected at 14 stations on Sager Creek and its tributaries in July, September, October, and November of 1993, and in January, April, and June of 1994. Sixteen parameters, including flow, were sampled during each sample event. In addition, 48-hour continuous D.O. and temperature profiles were taken above and below the Siloam Springs STP discharge during the summer and spring season. Periphyton production was measured at three stations on Sager Creek and in two reference streams in July, September and December of 1993 and in January of 1994. Macroinvertebrate communities were sampled from three stations on Sager Creek, from Flint Creek and from Battle Branch. Both reference streams, one station on Sager Creek above the STP and two stations below the STP were sampled for fish community structure in October 1993.

Sampling stations on Sager Creek and its tributaries are shown in Figure 1 and station descriptions are as follows:

SAG01 - At roadway bridge immediately west of golf course; this was just below the confluence of an ephemeral branch that contained flow only during rain events and the primary branch which is spring-fed.

SAG01A - The spring-fed branch of SAG01 above its confluence with the ephemeral branch. This was sampled only once during a major storm event.

SAGT01 - the ephemeral branch of SAG01; sampled only once during a major storm event.

SAGT02 - tributary adjacent to Simmons poultry processing plant and downstream of a spring.

SAG03 - Sager Creek about 1000 ft. above Main Street bridge; just above the downtown pool and park area.

SAG04 - At concrete dam and road crossing which forms one of the downtown pools.

SAGT05 - Tributary draining southern part of town; frequently no surface flow.

SAGT05S - A spring adjacent to the SAGT05 tributary; normally had flows.

SAGT06 - A tributary that drains the northern edge of town; flows were normally very low.

SAG07 - Sager Creek about 500 ft. above the STP outfall; periphyton, macroinvertebrate and fish communities collected at this site.

SAG08E - Siloam Springs STP effluent.

SAG09 - Sager Creek about 500 ft. below STP outfall.

SAGT10 - Tributary with spring influence from northern most drainage of basin; limited urban influences.

SAG11 - Sager Creek at county road bridge in Oklahoma; site of Arkansas' routine monitoring station ARK05; approximately 1.5 miles below STP; periphyton, macroinvertebrate and fish communities collected at this site.

SAG12 - Sager Creek at next county bridge crossing downstream; Oklahoma routine monitoring station; approximately 3.2 miles below STP.

SAG13 - Sager Creek approximately 0.4 miles from confluence with Flint Creek and approximately 4.3 miles below STP; periphyton, macroinvertebrate and fish communities collected at this site.

WATER QUALITY SAMPLING

Materials and Methods

Stream samples were collected, preserved, and analyzed according to the 16th Edition of Standard Methods for Examination of Water and Wastewater. Analysis was conducted under ADPC&E's existing Quality Assurance Program. Dissolved oxygen and stream temperature during sample collection were measured by a YSI Model 57 portable dissolved oxygen meter, which was calibrated by a Winkler titration prior to use. Three YSI Model 56 continuous dissolved oxygen meters were used to determine diurnal variation in the dissolved oxygen concentration. Stream pH was analyzed by an Orion Model 230A portable pH meter, which was calibrated using buffer solutions of pH 4,7 and 10. Stream flow was measured using a Marsh-McBirney Model 201 meter by obtaining a representative number of velocities and depths across suitable stream locations.

Results

Dissolved Oxygen

The spatial dissolved oxygen profile in Sager Creek was evaluated with portable meters seven times during the synoptic survey (July 1993-June 1994), and an additional three profiles were conducted at stations SAG07 through SAG13 during the August, 1994 wasteload evaluation survey (WLE). Saturation values fluctuated between 55% and 120% depending upon the station, time of year and time of day sampled. Low-flow saturation values were generally higher than high-flow values. Instantaneous Dissolved oxygen concentrations were above 6 mg/L at all stations at all times sampled, with the exception of the August 1994 WLE survey where pre-dawn concentrations declined from 6.1 mg/L at site SAG07 to 4.9 mg/L at site SAG11, 5.6 mg/L at site SAG12, and 5.5 mg/L at site SAG13. The pre-dawn sampling event also produced the lowest saturation values of the survey, ranging from 68% at SAG07 to 55% at SAG11. Dissolved oxygen concentrations were at their lowest generally just before daybreak due to respiration.

Diurnal dissolved oxygen (D.O.) profiles were conducted during three separate sampling events during the water quality survey, and an additional profile was measured during the August 1994 WLE survey. Continuous meters were installed at SAG07 above the STP and at SAG11(ARK05) below the STP during July 27-30, 1993. The continuous meter malfunctioned at SAG11 below the STP during this sampling period. To obtain comparative data below the STP at the SAG11 site, a continuous meter was reinstalled on August 3, 1993. Meters were again installed on September 13, 1993 at these same stations.

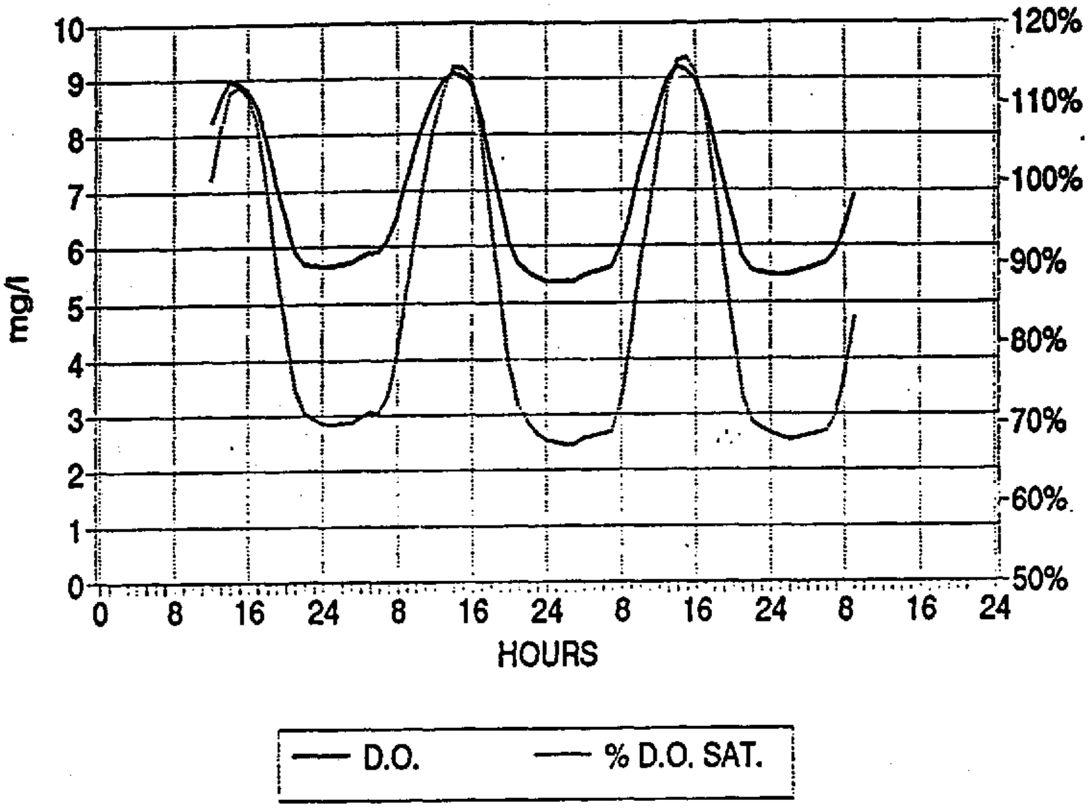
Two of these profiles were obtained at low-flow, sunny conditions, while the September 1993 evaluation was conducted under cloudy conditions. The July-August Sager Creek profile produced a fluctuation of 3.8 mg/L and a minimum D.O. of 5.3 mg/L at SAG07 (Figure WQ-1).

At the downstream site SAG11(ARK05) on August 3-4, 1993, the diurnal fluctuation was 3.7 mg/L with a minimum of 4.8 mg/L(Figure WQ-2). The September profile, conducted under cloudy conditions, produced a diel variation of 2.8 mg/L at SAG07 and 1.7 mg/L below the STP at SAG11 (Figures WQ-3 and WQ-4). Both stations had a minimum D.O. of 5.9 mg/L.

During the August 1994 WLE survey, three continuous dissolved oxygen meters were used to get an accurate measurement of the diurnal fluctuation in both dissolved oxygen and stream temperature at critical conditions of low flow and high temperature. A meter was placed at SAG07 above the STP; another was installed at SAG11(ARK05), and the third at SAG13. Figures WQ-5 thru WQ-7 show the dissolved oxygen fluctuations at each of these sites during this survey. The SAG07 meter indicated a diurnal fluctuation of 3.8 mg/L and a minimum D.O. of 5.9 mg/L. The site below the STP had a fluctuation of 4 mg/L and a minimum value of 4.5 mg/L which occurred for a one hour period. The overnight mode value was 4.7 mg/L. The SAG 13 site (further below the STP) revealed a dissolved oxygen fluctuation of 2.8 mg/L and a minimum of 5.3 mg/L. Sager Creek was at a low flow state during this survey, and the flow above the STP discharge was 2.2 CFS.

The diurnal dissolved oxygen data collected during this study showed similar patterns in D.O. deficits and minimum D.O.s between Sager Creek and the least disturbed ecoregion reference streams for the Ozark Highlands Ecoregion. A diel fluctuation of 4 mg/L and a minimum D.O. of 4.7 mg/L was measured in the ecoregion study at low flow conditions on Flint Creek, and on South Fork Spavinaw Creek the minimum D.O. was 4.5 mg/L with a fluctuation of 3.7 mg/L. As a result of these data from least-disturbed ecoregion streams, the Arkansas water quality standards for mid-range (10 mi^2 to 100 mi^2) streams in the Ozark Highlands provides for a minimum D.O. of 5 mg/L during the critical season and a diurnal depression of not more than 1 mg/L for more than an eight hour period.

Figure WQ-1
Dissolved Oxygen, July 27-30, 1993
Sager Creek, Above STP (SAG07)



Temperature, July 27-30, 1993
Sager Creek, Above STP (SAG07)

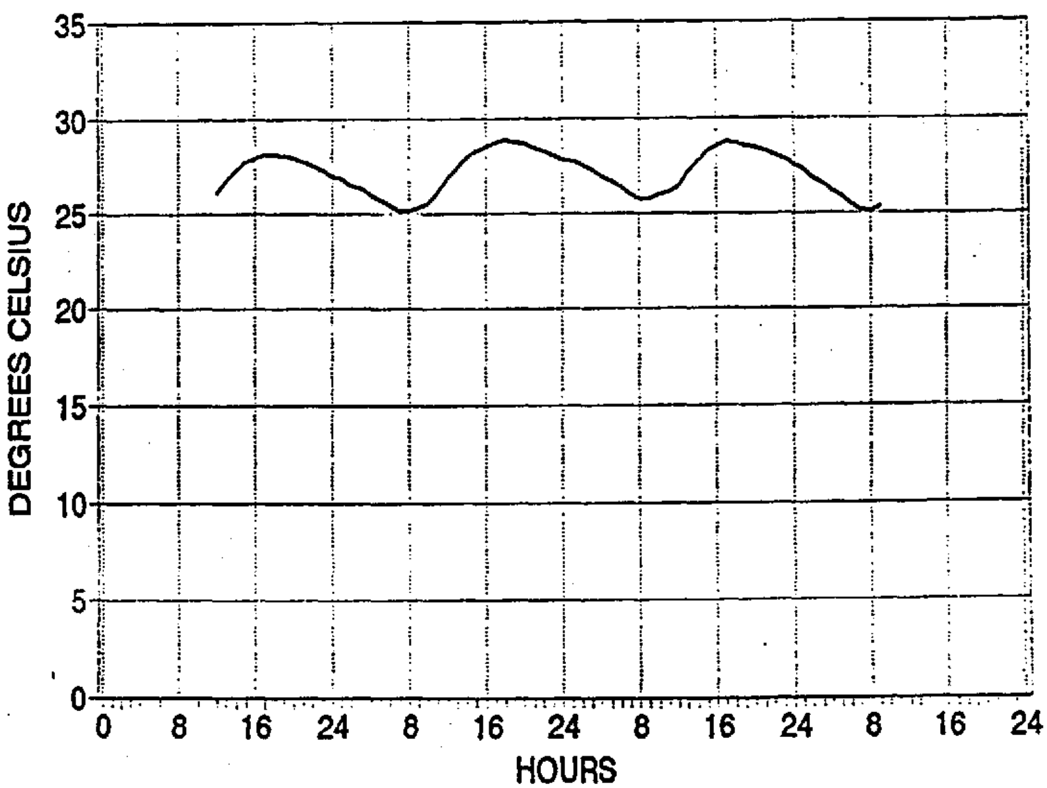
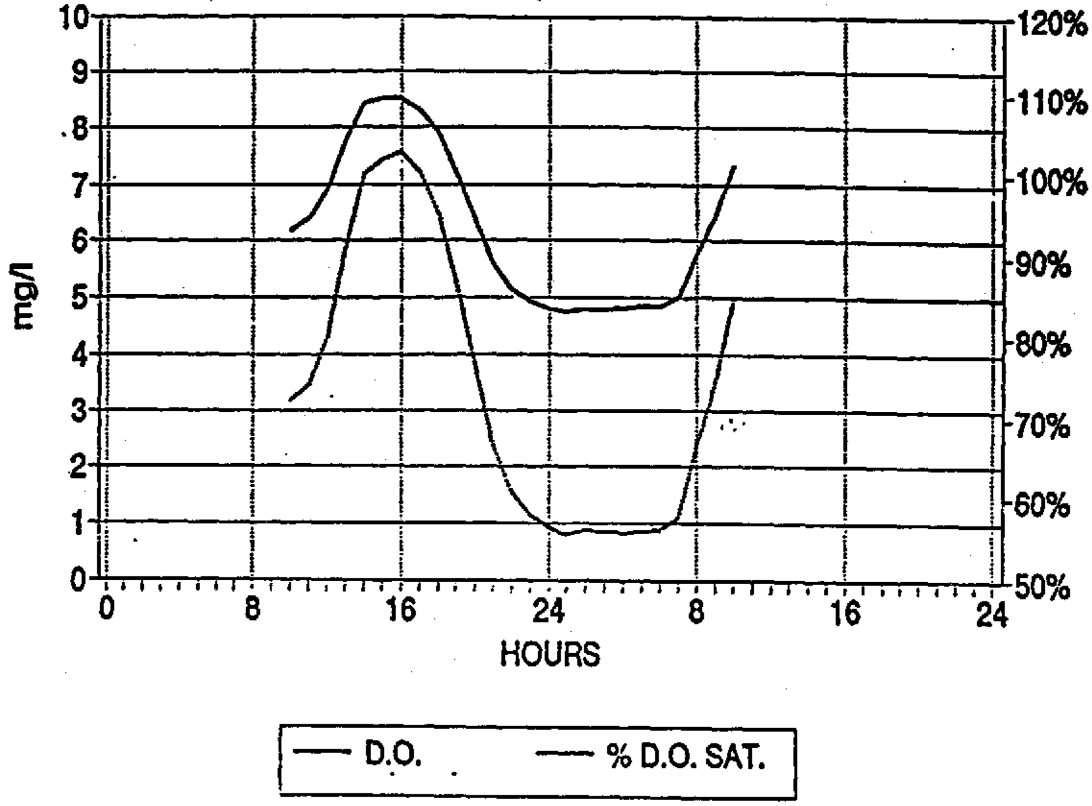


Figure WQ-2
Dissolved Oxygen, Aug. 3-4, 1993
Sager Creek @ ARK05 (Below STP)



Temperature, Aug. 3-4, 1993
Sager Creek, Below STP (ARK05)

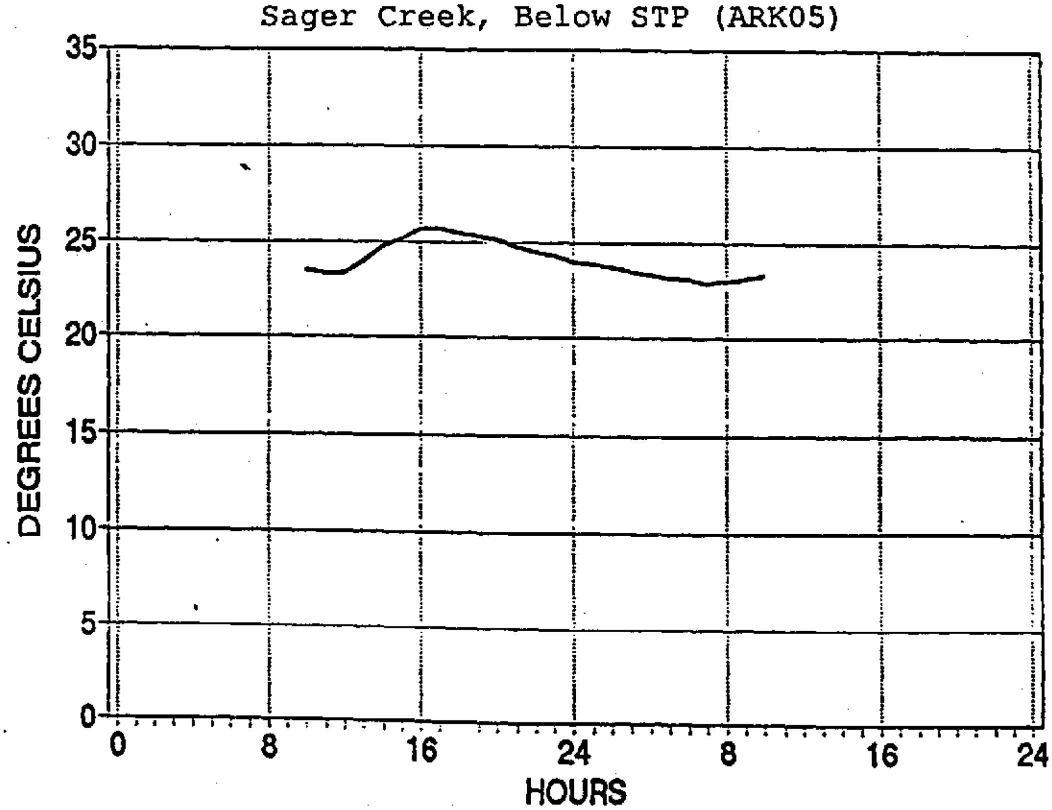
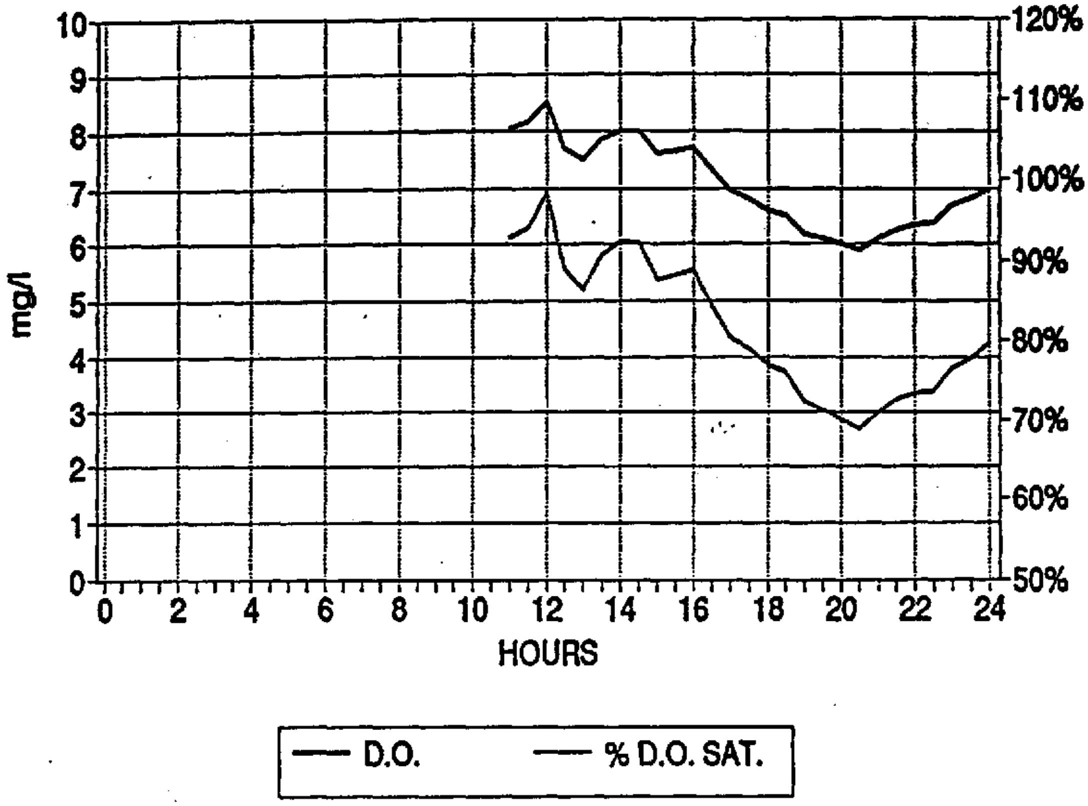


Figure WQ-3
Dissolved Oxygen, Sept. 13, 1993
Sager Creek, Above STP (SAG07)



Temperature, Sept. 13, 1993
Sager Creek, Above STP (SAG07)

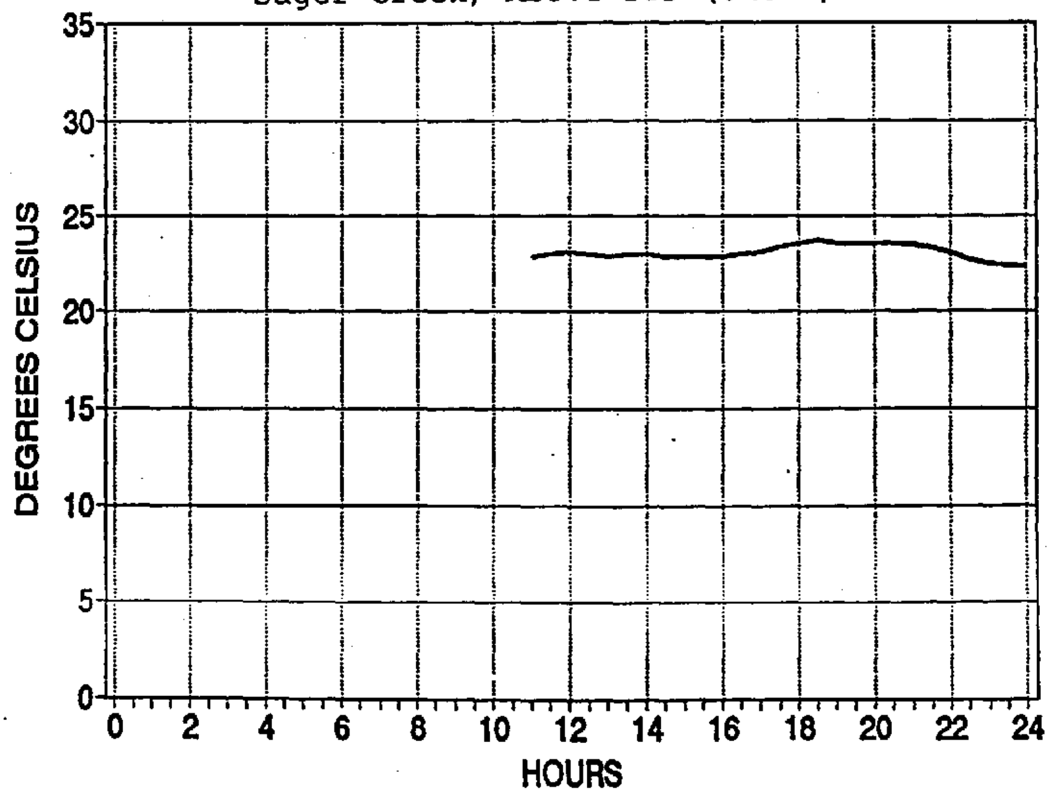
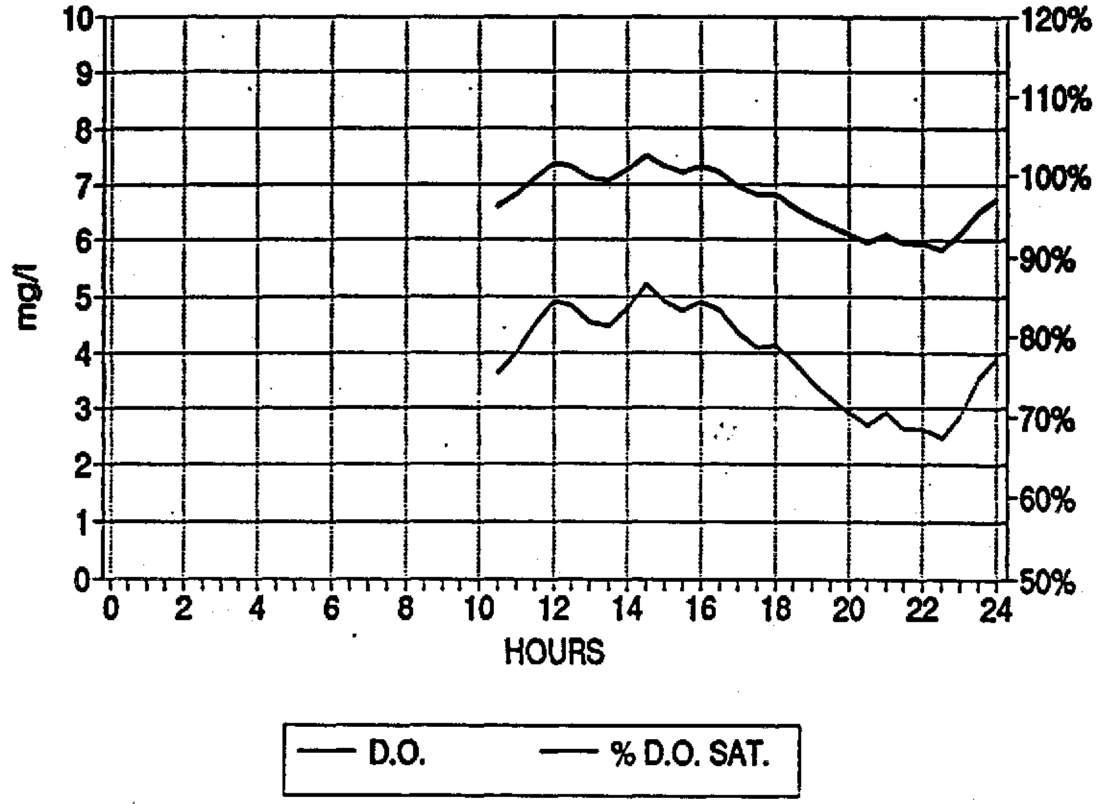


Figure WQ-4
Dissolved Oxygen, Sept. 13, 1993
Sager Creek, Below STP (ARK05)



Temperature, Sept. 13, 1993
Sager Creek, Below STP (ARK05)

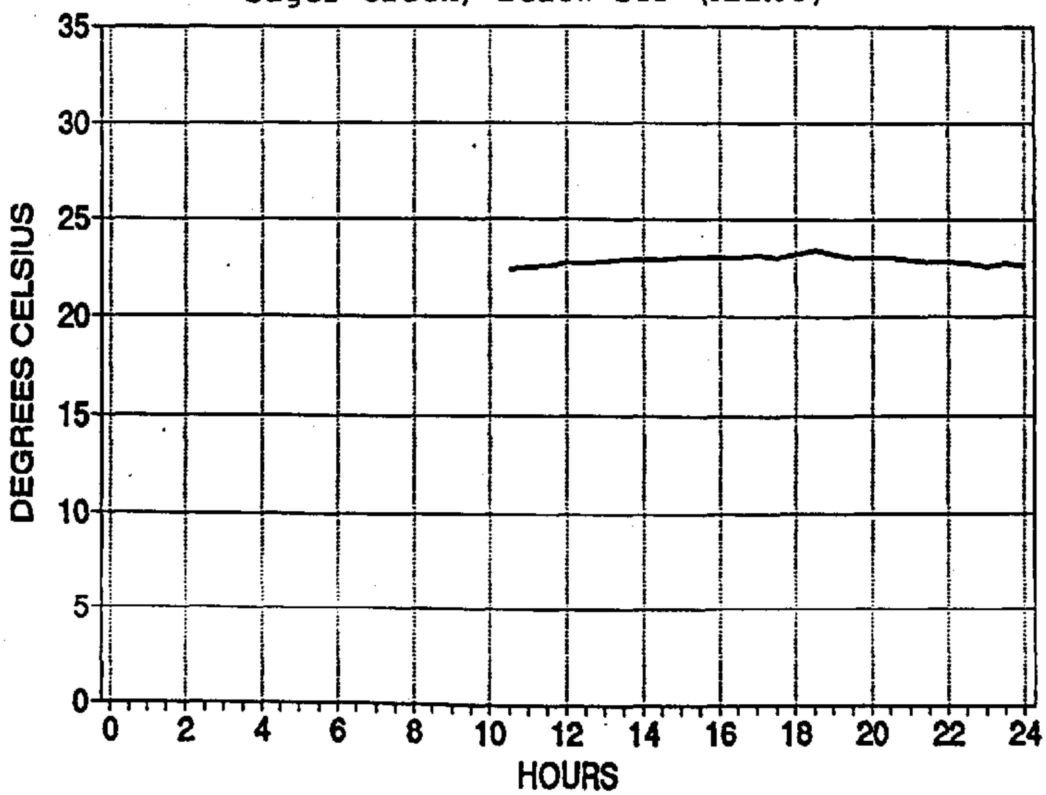


Figure WQ-5
Dissolved Oxygen, Aug. 22-24, 1994
Sager Creek, Above STP (SAG07)

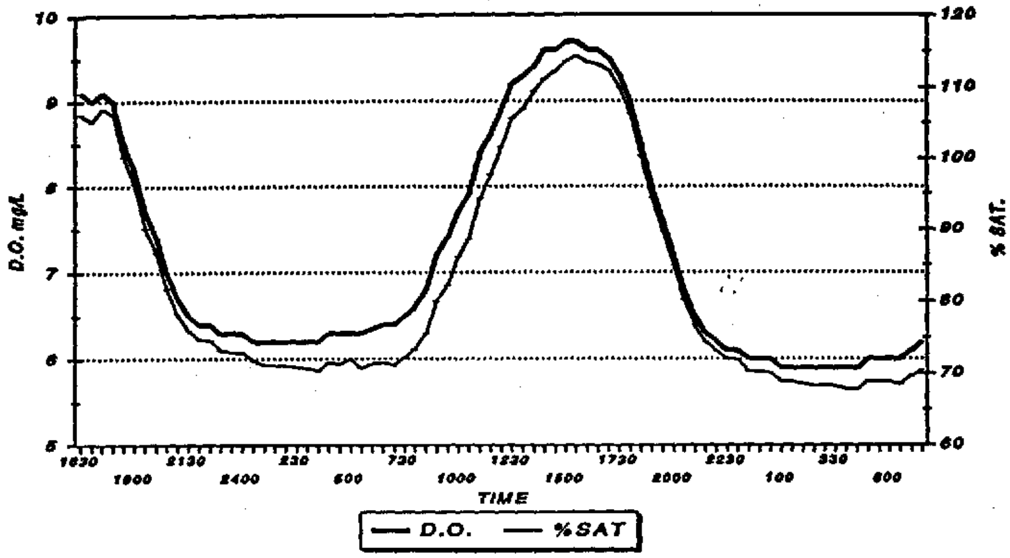


Figure WQ-6
Dissolved Oxygen, Aug. 22-24, 1994
Sager Creek, Below STP (SAG11)

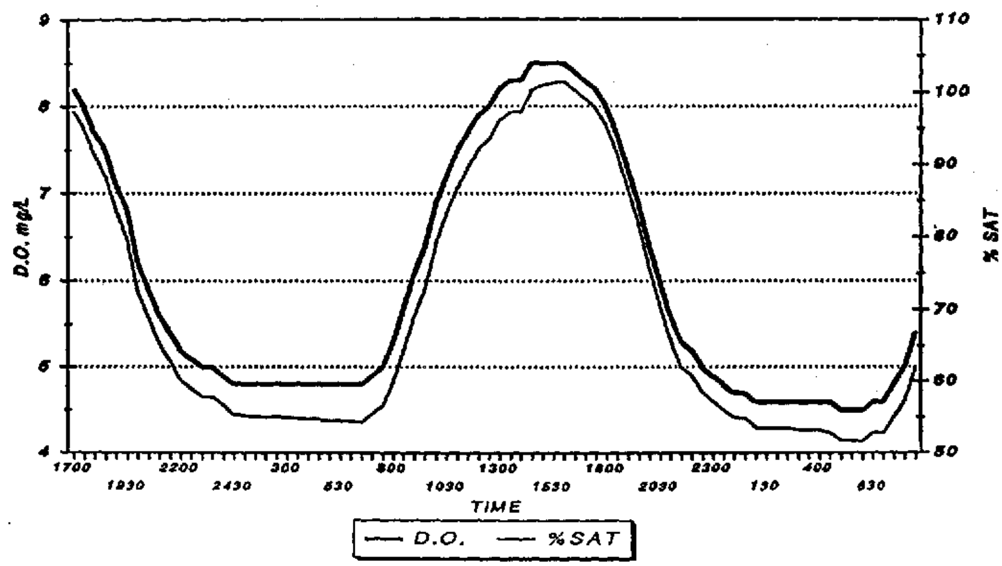
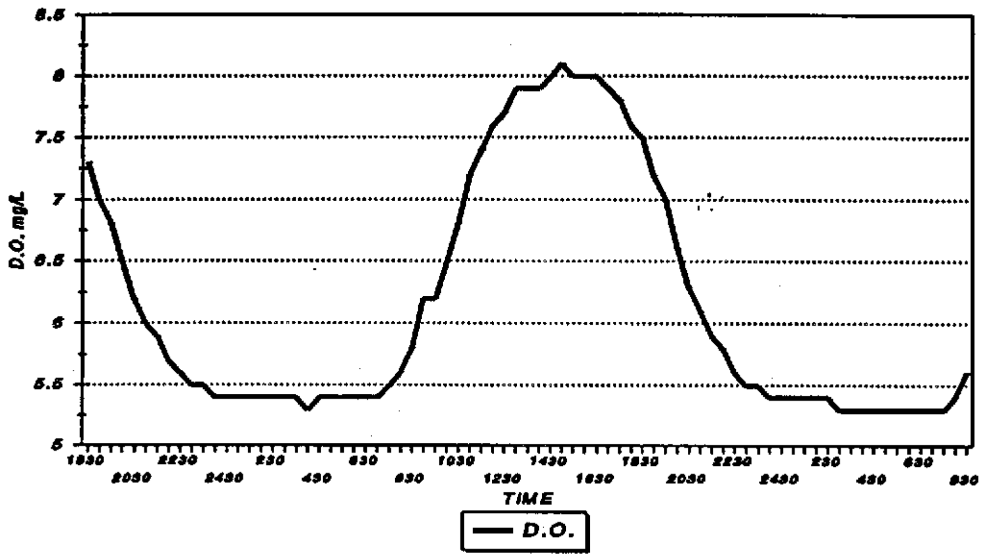


Figure WQ-7
Dissolved Oxygen, Aug. 22-24, 1994
Sager Creek, Below STP (SAG13)



pH and Temperature

Stream pH values measured during this survey were typical for streams in the Ozark Highlands ecoregion. The values ranged from 6.7 to 8.5 over the survey period. The lowest pH encountered was the spring flow dominated SAG01 site, which was generally sampled in the early morning hours. There was no definable pattern in the pH values over the survey period. No noticeable increases were observed at the stations below the STP compared to the upstream data. The 1984 ecoregion study indicated a summertime average pH of 7.6 for all size watersheds studied within the Ozark Highlands.

The stream temperatures measured during the summer months of the Sager Creek study were generally higher than those values measured in the small watershed streams of the ecoregion study. The ecoregion streams were surveyed in late September during a period of cooler weather. Summertime diurnal temperature fluctuations of approximately 3 °C were similar at all monitored stations at low flow conditions. The maximum stream temperature measured during the Sager Creek survey was 27.5 °C, which is likely due in part to the shallow depth and lack of canopy in many areas, allowing sunlight to increase the temperature. It is also noted, however, that the STP effluent has elevated temperatures.

Flow

There has been no long-term or continuous data base of flows established on Sager Creek. During this study the extremes in flows measured above the STP at SAG07 was a maximum of 47.9 CFS and a minimum of 2.9 CFS. At the furthest downstream station on Sager Creek(SAG 13) the flow extremes were 60 CFS for a maximum and 6.9 CFS as a minimum. As a comparison, the average annual flow of Flint Creek above its confluence with Sager Creek was 49.4 CFS for the period 1980-1993. This segment has a watershed size of 59.8 mi^2 . Using a watershed size ratio and assuming a similar run-off rate, the average annual flow in Sager Creek above of the STP discharge would be about 11 CFS.

Chlorides, Sulfates, and Total Dissolved Solids

A monthly water quality monitoring station has been functional on Sager Creek (ARK05) since 1974. The station is located about 1.5 stream miles below the Siloam Springs wastewater effluent discharge. This station, which was established for the purpose of monitoring the effects of the STP effluent on water quality, corresponds to the Sager Creek survey station SAG11. The 1994 biennial Water Quality Inventory Report (305-B) summarized two years of monthly samples from this site. The mean value for chlorides at this station was 30.7 mg/l, with a range from 9 mg/L to 57 mg/L. The 1983 ecoregion data indicates a "background" level of 8 mg/L for chlorides for small watershed streams in the Ozark Highlands Ecoregion. The seven survey samples collected at SAG 11 had a mean value of 38.6 mg/L. In contrast, the SAG07 station just above the STP, averaged 9.4 mg/L (Table 1).

As expected, increases were also noted in total dissolved solids (TDS). Data at ARK05, listed as a two year summary in the 1994 Water Quality Inventory Report, indicated a TDS range from 133 to 322 mg/L, with a mean of 216.4 mg/L. During the current study, TDS data at SAG11 averaged 258 mg/L. Above the STP discharge (SAG07) concentrations averaged 168 mg/L during this time frame. Ecoregion data indicated an average value of 161 mg/L for all Ozark Highland watersheds studied.

TABLE 1

SAGER CREEK WATER QUALITY DATA

STAT	DATE	TEMP °C	DO mg/l	pH	NH_3 mg/l	NO_3 mg/l	TPHOS mg/l	OPHOS mg/l	CL mg/l	TDS mg/l	SO_4 mg/l	THARD mg/l	TSS mg/l	TURB NTUs	TOC mg/l	BOD mg/l	FLOW cfs
SAG01	07/27/93	16.5	7.9	7.34	v.id	v.id	0.05	0.05	5.34	90	4.3	66.5	2	2.9	2.6	0.9	1.40
SAG01	09/13/93	20.3	9.4	8.05	0.05	v.id	0.06	0.04	4.88	126	4.5	73.8	4	3.5	2.6	1.4	0.60
SAG01	10/18/93	16.8	9.4	6.85	0.08	3.42	0.13	0.12	5.37	117	5.0	69.7	1	2.2	3.2	0.9	1.40
SAG01	11/16/93	14.7	8.1	6.92	0.08	3.11	0.12	0.03	4.53	99	6.5	48.0	2	12.0	2.0	0.8	8.50
SAG01	01/24/94	13.0	10.8	7.45	0.11	3.74	0.06	0.06	6.26	117	6.4	71.6	2	1.8	1.3	0.6	1.80
SAG01	04/11/94	15.3	8.4	6.68	0.16	1.37	v.id	0.21	4.01	129	8.0	59.4	100	58.0	vo.d	4.0	23.8
SAG01	06/28/94	16.8	7.8	7.33	0.05	3.49	0.03	0.03	7.05	113	5.1	58.5	1	2.5	2.6	1.3	1.30
SAG01A	04/11/94	13.9	9.3	6.54	0.54	3.02	v.id	0.03	4.15	96	4.8	58.2	1	4.6	vo.d	0.3	6.70
SAGT01	04/11/94	16.1	7.5	7.30	0.20	0.64	v.id	0.26	4.34	138	8.0	66.0	135	88.0	vo.d	6.6	17.1
SAGT02	07/27/93	19.0	4.8	7.21	v.id	v.id	0.15	0.08	15.40	159	10.0	124.0	3	2.5	7.3	3.0	0.05
SAGT02	09/13/93	21.2	7.5	7.89	0.05	v.id	0.10	0.06	15.80	196	11.2	122.0	2	1.2	2.3	1.2	0.11
SAGT02	10/18/93	17.4	8.4	7.09	0.07	4.58	0.08	0.08	13.70	181	11.2	112.0	2	3.8	4.1	1.1	0.07
SAGT02	11/16/93	14.6	6.9	6.88	0.05	4.44	0.08	0.03	7.12	159	18.4	95.8	2	3.0	vo.d	0.5	0.83
SAGT02	01/24/94	12.5	9.8	7.35	0.05	4.02	0.06	0.04	13.90	175	9.1	112.0	3	1.0	1.8	1.7	0.19
SAGT02	04/11/94	15.9	7.2	7.00	0.83	2.01	v.id	0.26	12.70	162	8.0	84.6	67	50.0	vo.d	8.4	3.93
SAGT02	06/28/94	18.9	6.6	7.24	0.05	2.80	0.07	0.03	13.80	162	8.4	104.0	1	0.9	2.3	0.9	0.06
SAG03	07/27/93	23.0	10.4	7.90	v.id	v.id	0.06	0.05	7.02	99	5.6	83.7	5	3.0	3.6	1.5	1.90
SAG03	09/13/93	22.8	10.8	8.45	0.05	v.id	0.05	0.03	7.99	140	6.5	90.5	4	4.7	1.9	1.2	1.10
SAG03	10/18/93	17.2	10.8	8.18	0.06	3.38	0.18	0.18	7.46	140	7.7	99.3	1	3.3	4.7	0.7	1.90
SAG03	11/16/93	12.1	9.1	6.97	0.05	3.21	0.15	0.03	4.95	121	9.9	70.8	3	12.0	vo.d	1.1	13.1
SAG03	01/24/94	10.9	11.7	7.91	0.05	3.22	0.10	0.07	7.46	138	8.3	97.3	4	2.3	1.9	1.0	3.20
SAG03	04/11/94	15.8	7.9	7.22	0.19	1.30	v.id	0.16	4.88	128	5.9	74.4	50	42.0	vo.d	4.4	37.8
SAG03	06/28/94	24.5	9.8	8.09	0.05	3.00	0.05	0.03	8.80	128	6.2	87.6	3	3.4	4.0	1.1	1.60
SAG04	07/27/93	26.0	7.2	7.70	v.id	v.id	0.07	0.04	8.23	113	6.8	102.0	4	2.5	5.4	1.2	1.20
SAG04	09/13/93	23.1	10.1	7.87	0.05	v.id	0.06	0.03	8.93	151	8.5	111.0	6	2.7	2.6	1.8	0.72
SAG04	10/18/93	17.2	7.7	7.50	0.14	3.27	0.05	0.05	7.92	147	8.9	102.0	1	2.5	3.1	1.1	2.10

TABLE 1

SAGER CREEK WATER QUALITY DATA

STAT	DATE	TEMP °C	DO mg/l	pH	NH_3 mg/l	NO_3 mg/l	TPHOS mg/l	OPHOS mg/l	CL mg/l	TDS mg/l	SO_4 mg/l	THARD mg/l	TSS mg/l	TURB NTUs	TOC mg/l	BOD mg/l	FLOW cfs
SAG04	11/16/93	11.9	9.0	v.id	0.05	2.92	0.22	0.09	5.02	126	11.0	73.2	4	14.0	vo.d	1.3	na
SAG04	01/24/94	8.5	10.3	7.55	0.05	3.02	0.06	0.05	8.44	144	8.3	103.0	1	1.4	1.6	0.5	1.40
SAG04	04/11/94	15.8	8.5	7.36	0.22	2.49	v.id	0.07	5.09	113	5.9	75.6	15	14.0	vo.d	1.6	na
SAG04	06/28/94	25.3	7.7	8.23	0.05	2.47	0.06	0.03	9.27	139	7.3	102.0	2	2.6	2.8	1.8	0.60
SAGT05S	07/27/93	19.5	11.4	7.23	v.id	v.id	0.03	0.04	11.20	165	4.3	141.0	2	1.3	4.8	1.2	0.08
SAGT05S	09/13/93	18.4	7.7	7.65	0.05	v.id	0.04	0.03	9.20	177	4.5	132.0	2	1.1	3.0	1.0	0.10
SAGT05S	10/18/93	16.9	9.0	7.31	0.05	3.08	0.05	0.05	7.84	160	6.5	117.0	1	1.3	2.0	0.4	0.07
SAGT05S	11/16/93	15.1	7.4	6.72	0.05	2.18	0.08	0.03	3.87	126	7.7	76.8	1	2.9	vo.d	0.9	0.27
SAGT05S	01/24/94	14.0	12.5	6.92	0.05	3.11	0.03	0.03	9.46	178	4.4	131.0	1	0.8	1.0	0.3	na
SAGT05S	04/11/94	14.2	6.5	6.65	0.05	2.61	v.id	0.07	5.50	141	3.7	96.6	5	9.4	vo.d	0.7	na
SAGT05S	06/28/94	17.6	5.1	7.24	0.05	3.02	0.04	0.03	11.20	178	5.1	130.0	1	0.4	2.7	1.5	na
SAGT05	07/27/93			.	.	.	.	.	.			.			.	.	dry
SAGT05	09/13/93			.	.	.	.	.	.			.			.	.	dry
SAGT05	10/18/93	17.5	8.9	7.90	0.06	1.37	0.05	0.06	7.00	142	6.5	111.0	1	1.3	5.8	0.6	0.01
SAGT05	11/16/93	14.0	8.7	v.id	0.05	2.10	0.08	0.03	3.77	2	7.7	80.3	2	2.9	vo.d	0.7	0.73
SAGT05	04/11/94	15.8	8.1	7.08	0.05	1.05	v.id	0.08	3.64	117	4.8	80.1	14	20.0	vo.d	1.8	1.08
SAGT05	06/28/94			.	.	.	.	.	.			.			.	.	dry
SAGT06	07/27/93	23.0	7.1	7.87	v.id	v.id	0.04	0.05	5.37	256	16.6	236.0	2	1.4	10.3	0.6	0.03
SAGT06	09/13/93	22.3	7.8	8.25	0.05	v.id	0.11	0.05	5.33	244	23.9	190.0	1	2.7	8.9	3.3	0.01
SAGT06	10/18/93	16.9	6.8	7.75	0.05	0.16	0.04	0.04	5.17	279	26.4	229.0	1	1.2	8.7	0.8	0.07
SAGT06	11/16/93	10.4	8.3	v.id	0.05	0.74	0.10	0.03	3.80	195	16.7	149.0	7	28.0	vo.d	1.7	0.21
SAGT06	01/24/94	6.8	11.0	7.71	0.05	0.14	0.03	0.03	5.36	224	23.7	192.0	1	2.0	2.6	0.5	0.15
SAGT06	04/11/94	16.2	8.1	7.62	0.17	0.25	v.id	0.07	4.68	165	11.9	105.0	48	58.0	vo.d	4.8	5.30
SAGT06	06/28/94	23.3	4.9	7.88	0.05	0.24	0.04	0.03	5.38	280	17.3	242.0	2	3.2	3.3	0.6	<0.1
SAG07	07/27/93	24.8	6.7	8.02	0.05	v.id	0.08	0.10	11.20	126	7.9	109.0	1	1.0	4.7	1.1	3.50
SAG07	09/13/93	23.0	8.6	8.94	0.05	v.id	0.05	0.06	8.60	157	9.4	110.0	2	1.3	2.1	1.0	2.90
SAG07	10/18/93	16.8	9.7	7.90	0.06	2.72	0.05	0.06	7.56	151	10.1	98.5	1	1.0	4.8	1.0	3.40

TABLE 1

SAGER CREEK WATER QUALITY DATA

STAT	DATE	TEMP °C	DO mg/l	pH	NH_3 mg/l	NO_3 mg/l	TPHOS mg/l	OPHOS mg/l	CL mg/l	TDS mg/l	SO_4 mg/l	THARD mg/l	TSS mg/l	TURB NTUs	TOC mg/l	BOD mg/l	FLOW cfs
SAG07	11/16/93	10.9	10.2	7.49	0.05	2.61	0.23	0.07	5.16	139	11.0	81.5	2	12.0	vo.d	1.2	22.0
SAG07	01/24/94	8.1	12.9	7.90	0.10	2.70	0.04	0.05	8.42	153	10.0	111.0	1	1.1	1.6	0.5	2.10
SAG07	04/11/94	16.0	8.6	6.95	0.20	v.id	v.id	0.08	5.99	128	9.0	80.1	19	21.0	vo.d	2.3	47.9
SAG07	06/28/94	25.7	8.2	7.80	0.05	1.94	0.07	v.id	9.66	151	7.3	105.0	1	1.7	2.5	0.6	2.90
SAG08E	07/27/93	28.6	7.0	7.63	0.05	v.id	2.48	2.04	104.00	422	28.7	140.0	2	2.3	9.4	0.6	4.40
SAG08E	09/13/93	24.2	8.8	7.33	0.05	v.id	2.34	2.13	90.10	402	34.8	137.0	6	2.0	6.1	3.2	5.90
SAG08E	10/18/93	21.2	9.9	7.60	0.05	10.30	2.28	2.26	67.70	337	35.7	129.0	2	3.5	7.3	2.5	4.60
SAG08E	11/16/93	13.3	10.8	7.58	0.05	7.74	0.91	0.48	47.40	270	22.4	109.0	8	4.9	vo.d	3.4	*6.2
SAG08E	01/24/94	12.5	11.0	7.60	0.08	13.60	2.66	2.28	90.60	392	26.5	131.0	7	4.7	8.6	1.1	4.20
SAG08E	04/11/94	16.9	9.4	6.95	0.13	v.id	v.id	1.48	10.80	265	18.8	111.0	26	7.4	vo.d	3.8	7.80
SAG08E	06/28/94	28.5	8.0	7.70	0.05	14.50	*3.15	v.id	121.00	468	21.2	142.0	2	1.4	5.7	0.7	4.20
SAG09	07/27/93	26.8	6.2	7.68	0.05	v.id	1.33	1.16	62.30	286	20.8	132.0	4	1.7	7.0	0.8	6.40
SAG09	09/13/93	24.7	7.7	7.64	0.05	v.id	1.77	1.65	70.20	345	29.7	132.0	6	3.0	6.2	3.5	10.6
SAG09	10/18/93	19.3	8.9	7.80	0.05	7.27	1.37	1.36	40.70	258	26.4	121.0	1	1.8	8.0	0.6	8.20
SAG09	11/16/93	12.1	10.1	7.64	0.05	4.02	0.39	0.19	14.90	173	15.8	94.8	4	8.8	vo.d	1.4	27.3
SAG09	01/24/94	10.4	11.2	7.20	0.05	8.58	1.39	1.22	51.00	284	18.6	124.0	4	2.4	3.8	1.0	7.30
SAG09	04/11/94	16.2	8.7	7.92	0.16	v.id	v.id	0.33	12.00	152	10.9	94.5	22	21.0	vo.d	2.7	65.0
SAG09	06/28/94	27.2	8.6	7.70	0.05	10.50	1.89	v.id	80.70	344	16.4	131.0	1	1.8	4.6	1.1	7.10
SAGT10	07/27/93	19.9	6.5	7.48	0.05	v.id	0.06	0.08	5.41	177	6.8	177.0	1	0.8	5.6	0.8	0.10
SAGT10	09/13/93	20.8	8.8	7.44	0.05	v.id	0.07	0.10	4.83	178	4.5	143.0	1	2.2	4.0	1.5	ef
SAGT10	10/18/93	16.8	10.1	7.30	0.05	2.47	0.07	0.09	5.63	221	11.2	177.0	1	1.0	6.9	1.4	0.10
SAGT10	11/16/93	12.2	9.3	7.35	0.05	2.30	0.17	0.04	4.18	175	14.0	134.0	1	4.4	vo.d	1.0	0.73
SAGT10	01/24/94	10.5	11.5	7.60	0.05	1.59	0.06	0.09	7.32	221	17.9	182.0	1	0.7	1.9	0.7	0.10
SAGT10	04/11/94	14.9	8.8	7.92	0.06	v.id	v.id	0.14	5.38	176	13.7	119.0	42	60.0	0.0	2.5	3.22
SAGT10	06/28/94	20.5	6.7	7.13	0.05	2.38	0.14	v.id	5.39	208	6.2	179.0	1	1.2	2.1	0.6	0.05
SAG11	07/27/93	24.2	6.9	7.71	0.05	v.id	0.70	0.60	41.30	226	14.8	139.0	1	0.7	7.0	0.7	7.90
SAG11	09/13/93	22.8	8.3	7.68	0.05	v.id	0.85	0.85	46.60	271	18.6	136.0	1	0.8	3.9	0.6	9.60

TABLE 1

SAGER CREEK WATER QUALITY DATA

STAT	DATE	TEMP °C	DO mg/l	pH	NH_3 mg/l	NO_3 mg/l	TPHOS mg/l	OPHOS mg/l	CL mg/l	TDS mg/l	SO_4 mg/l	THARD mg/l	TSS mg/l	TURB NTUs	TOC mg/l	BOD mg/l	FLOW cfs
SAG11	10/18/93	17.9	8.8	7.80	0.07	6.04	0.82	0.81	32.30	233	19.0	134.0	1	1.0	6.3	0.5	10.0
SAG11	11/16/93	12.1	9.5	7.32	0.05	3.67	0.35	0.17	11.20	170	13.0	104.0	2	6.6	vo.d	0.9	42.8
SAG11	01/24/94	10.0	11.1	7.60	0.05	7.44	0.65	0.60	36.90	244	15.6	137.0	1	1.0	2.6	0.9	11.4
SAG11	04/11/94	15.8	7.8	7.73	0.05	v.id	v.id	0.36	13.80	35	10.9	110.0	35	27.0	vo.d	2.7	84.6
SAG11	06/28/94	25.5	7.6	7.40	0.05	6.44	0.87	v.id	48.70	267	11.2	179.0	1	1.0	2.9	0.6	8.00
SAG12	07/27/93	24.8	7.2	7.82	0.05	v.id	0.61	0.53	40.80	221	13.9	146.0	1	1.0	5.4	0.4	5.20
SAG12	09/13/93	22.8	9.0	7.92	0.05	v.id	0.69	0.79	40.00	242	15.4	125.0	1	1.4	3.5	0.8	ef
SAG12	10/18/93	17.5	9.3	7.90	0.05	5.95	0.68	0.70	34.10	236	16.2	128.0	1	1.0	4.1	0.4	6.90
SAG12	11/16/93	11.7	9.5	7.51	0.05	3.44	0.36	0.20	10.20	161	12.0	100.0	2	4.2	vo.d	0.5	46.1
SAG12	01/24/94	9.1	12.0	7.80	0.05	6.90	0.50	0.50	34.80	236	14.1	134.0	1	0.8	2.1	1.0	10.1
SAG12	04/11/94	15.8	9.0	7.93	0.07	v.id	v.id	0.32	46.50	152	10.0	105.0	9	4.6	vo.d	1.0	68.4
SAG12	06/28/94	25.0	6.6	7.60	0.05	6.32	0.63	v.id	45.80	261	11.2	138.0	1	0.8	3.1	0.6	5.90
SAG13	07/27/93	22.9	6.8	7.66	0.05	v.id	0.46	0.41	33.10	216	12.0	138.0	1	1.1	4.0	0.6	6.90
SAG13	09/13/93	20.8	7.6	7.37	0.05	v.id	0.54	0.61	40.20	251	14.6	130.0	1	0.8	3.1	1.0	ef
SAG13	10/18/93	17.6	8.2	8.10	0.05	5.64	0.52	0.54	33.50	235	14.3	129.0	1	1.0	6.0	0.4	9.30
SAG13	11/16/93	12.1	9.1	7.17	0.05	3.40	0.40	0.22	11.50	162	12.0	102.0	5	5.3	vo.d	0.8	60.0
SAG13	01/24/94	9.4	11.2	7.50	0.05	5.96	0.38	0.37	30.60	214	12.5	131.0	1	0.7	1.7	0.4	12.2
SAG13	04/11/94	15.2	9.2	8.02	0.05	v.id	v.id	0.30	13.00	166	9.0	110.0	11	3.0	vo.d	0.8	77.1
SAG13	06/28/94	22.0	8.6	7.35	0.05	4.70	0.45	v.id	44.60	227	9.3	134.0	1	1.5	2.0	0.3	9.00

Voids -- Data did not meet laboratory QA/QC requirements.
ef -- Equipment failure.
na -- Unable to measure
* SAG08E -- flow data on 11/16/93 and TPhos on 6/28/94 are calculated values.

Sulfate concentrations in the Sager Creek watershed were relatively high when compared with background ecoregion data. The summertime ecoregion average for all Ozark Highland watersheds surveyed in the 1980's was only 5 mg/L, with the small watersheds averaging only 1.5 mg/L. Contrasting these low numbers is the SAG07 average of 9.2 mg/L. These high sulfates may reflect the nature of the watershed drained which includes urban dominated areas and a golf course adjacent to the stream. The SAG11 site averaged 17.1 mg/L sulfates during the survey, while the 1994 Water Quality Inventory data indicates an average concentration of 16.4 mg/L at this site.

Biochemical Oxygen Demand, Total Suspended Solids, and Turbidity

The Siloam Springs wastewater treatment facility is very efficient in BOD_5 and TSS removal. The Sager Creek survey data revealed BOD_5 concentrations slightly higher at the upstream site (SAG07) than below the STP at SAG11. These values, however, are very low at both locations and the effluent BOD_5 was not measured above 4 mg/L during the study. During low-flow sampling events, TSS values averaged just over 1 mg/L at both upstream and downstream locations. Only during one storm event did the TSS value at any station exceed 10 mg/L. As might be expected, turbidity values were also very low except during major storm events. All turbidity values were below 5 NTU except during the November 1993 and/or the April 1994 high-flow events. The highest values occurred in the upstream area of Sager Creek and in the tributaries during the April 1994 storm event. The downstream (below the downtown pools) areas had much lower turbidity values even during the highest flows. This may have been the result of settling some of the suspended materials in the pools of the downtown area.

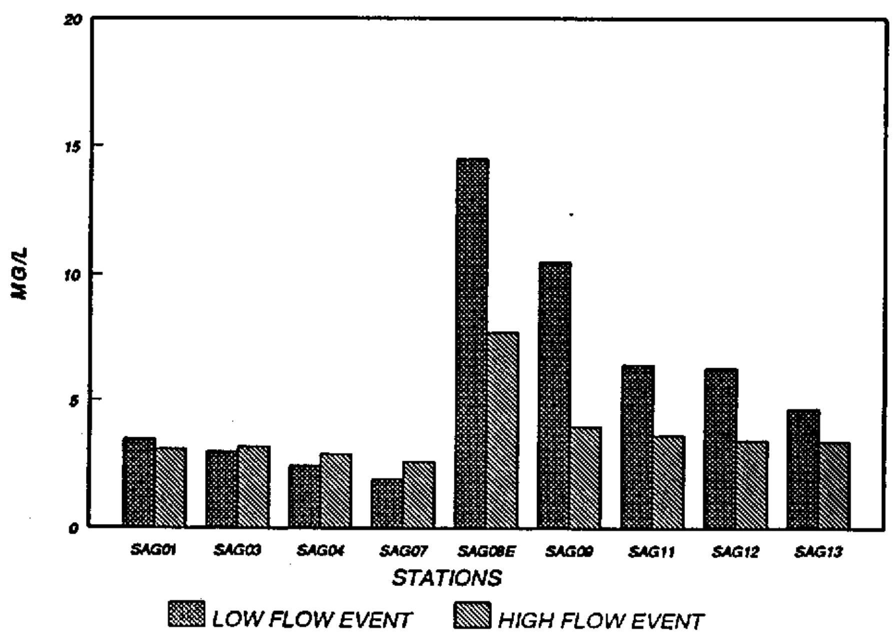
Nutrients

Ammonia nitrogen values were very low at all sites during the survey. However, slightly elevated levels were noticed at all stations during storm event flows; at site SAG01 where groundwater contributes to a large part of the total flow; and at SAG04 which is at the lower end of the downtown pools. The highest value was 0.83 mg/L at SAGT02 which is a small tributary that receives its base flow from a spring area. The high value, however, was recorded during a storm event and a sewer line overflow was noticed adjacent to this tributary. The Siloam Springs effluent discharge had ammonia nitrogen values below 0.2 mg/L during each sampling event.

Nitrite plus nitrate nitrogen, which will subsequently be referred to as "nitrates", demonstrated elevated values throughout much of the watershed. Stations with strong groundwater influence such as SAG01 and SAGT02 have nitrate values regularly in the 3.5 mg/L to 4 mg/L range except when elevated surface runoff occurs and causes dilution. These values may also be seasonally influenced with slightly higher values occurring during the dormant period of plant uptake. However, the most obvious input of nitrates into Sager Creek is the Siloam Springs STP. This discharge had nitrate values of 7.7 mg/L to 14.5 mg/L.

Figure WQ-8 shows the nitrate concentrations at all of the stations on Sager Creek during a low-flow sampling event and during a high-flow event. The low-flow period selected was on June 28, 1994, when the flow at the uppermost station on Sager Creek was 1.3 CFS and at the lowest station the flow was 9.0 CFS. In comparison, the high-flow sampling event occurred on November 16, 1993, when the upstream flow was 8.4 CFS and the downstream flow was 60 CFS.

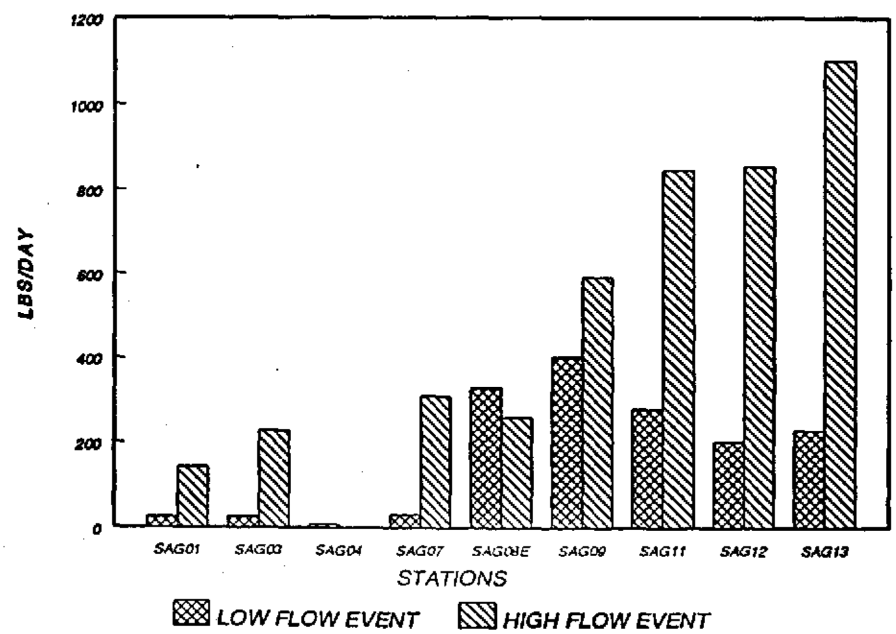
Figure WQ-8
Sager Creek Stations
Nitrate-Nitrogen Concentrations



During the low-flow event the nitrate concentration at the STP discharge was noticeably elevated over the upstream station (SAG07) and was somewhat higher than that recorded in the effluent during the high-flow event. Nitrate values decline rather sharply below the discharge during both low-flow and high-flow events. These declines are probably caused by plant-life utilization during the warm, low-flow period and by dilution during the high-flow event. The mass loading of nitrates (lbs/day) during the same sampling events are shown in Figure WQ-9. Nitrate loading was much higher above the STP during the high-flow event compared to the low-flow event. The loads from the discharge (SAG08E), however, were nearly the same. During the high-flow event, the nitrate load progressively increased in a downstream direction. Whereas, during the low-flow event, the load increased sharply below the effluent discharge, then began a gradual decline downstream.

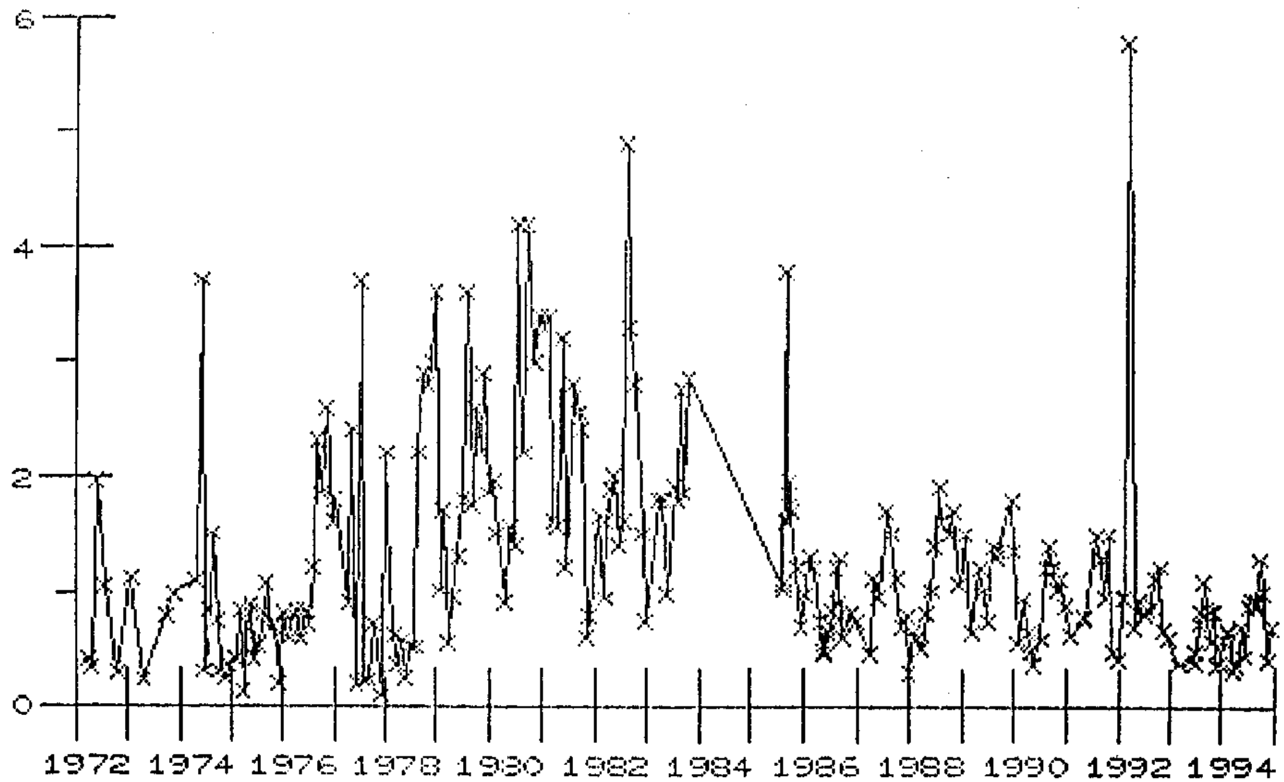
The total phosphorous values in Sager Creek over the past 22 years, at the routine monitoring station ARK05(SAG11) are plotted in Figure WQ-10. These results indicate a substantial reduction and a more consistent level of total phosphorous at this station since a major upgrade in the Siloam Springs STP was completed in the mid 1980's. During the synoptic survey the total phosphorous levels in the effluent were generally just over 2 mg/L. Above the STP, total phosphorous values were normally below 0.2 mg/L. The highest

Figure WQ-9
Sager Creek Stations
Nitrate-Nitrogen Loads



1116APCC 050005 ARK05 SAG11 36 11 50.0 094 35 00.0
SAGER C NR SILOAM SPRINGS ARK 40041 OKLAHOMA
D
ARKANSAS TULSA TO VAN BUREN SW LOWER MISSISSIPPI

665 PHOS-TOT MG/L P



1972-1994

Figure WQ-10

upstream value was 0.23 mg/L at SAG 07 during the November 1993 high-flow event. However, during the maximum storm event which was sampled on April 11, 1994, total phosphorus analyses were voided due to failure of quality control. It is likely these values were higher than the others due to the very heavy silt loads carried by this storm event.

Figure WQ-11 and WQ-12 are plots of the concentrations and loads of total phosphorus at all Sager Creek stations during the same high-flow and low-flow event selected for nitrate analyses. Upstream total phosphorus concentrations, although relatively low, were approximately three times higher at SAG07 during the high-flow event than during low-flow. As expected, the STP discharge had significantly higher levels than the upstream station during both sampling events. During the low-flow event, total phosphorus was about three times greater than the high-flow sample of the effluent (SAG08E). However, the phosphorus concentration of the effluent during the high-flow sample was a calculated value which was determined from the load difference between stations immediately upstream and downstream from the effluent discharge. The STP discharge caused phosphorus concentrations to be noticeably elevated immediately downstream during the low-flow event, but the concentration shows a sharp decline in a downstream direction below SAG09 which is the first station below the discharge. This is most evident during the low-flow event. Although concentrations also decline below SAG09 during the high-flow event this change was very slight and probably reflects a net change between dilution of the STP effluent and non-point source additions downstream.

As shown in Figure WQ-12 the total phosphorus load increases progressively from the headwater station to the last station on Sager Creek during the high-flow event, and the input from the point source is masked by the non-point contribution. During low-flow, the load increases from about 1 lb/day above the discharge to just over 70 lbs/day below the discharge, and as with the concentration, this load declines noticeably downstream from SAG09. This decline is primarily through the assimilation process rather than by dilution. First order decay rates were calculated between stations SAG09 and SAG12 using the total phosphorus loads and concentrations from the low-flow event example of June 28, 1994. The decay rate was -0.34/mile. This was a relatively high decay rate. It was similar but somewhat higher than rates calculated for other small streams in the area which receive STP discharges such as Spring Creek (Springdale STP) and upper Osage Creek (Rogers STP).

Figure WQ-11
Sager Creek Stations
Total Phosphorus Concentrations

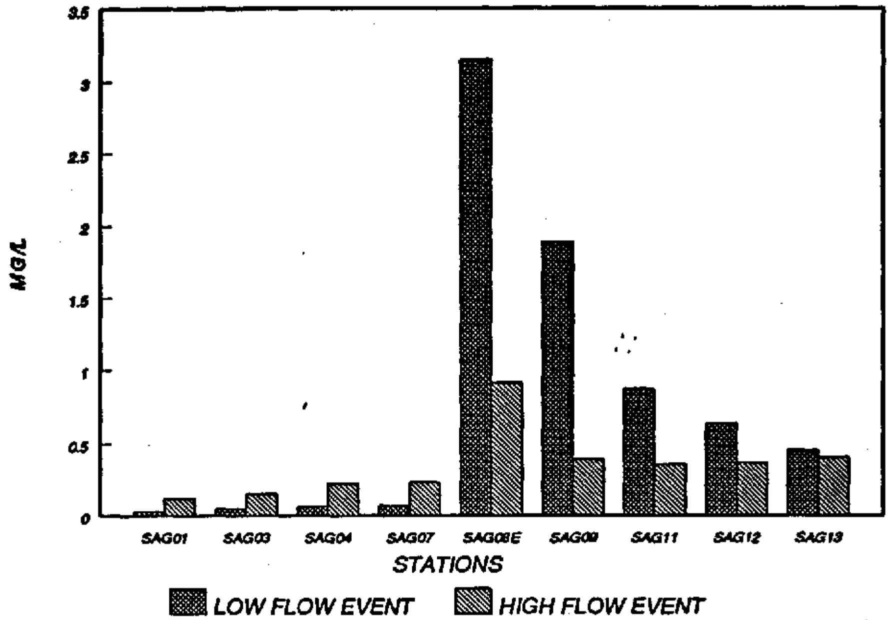
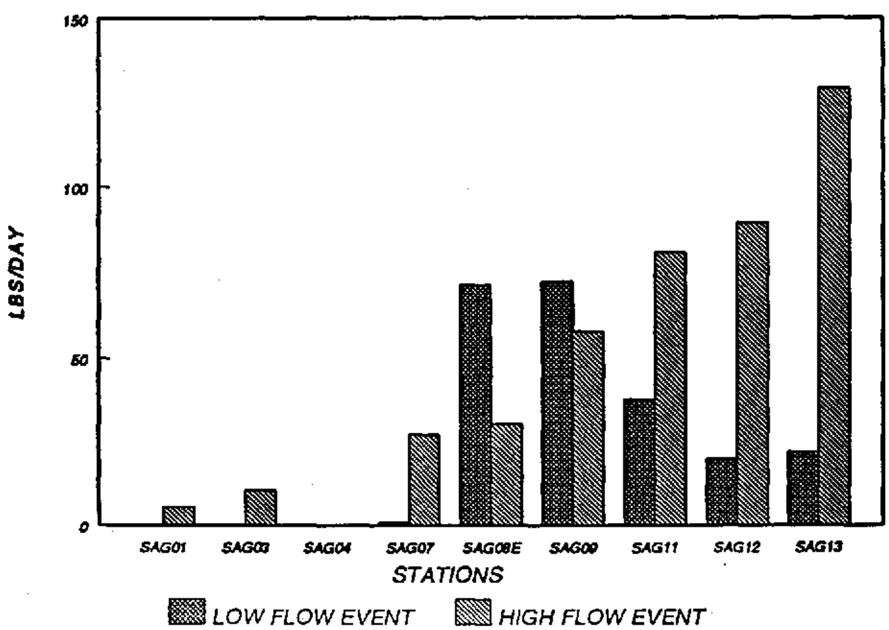


Figure WQ-12
Sager Creek Stations
Total Phosphorus Loads



PERIPHYTON PRODUCTION

Periphyton sampling was conducted by the Oklahoma Conservation Commission employees by using artificial substrate periphytometers. The procedures used were as described in their "Standard Operating Procedures for Placement and Retrieval of Periphytometers". Sampling was performed at stations SAG07 (above the STP), at SAG11, and SAG13 below the discharge and in the reference streams of Battle Branch in Oklahoma and Flint Creek in Arkansas. Samples were collected after a two week incubation period in July, September, and December of 1993, and in January of 1994. Five periphytometers were installed at each site during each sampling period. The results reported are the mean values of the five replicates.

Figures P-1 and P-2 show the results of chlorophyll ā and pheophytin at the Sager Creek sites and the two reference streams during the warm weather sampling in July and September. The first station below the discharge (SAG11) shows higher values of chlorophyll ā and pheophytin than the other stations on Sager Creek; however, the next downstream station shows a substantial reduction to near or below background and/or reference stream values. Very high average values were recorded in the Arkansas reference stream (Flint Creek) in the September sample. This resulted from two of the five periphytometers yielding values 10 fold higher than the other three. This produced a standard deviation of the sample of 93% of the mean value. Similarly the standard deviation of the SAG11 sample in September was greater than the mean value because of one very high value.

Pheophytin, which is a by-product of chlorophyll ā degradation, is often used as an indication of the health of the periphyton community. Although station SAG11 had the highest pheophytin values, all pheophytin values are very low in relation to the healthy chlorophyll ā at all stations during both warm weather samples.

In late June of 1978, artificial substrate periphytometers of a different type were installed in Sager Creek above and below the Siloam Springs STP at locations near the SAG07 and SAG11 stations. During the earlier study, chlorophyll ā values were three to four times lower on the periphytometers than in 1993; however, the natural substrate below the STP was described in the 1978 report as heavily overgrown with long strands of filamentous algae and other epilithic growths. Also, the pheophytin values at the downstream station were greater than the chlorophyll ā values, indicating a very unhealthy periphyton community. An autotrophic index in 1978 for this station indicated excessive organic pollution.

Figure P-1
Periphyton Production
July 1993

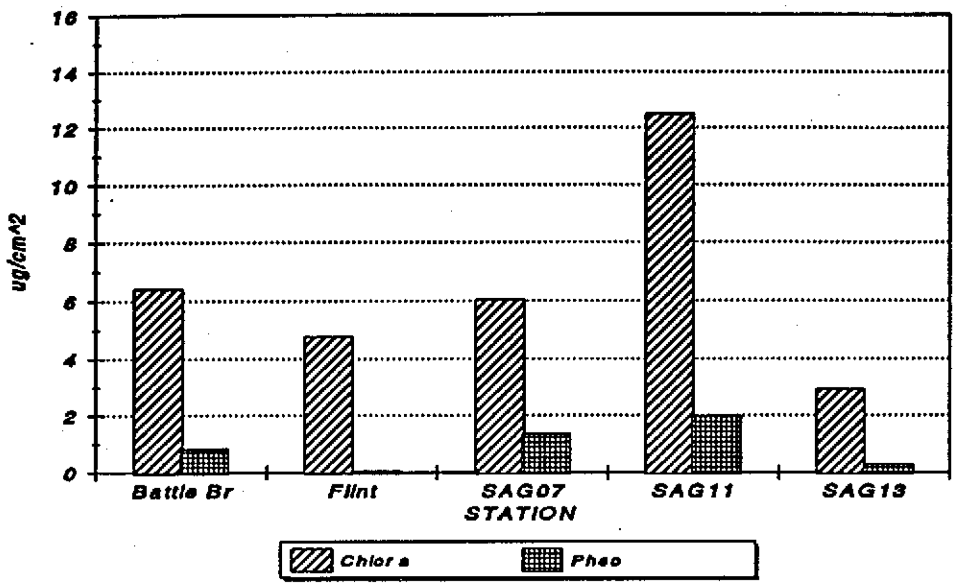
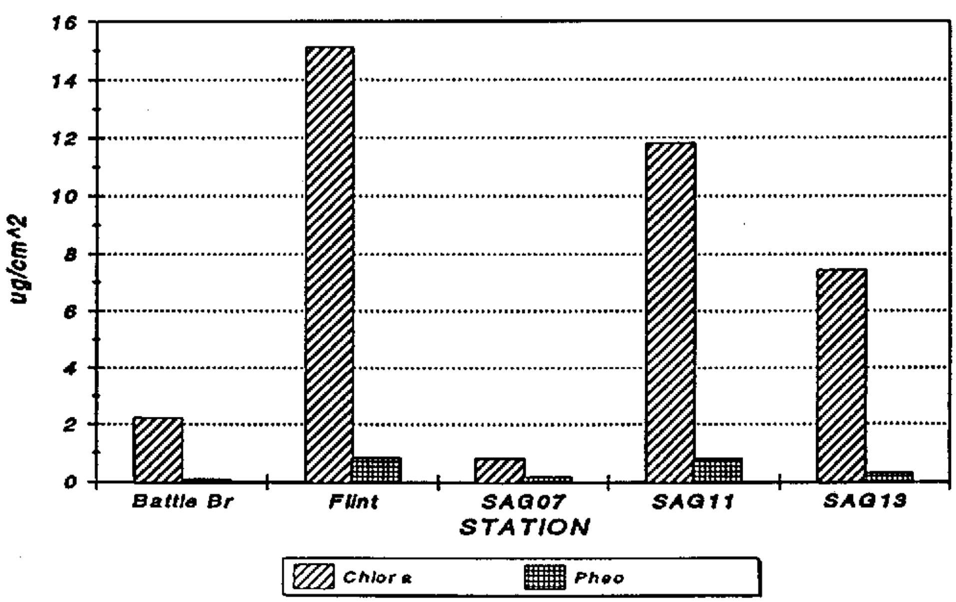


Figure P-2
Periphyton Production
September 1993



Although the recent data shows an increase in chlorophyll ā at the first station below the discharge, this data indicates these periphyton communities are relatively normal and healthy. In addition, visual comparisons indicate a notable improvement since 1978, and the absence of the prolific growths of long-strand filamentous algae. This is due to the upgrade of the Siloam Springs sewage treatment plant in 1988.

Figures P-3 and P-4 display the periphyton data from December, 1993 and January, 1994. The scale on these figures represent a four fold reduction from Figures P-1 and P-2. Chlorophyll ā and pheophytin values during this period were significantly reduced and were generally quite similar among all stations. The seasonal variability of chlorophyll ā is demonstrated in Figure P-5.

Figure P-3
Periphyton Production
December 1993

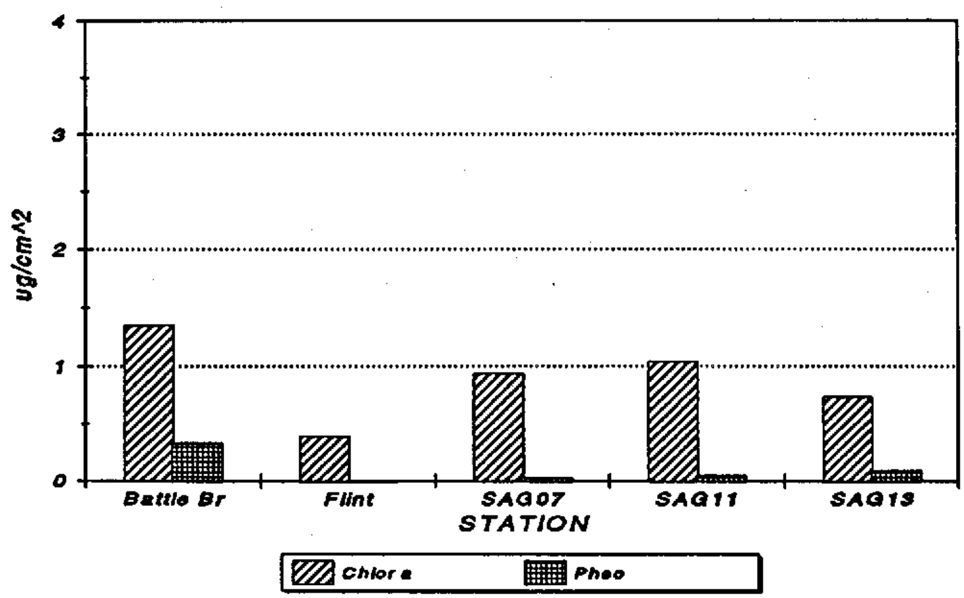


Figure P-4
Periphyton Production
January 1994

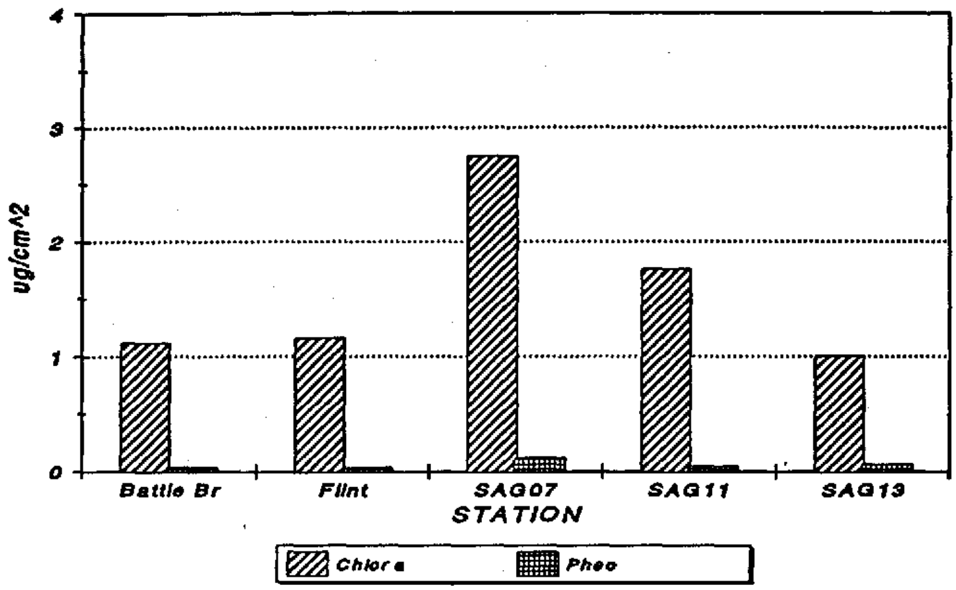
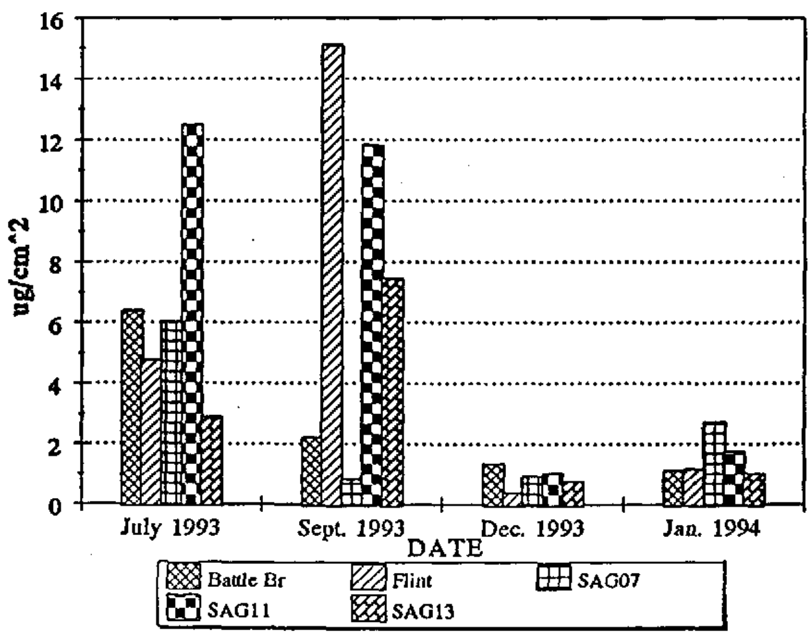


Figure P-5
Chlorophyll ā



MACROINVERTEBRATE COMMUNITIES

Macroinvertebrates were collected from Sager Creek and selected reference streams on October 5 and 6, 1993 by Oklahoma Water Resources Board (OWRB) staff. The selected reference streams included Battle Branch Creek and Flint Creek. Sager Creek sites 7 11, and 13 were sites sampled on Sager Creek. Sager Creek site 7 was upstream of the Siloam Springs Sewage Treatment Plant (STP) and Sager Creek sites 11 and 13 were downstream of the Siloam Springs STP. One site was selected on each of the reference streams.

METHODOLOGY

Rapid Bioassessment Protocols for Use in Streams and Rivers (EPA 440/4-89-001, May 1993) was used as guidance for the collection of aquatic macroinvertebrates. Habitat type at each site was assessed for representativeness and availability. At all sites (including reference sites and Sager Creek sites), riffle areas were most abundant. Other habitat (i.e., woody debris and streamside vegetation) was not sampled for this study.

A 1.0 meter by 1.0 meter benthic seine was used to sample aquatic macroinvertebrates. The seine was positioned downstream of riffle areas. The riffle was agitated allowing the organisms to drift into the seine. Agitation of the riffle continued for a total of three (3) minutes or until a representative sample was collected from the site. Macroinvertebrate samples were preserved in 90% ethanol for identification in the laboratory.

In the laboratory, macroinvertebrates were rinsed and placed in a plastic tray with numbered grids. A random number chart was used to select grids from which organisms were subsampled and placed into a vial containing 90% ethanol. This method continued until all grids were exhausted or the subsample consisted of 100 organisms. The subsample was identified to family level using The Aquatic Insects of North America, 2nd ed. (Merritt and Cummins) and Freshwater Invertebrates of the United States, 3rd ed. (Pennak). Subsequent to identification, data was entered into a lotus spreadsheet containing calculation metrics for aquatic macroinvertebrates.

RESULTS AND DISCUSSION

Data analysis techniques included the use of eight (8) metrics developed for Rapid Bioassessment Protocol II (RBP II). These metrics consisted of the following: Taxa Richness; Family Biotic Index (FBI); Ratio of Scraper and Filtering Collector Functional Feeding Groups; Ratio of Ephemeropteran, Plecopteran, Trichopteran (EPT) and Chironomidae Abundances; Percent Contribution of Dominant Family; EPT Index; Community Loss Index; and Functional Group % Similarity. Although a 100 organism subsample is generally used in RBP II, some instances exist where the total number of organisms is less than 100. In general, metric variability increases with decreasing sample size. In this case, some variability exists due to the low number of individuals collected at Sager Creek site 13. During this assessment, only 41 total organisms were collected from Sager Creek site 13, whereas, over 100 total organisms were collected from the reference sites and Sager Creek sites 7 and 11. The low number of individuals at site 13 may reflect potential impacts during the sampling event. Subsequent assessments are necessary to confirm natural instream conditions of Sager Creek.

Table M-1 is a list of taxa collected from the reference sites and Sager Creek sites. The table also indicates taxa richness to the family level and total number of individuals. Results of the metric calculations are discussed later and shown in subsequent tables and graphs. Additional information regarding the metrics for RBP II can be obtained from Rapid Bioassessment Protocols for Use in Streams and Rivers (EPA, 1989).

Assumptions regarding stream impairment as a result of point source impacts are difficult to determine based on a single sampling event. Additionally, activities resulting in nonpoint source impacts on an aquatic community must be considered for a more accurate assessment. The existing biological condition of Sager Creek can be determined with some degree of certainty using the criteria for characterization of biological condition for RBP II (Table M-2 and M-3); however, some uncertainty is inherent in the sampling protocol. Bar graphs representing metric comparisons between Sager Creek and the reference streams (Figures M-1 through M-8) and pie charts illustrating functional feeding group distribution (Figure M-9) show the overall relative condition of Sager Creek.

Table M-1. Sager Creek Macroinvertebrate Community

Order	Family	FBI Tol	Feeding Group	Battle Br.	Flint Ck.	Sager Ck. Site 7	Sager Ck. Site 11	Sager Ck. Site 13
Oligochaeta	Tubificidae	10	Col					1
Hirudinea		8	Pre	1			2	
Gastropoda	Lymnaeidae	9	Scr					
	Pleuroceridae	4	Scr					17
Isopoda	Asellidae	8	Col	1	5			2
Amphipoda	Talitridae	7	Col	2				
Decapoda	Cambaridae	5	Col	1	2	1	1	1
Ephemeroptera	Baetidae	4	Col	20	5	11	35	9
	Caenidae	7	Col			5		
	Heptageniidae	4	Scr	3	13	18	4	2
	Oligoneuriidae	2	Col	1		3	3	
Anisoptera	Gomphidae	1	Pre	1				
Zygoptera	Coenagrionidae	9	Pre			2		
Plecoptera	Perlidae	1	Pre	5	9		7	1
Coleoptera	Elmidae	4	Scr	1	3	3	19	2
	Psephenidae	4	Scr	34	22	15	12	5
Megaloptera	Corydalidae	3	Pre		3	6	7	1
Diptera	Chironomidae	6	Col	1	2	8	2	
	Tabanidae	6	Pre		2			
Trichoptera	Hydropsychidae	4	Fil	23	14	18	5	
	Philopotamidae	3	Fil	3	6	1		
	Polycentropodidae	6	Pre	4	15	7		
Total Number of Individuals:				101	101	98	97	41
Taxa Richness (Family):				15	13	13	11	10

Table M-2 represents the metric value comparison of Sager Creek sites 11 and 13 with Flint Creek. Number of taxa, FBI, functional feeding group abundance for specified taxa, and the EPT index were scored based on criteria outlined in Rapid Bioassessment Protocols for Use in Streams and Rivers (EPA, 1989). The total scores indicate sites 11 and 13 may be moderately impaired when compared to metrics calculated from Flint Creek data. Table M-3 represents the metric value comparison of Sager Creek sites 7, 11, and 13 with Battle Branch Creek. The total score indicates potential moderate impairment of the Sager Creek sites.

Metric Evaluation

Taxa Richness

Figure M-1 is a plot representing taxa richness at each site. Taxa Richness was highest at the reference streams and Sager Creek site 7. Taxa Richness was lowest at Sager Creek sites downstream of the STP. Low taxa richness may be the result of a shift in available food sources and habitat availability. Collectors and scrapers were the dominant functional feeding groups at the downstream sites indicating the primary food source was fine particulate organic matter (FPOM) and periphyton. The increase in FPOM is often the result of an overabundance of filamentous algae. Causes for the lower diversity at Sager Creek site 13 are not known at this time; although it could be related to the less than optimum number of organisms collected at this site. Therefore, subsequent sampling events are necessary to verify macroinvertebrate community conditions at Sager Creek site 13.

Family Biotic Index

Figure M-2 is a plot representing the modified FBI at each site. The modified FBI was developed from Hilsenhoff (Hilsenhoff, 1988) to detect organic pollution. Tolerance values range from 0 to 10, increasing as organisms tolerant to organic pollution increase. Data collected during this study indicate Sager Creek site 7 (above STP) and site 13 (the farthest downstream site) have higher FBI values reflecting an aquatic community that is more tolerant of organic enrichment.

Table M-2. Metric Value Comparison of Sager Creek Sites 11 and 13 with Flint Creek

7	Sager 11	Score	Sager 13	Score
Number of Taxa[a]	85%	6	77%	3
Family Biotic Index[b]	111%	6	99%	6
Scrapers/(Filterer + Scraper) Abundances[a]	134%	6	153%	6
EPT/(Chironomid + EPT) Abundances[a]	100%	6	103%	6
EPT Index[a]	83%	3	50%	0
TOTAL SCORE	27		21	
Biological Condition Category	Moderately Impaired[c]		Moderately to severely Impaired[c]	

Table M-3. Metric Value Comparison of Sager Creek Sites with Battle Branch Creek

	Sager 07	Score	Sager 11	Score	Sager 13	Score
Number of Taxa[a]	87%	6	73%	3	67%	3
Family Biotic Index[b]	91%	6	106%	6	94%	6
Scrapers/(Filterer + Scraper) Abundances[a]	110%	6	147%	6	168%	6
EPT/(Chironomid + EPT) Abundances[a]	90%	6	98%	6	102%	6
EPT Index[a]	100%	6	71%	6	43%	3
TOTAL SCORE	30		27		24	
Biological Condition Category	Moderately Impaired		Moderately Impaired[c]		Moderately Impaired[c]	

(a) Ratio of the study site to the reference site expressed as a percentage.
(b) Ratio of the reference site to the study site expressed as a percentage.
(c) Values obtained that are intermediate to the above averages require the use of habitat assessment and water quality data to determine the biological condition category.

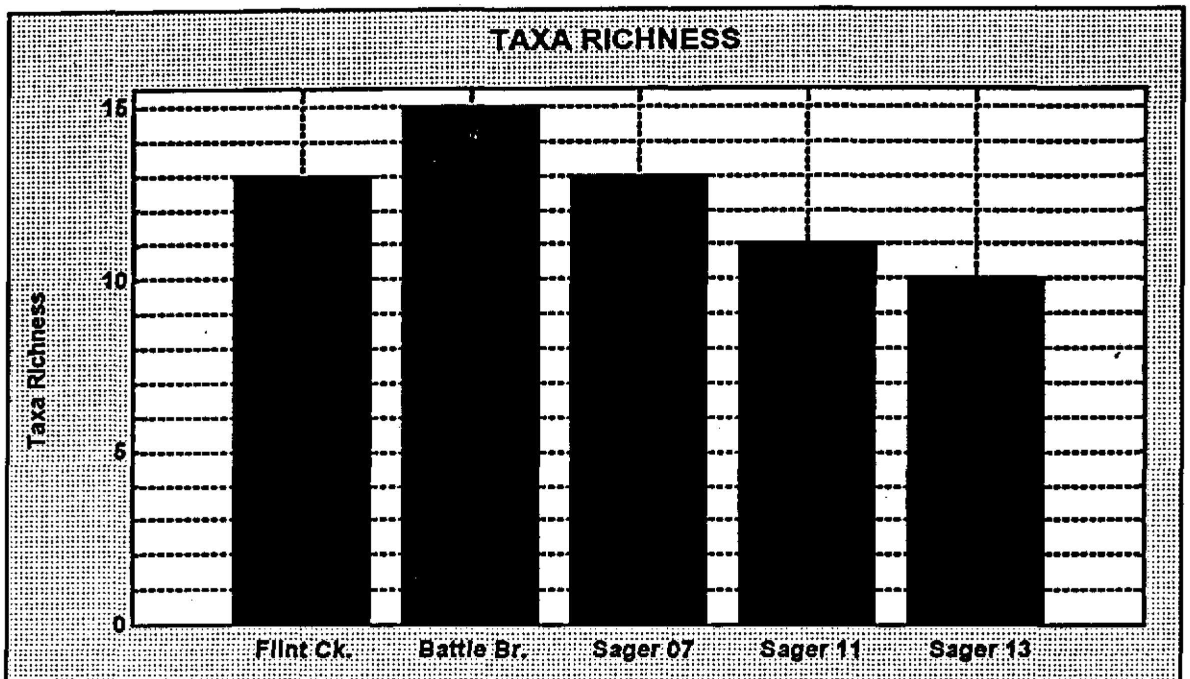


Figure M-1. Plot Representing Taxa Richness at Each Site

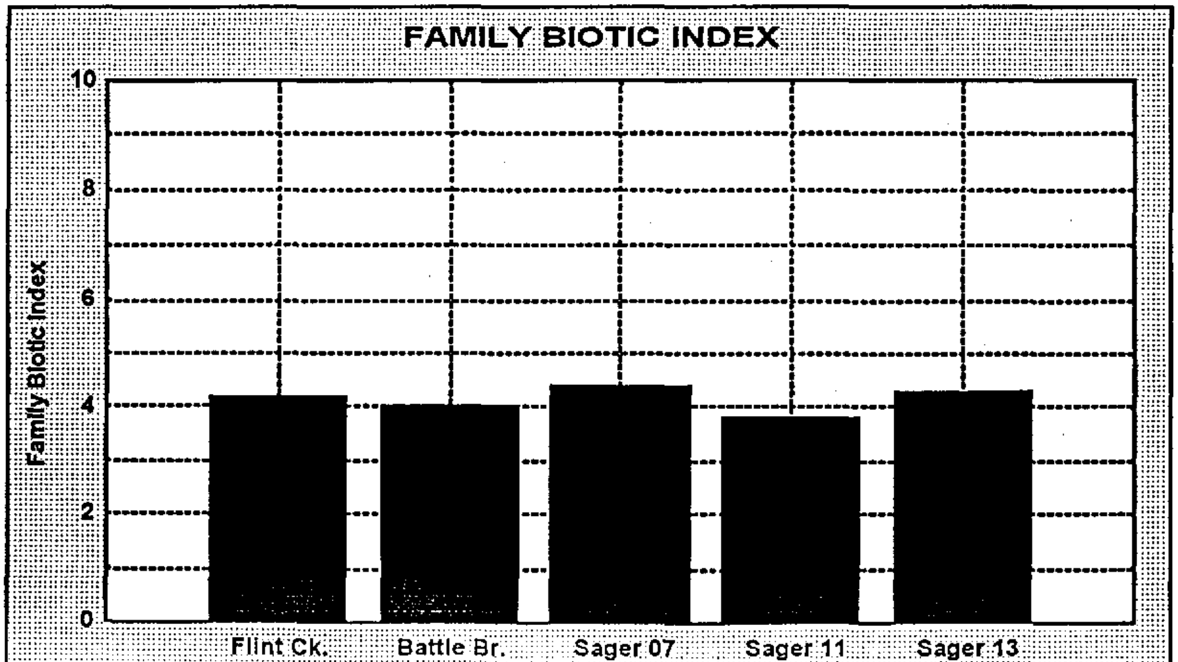


Figure M-2. Plot Representing the Family Biotic Index

Scraper/(Filterer + Scraper) Abundances

Figure M-3 is a plot representing the ratio of scraper and filtering collector functional feeding groups. Data indicate an increase in scrapers at Sager Creek sites 11 and 13, downstream of the STP. This dominance indicates an increase in primary production at the downstream sites relative to the upstream site of Sager Creek and reference sites. Additional insight concerning the shift in functional feeding groups is provided by the FBI and EPT index.

EPT/(Chironomidae + EPT) Abundances

Figure M-4 is a plot representing the EPT/(Chironomidae + EPT) abundances. This ratio considers the abundance of chironomids relative to more sensitive organisms. This metric does not clearly indicate the degree of organic enrichment at the Sager Creek sites relative to the reference streams; therefore, it may not be useful for this assessment. Data indicate an increase in chironomids at Sager Creek site 7 (upstream of the STP) and no chironomids at Sager Creek site 13 (downstream of the STP). The decreased number of individuals, as well as, community imbalance at Sager Creek site 13 may be the result of nonpoint source impacts, a recent scouring event, available food sources, or acute disturbances. It is difficult to determine from a one time sampling event the reason for community imbalance and reduced number of individuals.

Percent Contribution of Dominant Taxa

Figure M-5 is a plot representing the percent contribution of dominant taxa. This metric is closely related to the metric involving EPT to chironomid abundances in that it too determines community balance at the family level. This metric reflects the shift in taxa among sites based on the contribution of the dominant taxa. A decrease in the percent contribution of the dominant taxa indicates increased community balance. Data indicate Sager Creek site 7 had better community balance than Sager Creek sites 11 and 13, and the two reference streams. The primary difference between the ratio of EPT to chironomid abundances and percent contribution of dominant taxa is the number of taxa used in the calculation. While the percent contribution of dominant taxa more accurately reflects community balance, it does not consider other essential information relating to taxon characteristics (i.e., tolerance, functional feeding group, life cycle, etc...).

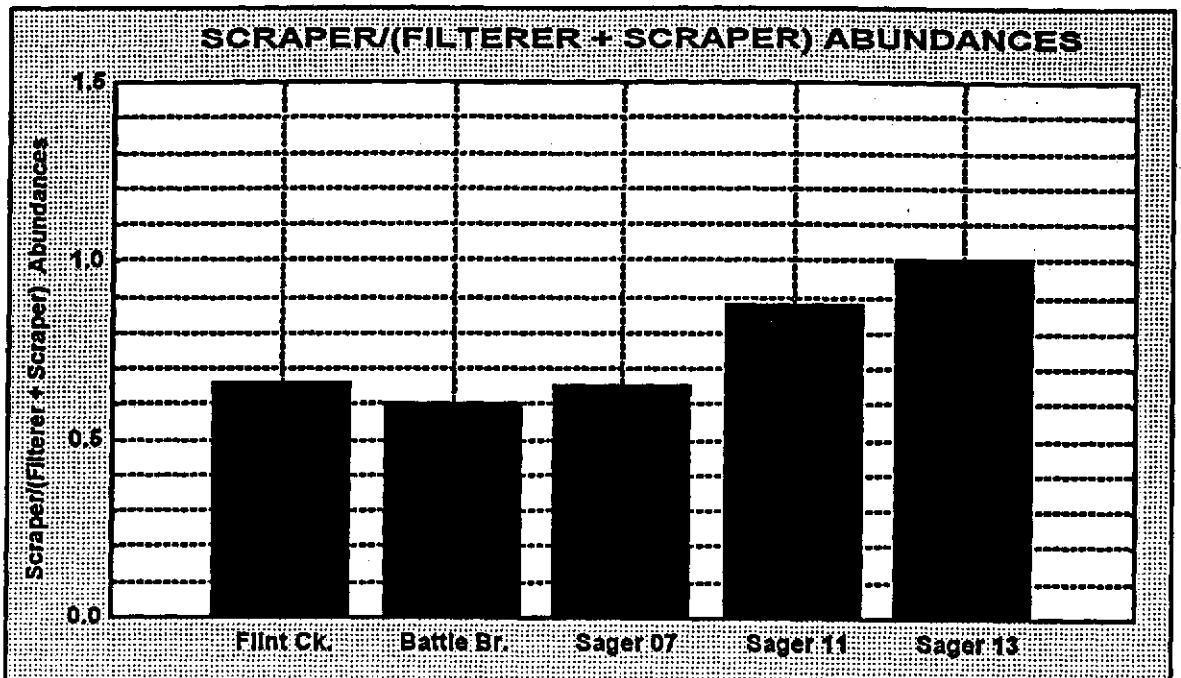


Figure M-3. Plot Representing Scraper/(Filterer + Scraper) Abundances

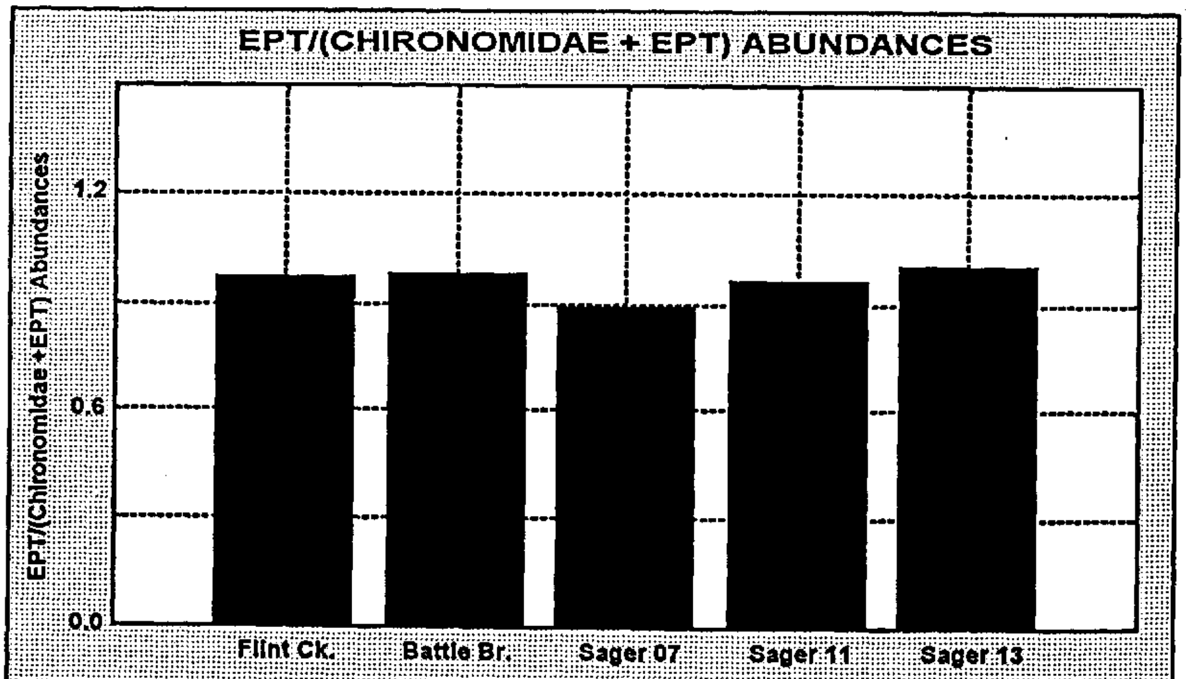


Figure M-4. Plot Representing EPT/(Chironomidae + EPT) Abundances

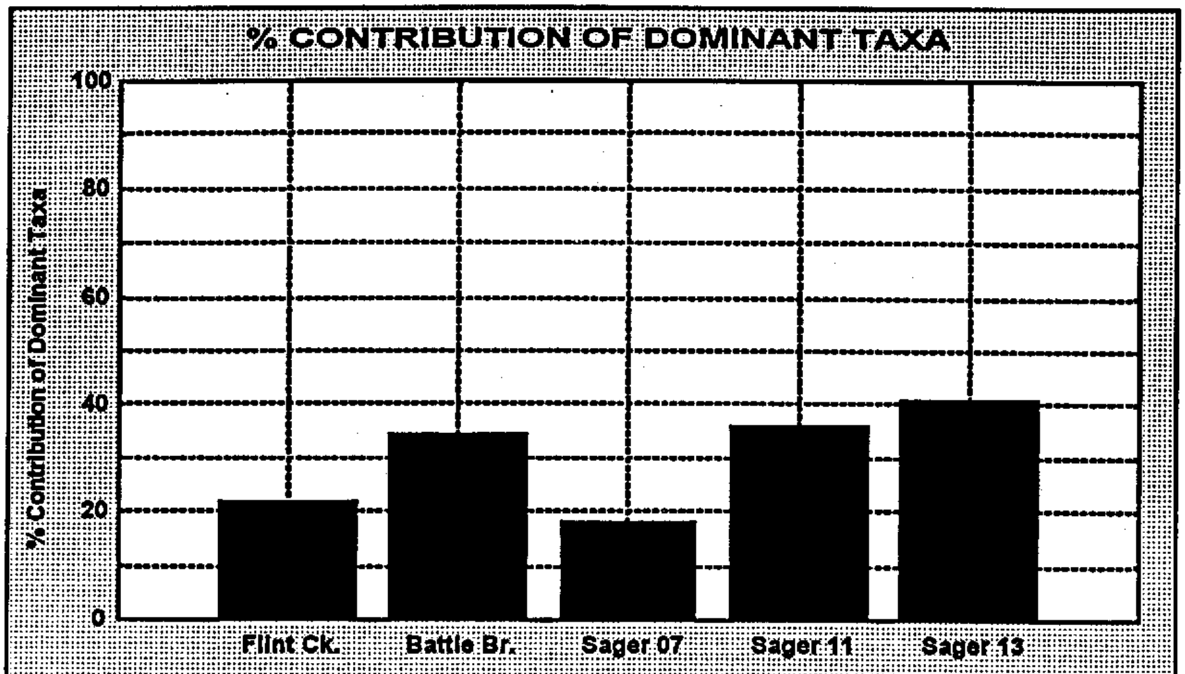


Figure M-5. Plot Representing % Contribution of Dominant Taxa

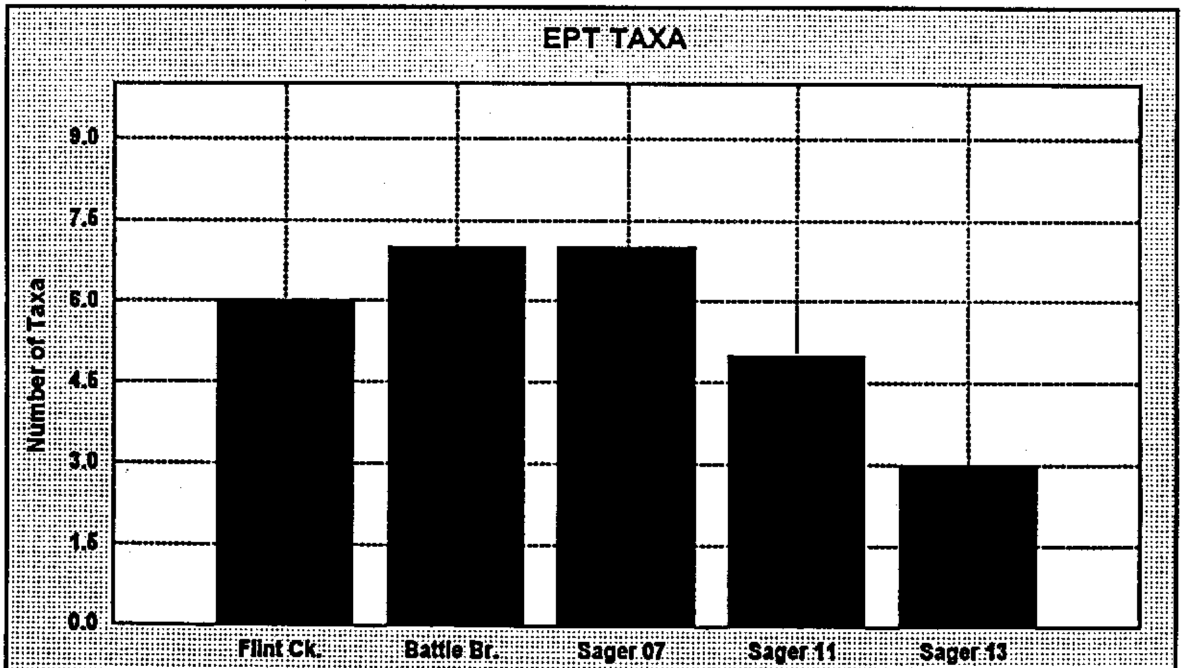


Figure M-6. Plot Representing the Number of EPT Families

EPT Index

Figure M-6 is a plot representing the number of EPT taxa based on family level. The EPT index is the ratio of EPT taxa of the study site compared to the reference site. As a result, the EPT index generally increases with increasing water quality of the study stream as discussed in the RBP guidance. The graph indicates the reference streams and upstream Sager Creek site had the highest number of EPT taxa, and the EPT index indicates that sites 11 and 13 had the lowest water quality when compared to the reference streams (Table M-2 and M-3).

Community Loss Index

Figure M-7 is a plot representing the community loss index relative to the reference sites which is helpful in determining the overall health of the study streams. In general, the value for the community loss index increases as dissimilarity with the reference streams increases. The graph indicates taxa collected from Sager Creek site 13 had the greatest dissimilarity relative to the reference streams. Taxa collected at site 7 had the least amount of dissimilarity with the reference streams.

Functional Group Percent Similarity

Figure M-8 is a plot representing functional group percent similarity. This metric allows for an examination of the shredder or collector relative abundance as indicators of toxicity. The metrics may also indicate abundance of coarse particulate organic matter (CPOM) on which the shredder community depends for food. The graphs indicate Sager Creek sites 11 and 13 had fewer shredders than the upstream Sager Creek site and both reference streams. The downstream segment of Sager Creek may be impacted by both point source pollution and nonpoint source pollution resulting in an increase in functional feeding groups dependent on FPOM and other means of organic enrichment.

Functional Feeding Group Distribution

Four (4) functional feeding groups were represented among the sites. These groups include scraper, filterer, predator, and collector. Figure M-9 consists of pie charts illustrating functional feeding group distributions for reference streams and Sager Creek sites.

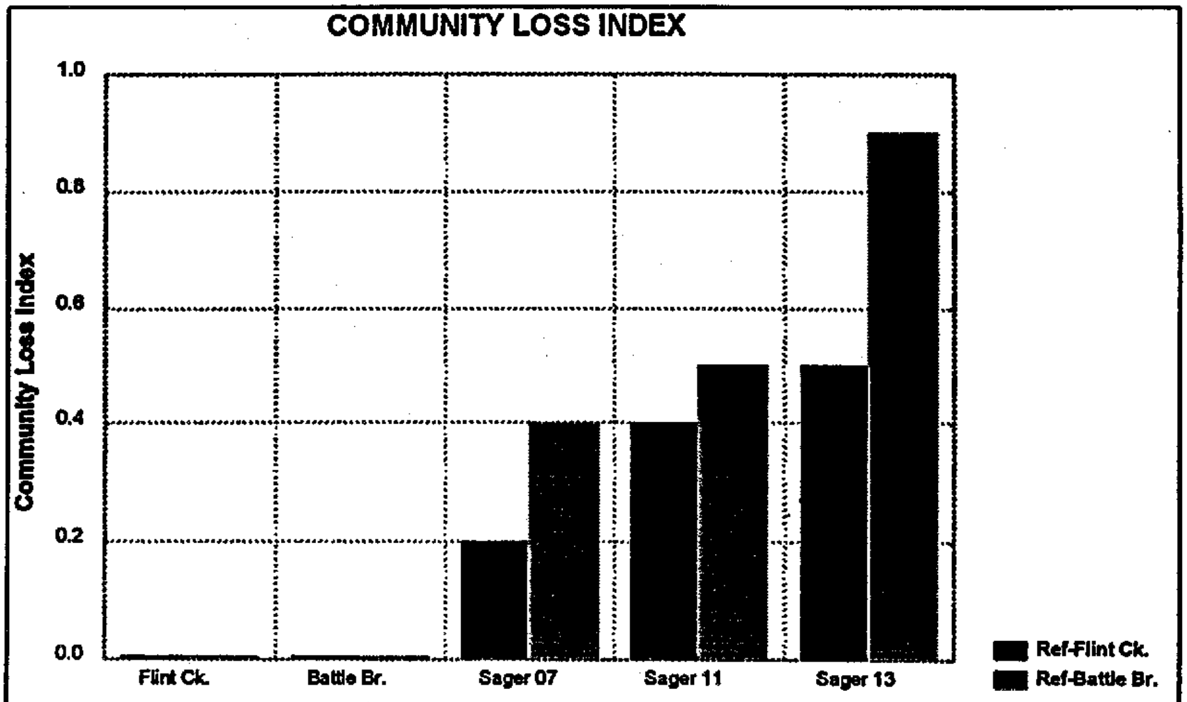


Figure M-7. Plot Representing the Community Loss Index

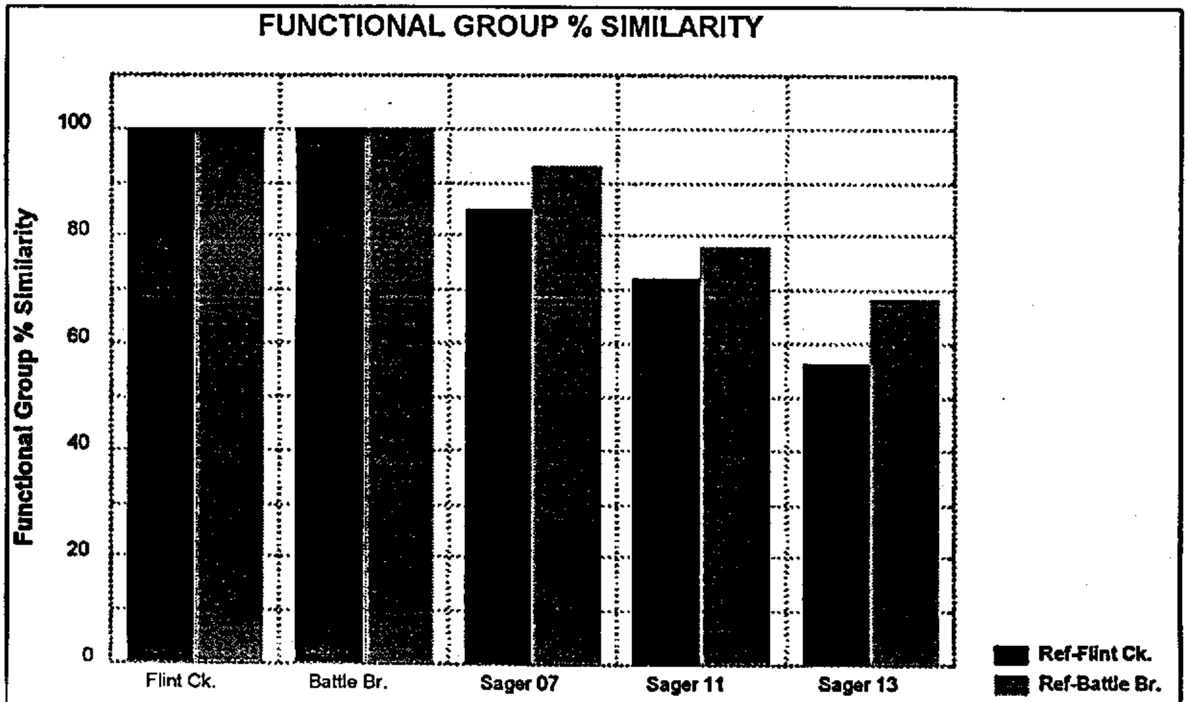


Figure M-8. Plot Representing Functional Group % Similarity

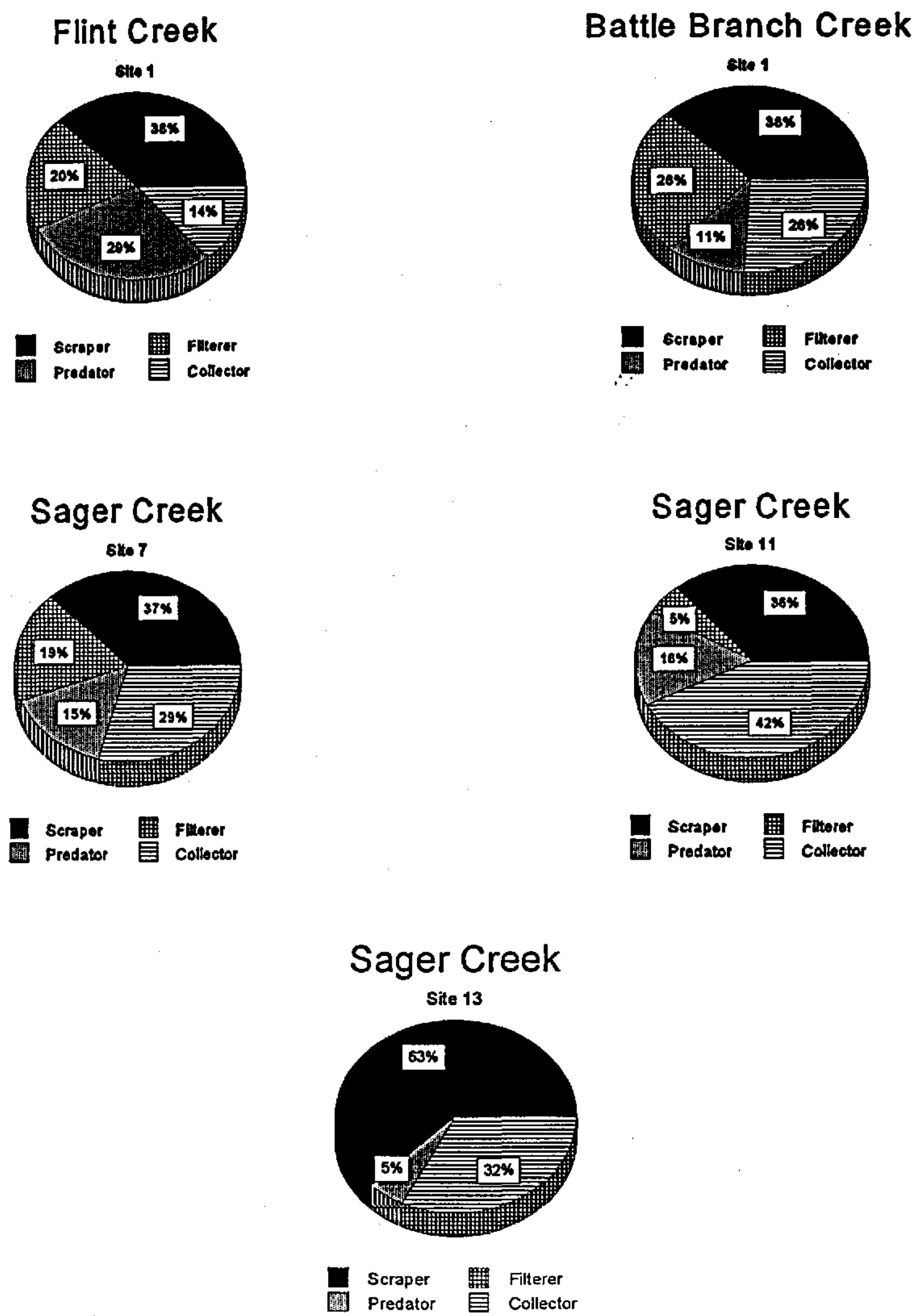


Figure M-9. Functional Feeding Group Distributions of Macroinvertebrates

Scrapers

Scrapers were most abundant (63%) at Sager Creek site 13. Sager Creek sites 7 and 11 had 37% and 36% scrapers, respectively. Both reference sites had scraper distributions of 38%. In order to make inferences concerning existing instream conditions, the ecological dynamics of functional feeding group distributions must be considered for each site. Although the scraper distribution at the reference sites and Sager Creek site 7 were similar, the distribution of other functional feeding groups differed between sites. The shift in the overall functional feeding group distribution indicates a change in the instream conditions. The functional feeding group shift at the downstream sites indicates more abundant periphyton as a result of organic impacts from the STP.

Filterers

Filterers appeared most abundant at Battle Branch Creek. There was a decrease in filterers at Sager Creek site 11 and an absence of filterers at Sager Creek site 13 . Filterer abundance indicates the amount of fine particulate organic matter (FPOM) and potential attachment sites (i.e., filamentous algae and aquatic mosses). The percentage of filterers are also indicative of algal community composition (diatoms and loosely attached, filamentous, stalked, or colonial algae), and trophic organization. The absence of filterers at site 13 may be directly related to the abundance of scrapers which are efficient grazers of periphyton. As a result of grazing, the scrapers may have inadvertently reduced the number of attachment sites utilized by the filterers, ingested or scraped the filterers loose. Additional data are necessary to determine other possible causes for the decrease in filterers downstream of the STP.

Predators

Predators were most abundant in Flint Creek. This distribution may not reflect the relative health of the Sager Creek sites. It may, however, reflect periodic prey abundance or downstream drift of predators. Data from multiple sampling events are necessary to support a more accurate conclusion.

Collectors

Collectors were most abundant at Sager Creek Site 11. Collectors were less abundant at Sager Creek sites 7 and 13. The abundance of collectors further decreased at the reference sites. Trophic organization, available habitat and food resources must be considered. In general, collectors are generalists. Generalists are capable of acquisition and assimilation of a wider range of food resources, but not with the same efficiency as a specialist (Merritt and Cummins, 1984). Generalists are often more successful than specialists when environmental conditions alter resources normally available (Merritt and Cummins, 1984). The shift in the functional feeding group distribution consisting of primarily generalists at the downstream Sager Creek sites may be related to algal composition and associated palatability as a result of the STP. Further investigation on a taxonomical level for both macroinvertebrates and periphyton would provide additional insight.

CONCLUSION

The metrics and functional feeding group distribution indicate potential organic impact at the Sager Creek sites relative to the reference streams. However, limitations exist in the ability to determine the magnitude and extent of the impact from a one time sampling event, because other factors (i.e., nonpoint source impacts and seasonal fluctuations) are not considered in the assessment.

References Cited

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FISH COMMUNITIES

On October 5 and 6, 1993 personnel from the Oklahoma Water Resources Board and the Department of Pollution Control and Ecology accomplished fish community surveys at the stations listed below:

STATION DESCRIPTION

SAG07 Sager Creek above Siloam Springs STP, (AR, Sec 36, T18N, R34W). This stream length included 54% pools, 23% riffles, and 23% runs. Pool sizes were 100-120 feet long, 30 feet wide and average depth of 2 feet. Instream cover was bedrock, ledges, roots, woody debris and undercut banks. Substrate was cobble, bedrock, gravel and boulders.

SAG11 Sager Creek approx 1.5 mi downstream of the Siloam Springs STP, (OK, Sec 19, T20N, R25E). This section of Sager Creek had an approximate 60% of the stream length in pools, 25%in riffles and 15% in runs. The size of the average pool was 125 feet long, 25 feet wide and 3 feet deep. The riffles were 20-30 feet long, 30 feet wide, and six inches deep. Substrate was mainly a cobble/gravel mixture with some boulders and some sand. Instream cover was roots, undercut banks, and woody debris.

SAG13 Sager Creek approx 0.25 mi above Flint Creek confluence, (OK, Sec 15, T20N, R25E). This segment length was composed of, 34% pools, 25% riffles, and 41% runs. The average pool was 100 feet long by 25 feet wide and averaged about 2.5 feet in depth. Undercut banks, roots and treetops were abundant. The riffles were approximately 20 feet long, 15 feet wide and eight inches deep. The substrate was mainly cobble and gravel, some boulders and bedrock.

FLTCR Flint Creek above AR Hwy 59 bridge (AR, Sec 15, T18N, R33W). This section of Flint Creek was composed of 10% pools, 35% riffles, and 55% shallow runs. The size of the average pool was 75 feet long, 60 feet wide, and 1.5 feet deep with an equally distributed substrate of gravel and cobble. The average riffle was 40 feet long, 25 feet wide, and 4 inches deep. The substrate was dominated by cobble and gravel. The instream cover was woody debris, roots, and undercut banks.

BTLBR Battle Branch 2.25 mi N on OK Co RD D0550, approx. 8 mi W on US 59 from AR State line (OK, SW¼ Sec 18, T20N, R25E) The length of stream was composed of 40% pools, 45% riffles, and 15% runs. The average pool was 75 feet long, 20 feet wide and 1.5 feet deep. The substrate consisted mainly of gravel with cobble, sand, boulder and bedrock. The average riffle was 50 feet long, 20 feet wide and 4 inches deep with a substrate dominated by gravel and cobble.

METHODOLOGY

Two Smith-Root model 15-B backpack electrofishing devices with pulsed DC current were used to collect fish from these sites. The devices were used in the shallow pools and along the pool edges while wading upstream and dipping the stunned fishes from the water with dip nets. The riffles were collected by posting a twenty foot seine near the toe of the riffle and while working the electrofisher in a downstream direction through the riffle, the bottom substrate was overturned and the fish were herded into the seine or washed in by the current.

Fish species of all types were collected from all available habitat within the sample area until a fully representative sample of the species in the area was thought to be obtained. Larger specimens were field identified and released. The smaller specimens and those unidentifiable in the field were preserved in a ten percent (10%) formalin solution and returned to the lab for identification.

Two independent teams worked side-by-side in the stream collecting fishes. Personnel from the Oklahoma Water Resources Board identified and enumerated one set of samples and ADPCE personnel reported the duplicate sample. This report combined the two fish collections for a total fish community at each site.

RESULTS

Fish community samples were collected at all stations on October 5 and October 6, 1993. There were 21 species of fish collected from Sager Creek above the STP (SAG07); 20 species 1.5 miles below the discharge (SAG11); and 22 species from near the mouth (SAG13). The reference streams yielded 19 species from Flint Creek (FLTCR) and 15 species from Battle Branch (BTLBR). A list of species and their relative abundance as percent of the total community is in Table F-1. Figure F-1 depicts the percent community and family composition comparisons between sampling stations.

TABLE F-1 SAGER CREEK FISH COMMUNITY

Fish Family & Species		SAG07 # spc	SAG07 % com	SAG11 # spc	SAG11 % com	SAG13 # spc	SAG13 % com	FLTCR # spc	FLTCR % com	BTLBR # spc	BTLBR % com
Cyprinidae	Minnows										
Campostoma anomalum	Stoneroller	700	47.7	713	48.4	537	29.0	77	8.1	810	40.0
Cyprinus carpio	Common carp			3	0.2						
Luxilus cardinalus	Cardinal shiner	256	17.4	347	23.6	708	38.1	126	13.3	484	23.9
Nocomis asper	Redspot chub	9	0.6	22	1.5	82	4.4	65	6.9	14	0.7
Notropis nubilus	Ozark minnow	13	0.9	21	1.4	45	2.4	2	0.2	54	2.7
Phoxinus erythrogaster	Southern redbelly dace	2	0.1			33	1.8	10	1.1	87	4.3
Semotilus atromaculatus	Creek chub	2	0.1	2	0.1	72	3.9	18	1.9	36	1.8
Catostomidae	Suckers										
Hypentelium nigricans	Northern hogsucker			1	0.1	5	0.3			4	0.2
Moxostoma duquesnei	Black redhorse			1	0.1			1	0.1	2	0.1
Moxostoma erythrurum	Golden redhorse			5	0.3	5	0.3				
Ictaluridae	Freshwater catfishes										
Ameiurus natalis	Yellow bullhead	1	0.1	1	0.1						
Noturus exilis	Slender madtom	61	4.2	3	0.2	60	3.2	155	16.3	147	7.3
Cyprinodontidae	Topminnows										
Fundulus catenatus	Northern studfish					2	0.1				
Fundulus olivaceus	Blackspotted topminnow	1	0.1					3	0.3		
Poeciliidae	Livebearers										
Gambusia affinis	Mosquitofish	1	0.1			4	0.2				
Centrarchidae	Sunfishes										
Ambloplites ariommus	Shadow bass							80	8.4	5	0.3
Lepomis cyanellus	Green sunfish	83	5.7	18	1.2	4	0.2	4	0.4	6	0.3
Lepomis macrochirus	Bluegill sunfish	14	1.0	14	1.0	5	0.3	3	0.3		
Lepomis megalotis	Longear sunfish	214	14.6	38	2.6	7	0.4	11	1.2		
Lepomis microlophus	Redear sunfish							2	0.2		
Lepomis hybrid	Hybrid sunfish (g-b)	1	0.1	1	0.1	2	0.1				
Micropterus dolomieu	Smallmouth bass	6	0.4	72	4.9	35	1.9	9	1.0		
Micropterus punctulatus	Spotted bass	3	0.2	3	0.2						
Micropterus salmoides	Largemouth bass	5	0.3	14	1.0			1	0.1		
Percidae	Perches										
Etheostoma blennioides	Greenside darter					2	0.1				
Etheostoma flabellare	Fantail darter	1	0.1							10	0.5
Etheostoma punctulatum	Stippled darter	7	0.5			11	0.6	4	0.4	3	0.2
Etheostoma spectabile	Orangethroat darter	87	5.9	86	5.8	84	4.5	110	11.6	33	1.6
Etheostoma zonale	Banded darter					1	0.1				
Percina caprodes	Logperch			1	0.1	2	0.1				
Cottidae	Sculpins										
Cottus carolinae	Banded sculpin	2	0.1	107	7.3	151	8.1	268	28.2	332	16.4
	Total Species	21		20		22		19		15	
	Total Specimens	1469		1473		1857		949		2027	

The Cyprinidae community made up approximately 67% of the community in Sager Creek above the STP discharge (SAG07) and between 75% and 80% below the discharge at SAG11 and SAG13 (Figure F-1). Stonerollers dominated the cyprinid community just above and below the discharge and the cardinal shiner was sub-dominant at both stations. However, the cardinal shiner dominated the Cyprinidae community at SAG13 and the stoneroller was subdominant. Also, at the Flint Creek reference stream site (FLTCR), the cardinal shiner was dominant and the stoneroller was sub-dominant. However, in the Oklahoma reference stream (Battle Branch), the stoneroller was dominant and the cardinal shiner was sub-dominant (Figure F-2).

Also, as shown in Figure F-2, the "other" Cyprinid species make up a relatively small proportion of the community. It is noted that the redspot chub and the creek chub populations are much greater at the lower Sager Creek site (SAG13) than at the SAG07 or SAG11. These differences within the Cyprinid populations suggest that there is more of a herbivorous community just above and below the discharge and more of an insectivorous/predacious community at SAG13.

Of special interest is the relatively low stoneroller population in Flint Creek. Ozark Highland streams are generally dominated by stonerollers, as is evident in Sager Creek and Battle Branch. In the 1983 sampling of Flint Creek[1] at this location, stonerollers made up almost 35% of the total community and were the dominant Cyprinid. It is not immediately clear why the stoneroller population was low in Flint Creek in this sample since other riffle species often associated with stonerollers were collected in typical numbers (Figure F-4).

The Centrarchidae family (sunfishes) demonstrated a dramatic decrease in percent of community composition in Sager Creek in a downstream direction (Figure F-1). This family comprised 22% of the total community at SAG07, 11% at SAG11 and 3% at SAG13. Also, it comprised 12% of the total community in Flint Creek and less than 1% of the community in Battle Branch. The largest decrease in Sager Creek was in the typical sunfish (green-bluegill-longear sunfish) population where they decreased in dominance from over 21% of the total community at SAG07 to about 5% at SAG11 to less than 1% at SAG13 (Figure F-3). The smallmouth bass was the dominant Centrarchid below the STP discharge at SAG11 and SAG13, and an unusually large number of smallmouth bass was collected at the first station below the STP discharge (SAG11).

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[1]Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions. ADPC&E. 1987.

Figure F-1

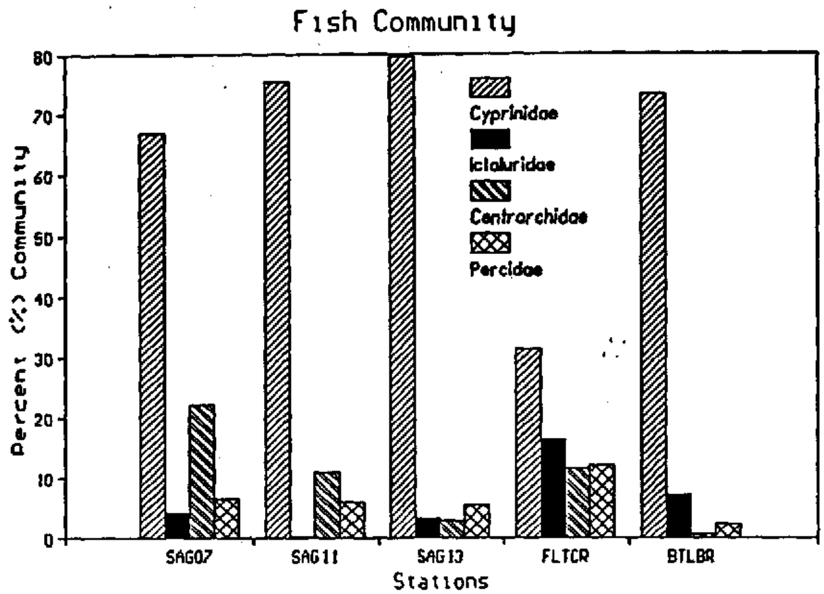


Figure F-2

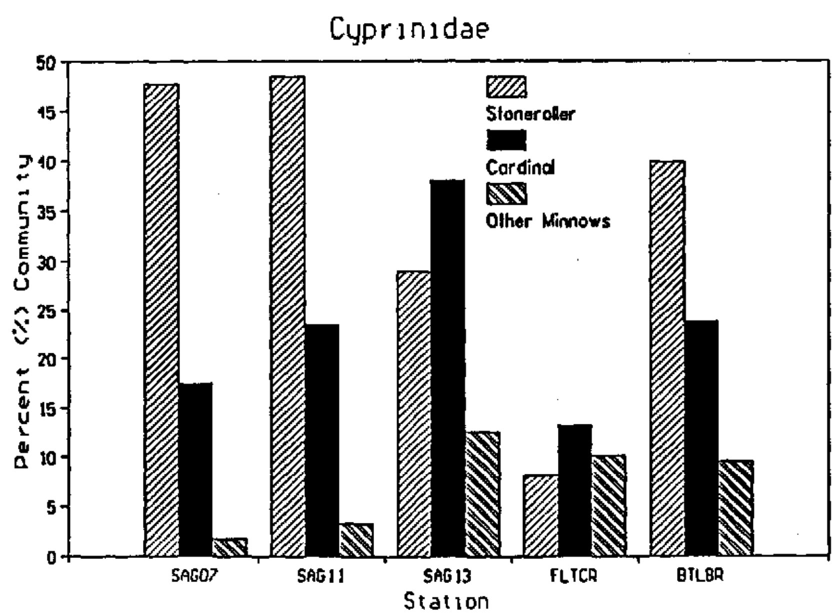


Figure F-3

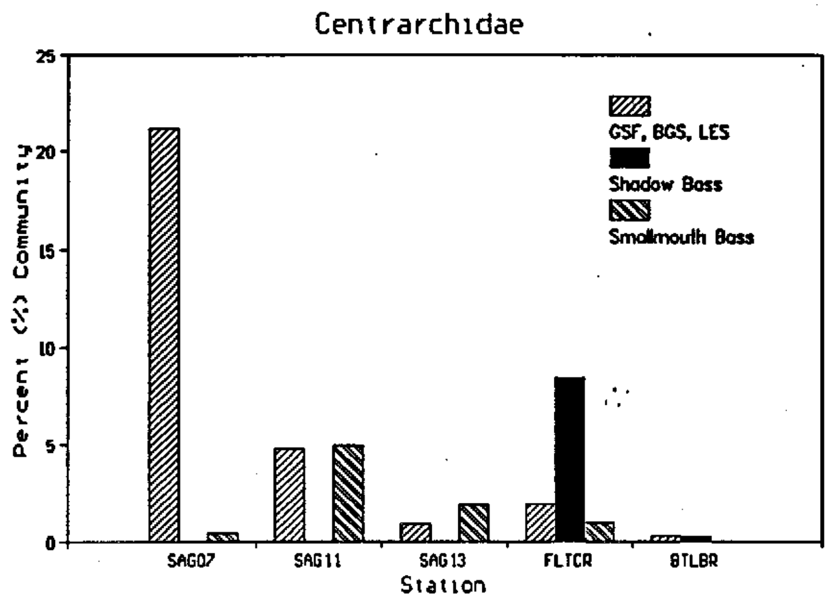
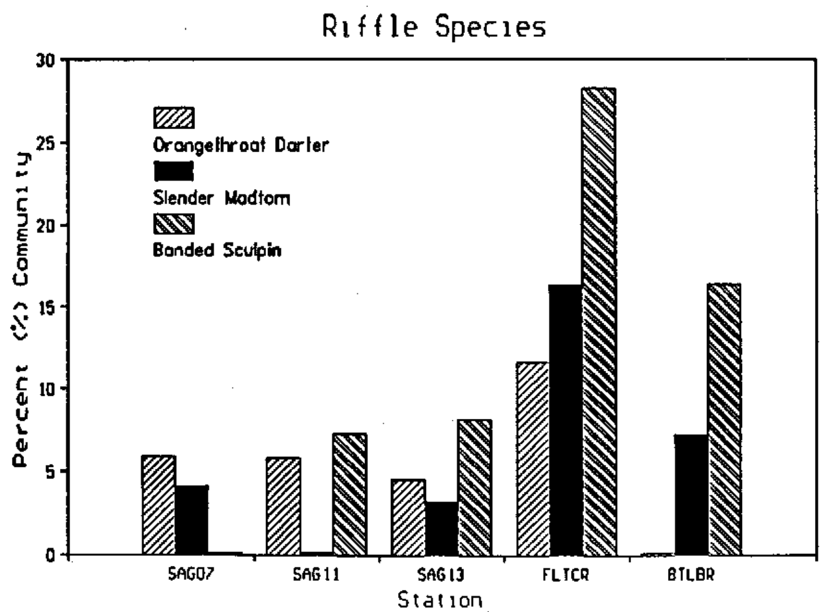


Figure F-4



The atypically large population of sunfishes at SAG07 can probably be attributed to a series of small impoundments through downtown Siloam Springs created by low-water dams. These impoundments are perfect habitat for the typical sunfish species. During storm flows when waters flow over the top of the low-water dams, these sunfish may migrate downstream, only to become trapped as the storm waters subside and the low-water dams become barriers to upstream migration.

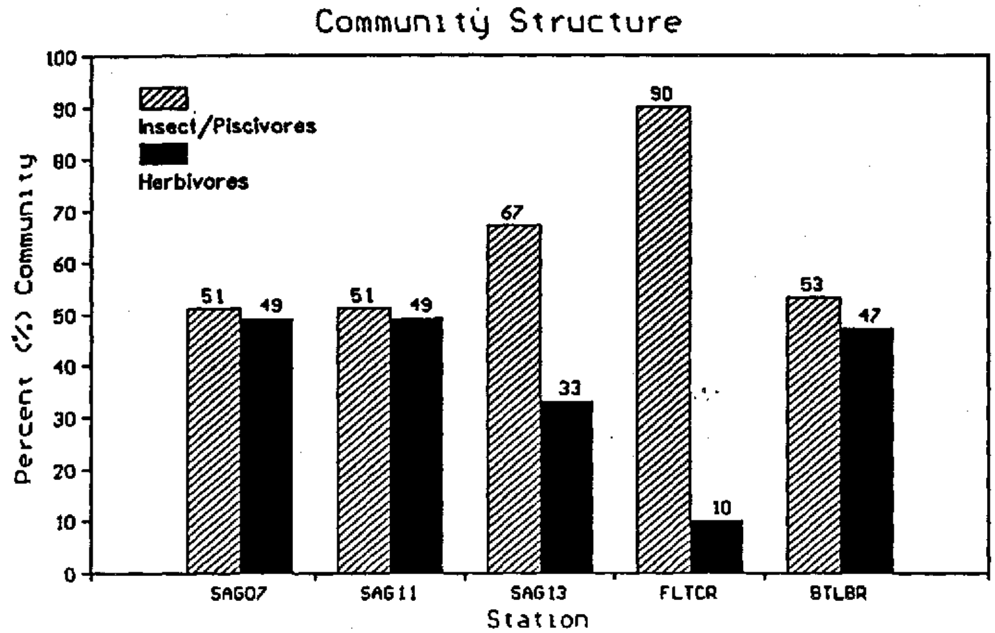
The slender madtom was abundant at SAG07 and SAG13, but decreased dramatically just below the discharge at SAG11(Figure F-4). Also, excellent populations were collected at both reference stream sites. The decrease in madtom populations below STP discharges has been documented in previous studies performed by the Department (Harrison, 1985; Huntsville, 1993; Mena, 1994). The reason for this decrease is not fully understood. Speculations have included that these fishes are very sensitive to some form of toxicity, excessive embeddedness from suspended solids, species replacement, reduction or replacement of a preferred food source, or a combination of these and/or other impairments.

The Percidae family comprised approximately 6% of the total community at the three stations on Sager Creek, 12% at Flint Creek and 2% at Battle Branch (Figure F-1). The orangethroat darter was the dominant darter at each location. The SAG07 site had three Percid species (one fantail darter, seven stippled darters and the orangethroat); SAG11 had two species (one logperch and the orangethroat); and SAG13 had 5 different species (the orangethroat, the stippled darter and remnant populations of the greenside, banded and logperch darters). Flint Creek had only two species, the stippled darter and orangethroat, and Battle Branch had these two species plus ten specimens of the fantail darter. The Percidae family at all stations was quite similar; the apparently more diverse community at SAG13 is probably related to the proximity of the site to the larger water below the Flint Creek confluence with Sager Creek.

The banded sculpin was collected at all sites, but in increasing numbers in a downstream direction in Sager Creek. Flint Creek had the largest percent population, approximately 28%, and Battle Branch had the next highest, approximately 16% (Figure F-4). At each of these two reference sites, the sculpin was either the dominant species overall, or the first subdominant species. This species is most often associated with cool, spring-fed waters.

In Figure F-5 the herbivorous fish community is compared to the insectivorous plus predacious community for each station. Herbivores made up just under 50% of the fish community in the

Figure F-5



upstream and immediately downstream of the STP discharge sites in Sager Creek. The reference stream in Oklahoma has a very similar ratio of herbivores to insectivore plus predators. The Arkansas reference stream shows an anomalous ratio due to the atypically low numbers of stonerollers collected. The farthest downstream station on Sager Creek (SAG13) shows a slightly lower percentage of herbivores. Although this data may be indicative, its significance is difficult to determine.

Analysis of all the fish communities sampled does not indicate significant impairment of any of the communities. The major differences noted are generally related to natural differences among the streams sampled. The two reference streams selected had limited usefulness in evaluating impacts in Sager Creek since the Battle Branch site was a small, spring-water dominated base flow stream with limited habitat diversity. Flint Creek was much wider and shallower, except for pools where large amounts of gravel had been removed, and the anomalous samples of stonerollers at this site skewed the community structure. However, the three stations sampled on Sager Creek may provide some cause and effect relationships although the differences may not be significant. The upstream station on Sager Creek (SAG07) had atypically large communities of Centrarchids, particularly the *Lepomis species*. These are likely migrants from the large pools impounded through the downtown Siloam Springs area. This community also seemed to be reflecting slight nutrient enrichment possibly from the upstream impoundments, urban runoff, storm sewer overflows and a large population of semi-tame waterfowl inhabiting the pools and the downstream area. Below the STP discharge (SAG11) the community was distinctly dominated by the herbivorous stoneroller, but it also contained an exceptional population of smallmouth bass. The darter community was almost one-species limited and there was a notable rarity of madtoms. Otherwise, the community was typical of a small Ozark Mountains stream in the Illinois River basin drainage. The Sager Creek station near the mouth (SAG13) reflected the larger stream influence of its confluence with Flint Creek. It had a slightly greater diversity of species, particularly among the Percids. The stonerollers became subdominant to the more insectivorous cardinal shiner, the madtom community was more typical and an excellent smallmouth bass population existed.

SUMMARY AND CONCLUSIONS

1. Sampling conducted in the Sager Creek watershed included water quality from 14 stations taken seven times between June 1993 and July 1994. Sixteen parameters, including flow, were monitored on each sample date. Quantitative periphyton sampling was conducted four times during the study at three stations on Sager Creek and on two reference streams. Macroinvertebrate communities and fish communities were sampled once during the study at the same five sites where periphyton was sampled.

2. Diel dissolved oxygen profiles during the low-flow, high-temperature period of July, August and early September produced daily D.O. fluctuations of from 1.7 mg/L to 3.8 mg/L. A 3 mg/L to 4 mg/L daily fluctuation was typically observed in Ozark Highland streams during Arkansas least-disturbed ecoregion stream studies. The lowest daily fluctuation during this study was 1.7 mg/L which occurred during an overcast period. The lowest minimum D.O. value recorded during the pre-dawn period was 4.5 mg/L at SAG11(below the discharge). During the ecoregion, reference-stream study minimum D.O.'s were 4.7 mg/L on Flint Creek and 4.5 mg/L on South Fork Spavinaw Creek.

3. The range of stream flow values sampled on Sager Creek was 2.9 CFS to 47.9 CFS at the uppermost station and 6.9 CFS to 60 CFS at the last downstream station.

4. BOD_5 values of the STP discharge were not found above 4 mg/L, and the BOD_5 above the STP was slightly higher than below.

5. Nitrite plus nitrate-nitrogen values in the STP discharge ranged from 7.7 mg/L to 14.5 mg/L. Background values were highest in the groundwater dominated sites, and they generally ranged from 3 mg/L to 4 mg/L. During low flows, nitrate values below the STP were approximately four times higher than above. The concentration declined sharply downstream to less than one-half the "below-discharge" level when measured near the mouth of Sager Creek. During high-flow events, nitrate concentrations were only very slightly elevated below the discharge when compared to stations above the STP. Nitrate loads(lbs/day) were very low above the STP during low-flow periods, but the loads increased substantially below the STP. However, during high-flow events the nitrate loads showed a sharp and consistent increase in a downstream direction and the discharge load was masked by the non-point source load which was two to three times the point source load.

6. Historical phosphorus values in Sager Creek have decreased significantly and became more consistent since the Siloam Spring STP was upgraded in the mid 1980's. During this survey, total phosphorus values in the STP discharge were normally about 2 mg/L. The total phosphorus pattern in Sager Creek was very similar to that of the nitrates although the levels were much different. During low-flow events phosphorus concentrations increased sharply below the STP discharge, then declined rapidly through the assimilation process. However, concentrations remained four to five times higher at the mouth of Sager Creek than above the discharge. During high-flow events, phosphorus levels doubled or tripled above the STP. Below the STP, values were about 0.4 mg/L compared to approximately 0.2 mg/L above. Phosphorus loads were almost totally from the STP during low-flow periods, but they declined by about 65% near the mouth of Sager Creek. In contrast, during high-flow events phosphorus loads increased progressively at each station in a downstream direction. This was driven by non-point source inputs rather than the point source.

7. During the summer period periphyton production showed a pattern of increased production at the first station below the STP, then a sharp decline at the last downstream station. Reference stream stations and the Sager Creek station above the STP discharge normally had periphyton levels lower than the first station below the STP. Low pheophytin levels at all stations indicated healthy periphyton communities. This is in contrast to conditions of excessive filamentous algae and fungi growths below the STP before the facility was upgraded. Winter time production of periphyton was substantially lower than during the summer period, and very little differences were found between stations during the winter period.

8. Macroinvertebrate communities at both sites in Sager Creek below the STP were slightly altered when compared to the reference stream sites. Alterations appeared to be related to increases in functional feeding groups of macroinvertebrates which favor increases in periphyton and associated organic enrichment. Impacts appeared greatest at the farthest downstream site on Sager Creek (SAG13) where less than the desired number of organisms were collected.

9. Fish community comparisons did not indicate any significant impairment related to the point source discharge. The most appropriate comparisons can be made among the three Sager Creek samples. The station above the STP had an atypically large community of sunfishes (Lepomis sp.), probably as a result of the impoundments in the park area of the city. Typical of Ozark Highland ecoregion fish communities, Cyprinidae was the dominant

fish family in all samples. Stonerollers were the dominant cyprinidae in all samples except the farthest downstream station on Sager Creek and in Flint Creek. The Flint Creek stoneroller community was unexplainably anomalous and the Sager Creek cyprinid community near the mouth was dominated by the cardinal shiner. The Sager Creek station just below the STP had a larger herbivorous community than the most downstream station, but it was similar in proportion to that above the STP and in the Oklahoma reference stream. Also, the fish community just below the effluent had a notable rarity of madtoms, a Percid Community comprised of one species (with the exception of one individual), and an exceptionally abundant smallmouth bass population.

10. Water quality, macroinvertebrate communities and fish communities were altered in Sager Creek below the discharge from the Siloam Springs STP. Water quality changes from the effluent were greatest during low-flow periods. During high flows, nonpoint sources dominate the point source input. Nutrients from the STP show rapid assimilation and recovery near the mouth of Sager Creek, although they remained above background levels. Fish communities show the greatest changes below the discharge but recover to a typical community near the mouth. However, both stations below the discharge have exceptional smallmouth bass communities. Macroinvertebrate communities were slightly altered at both stations below the STP; however the greater alterations were at the farthest downstream station. All differences measured in Sager Creek were minimal, both in magnitude and spatially, even though their significance may be debatable.