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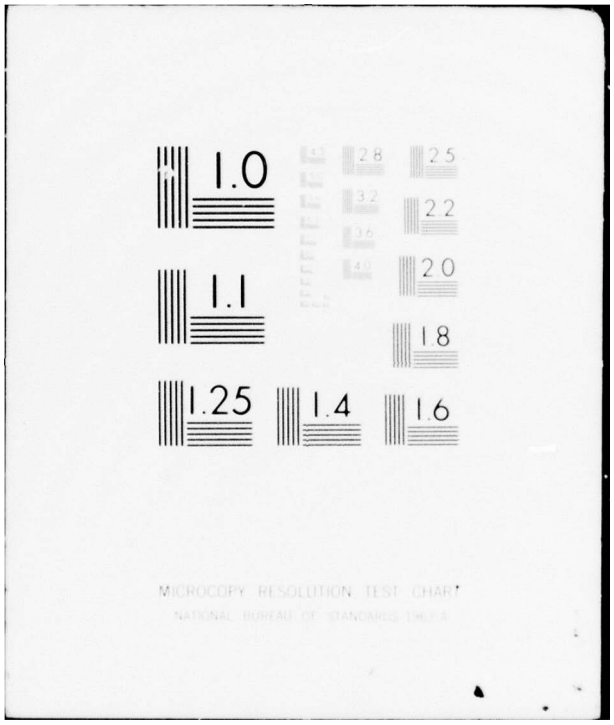
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RESULTS OF AQUATIC ECOLOGICAL SURVEYS AT SUNFLOWER ARMY AMMUNITION PLANT, LAWRENCE, KANSAS PART I: MACROINVERTEBRATES AND WATER QUALITY

by

J. Gareth Pearson
Edward S. Bender
Daniel J. Taormina
Val J. Kelmeckis
Paul F. Robinson
Arthur E. Aaski

Ecology Branch

July 1977

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
Chemical Systems Laboratory
Aberdeen Proving Ground, Maryland 21010

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Aquatic ecological surveys are initiated in the principal drainages from Sunflower Army Ammunition Plant (SAAP), Lawrence, Kansas, and in the Kansas River. Baseline ecological surveys were initiated in the spring of 1975 before the construction of a new nitroguanidine facility at SAAP to establish the present condition of aquatic communities in the receiving stream, and to compare them with conditions after the survey. Sampling consisted of benthic macroinvertebrate collections from up to eight locations and water-quality measurements from seven locations, which are reported here. Other studies of periphyton will be discussed in a future report. Macroinvertebrates were collected from rock-filled barbecue baskets (suspended in

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20. Abstract (cont'd)

the Kansas River and attached to the substrate in the creeks), from portable invertebrate box samplers in riffles, and from dip-net and hand collections. Fauna from the creeks was predominately riffle beetles, caddisflies, and mayflies; caddisflies and mayflies were the most abundant species in the rock-filled baskets from the river. Blackfly larvae were predominant in Spoon Creek, which had a high organic load from farmland runoff before it entered SAAP. No adverse conditions were observed in temperature, dissolved oxygen, and pH during several days of continuous monitoring. Changes in hardness, turbidity, alkalinity, nutrients, and chloride were directly related to fluctuations in discharge. Construction activity, production testing, and startup operations will be the major impact from the new nitroguanidine facility. These impacts are expected to be mitigated by erosion control and recent proposals to recycle process wastewaters. During the preparation of this report, a new discharge location in Kill Creek was approved for the nitroguanidine facility. The survey results given in this report are not intended to evaluate this discharge location, and they are not directly applicable to the new site.

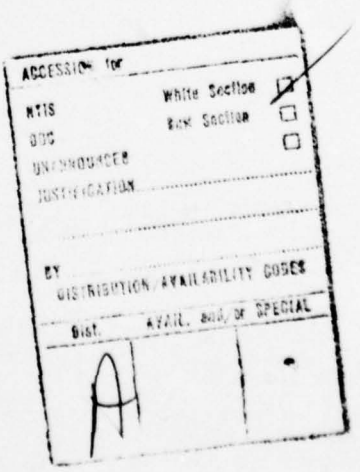
PREFACE

The work described in this report was authorized under Task No. 2, Subproject 3, PAA5754114, Development of Methods to Minimize Environmental Contamination, Ecological Surveys of Environmental Conditions at DARCOM Installations.

In conducting such ecological surveys, a three-phase program has been developed. Phase I (Initial Site Visit) was completed at Sunflower Army Ammunition Plant (SAAP) in October 1973. Phase II (Preliminary Environmental Survey) was conducted from 19 to 26 August 1974 and a report of findings was prepared in 1975. Phase III (Ecological Surveys) was assigned on the basis of the findings in the Phase II report. Ecological Surveys were initiated in April 1975 and have consisted of two survey periods: 28 May to 10 June 1975 and 26 August to 10 September 1975. This report contains the results of the water-quality and macroinvertebrate portions of the survey. A second report will contain the results of the primary productivity portion of the surveys.

Acknowledgments

The authors wish to acknowledge the excellent cooperation and assistance of C. L. Caines of Hercules, Incorporated, Lawrence, Kansas, and Jane Dierdorff and Phyllis K. Schultz of the Chemical Systems Laboratory. We also wish to acknowledge the special assistance of Donald G. Huggins, Kansas State Biological Survey, Lawrence, Kansas, in identifying macroinvertebrates.



SUMMARY

If the proposed nitroguanidine facility and support facility operate according to its design criteria, the industrial discharge will have essentially no impact on water quality in the Kansas River. The primary impacts may occur from siltation in Captain Creek during construction. The paucity of aquatic toxicity and chemical data about nitroguanidine, its potential byproducts, and the potential for operational failures preclude a casual *a priori* statement that no impact on water quality will occur from construction and operation of the nitroguanidine facility.

Water in the Kansas River and the creeks draining SAAP has high nutrient loads, suspended solids (residue), and chlorides. Flow and water quality in the creeks, in particular, vary with season and rainfall. During low flow Kill Creek is maintained by discharges from SAAP, which are of sufficient quality to maintain an aquatic community of moderate diversity, including some species that tolerate moderate levels of organic pollution.

The best quantitative sampling results were achieved in the creeks by taking five replicate portable invertebrate box samples in riffle areas with similar substrate, depth, and current speed. Rock-filled basket samples were most useful to sample macroinvertebrates in the Kansas River. Because habitat was limited and siltation was common in the river, suspended artificial substrates were the most practical method. It was found that each method excluded some members of the aquatic community.

The new location of the nitroguanidine discharge is downstream of any of the monitoring stations on Kill Creek and on the Kansas River. Although results from this study will assist future survey work at SAAP, they are not sufficient to provide a baseline for the new discharge point. Therefore, baseline studies in lower Kill Creek and in the Kansas River are recommended before the completion of the nitroguanidine facility.

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RESULTS OF AQUATIC ECOLOGICAL SURVEYS AT SUNFLOWER ARMY AMMUNITION PLANT, LAWRENCE, KANSAS PART I: MACROINVERTEBRATES AND WATER QUALITY

I. INTRODUCTION.

The first nitroguanidine production facility in the United States is being constructed at Sunflower Army Ammunition Plant (SAAP), Lawrence, Kansas. The facility is to be designed to produce 45 tons of nitroguanidine per day by the reaction of cyanamide with ammonium nitrate, forming guanidine nitrate. The guanidine nitrate is dehydrated by strong sulfuric acid to form nitroguanidine.

Streams of industrial water will be completely recycled within the plant so that no process wastewater will leave. However, about 1,075,680 gal/day of other wastewaters will be discharged into the Kansas River:* these aqueous wastes will consist of condensates from evaporation and vacuum crystallization, cooling tower blowdown, and washwater from the zeolite softeners and silica removers. Figure 1 shows the location of the proposed discharge point from the nitroguanidine facility. Table 1 shows the chemical composition and quantity of wastewaters emitted from the nitroguanidine facility and its probable impacts on water quality in the Kansas River. If the discharge is as predicted, the impact should be small. However, because this facility is the first nitroguanidine facility in the country, discharge standards for this type of operation have not yet been promulgated and potential synergistic effects of the constituents of the discharge cannot be predicted. Therefore, baseline ecological surveys of the Kansas River were initiated in the spring of 1975 to establish current conditions and to compare them with conditions after discharge. A portion** of those survey results are presented here. During these initial surveys, sampling was also conducted on the creeks surrounding the plant to determine if past plant activites had caused adverse impacts and to gather baseline data to measure any impacts from the construction of the facility. Results of these surveys are also included. Details of past and present activities at SAAP are contained in the report from the preliminary environmental survey.

II. DESCRIPTION OF STUDY AREA.

Drainage from the plant is through Kill Creek, Spoon Creek, and Captain Creek, all of which flow north and eventually enter the Kansas River at two points (figure 1). The creeks (which also drain large farming areas upstream) receive runoff and ground water from the plant. Eight sampling sites were established. Six were located in creeks. They are Captain Creek Stations 1 to 3 (CC 1 to CC 3), Kill Creek Stations 1 and 2 (KC 1 and KC 2), and Spoon Creek Station 1 (SPC 1). (See figure 2.) Two were located in the Kansas River. They are Kansas River Stations 1 and 2 (KR 1 and KR 2). (See figure 1.)

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*Currently this discharge will be into Kill Creek. However, all waters may be recycled for use in the potable-water system if studies by the Surgeon General show there is no toxicity problem associated with these treated waters.

**Part II, *Periphyton* and Primary Productivity, will follow this report.

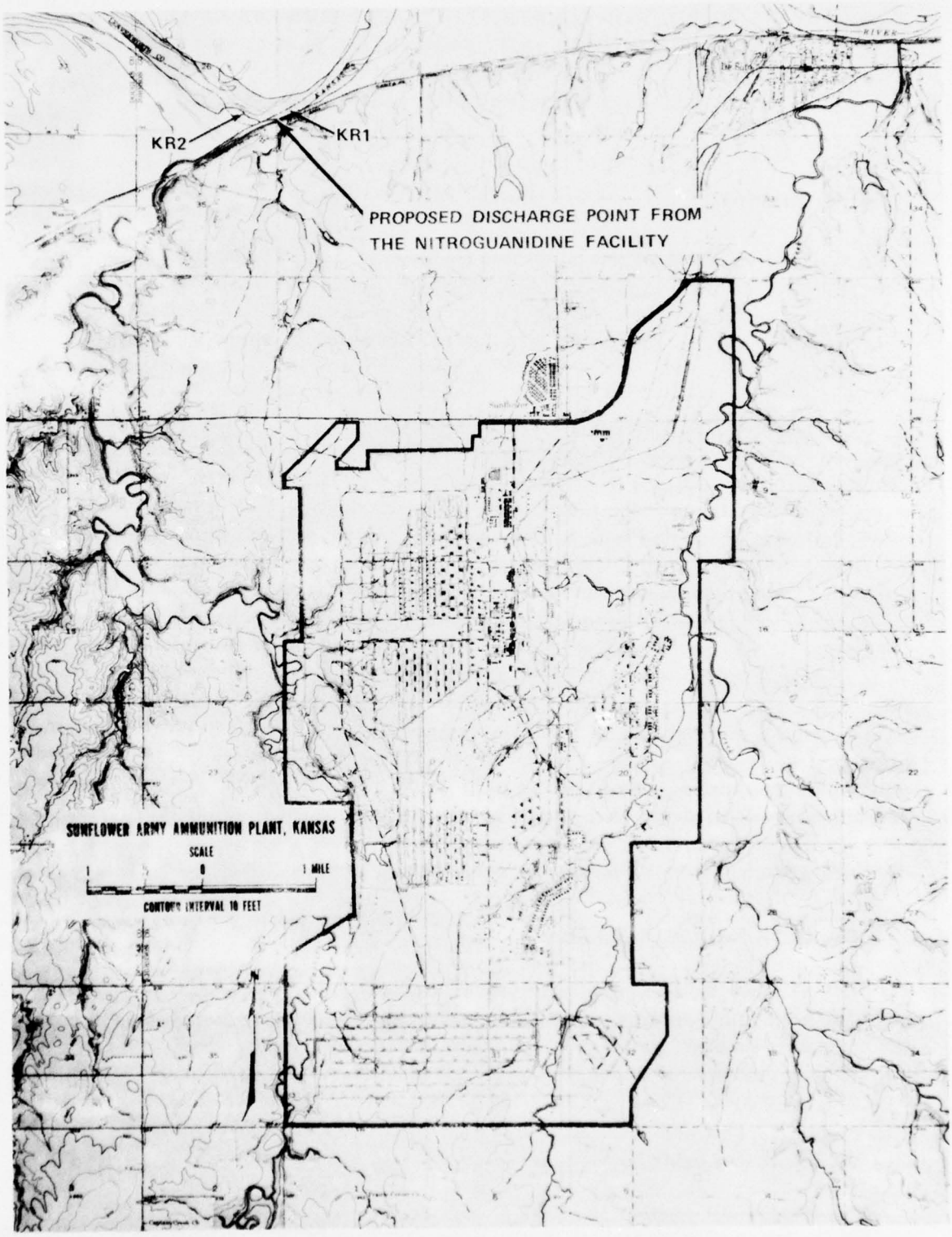

Figure 1. Location of Proposed Discharge Point From the Nitroguanidine Facility and Sampling Locations in the Kansas River

Table 1. Composition and Amounts of Wastewater From the Nitroguanidine Facility and Its Subsequent Impact on the Water Quality of the Kansas River[a]

Type of water	Flow		Concentration of mineral (mg/l)											BOD (COD)[b]	pH
			SO_4	Ca	Cl	Na	SiO_2	Mg	K	NO_3	PO_4	Fe	Total dissolved solids		
	ft^3/min	gal/day													
Waste streams:															
Cooling-tower blowdowns	88	126,720	1014	260	130	110	130	78	32	13	20	1.1	1972	10	6.5-7.0
Guanidine nitrate process	200	288,000	48	23	11	10	11	8	3	1	.05	.1	115	0	7.0
Nitroguanidine process	189	272,180	82	88	77	53	7	15	6	4	.6	.04	333	0	7.0
Total steam condensates	270	388,800	([c])	([c])	0	([c])	.03	([c])	([c])	([c])	([c])	.10	–	–	5.7
Combined effluent to river	747	1,075,680	153.0	59.0	38.0	29.0	20.00	15.0	6.10	2.80	2.50	.20	326.00	–	6.5-9.0
River:[d]															
Lowest known flow	224,877	–	.51	.20	.13	.10	.07	.05	.02	.009	.008	.0002	1.03	.004	([e])
Minimum flow	377,077	–	.34	.13	.08	.06	.04	.03	.01	.006	.006	.0004	3.16	.002	([e])
Normal flow	565,965	–	.202	.080	.049	.038	.027	.020	.008	.003	.003	.0003	.429	.002	([e])

[a]Calculated from data supplied by Sunflower Army Ammunition Plant.

[b]BOD = biological oxygen demand; COD = chemical oxygen demand.

[c]This mineral might occur in trace amounts from surges in the boiler; however, it will normally be undetectable.

[d]Increases of constitutents were calculated with the assumption that the concentration of each constituent normally is 0 in the Kansas River.

[e]No change.

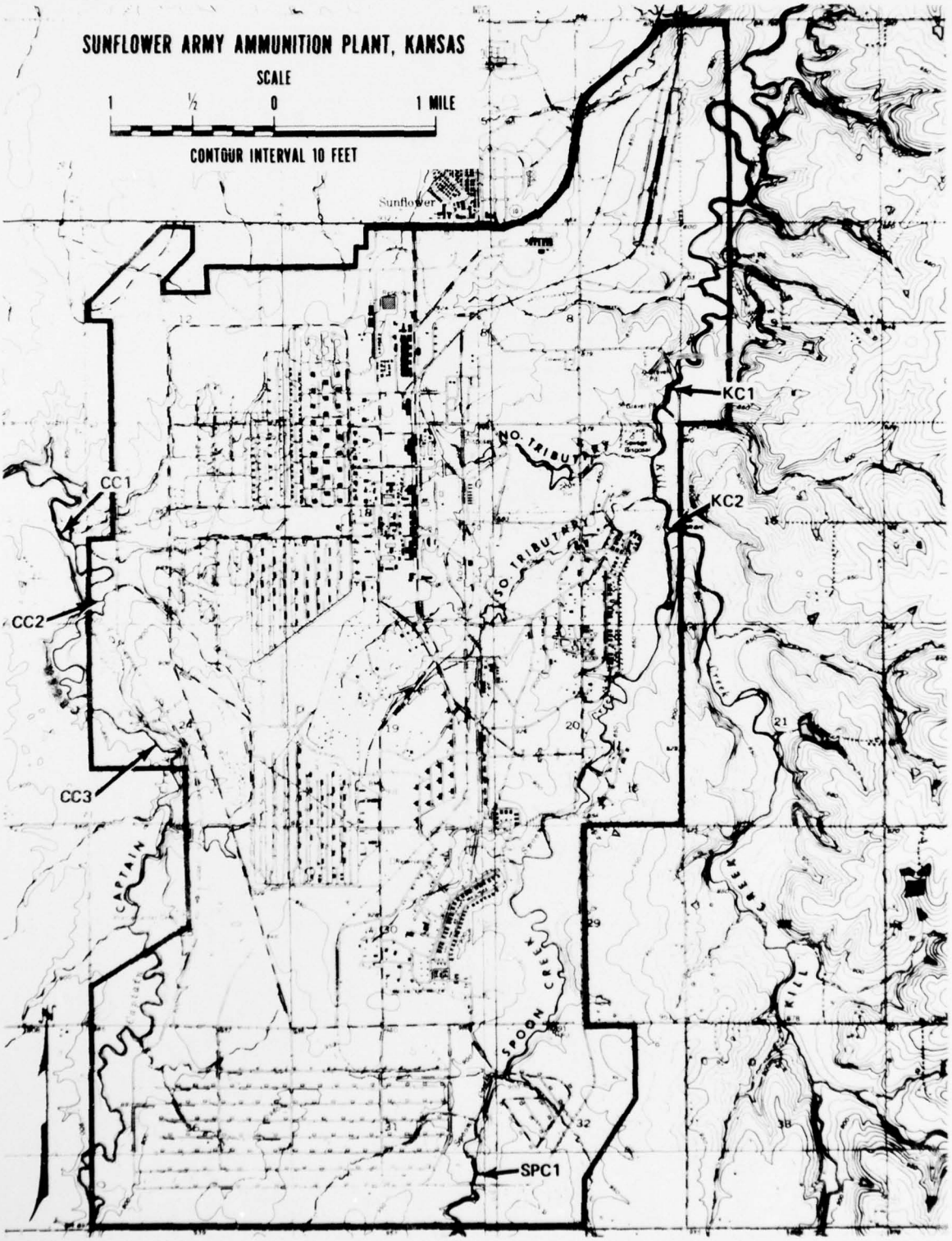

Figure 2. Sampling Locations on Sunflower Army Ammunition Plant

A. Creeks.

Captain Creek receives runoff and ground water from the western portion of the plant including part of the storage area, all of the burning grounds, solvent area, and the construction site for nitroguanidine facility (figure 3). It originates off the plant and has a total drainage area of approximately 48 mi^2, most of which is agricultural. There are no effluent discharges from the plant into Captain Creek. Spoon Creek receives runoff and ground water from the southeastern portion of the plant, which includes the remainder of the storage area, munitions-production area (N line), and mechanized-roll area. In addition, Spoon Creek received washdown discharges from N line when that line was operating. Spoon Creek will also receive discharges of 0.125 million gallons per day (Mgal/day) from the mechanized-roll facility, which is now under construction. Pearson *et al.*[1] provided a detailed description of the various plant areas and all plant discharges and their chemical characteristics. Outside the installation, Spoon Creek drains approximately 13 mi^2 of predominantly agricultural land, before converging with Kill Creek.

Kill Creek drains the remainder of the plant via two main tributaries, both of which enter the creek above station KC 1 but below KC 2 (figure 2). The South Tributary of Kill Creek received discharges from a munitions-production area (F line), the paste and nitroglycerine areas, and from the south acid area. The North Tributary received discharges from the nitrocellulose production area, north acid area, and powerhouse No. 3. During low flow, Kill Creek discharges from the photography laboratory, package boilers, and the sewage treatment plant (0.15 Mgal/day) through the South Tributary and overflow from pond B through the North Tributary of Kill Creek. Kill Creek originates off the plant where one of its branches is impounded as Gardner Reservoir. It drains approximately 40 mi^2, including the town of DeSoto, which is downstream from the plant near the Kansas River.

Riffle habitats comparable with one another (in depth and current-flow rates) were chosen as sampling sites in each of the creeks to reduce variability in sampling. Table 2 shows the ranges of creek depth, width, velocity, and mean substrate size for each of the six creek stations. The mean substrate size was computed as the longest dimension of 50 stones from each of the five 1-ft^2 areas of a riffle divided by the number of stones.

Data in table 2 indicate that stations on Captain Creek have a smaller range about their mean substrate size than do the other stations, suggesting greater substrate similarity among these stations. Stream velocity was variable at all stations with no observable trends. Both parameters are known to significantly affect the distributions of aquatic macroinvertebrates.[2]

B. Kansas River.

The two stations on the Kansas River were located below and above the originally proposed nitroguanidine production facility discharge (figure 1). The river is approximately 200 meters wide at the discharge point and the flow upstream is divided by an island. During low flow, approximately 70% of the flow is confined to the south side, where the sampling stations and proposed dicsharge site are located. Stream velocity at KR 2 ranged from 0.30 to 0.75 m/sec during the September sampling trip. The river sediments consisted of shifting coarse sand with some limited areas of mud in slack water areas near the banks and river islands. The Kansas River in this region has a drainage area of approximately 154,768 km^2 (59,756 mi^2).[3]

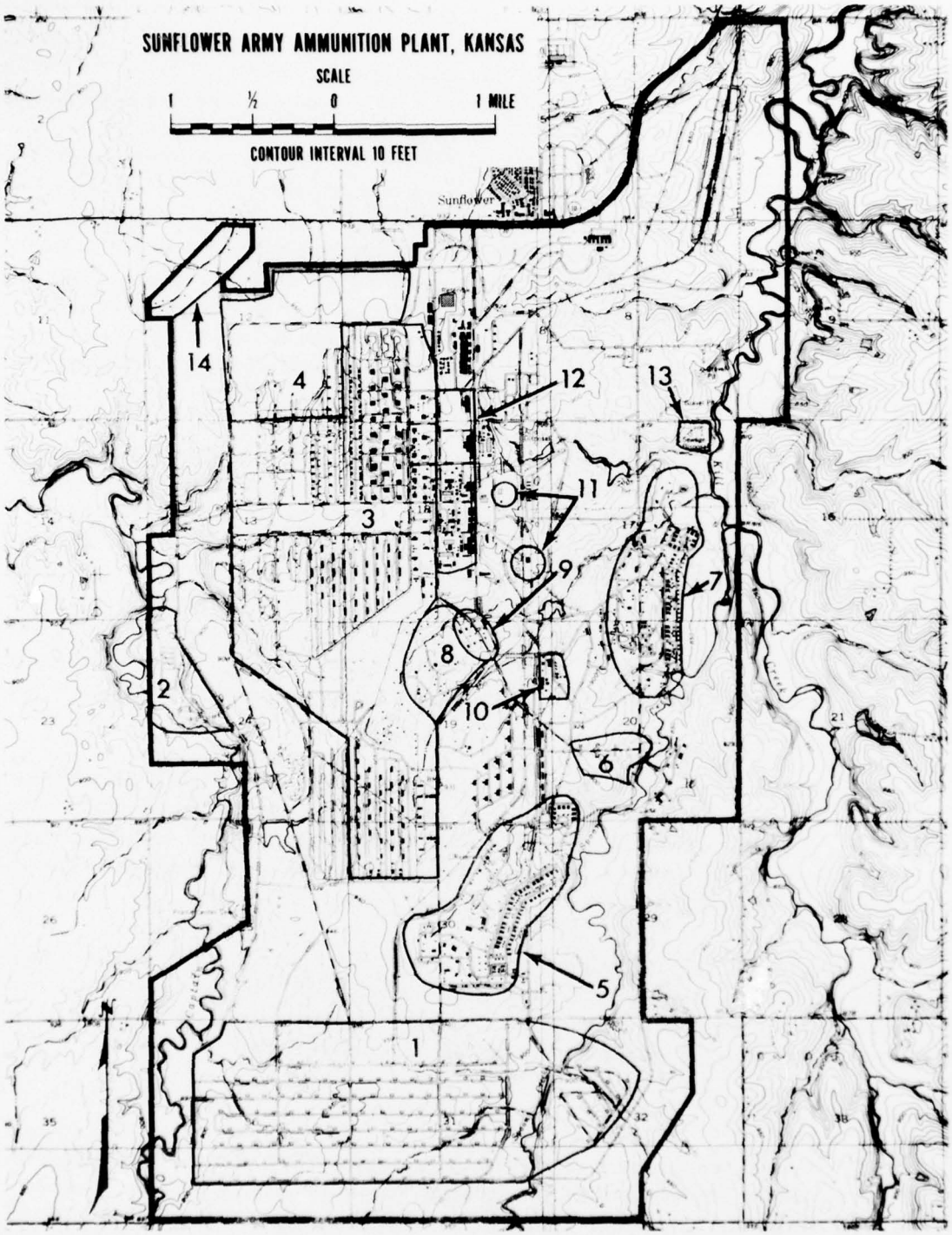

Figure 3. General Areas on Sunflower Ammunition Plant: (1) Storage Area, (2) Burning Grounds, (3) Solvent Area, (4) Nitroguanidine Facility, (5) N Line Munitions Production Area, (6) Mechanized Roll Area, (7) F Line, (8) Nitroglycerine, (9) Paste Area, (10) South Acid Area, (11) Powerhouse Area, (12) Nitrocellulose Area, (13) Sewage Treatment Plant, (14) Staff Housing

Table 2. Width, Depth, Substrate Size, and Stream Velocity at Sampling Stations on Captain Creek, Kill Creek, and Spoon Creek During the May-to-June Survey

Sample location	Width	Depth	Mean substrate size	Stream velocity
	m	cm	cm	m/sec
Captain Creek:				
CC 1	6-9	15-38	3.5	0.65-0.95
CC 2	3-6	25-48	4.5	.70-1.20
CC 3	3-9	10-33	4.8	.55-1.70
Kill Creek:				
KC 1	4-9	10-46	4.9	.80-1.30
KC 2	3-6	5-35	3.5	1.50-2.40
Spoon Creek: SPC 1	1-6	8-46	3.2	.45-.70

III. METHODS.

A. Chemical and Physical.

The date, type, and location of water samples taken for chemical and physical determinations are shown in table 3. Two types of water analyses were conducted: wet-lab chemistry on 24-hour composite samples, and continuous *in situ* measurements of pH, dissolved oxygen, temperature, and conductivity.

Table 3. Date, Type, and Location of Chemical Sampling

Station	Dates of collection	
	24-hr composite	*Continuous*
Captain Creek:		
CC 1	3-4 June 1975	3-4 June 1975
CC 2	(*)	(*)
CC 3	3-4 June 1975	3-4 June 1975
Kill Creek:		
KC 1	2-3 June 1975	28 May to 3 June 1975
	30-31 August 1975	29 August to 7 September 1975
KC 2	28-29 May 1975	28-30 May 1975
Spoon Creek: SPC 1	1-2 June 1975	30 May to 3 June 1975
Kansas River:		
KR 1	(*)	(*)
KR 2	5 June 1975**	5 June 1975
	27-28 August 1975	27 August to 9 September 1975
	29-30 August 1975	–
	4-5 September 1975	–
	6-7 September 1975	–

*Not sampled.
**6-hour composite sample.

Discrete water samples were collected with a No. 1392-X wastewater sampler* by taking hourly samples of equal volume. These samples were collected in separate containers that had been washed with phosphate-free detergent, rinsed with dilute nitric acid, and triple-rinsed with distilled water. The samples were kept in an ice bath (at 4° C) until chemical analyses were performed. These hourly samples were further composited by taking equal volumes from three consecutive samples. Chemical analyses were then performed on the eight samples (a 24-hour period) on the same day the sampler was recovered from the field. The following parameters were measured for all composite water samples according to standard methods:[4] total alkalinity (titration to pH 5.1); chloride (mercuric-nitrate method); total hardness (titration method); nitrogen, nitrate (diazotization method); phosphate, ortho (ascorbic acid method); total residue; filterable residue; nonfilterable residue; and sulfate (turbidimetric method). Turbidity was determined using an absorptometric method[5] on a Spectronic 20.**

All other analyses used Hach chemicals,† and spectrophotometric determinations were conducted with a Hach DR-2 spectrophotometer.

In situ water measurements were made with two model 6D Hydrolab Surveyors.†† Continuous recording was accomplished by using a Hydrolab model 400 recorder and model 10S1 data scanner with one unit, and a model 4A controller/digital data logger§ with the other unit. The pH probe of the data-logger unit did not function during the May to June survey. Conductivity, temperature and pH probes were calibrated against laboratory standards before field use and thereafter every 3 days while in the field. The dissolved oxygen probes were calibrated every 3 days with the use of the partial pressure of O_2 in air corrected for barometric pressure as a standard. Stream velocity was measured with a model 665-E direct-read Gurley current meter.§§

B. Biological.

Macroinvertebrate collections were made at all six creek sampling locations on 30 May and 1 June 1975 and only at KC 1 on 6 September 1975 because it was the only creek station that had flowing water. Sampling consisted of five replicate 1-ft^2 (0.093 m^2) samples taken in riffles with a portable invertebrate box sampler (PIBS).‖ All rubble was removed from the sample area and was scrubbed with a soft-bristle brush, or the invertebrates were removed by hand. The contents of the sampler were washed into a No. 30 mesh sieve bucket (0.595-mm openings) and were then transferred to jars containing 70% isopropyl alcohol and 150 mg/l of rose bengal dye. The organisms were sorted from the debris in a white enamel pan and were preserved in 70% isopropyl alcohol for later identification and enumeration. Collections of macroinvertebrates were made in the Kansas River at two locations (KR 1 and KR 2) during the May-to-June survey and at one station (KR 2) during the August-to-September survey. During the May-to-June survey three replicate artificial substrate samplers[6] (barbecue baskets) were suspended 0.5 meters below the surface from buoys at both stations. In August, two sets of three replicate artificial substrates were also suspended 0.5 meters below the surface at KR 2. The artificial substrate samplers were allowed

*Instrumentation Specialties Company, Lincoln, Nebraska.
**Bausch and Lomb, Inc., Rochester, New York.
†Hach Chemical Company, Ames Iowa.
††Hydrolab Corporation, Austin, Texas.
§New England Research Associates, Inc., Lexington, Massachusetts.
§§Teledyne Gurley Hydrological Instruments, Troy, New York.
‖Ellis-Rutter Associates, Douglasville, Pennsylvania.

to be colonized by organisms for 30 days, from May to June, and for 15 days from late August to mid-September.

During the August-to-September survey, two round multiplate, variably-spaced samplers[7] were also used at KR 2 to compare the efficiency of the two types of samplers. A detailed comparison of the two methods will be presented in a separate report. The artificial substrate samplers (barbecue baskets)* were 7 by 11 inches (17.8 by 28 cm) containing unglazed lapped porcelain spheres** exposing 2.62 ft^2 (0.24 m^2) of surface.[7] When filled with 30 spheres, the baskets were wired shut and were suspended with 1/8-inch stainless-steel cable 0.5 meters below the surface from a ring of six 1-gal jugs filled with styrofoam. The float was anchored to 220 pounds (100 kg) of concrete blocks bound together with 1/8-inch stainless-steel cable.

During sample collection, a No. 30 sieve bucket was placed around the baskets before they were removed from the water. Once out of the water, they were placed in a dishpan, and the spheres were removed and scrubbed. Samples were then treated as previously described.

All organisms were identified to species when possible with the use of common taxonomic references,[8-17] followed by consultations with taxonomists† for confirmation of our identification. For this study an acceptable error of ±20% was used for estimates of the true mean. Taxonomic treatment of each group of organisms was uniform throughout the study and the lowest level of identification for each kind of organism was considered as one taxon when determining the total number of taxa in each sample.

C. Statistical Analysis.

Means, standard deviations, and ranges were calculated for all chemical and physical parameters in each sample.

Data resulting from identification of benthic macroinvertebrates were grouped and coded for computer analysis by stream, station, and sample number. The Shannon diversity index[18] was calculated for each replicated sample according to the formula

$$\bar{d} = -\sum_{i=1}^{s} \frac{N_i}{N} \log_2 \frac{N_i}{N}$$

where N is the total number of individuals collected for all species (s) and N_i is the number of individuals for a single species (i).[19] Shannon diversity measures the uncertainty of collecting a specimen of a particular species at random from the community. When the number of species increases, and the number of individuals for each species is equal, the uncertainty of collecting a particular species is high, and, hence, the diversity is also high. In monospecific collections there is no uncertainty because only one species is collected; then the diversity $d = 0$. The diversity index considers the number of species and the distribution of individuals among the species and is useful

*Paramount Wire, Inc., Alhambra, California.

**Ferro Corporation, Refractories Division, East Liverpool, Ohio.

†These were Donald G. Huggins (*Odonata, Esphemeroptera, Trichoptera, Megaloptera,* and *Neuroptera*), Paul M. Liechti (*Hemiptera*), Dave Roukik (*Coleoptera*), all affiliated with the State Biological Survey of Kansas, Lawrence, Kansas; Kenneth W. Steward and William Stark (*Plecoptera*), North Texas State University, Denton, Texas; and John S. Dendy and Kenneth L. Manuel (*Chironomidae* and other *Diptera*), Auburn University, Auburn Alabama.

for comparing macroinvertebrate communities between different locations. These indices were grouped by station and analyzed by a one-way analysis of variance (ANOVA) to detect statistically significant differences between mean-station diversities.* ANOVA was also performed on the number of species and number of individuals to test for differences in these means between stations. The data were also tested to determine whether they met the assumptions underlying an ANOVA (such as having a normal distribution). Accordingly, the number X of individuals of macroinvertebrates, X, was transformed to $\log_{10}(X + 1)$ to satisfy the assumptions of ANOVA. Because one-way ANOVA cannot be used to show differences between specific stations in means, a means separation test, the Student-Newman-Keuls test,[20] was used to rank and measure the differences between stations in means.

The index of biotic similarity[21] B was calculated for macroinvertebrate distributions among stations according to the formula

$$B = \frac{1}{k} \sum_{i=1}^{k} \frac{\min (X_{i,a}, X_{i,b})}{\max (X_{i,a}, X_{i,b})}$$

where $X_{i,a}$ and $X_{i,b}$ are the numbers of individuals of species i at stations a and b, respectively. This was based on a matrix of numerically dominant species that had both significant distributions (ANOVA, $\alpha = 0.10$) and were collected in numbers at least the number of replications being analyzed. The level for $\alpha = 0.10$ was employed in these ANOVA tests instead of the more stringent level for $\alpha = 0.05$ to reveal trends or patterns in station differences rather than to establish proof of differences.

An important feature of B is that it allows the user to omit matches in which a particular species is absent from both stations (0-0 matches ignored) or to assign them the maximum value (0-0 matches equal 1.) This feature allows the user to incorporate or exclude mutual-absence-type data when generating the similarity index, depending upon the judgment of the users upon the validity of these matches. For example, in a set of data in which there are many rare species, there would also be numerous mutual-absence-type matches, therefore, the option for 0-0 matches to be ignored would be the one of choice because these matches are probably insignificant. However, if the rare or insignificant occurrences were removed from the data, as was done in this case, then mutual-absence-type matches would reflect actual similarity between stations, and, therefore, the option for 0-0 matches equal 1 would be appropriate.

The matrix of coefficients of biotic similarity between stations was then subjected to cluster analysis.[22] We have used the unweighted pair-group method, which has been shown to introduce the least distortion in the clusters.[23] The results of the cluster analysis are displayed in the form of a dendrogram. The amount of distortion in the dendrogram caused by the cluster method was determined for each analysis by the calculation of a cophenetic correlation coefficient r_{sc}.[24] Interpretations of dendrograms with cophenetic correlations $r_{sc} < 0.75$ must be cautious. A detailed discussion of cluster analysis methods can be found in the work of Sneath and Sokal.[25]

*Cimba, P. A., Asaki, A. E., Pearson, J. G., and Bender, E. S. ARCSL-TR-77035. A Computer Program for the Analysis of Macroinvertebrate Data From Water Quality Surveys. May 1977. UNCLASSIFIED Report.

Spearman's rank-correlation coefficients[20] r_s were also calculated between stations based on species ranked in order of their abundance. The statistical significance of these coefficients was determined according to Dixon and Massey.[26]

IV. RESULTS.

A. Chemical and Physical.

Flow data for the Kansas River from the DeSoto, Kansas, gaging station was obtained from the Department of Interior* (Table 4). Flow during the first survey (14,319 ft^3/s, average, with a standard deviation of 8,956 ft^3/s. This is considered to be typical seasonal variation for the Kansas River.*

Flow data for the sampling station on the creeks surrounding SAAP were presented in table 2.

Rainfall data for SAAP during the surveys are shown in table 5. Rainfall during the spring trip was normal, but subsequently Kansas suffered one of its lowest summer rainfalls in many years. The rain that occurred in August had very little effect on flow in the Kansas River. Even after 17 inches of rainfall on 26 August, there were no detectable flow in the creeks around SAAP.

Table 4. Flow Data From Kansas River at DeSoto, Kansas, During the Survey, May to September 1975

Date	Flow	Date	Flow
	ft^3/s		ft^3/s
27 May	2,680	26 Aug.	3,850
28 May	3,390	27 Aug.	3,780
29 May	8,570	28 Aug.	3,930
30 May	9,790	29 Aug.	3,670
31 May	14,000	30 Aug.	3,430
1 June	10,800	31 Aug.	3,060
2 June	8,290	1 Sept.	2,960
3 June	8,570	2 Sept.	2,840
4 June	18,500	3 Sept.	2,810
5 June	17,200	4 Sept.	2,690
6 June	16,700	5 Sept.	2,590
7 June	17,200	6 Sept.	3,070
8 June	16,800	7 Sept.	3,890
9 June	23,400	8 Sept.	3,380
10 June	38,900	9 Sept.	2,510
Mean	14,319	10 Sept.	2,240
Standard deviation	8,956	Mean	3,169
		Standard deviation	546

*Curtis, R., Water Resources Division, U.S. Geological Survey, Lawrence, Kansas, personal communication, 1975.

Table 5. Precipitation at Sunflower Army Ammunition Plant, May to September 1975

Date	Amount	Date	Amount	Date	Amount
	inches		inches		inches
8 May	0.40	3 June	0.44	26 August	1.70
12 May	0.58	4 June	0.01	28 August	0.15
23 May	1.27	9 June	1.05	29 August	0.95
27 May	0.60	11 June	0.82	Monthly total	2.80
28 May	0.26	17 June	0.42	Monthly mean*	3.93
29 May	1.76	Monthly total	2.74	5 September	0.12
30 May	0.42	Monthly mean*	4.88	11 September	1.40
Monthly total	5.29	24 July	0.35	12 September	0.18
Monthly mean*	4.65	Monthly total	0.35	Monthly total	1.70**
		Monthly mean*	3.93	Monthly mean*	4.32

*39-year mean from ref 27.
**Based on first 12 days of September 1975.

1. Creeks.

Summaries of water-quality data collected during the May-to-June survey for five of the creek sampling stations are presented in tables A-1 to A-5 in appendix A. These data were collected during a period of highly variable flow as a result of runoff (table 5). This condition is reflected in the high and variable mean total residue value X = 1843.6 mg/l, with a standard deviation of 785.3, from KC 1. All values for parameters from KC 1, KC 2, and SPC 1 were similar and within the bounds of values previously reported from the creeks.[1] The values from Captain Creek are probably within normal values for that drainage, although no comparable data are available.

Comparing values between KC 1 and CC 1 (the two downstream stations for the respective drainages) revealed that KC1 had higher mean values for total alkalinity (198.5 versus 87.5 mg/l), total hardness (156.7 versus 113.8 mg/l), and conductivity (419.1 versus 269.3 μS/cm) between the two drainages. That these values are higher appears to be related to higher concentrations of dissolved materials and the greater buffering capacity of Kill Creek.

Water-quality data from the creeks were limited to KC 1 during the August-to-September survey, because it was the only station with a flow. The flow at KC 1 was sustained by discharges from the sewage treatment plant and the south acid area via the South Tributary and overflow from Pond B via the North Tributary. The data from KC 1 are shown in tables A-6 and A-7 in appendix A. Comparing these data to the May-to-June data shows that alkalinity and residues decreased, whereas chloride, hardness, nitrate, sulfate, temperature, and conductivity increased. The higher water temperature and lower residues were related to higher ambient air temperatures and lower runoff, respectively. Increased chloride, hardness, sulfate, and conductivity were probably caused by discharges from the south acid plant, and part of the increased nitrate level might also be attributable to the sewage treatment plant.

Plots of continuous measurements of water temperature, conductivity, pH, and dissolved oxygen for CC 1 during the August-to-September survey are shown in figures 4 to 7. Table 6 is a summary of the data presented in the plots.

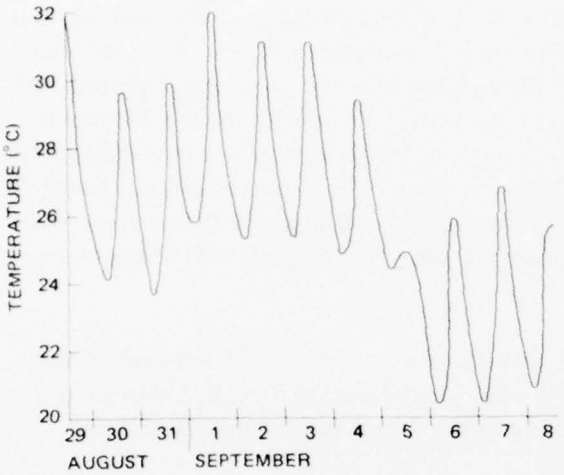

Figure 4. Temperature at Kill Creek Station 1, 29 August to 8 September 1975

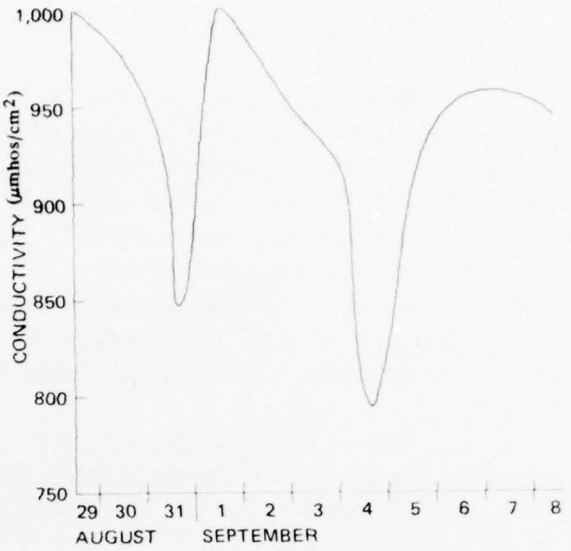

Figure 5. Conductivity at Kill Creek Station 1, 29 August to 8 September 1975

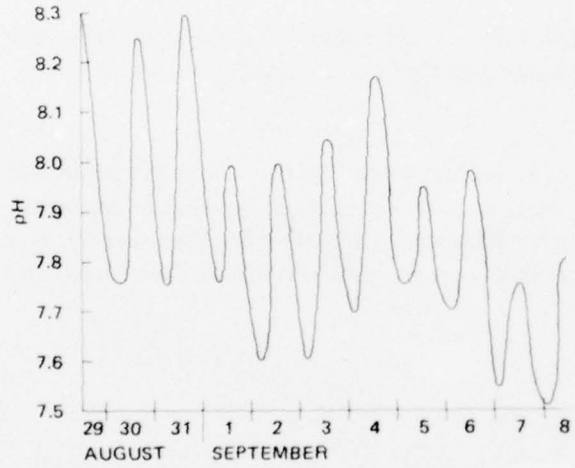

Figure 6. pH at Kill Creek Station 1, 29 August to 8 September 1975

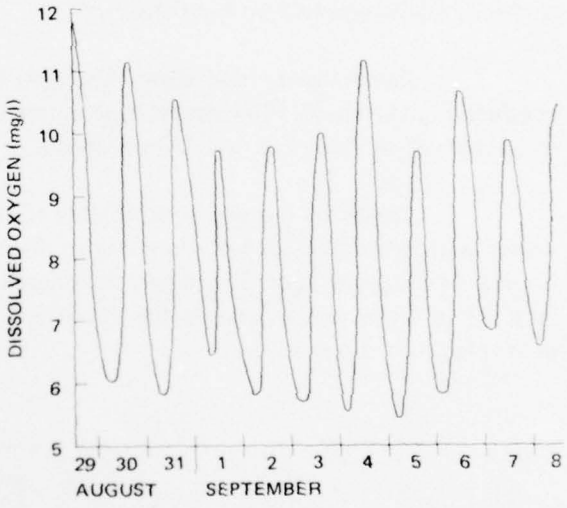

Figure 7. Dissolved oxygen at Kill Creek Station 1, 29 August to 8 September 1975

Table 6. Summary of Continuous Monitoring of Water Quality at Kill Creek Station 1, 29 August to 8 September 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Conductivity, μS/cm*	625	938.5	49.69	795.0	1000.0
Oxygen, dissolved, mg/l	588	7.84	1.54	5.4	11.8
pH	623	7.85	.18	7.50	8.30
Temperature, °C	619	26.01	2.73	20.2	32.2

*1 S = 1 ohm^{-1} = 1 mho.

2. Kansas River.

Summaries of water-quality data collected at KR 2 during the May-to-June and August-to-September surveys are shown in tables A-8 to A-12 in appendix A. The values obtained from limited sampling during the May-to-June survey agree well with those previously reported. The same is true for data from the second survey, except the data for turbidity during the last two samplings. There were significant increases in alkalinity, chloride, hardness, sulfate, conductivity, and water temperature between the two survey periods. These are normal and are probably the result of changes in flow and ambient air temperatures. During the August-to-September survey there was a significant decrease in nonfilterable residue and turbidity in early September 1975. These changes appear to be the result of decreased flow (table 4).

Plots of temperature, conductivity, pH, and dissolved oxygen measurements for KR 2 during the second survey are shown in figures 8 to 11. Flow for the Kansas River at DeSoto, Kansas (table 4), is also shown on figure 9. Table 7 is a summary of the data presented in these figures.

Diurnal fluctuation in water temperature (approximately 4°C) was similar throughout the study. However, there was a warming trend through 3 September after which temperatures declined and remained stable from September 5 to 9. Changes in water temperatures followed changes in daily ambient air temperatures.

Conductivity and flow (figure 9) showed an inverse relationship: as flow decreased conductivity increased. Flow generally decreased through 5 September, then there was an extremely rapid increase in flow, followed by a decrease.

Dissolved oxygen and pH showed the same basic pattern (figures 10 and 11), moderate values with restricted diurnal fluctuations from 27-30 August, the increasing values with higher diurnal fluctuations from 31 August to 6 September, when both parameters declined sharply. The increase in these parameters is the result of increased primary production, probably from the phytoplankton community.

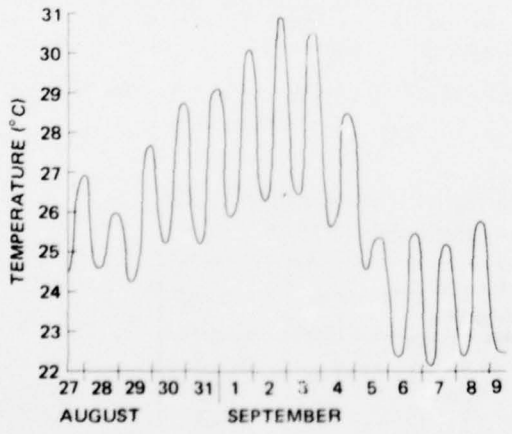

Figure 8. Water temperature at Kansas River Station 2, 27 August to 9 September 1975

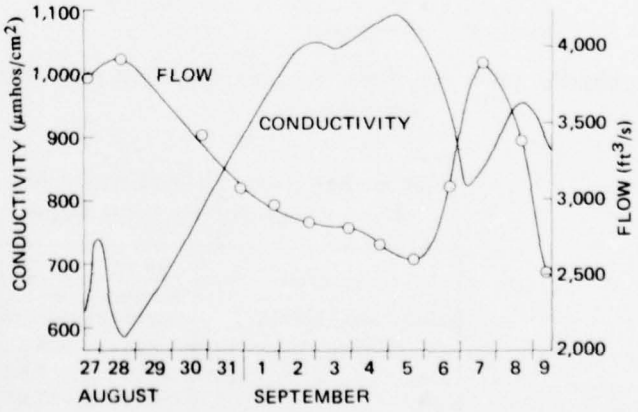

Figure 9. Conductivity and flow at Kansas River Station 2, 27 August to 9 September 1975

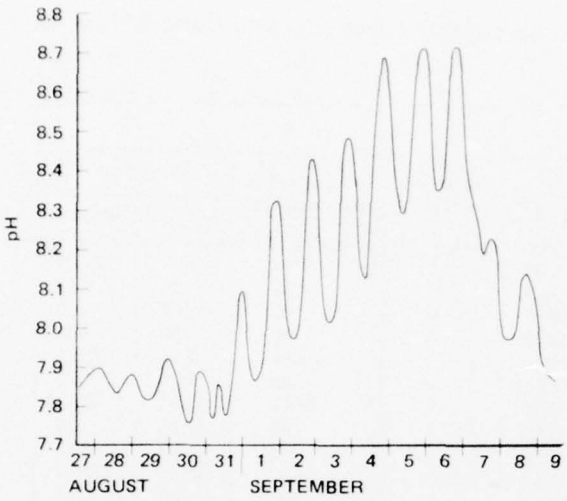

Figure 10. pH at Kansas River Station 2, 27 August to 9 September 1975

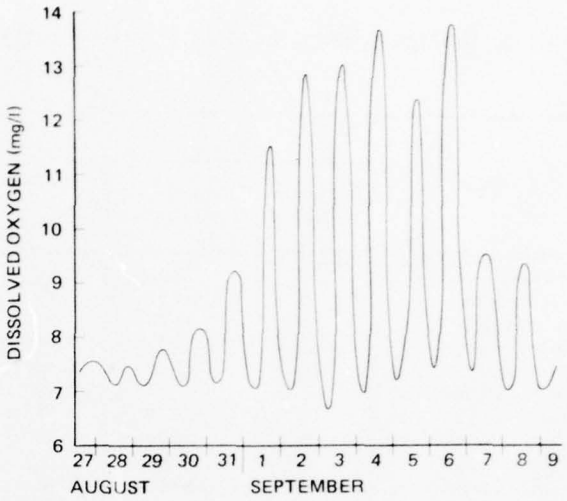

Figure 11. Dissolved oxygen at Kansas River Station 2, 27 August to 9 September 1975

Table 7. Summary of Continuous Monitoring of Water Quality at Kansas River Station 2, 27 August to 9 September 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Conductivity, μmhos/cm^2)	1,234	896.4	148.2	565	1,160
Oxygen, dissolved, mg/l	1,234	8.56	1.72	6.5	13.7
pH	1,234	8.13	.28	7.74	8.75
Temperature, °C	1,234	26.11	2.14	22.1	31.1

B. Biological.

1. Creeks.

a. May-to-June Survey.

The distributions and abundances of macroinvertebrates collected with the PIBS during the May-to-June survey at all six creek stations are shown in tables 8 to 10. A summary of these data is given in table 11. These data represent the total of five replicate samples at each of the six stations. Appendix B contains the data for the five replicate samples at each station. A total of 7,799 individuals and 53 taxa were collected. Thirteen taxa comprised 93.37% of all the individuals collected: *Cheumatopsyche* sp. (38.56%), *Stenelmis* sp. (29.66%), *Simulium* sp. (5.04%), *Polypedilum* sp. (4.12%), *Isonychia* sp. (3.22%), *Oligochaeta* sp. (2.94%), *Pentaneura* sp. (2.27%), *Microtendipes* sp. (2.01%), *Baetis* sp. (1.53%), *Physa hawnii* (1.13%), *Caenis* sp. (1.04%), *Cricotopus* sp. (0.95%), and *Stenonema* sp. (0.90%).

Table 8. Biological Data (Sum of Five Replicates) From Captain Creek Stations 1 and 2, May to June 1975

Taxon	CC 1				CC 2			
	Individuals per sample	Individuals per square meter	Abundance		Individuals per sample	Individuals per square meter	Abundance	
			Relative	Absolute			Relative	Absolute
Argia moesta	1	2.15	.06	25.00	1	2.15	.07	25.00
Astacidae sp.	2	4.31	.11	6.67	2	4.31	.14	6.67
Atherix sp.	2	4.31	.11	28.57	0	.00	.00	.00
Athripsodes sp.	1	2.15	.06	100.00	0	.00	.00	.00
Baetis sp.	46	99.03	2.60	38.66	39	83.96	2.69	32.77
Branchiura sowerbyi	21	45.21	1.19	53.85	0	.00	.00	.00
Caenis sp.	17	36.60	.96	20.99	29	62.43	2.00	35.80
Ceratopogonidae sp.	2	4.31	.11	33.33	0	.00	.00	.00
Chaoborus sp.	0	.00	.00	.00	0	.00	.00	.00
Cheumatopsyche sp.	975	2099.03	55.08	32.42	665	1431.65	45.93	22.12
Chironomus sp.	1	2.15	0.06	20.00	0	.00	.00	.00
Chrysops sp.	0	.00	.00	.00	0	.00	.00	.00
Collembola sp.	0	.00	.00	.00	0	.00	.00	.00
Corixidae sp.	2	4.31	.11	100.00	0	.00	.00	.00
Corydalus sp.	1	2.15	.06	33.33	1	2.15	.07	33.33
Coryneura sp.	0	.00	.00	.00	0	.00	.00	.00
Cricotopus sp.	9	19.38	.51	12.16	0	.00	.00	.00
Cryptochironomus sp.	3	6.46	.17	15.79	0	.00	.00	.00
Dicrotendipes sp.	6	12.92	.34	18.75	0	.00	.00	.00
Dubiraphia sp.	12	25.83	.68	30.00	8	17.22	.55	20.00
Eukiefferiella sp.	0	.00	.00	.00	0	.00	.00	.00
Ferrissia kirklandi	1	2.15	.06	16.67	2	4.31	.14	33.33
Glyptotendipes sp.	0	.00	.00	.00	1	2.15	.07	50.00
Hemiptera unk	1	2.15	.96	100.00	0	.00	.00	.00
Hirudinea unk	3	6.46	.17	13.64	0	.00	.00	.00
Hyallela azteca	2	4.31	.11	10.53	11	23.68	.76	57.89
Hydrophilus sp.	0	.00	.00	.00	0	.00	.00	.00
Hydroptila sp.	9	19.38	.51	56.25	0	.00	.00	.00
Ischnura sp.	0	.00	.00	.00	1	2.15	.07	100.00
Isonychia sp.	103	221.74	5.82	41.04	128	275.57	8.84	51.00
Licerus sp.	0	.00	.00	.00	0	.00	.00	.00
Lymnaea sp.	0	.00	.00	.00	1	2.15	.07	14.29
Microtendipes sp.	9	19.38	.51	5.73	0	.00	.00	.00
Neoperla sp.	1	2.15	.06	33.33	2	4.31	.14	66.67
Oligochaete sp.	18	38.75	1.02	7.85	13	27.99	.90	5.68
Parachironomus sp.	0	.00	.00	.00	0	.00	.00	.00
Pentaneura sp.	27	58.13	1.53	15.25	36	77.50	2.49	20.34
Pericoma sp.	0	.00	.00	.00	0	.00	.00	.00
Perlesta placida	2	4.31	.11	28.57	1	2.15	.07	14.29
Physa hawnii	8	17.22	.45	9.09	1	2.15	.07	1.14
Plecoptera unk	1	2.15	.06	100.00	0	.00	.00	.00
Polypedilum sp.	45	96.88	2.54	14.02	24	51.67	1.66	7.48
Procladius sp.	0	.00	.00	.00	2	4.31	.14	13.33
Psectrocladius sp.	0	.00	.00	.00	0	.00	.00	.00
Pseudochironomus sp.	14	30.14	.79	50.00	1	2.15	.07	3.57
Rheotanytarsus sp.	6	12.92	.34	16.22	0	.00	.00	.00
Simulium sp.	20	43.06	1.13	5.09	52	111.95	3.59	13.23
Sphaerium sp.	33	71.04	1.86	67.35	3	6.46	.21	6.12
Stenelmis sp.	328	706.14	18.53	14.18	388	835.31	26.80	16.77
Stenonema sp.	22	47.36	1.24	31.43	31	66.74	2.14	44.29
Strictochironomus sp.	6	12.92	.34	23.08	0	.00	.00	.00
Tanytarsus sp.	1	2.15	.06	50.00	0	.00	.00	.00
Tricorythodes sp.	9	19.38	.51	60.00	5	10.76	.35	33.33

Table 9. Biological Data (Sum of Five Replicates) From Captain Creek Station 3 and Kill Creek Station 1, May to June 1975

Taxon	CC 3				KC 1			
	Individuals per sample	Individuals per square meter	Abundance		Individuals per sample	Individuals per square meter	Abundance	
			Relative	Absolute			Relative	Absolute
Argia moesta	1	2.15	0.14	25.00	0	0.00	0.00	0.00
Astacidae sp.	0	.00	.00	.00	5	10.76	.71	16.67
Atherix sp.	4	8.61	.56	57.14	0	.00	.00	.00
Athripsodes sp.	0	.00	.00	.00	0	.00	.00	.00
Baetis sp.	8	17.22	1.12	6.72	12	25.83	1.69	10.08
Branchiura sowerbyi	0	.00	.00	.00	18	38.75	2.54	46.15
Caenis sp.	14	30.14	1.95	17.28	3	6.46	.42	3.70
Ceratopogonidae sp.	1	2.15	.14	16.67	1	2.15	.14	16.67
Chaoborus sp.	0	.00	.00	.00	2	4.31	.28	8.33
Cheumatopsyche sp.	343	738.43	47.84	11.41	57	122.71	8.05	1.90
Chironomus sp.	0	.00	.00	.00	3	6.46	.42	60.00
Chrysops sp.	5	10.76	.70	26.32	1	2.15	.14	5.26
Collembola sp.	1	2.15	.14	100.00	0	.00	.00	.00
Cortxidae sp.	0	.00	.00	.00	0	.00	.00	.00
Corydalus sp.	0	.00	.00	.00	1	2.15	.14	33.33
Coryneura sp.	0	.00	.00	.00	0	.00	.00	.00
Cricotopus sp.	5	10.76	.70	6.76	7	15.07	.99	9.46
Cryptochironomus sp.	0	.00	.00	.00	4	8.61	.56	21.05
Dicrotendipes sp.	1	2.15	.14	3.13	2	4.31	.28	6.25
Dubiraphia sp.	17	36.60	2.37	42.50	2	4.31	.28	5.00
Eukiefferiella sp.	0	.00	.00	.00	1	2.15	.14	100.00
Ferrissia kirklandi	3	6.46	.42	50.00	0	.00	.00	.00
Glyptotendipes sp.	1	2.15	.14	50.00	0	.00	.00	.00
Hemiptera unk	0	.00	.00	.00	0	.00	.00	.00
Hirudinea unk	15	32.29	2.09	68.18	0	.00	.00	.00
Hyallela azteca	2	4.31	.28	10.53	2	4.31	.28	10.53
Hydrophilus sp.	0	.00	.00	.00	0	.00	.00	.00
Hydroptila sp.	3	6.46	.42	18.75	0	.00	.00	.00
Ischnura sp.	0	.00	.00	.00	0	.00	.00	.00
Isonychia sp.	13	27.99	1.81	5.81	2	4.31	.28	.80
Licerus sp.	0	.00	.00	.00	4	8.61	.56	44.44
Lymnaea sp.	0	.00	.00	.00	0	.00	.00	.00
Microtendipes sp.	8	17.22	1.12	5.10	57	122.71	8.05	36.31
Neoperla sp.	0	.00	.00	.00	0	.00	.00	.00
Oligochaeta sp.	8	17.22	1.12	3.49	143	307.86	20.20	62.45
Parachironomus sp.	11	23.68	1.53	73.33	0	.00	.00	.00
Pentaneura sp.	19	40.90	2.65	10.73	35	75.35	4.94	19.77
Pericoma sp.	1	2.15	.14	100.00	0	.00	.00	.00
Perlesta placida	0	.00	.00	.00	2	4.31	.28	28.57
Physa hawnii	16	34.45	2.23	18.18	7	15.07	.99	7.95
Plecoptera unk	0	.00	.00	.00	0	.00	.00	.00
Polypedilum sp.	38	81.81	5.30	11.84	51	109.80	7.20	15.89
Procladius sp.	0	.00	.00	.00	5	10.76	.71	33.33
Psectrocladius sp.	1	2.15	.14	100.00	0	.00	.00	.00
Pseudochironomus sp.	2	4.31	.28	7.14	7	15.07	.99	25.00
Rheotanytarsus sp.	6	12.92	.84	16.22	3	6.46	.42	8.11
Simulium sp.	28	60.28	3.91	7.12	4	8.61	.56	1.02
Sphaerium sp.	4	8.61	.56	8.16	0	.00	.00	.00
Stenelmis sp.	133	286.33	18.55	5.75	252	542.52	35.59	10.89
Stenonema sp.	5	10.76	.70	7.14	1	2.15	.14	1.43
Strictochironomus sp.	0	.00	.00	.00	12	25.83	1.69	46.15
Tanytarsus sp.	0	.00	.00	.00	1	2.15	.14	50.00
Tricorythodes sp.	0	.00	.00	.00	1	2.15	.14	6.67

Table 10. Biological Data (Sum of Five Replicates) From Kill Creek Station 2 and Spoon Creek Station 1, May to June 1975

Taxon	KC 2				SPC 1			
	Individuals per sample	Individuals per square meter	Abundance		Individuals per sample	Individuals per square meter	Abundance	
			Relative	Absolute			Relative	Absolute
Argia moesta	0	0.00	0.00	0.00	1	2.15	0.10	25.00
Astacidae sp.	20	43.06	.94	66.67	1	2.15	.10	3.33
Atherix sp.	0	.00	.00	.00	1	2.15	.10	14.29
Athripsodes sp.	0	.00	.00	.00	0	.00	.00	.00
Baetis sp.	12	25.83	.57	10.08	2	4.31	.19	1.68
Branchiura sowerbyi	0	.00	.00	.00	0	.00	.00	.00
Cl[illegible] sp.	11	23.68	.52	13.58	7	15.07	.67	8.64
Ceratopogonidae sp.	1	2.15	.05	16.67	1	2.15	.10	16.67
Ch[illegible]borus sp.	13	27.99	.61	54.17	9	19.38	.87	37.50
Cheumatopsyche sp.	688	1481.16	32.50	22.88	279	600.65	26.85	9.28
Chironomus sp.	1	2.15	.05	20.00	0	.00	.00	.00
Chrysops sp.	0	.00	.00	.00	13	27.99	1.25	68.42
Collembola sp.	0	.00	.00	.00	0	.00	.00	.00
Corixidae sp.	0	.00	.00	.00	0	.00	.00	.00
Corydalus sp.	0	.00	.00	.00	0	.00	.00	.00
Coryneura sp.	1	2.15	.05	100.00	0	.00	.00	.00
Cricotopus sp.	26	55.97	1.23	35.14	27	58.13	2.60	36.49
Cryptochironomus sp.	11	23.68	.52	57.89	1	2.15	.10	5.26
Dicrotendipes sp.	3	6.46	.14	9.38	20	43.06	1.92	62.50
Dubiraphia sp.	1	2.15	.05	2.50	0	.00	.00	.00
Eukiefferiella sp.	0	.00	.00	.00	0	.00	.00	.00
Ferrissia kirklandi	0	.00	.00	.00	0	.00	.00	.00
Glyptotendipes sp.	0	.00	.00	.00	0	.00	.00	.00
Hemiptera unk	0	.00	.00	.00	0	.00	.00	.00
Hirudinea unk	3	6.46	.14	13.64	1	2.15	.10	4.55
Hyallela azteca	2	4.31	.09	10.53	0	.00	.00	.00
Hydrophilus sp.	1	2.15	.05	50.00	1	2.15	.10	50.00
Hydroptila sp.	4	8.61	.19	25.00	0	.00	.00	.00
Ischnura sp.	0	.00	.00	.00	0	.00	.00	.00
Isonychia sp.	5	10.76	.24	1.99	0	.00	.00	.00
Licerus sp.	1	2.15	.05	11.11	4	8.61	.38	44.44
Lymnaea sp.	6	12.92	.28	85.71	0	.00	.00	.00
Microtendipes sp.	76	163.62	3.59	48.41	7	15.07	.67	4.46
Neoperla sp.	0	.00	.00	.00	0	.00	.00	.00
Oligochaeta sp.	0	.00	.00	.00	47	101.18	4.52	20.52
Parachironomus sp.	1	2.15	.05	6.67	3	6.46	.29	20.00
Pentaneura sp.	22	47.36	1.04	12.43	38	81.81	3.66	21.47
Pericoma sp.	0	.00	.00	.00	0	.00	.00	.00
Perlesta placida	2	4.31	.09	28.57	0	.00	.00	.00
Physa hawnii	13	27.99	.61	14.77	43	92.57	4.14	48.86
Plecoptera unk	0	.00	.00	00	0	.00	.00	.00
Polypedilum sp.	62	133.48	2.93	19.31	101	217.44	9.72	31.46
Procladius sp.	2	4.31	.09	13.33	6	12.92	.58	40.00
Psectrocladius sp.	0	.00	.00	.00	0	.00	.00	.00
Pseudochironomus sp.	0	.00	.00	.00	4	8.61	.38	14.29
Rheotanytarsus sp.	0	.00	.00	.00	22	47.36	2.12	59.46
Simulium sp.	13	27.99	.61	3.31	276	594.19	26.56	70.23
Sphaerium sp.	9	19.38	.43	18.37	0	.00	.00	.00
Stenelmis sp.	1093	2353.07	51.63	47.25	119	256.19	11.45	5.14
Stenonema sp.	11	23.56	.52	15.71	0	.00	.00	.00
Strictochironomus sp.	3	6.46	.14	11.54	5	10.76	.48	19.23
Tanytarsus sp.	0	.00	.00	.00	0	.00	.00	.00
Tricorythodes sp.	0	.00	.00	.00	0	.00	.00	.00

The relative abundances of the 13 most common taxa collected at the creek stations are shown in table 12. *Cheumatopsyche* sp. was the most abundant taxon at four (CC 1, CC 2, CC 3, and SPC 1) of the six stations, and *Stenelmis* sp. was most abundant at the other two stations (KC 1 and KC 2).

Table 11. Summary of Biological Data From the Six Creek Stations, May to June 1975

Station	Species present	Total no. of individuals	Species diversity		Redundancy	
			Mean	Standard deviation	Mean	Standard deviation
Captain Creek:						
CC 1	39	1770	2.68	0.74	0.38	0.21
CC 2	26	1448	2.32	.36	.40	.06
CC 3	31	717	2.63	.37	.34	.10
Kill Creek:						
KC 1	33	708	2.70	.38	.31	13
KC 2	31	2117	2.05	.17	.51	.07
Spoon Creek: SPC 1	27	1039	2.71	.73	.30	.13

The absolute abundances (percent of individuals of a particular taxon at each station) for the numerically dominant taxa are shown in table 13. Most of the mayflies *Isonychia* sp. (92.04%), *Baetis* sp. (71.43%), *Caenis* sp. (56.79%), and *Stenonema* sp. (75.72%) occurred at CC 1 and CC 2. Most of the *Oligochaeta* sp. (62.45%) occurred at KC 1, which also had a high number of *Microtendipes* sp. (36.31%).

SPC 1 had the highest number of *Simulium* sp. (70.23%), *Polypedilium* sp. (31.46%), *Physa hawnii* (48.86%), and *Cricotopus* sp. (36.49%). *Stenelmis* sp. (47.25%) was highest at KC 2 and *Cheumatopsyche* sp. and *Pentaneura* sp. were highest at KC 1.

Table 12. Relative Abundance of the 13 Most Abundant Taxa at the Six Creek Stations, May to June 1975

Taxon	CC 1		CC 2		CC 3		KC 1		KC 2		SPC 1	
	RA	Rank	RA	Rank	RA	Rank	RA	Rank	RA	Rank	RA	Rank
	%		%		%		%		%		%	
Baetis sp.	2.60	4	2.69	5	1.12	9.33	1.69	7	.57	9	.19	11
Caenis sp.	.96	10	2.00	8	1.95	7	.42	11	.52	10.5	.67	10
Cheumatopsyche sp.	55.08	1	45.93	1	47.84	1	8.05	3.5	32.5	2	26.85	1
Cricotopus sp.	.51	11.5	0	12.5	.70	12.5	.99	8.5	1.23	5	2.60	8
Isonychia sp.	5.82	3	8.84	3	1.81	8	.28	12	.24	12	0	12.5
Microtendipes sp.	.51	11.5	0	12.5	1.12	9.33	8.05	3.5	3.59	3	.67	9
Oligocheata sp.	1.02	9	.90	1.0	1.12	9.33	20.20	2	0	13	4.52	6
Pentaneura sp.	1.53	6	2.49	6	2.65	5	4.94	6	1.04	6	3.66	7
Physa hawnii	.45	13	.07	11	2.23	6	.99	8.5	.61	7.5	4.14	5
Polypedilum sp.	2.54	5	1.66	9	5.30	3	7.20	5	2.93	4	9.72	4
Simulium sp.	1.13	8	3.59	4	3.91	4	.56	10	.61	7.5	26.56	2
Stenelmis sp.	18.53	2	26.80	2	18.55	2	35.59	1	51.63	1	11.45	3
Stenonema sp.	1.24	7	2.14	7	.70	12.5	.14	13	.52	10.5	0	12.5

Notes:
RA = relative abundance.
Rank is taxon rank within the station.

Table 13. Absolute Abundance of the 13 Most Abundant Taxa at the Six Creek Stations, May to June 1975

Taxon	CC 1		CC 2		CC 3		KC 1		KC 2		SPC 1	
	RA	Rank	RA	Rank	RA	Rank	RA	Rank	RA	Rank	RA	Rank
	%		%		%		%		%		%	
Baetis sp.	38.66	2	32.77	4	6.72	9	10.08	6	10.08	16	1.68	11
Caenis sp.	20.99	5	35.80	3	17.28	2	3.70	9	13.58	8	8.64	8
Cheumatopsyche sp.	32.42	3	22.12	5	11.41	4	1.90	10	22.88	4	9.28	7
Cricotopus sp.	12.16	9	0	12.5	6.76	8	9.46	7	35.14	3	36.49	3
Isonychia sp.	41.04	1	51.00	1	5.18	11	.80	13	1.99	12	0	12.5
Microtendipes sp.	5.73	12	0	12.5	5.10	12	36.31	2	48.41	1	4.46	10
Oligocheata sp.	7.86	11	5.68	10	3.49	13	62.45	1	0	13	20.52	6
Pteronarcys sp.	15.25	6	20.34	6	10.73	5	19.77	3	12.43	9	21.47	5
Physa hawnii	9.09	10	1.14	11	18.18	1	7.95	8	14.77	7	48.86	2
Polypedilum sp.	14.02	8	7.48	9	11.84	3	15.89	4	19.31	5	31.46	4
Simulium sp.	5.09	13	13.23	8	7.12	7	1.02	12	3.31	11	70.23	1
Stenelmis sp.	14.18	7	16.77	7	5.75	10	10.89	5	47.25	2	5.14	9
Stenonema sp.	31.43	4	44.29	2	7.14	6	1.43	11	15.71	6	0	12.5

ANOVA of the mean number of taxa for stations gave F_{α} (5, 24) = 2.62 when α = 0.05. Therefore the null hypothesis cannot be rejected; that is, there is no statistically significant difference between the mean number of taxa at the six creek stations. ANOVA of mean total number of individuals of the 13 most abundant taxa for stations gave $F(5, 72) = 182$. The null hypothesis was rejected for the mean number of individuals.

Mean species diversities and redundancies for each station are shown in table 11. KC 2 had the lowest mean diversity (2.05) and highest mean redundancy (0.51) because of the dominance of *Stenelmis* sp. The remaining mean diversities for the creeks ranged from 2.32 to 2.70. ANOVA of mean diversity gave an $F(5, 24) = 1.47$; here again the null hypothesis could not be rejected.

Thus, rigid statistical techniques (ANOVA) showed that there were no statistical differences between the six creek stations based on the mean number of taxa, mean total number of individuals, and mean diversity. However, because there were no statistical differences between stations does not necessarily mean that there were no biological differences.

Therefore, similarity between stations was examined by calculating the index of biotic similarity B from the occurrence and abundance of the 10 taxa that had significant distributions, those for which $F_{0.10}(5, 24)$ was exceeded (table 14), and also by calculation of rank correlation coefficients r_s for the absolute abundance of the numerically dominant taxa at the six creek stations (table 15). CC 1 and CC 2 had the only significant positive rank correlation ($r_s = 0.845$), whereas, SPC 1 versus CC 1 and CC 2 had the highest significant negative rank correlations (-0.661 and -0.629, respectively). KC 1 versus CC 2 also showed a significant negative rank-correlation (r_s = -0.578). High positive rank-correlation coefficients indicate a high degree of similarity, and negative rank-correlation coefficients, high in absolute value, indicate a low degree of similarity. Rank

Table 14. Matrix of Biotic Similarity Values B Between Creek Stations, May to June 1975

	CC 1	CC 2	CC 3	KC 1	KC 2	SPC 1
CC 1	1.000	0.571	0.466	0.269	0.385	0.252
CC 2	.571	1.000	.303	.150	.273	.151
CC 3	.466	.303	1.000	.271	.429	.398
KC 1	.269	.150	.271	1.000	.367	.190
KC 2	.385	.273	.429	.367	1.000	.176
SPC 1	.252	.151	.398	.190	.176	1.000

Table 15. Matrix of Rank Correlation Coefficients r_s Between Stations Based on Species Ranks Served From Their Absolute Abundances

	CC 1	CC 2	CC 3	KC 1	KC 2	SPC 1
CC 1	1.000	0.845*	0.151	0.407	-0.143	-0.661*
CC 2	.845*	1.000	.122	-.578**	-.389	-.629**
CC 3	.151	.122	1.000	-.385	.121	.422
KC 1	.407	-.578**	-.385	1.000	.209	.122
KC 2	-.143	-.389	.121	.209	1.000	-.026
SPC 1	-.661*	-.629**	.422	.122	-.026	1.000

*Highly significant.
**Significant.

correlations are significant when $|r_s| = 0.521$ and are highly significant when $|r_s| = 0.685$. Examination of the absolute abundances (table 13) will show which taxa distributions are responsible for similarity or dissimilarity. For example, most of the mayflies were collected from CC 1 and CC 2 causing them to be similar to one another but different from the remaining stations.

The matrix of biotic similarity values (table 14) again showed CC 1 and CC 2 to have the highest similarity ($B = 0.571$). Subsequent cluster analysis of those values resulted in the dendrogram in figure 12. This shows that SPC 1 and KC 1 are distinguishable through the distribution and abundance of taxa from CC 3, KC 2, CC 1, and CC 2, which were all relatively similar to each other ($B = 0.36$). The differences of KC 1 and SPC 1 are the result of the distribution of *Cheumatopsyche* sp., *Oligochaeta* sp., and *Microtendipes* sp. at KC 1 and *Simulium* sp., *Physa hawnii*, *Cricotopus* sp., and *Oligochaeta* sp. at SPC 1.

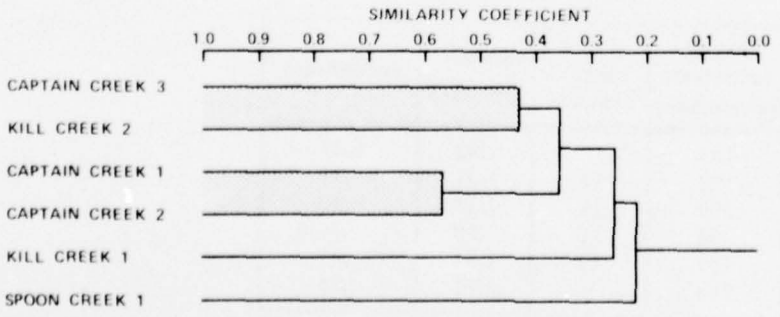

Figure 12. Dendogram of Creek Stations Based on the Index of Biotic Similarity, May to June 1975 ($r_{cs} = 0.78$)

Table 16. Biological Data From Kill Creek Station 1, September 1975

Taxon	Number observed by replicate					Total	Relative abundance
	1	2	3	4	5		
							%
Argia moesta	4	7	6	4	4	25	2.98
Astacidae sp.	3	1	1	1	4	10	1.19
Branchiura sp.	1	3	0	0	0	4	.48
Branchiura sowerbyi	0	0	2	0	0	2	.24
Caenis sp.	1	3	13	0	7	24	2.86
Cheumatopsyche sp.	15	3	1	20	1	40	4.77
Corydalus sp.	0	0	1	0	0	1	.12
Cryptochironomus sp.	0	0	1	0	0	1	.12
Harnischia sp.	0	0	2	0	0	2	.24
Hirudinea sp.	0	0	0	1	0	1	.12
Lymnaea sp.	0	1	1	1	1	4	.48
Microtendipes sp.	3	2	0	3	2	10	1.19
Oligochaeta sp.	0	0	3	0	3	6	.72
Pentaneura sp.	4	1	1	2	1	9	1.07
Polypedilum sp.	5	0	0	2	2	9	1.01
Rheotanytarsis sp.	0	1	2	0	1	4	.48
Stenelmis sp.	85	153	60	272	73	643	76.73
Stenonema sp.	12	3	15	3	10	43	5.13
Total number of individuals per replicate	133	178	109	309	109	838	–

b. August-to-September Survey.

During the August-to-September survey only KC 1 had flowing water. Therefore, it was the only station sampled. The abundance and diversity of macroinvertebrates collected at KC 1 are shown in tables 16 and 17. A total of 838 individuals from 18 taxa were collected. *Stenelmis* sp. accounted for 76.73% of the total number of individuals.

Mean species diversity (d = 1.59) for the August-to-September survey was lower than for the May-to-June survey (d = 2.70) because of the numerical dominance of *Stenelmis* sp. and the fewer taxa collected.

Table 17. Number of Individuals, Number of Observed Taxa, Species Diversity, and Redundancy From Biological Data From Kill Creek Station 1, September 1975

Replicate	No. of individuals per replicate	No. of taxa observed	Species diversity	Redundancy
1	133	10	1.92	0.42
2	178	11	1.01	.71
3	109	14	2.30	.40
4	309	10	.80	.76
5	109	12	1.91	.47
Average	168	–	1.91	.55

2. Kansas River.

a. May-to-June Survey

The distributions and abundances of macroinvertebrates collected with the basket samplers exposed for 30 days in the Kansas River are shown in table 18. Because of the tremendous biomass that had accumulated during the 30-day incubation period less than half of each sample was sorted, identified, and enumerated. A total of 8,159 individuals from 26 taxa were identified. Sixteen taxa comprised 99.45% of the total number of individuals identified: *Hydropsyche orris* (41.75%), *Hydropsyche frisoni* (12.98%), *Polypedilum* sp. (9.39%), *Cheumatopsyche* sp. (7.80%), *Rheotanytarsus* sp. (7.75%), *Potamyia flava* (6.42%), *Hydropsyche* spp. (immature) (2.81%), *Caenis* sp. (2.98%), *Isonychia* sp. (1.54%), *Baetis* sp. (1.08%), *Perlesta placida* (1.05%), *Dicrotendipes* sp. (0.99%), *Pentaneura* sp. (0.97%), *Stenonema* sp. (0.71%), *Stenelmis* spp. (0.65%), and *Glyptotendipes* sp. (0.58%).

Table 18. Biological Data From Kansas River Stations, May to June 1975

Taxon	KR 1					KR 2				
	No. observed by replicate			Total	RA	No. observed by replicate			Total	RA
	1	2	3			1	2	3		
					%					%
*Baetis cingulatus**	9	3	8	20	.54	14	29	25	68	1.53
Caenis sp.	12	5	27	44	1.18	75	112	12	199	4.49
Ceratopogonidae sp.	0	0	0	0	.00	0	1	0	1	.02
Cheumatopsyche sp.	102	89	114	305	8.19	131	110	90	331	7.46
Chironomus sp.	1	3	2	6	.16	2	15	0	17	.36
Corydalus sp.	0	0	0	0	.00	0	0	1	1	.02
Cricotopus sp.	1	0	0	1	.03	0	1	0	1	.02
Dicrotendipes sp.	9	5	27	41	1.10	13	27	0	40	.90
Glyptotendipes sp.	5	1	3	9	.24	12	16	10	38	.86
Hyallela azteca	0	0	0	0	.00	0	0	1	1	.02
Hydropsyche spp. (immature)	31	26	56	113	3.04	48	47	21	116	2.61
Hydropsyche frisoni	138	102	285	525	14.11	223	214	97	534	12.04
Hydropsyche orris	718	434	543	1695	45.54	816	603	292	1711	38.56
Isonychia sp.	19	7	19	45	1.21	31	49	1	81	1.83
Neureclipsis sp.	0	0	0	0	.00	1	0	0	1	.02
Oligocheate sp.	0	2	0	2	.05	0	0	0	0	.00
Pentaneura sp.	2	3	20	25	.67	19	22	13	54	1.22
Perlesta placida	0	0	2	2	.05	39	38	7	84	1.89
Polypedilum sp.	128	28	149	305	8.19	151	214	96	461	10.39
Polypedilum illinsense	0	2	0	2	.05	0	0	0	0	.00
Potamyia flava	121	27	113	281	7.55	126	108	9	243	5.48
Psectrocladius sp.	0	1	0	1	.03	0	0	0	0	.00
Rheotanytarsus sp.	115	54	98	267	7.17	109	129	127	365	8.23
Stenelmis spp.	6	2	5	13	.35	24	13	3	40	.90
Stenonema sp.	1	10	9	20	.54	14	19	5	38	.86
Tricorythodes sp.	0	0	0	0	.00	0	12	0	12	.27
Total number of individuals	1418	804	1500	–	–	1848	1779	810	–	–

*Identity uncertain.

Table 19. Number of Individuals, Number of Observed Taxa, Species Diversity, and Redundancy From Biological Data From Kansas River Stations, May to June 1975

Replicate	KR 1				KR 2			
	No. of individuals	No. of taxa observed	Species diversity	Redundancy	No. of individuals	No. of taxa observed	Species diversity	Redundancy
1	1418	17	2.46	0.40	1848	18	2.87	0.31
2	804	19	2.37	.44	1779	20	3.25	.25
3	1500	17	2.87	.30	810	17	2.83	.31
Average	1240.7	17.64	2.57	.38	1479.0	18.33	2.98	.29

The relative abundances of all taxa at both stations are also shown in table 18. *Hydropsyche orris* was the numerically dominant species at both stations. *Hydropsyche* spp. (all species) comprised 62.70% and 53.21% of the total number of individuals at KR 1 and KR 2, respectively. Table 19 shows species diversity and redundancy for the stations.

Analysis of variance of mean number of taxa, mean number of individuals, and mean diversity between KR 1 and KR 2 showed that the stations were not significantly different; i.e., $F_{0.05}\ (1, 4) = 7.71$ was not exceeded.

Similarity between the two river stations was further examined by calculation of Spearman's rank-correlation coefficient and the index of biotic similarity for the 16 numerically dominant taxa. Spearman's index ($r_s = 0.93$) and the index of biotic similarity ($B = 0.61$) both indicate a high degree of similarity. The similarity within each station (between replicates of the same station) at KR 1 and KR 2 again indicated high biotic similarity between the river stations. The average similarity B is 0.51 at KR 1, and B is 0.53 at KR 2. These values are lower than the between-station similarity.

b. August-to-September Survey.

Because analysis of the May-to-June survey data from the Kansas River showed that the two stations were not significantly different, KR 1, which was downstream of the river access point, was not sampled during the August-to-September survey. Table 20 shows the data from six replicate samples taken at KR 2 from basket samplers exposed for 15 days. Table 21 shows the species diversity and redundancy for these samples. *Rheotanytarsus* sp. was not qualitatively analyzed because of the great abundance (over 500 individuals in each replicate) of its early instars, which were too small to be retained by the sieve mesh. A total of 3, 064 individuals from 20 taxa were collected. Eight taxa constituted 98.39% of the total number of individuals collected: *Hydropsyche orris* (30.68%), *Hydropsyche frisoni* (21.70%), *Potamyia flava* (16.45%), *Baetis cingulatus* (14.20%), *Hydropsyche* spp. (immature) (7.44%), *Polypedilum* sp. (3.39%), *Stenonema* sp. (2.87%), and *Simulium* sp. (1.66%). *Hydropsyche orris* was again the most abundant taxon; all species and immatures of *Hydropsyche* spp. comprised 59.82% of the individuals identified. Fewer taxa (an average of 11.33 versus the earlier value of 18.33) and a lower mean diversity d (2.59 vs. 2.98) occurred at KR 2 during the August-to-September survey as compared with the earlier survey.

Table 20. Biological Data From Kansas River Station 1, August to September 1975[a]

Taxon	KR 2						Total	RA
	No. observed by replicate							
	1	2	3	4	5	6		
								%
Acroneuria spp.[b]	1	0	1	0	0	0	2	.07
Argia moesta	0	0	1	0	0	0	1	.03
Baetis cingulatus[c]	45	51	70	97	109	63	435	14.20
Caenis sp.	2	0	12	0	0	0	14	.46
Hydropsyche spp. (immature)	36	13	50	41	51	37	228	7.44
Hydropsyche frisoni	85	73	121	110	113	163	665	21.70
Hydropsyche orris	105	91	190	203	130	221	940	30.68
Isonychia sp.	0	0	5	3	0	2	10	.33
Mayatrichia sp.	0	2	0	0	1	0	3	.10
Neoperla sp.	0	1	0	2	0	0	3	.10
Neoperla clymene	0	0	3	0	0	0	3	.10
Oxyethira sp.	0	0	1	0	0	0	1	.03
Paragneteria kansensis	0	0	0	1	0	0	1	.03
Pentaneura sp.	0	0	2	0	5	0	7	.23
Plecoptera (immature)	0	0	0	0	0	1	1	.03
Polypedilum sp.	5	25	3	25	14	32	104	3.39
Potamyia flava	63	41	155	81	119	45	504	16.45
Simulium sp.	3	13	2	10	12	11	51	1.66
Stenelmis spp.[d]	2	0	0	0	1	0	3	.10
Stenonema sp.	15	19	3	21	21	9	88	2.87
Total number of individuals	362	329	619	594	576	584	–	–

[a]Early instars of *Rheotanytarsus* sp. occurred in amounts greater than 500, but were not quantitatively evaluated.

[b]*Acroneuria* spp. here are three species: *Acroneuria abnormis*, *Acroneuria mela*, and *Acroneuria ruralis*. They were all collected from debris in the Kansas River.

[c]Identity uncertain.

[d]*Stenelmis* spp. here are five species: *Heterlmis vulnerata*, *Maeronychus glabratus*, *Microcyllopeus pussilus*, *Stenelmis decorata*, and *Stenelmis vitlipennis*. They were all collected from debris in the Kansas River.

Table 21. Number of Individuals, Number of Observed Taxa, Species Diversity, and Redundancy From Biological Data from Kansas River Station 1, August to September 1975

Replicate	No. of individuals	No. of taxa observed	Species diversity	Redundancy
1	362	11	2.59	0.25
2	329	10	2.75	.17
3	619	15	2.51	.36
4	594	11	2.61	.25
5	576	11	2.69	.22
6	584	10	2.40	.28
Average	510.3	11.33	2.59	.26

Table 22. Comparative Abundances of the Dominant Taxa During the Entire Sampling Period*

Taxon	May to June		August to September	
	RA	Individuals per square meter	RA	Individuals per square meter
	%		%	
*Baetis cingulatus***	1.08	163	14.20	302
Caenis sp.	2.98	450	.46	10
Dicrotendipes sp.	0.99	150	0	0
Cheumatopsyche sp.	7.80	1178	0	0
Glyptotendipes sp.	0.58	87	0	0
Hydropsyche spp. (immature)	2.81	424	7.44	158
Hydropsyche frisoni	12.98	1961	21.70	462
Hydropsyche orris	41.75	6307	30.68	652
Isonychia sp.	1.54	233	.33	7
Perlesta placida	1.05	159	0	0
Polypedilum sp.	9.39	4	3.39	72
Potamyia flava	6.42	970	16.45	350
Simulium sp.	0	0	1.66	35
Stenelmis spp.	0.65	98	.10	2
Stenonema sp.	0.71	107	2.87	61

*Excludes *Rheotanytarsus* sp.
**Identity uncertain.

When the dominant faunal assemblages from the two sampling periods (table 22) are compared, large differences in abundances are evident. However, one must be cautious in assigning significance to these differences because the samples also reflect different seasons and different lengths of exposure. Some taxa had increases in their abundance (*Polypedilum* sp.), which probably reflected significant shifts in their normal seasonal abundance. The remaining taxa showed decreases in the number of individuals per square meter even though their relative abundances might have increased. It cannot be determined whether these decreases in abundance reflect normal seasonal changes, or they are merely the result of different incubation periods.

V. DISCUSSION.

The construction of a nitroguanidine facility at Sunflower Army Ammunition Plant will not be completed until late 1979. However, the National Pollution Discharge Elimination Permit System has established certain discharge criteria that the plant must meet.[1] All projections of the impact are based on the design criteria of the treatment system, although the effect of nitroguanidine and its byproducts in the aquatic environment (accumulation, toxicity, and carcinogenicity) has not been thoroughly elucidated. In addition, there are usually malfunctions, equipment failures, and spill conditions associated with the construction and operation of a complex manufacturing facility. Finally, there will be an increase in discharges and emissions from all the support facilities on SAAP that will alter the physical and chemical nature of the environment. These three areas, associated with construction and operation of the facility, are potential sources for environmental impact. Therefore it is prudent that a baseline of the environmental quality be established before construction and after the plant begins production to assess its effect on the environmental quality. Furthermore, because the environment is not pristine,

a survey must evaluate quality with respect to current contamination in the surrounding area, as well as the plant.

The communities of macroinvertebrates in the streams and Kansas River are very sensitive to the stress, and thus serve as a useful tool for detecting environmental perturbations resulting from introduced contaminants such as nitroguanidine. Macroinvertebrate communities have complex interactions between various trophic levels and the chemical environment in which they live. The kinds of species and their relative abundances are directly affected by the physical and chemical properties of their environment. Physical and chemical measurements are only indicative of conditions at the time the measurements were made. Obviously it is impossible to measure all possible chemical and physical constituents of the environment. Therefore, much time and expense can be saved by examining the variation of certain ultimate factors (dissolved oxygen, pH, water temperature, and flow) that affect water quality and aquatic organisms.

The natural variations in water quality and macroinvertebrate populations require that all sampling be replicated. The results of the two surveys are synoptic in that an estimate of variation (standard deviation) is provided for all measurements used in the baseline. Now we will discuss the effect of chemical and physical parameters on the organisms that were collected during the survey. This includes the environmental requirements and response of these fauna to concentration changes in the environment. The projected impact of the nitroguanidine facility on each of these environmental requirements will also be discussed.

The creeks surrounding SAAP are generally well-buffered, nutrient enriched, hardwater streams that vary in organic content with discharge. The limestone in the streambed is primarily responsible for the well-buffered nature of the water and the alkaline pH values measured. During low-flow periods, conductivity, alkalinity, and hardness increase, and turbidity and suspended solids decrease. Dissolved oxygen concentrations also decrease during the low-flow periods as a result of increased water temperature, which lowers the dissolved oxygen saturation level, and decreased turbulence, which reduces physical aeration. There is also increased deposition (siltation) during this period and for taxa that live in riffles (such as *Baetis* sp., *Stenelmis* sp., and *Corydalus* sp.) significant portions of their habitat may be eliminated.

Gaufin and Tarzwell[28] concluded from a study on an Ohio stream that it was necessary to consider such factors as variations in flow and water temperature, the nature of the watershed, and the type of bottom to determine the effects of a domestic discharge on a macroinvertebrate community. Data presented in this report indicate that Kill Creek and Captain Creek are similar in drainage and nutrient input. All sampling stations were selected so that the sediments and flow rates were comparable. Spoon Creek was somewhat different from the other stations in flow and drainage, and this difference is shown in the fauna collected from that creek. Dissolved oxygen and water temperature are important abiotic factors because their variation is critical to survival and abundance of macroinvertebrates. Similar variations in dissolved oxygen and temperature occurred in all drainages during the May-to-June survey. The variations observed were well within the ranges recommended for the support of aquatic life.[29] Variations in temperature and dissolved oxygen were greater at KC 1 during the second survey. However, they were still within the ranges recommended for aquatic life.[29]

A review of water-quality information collected by the Kansas State Department of Health and Environment indicated that our data were within the previously reported ranges recorded from Kill Creek and Spoon Creek. No comparative data were available from Captain Creek. All of these drainages are considered by the State of Kansas to be of moderate to good water quality. During periods of high flow, the state standards for fecal coliforms have been exceeded in both Spoon and Kill Creek. The state attributes this to contamination through runoff. The presence of high fecal coliforms indicates high organic loading from domestic sewage. The sewage treatment plant at SAAP must maintain high biochemical oxygen demand (BOD) removal at higher levels of employment to avoid deleterious impacts on the organic loading of Kill Creek.

Examination of the diurnal data for conductivity, pH, and dissolved oxygen at KR 2 during the second survey (figures 9 to 11, respectively) shows marked declines in their daily means between 5 and 6 September. During this same period in which no rainfall was recorded at SAAP, there was a significant increase in the discharge rate of the Kansas River. However, on 4 and 5 September a total of 1.51 inches was recorded at Kansas City International Airport, (north and east of SAAP), and 1.21 inches at Topeka (north and west of SAAP).* The same type of peak in flow was observed at the U.S. Geological Survey (USGS) gaging station at Lecompton, Kansas, upstream from SAAP.** The rainfall had a significant effect on discharge far downstream without changing flow in the tributaries in the study area. The rain water probably had lower dissolved solids and oxygen than the river water, which would at least account for some of the observed decrease in conductivity and dissolved oxygen. In addition, the rain water was probably slightly acidic, (ph $<$ 7.0), which would have lowered the pH. The increased discharge also dispersed the phytoplankton in the river and probably increased turbidity and suspended solids, both of which decrease the depth to which light penetrates. The net effect of this would be to reduce primary productivity (photosynthesis). Conditions like the one described have been previously shown to reduce productivity in large rivers.[2,†] The increased discharge could have dislodged many organisms including the photosynthetic algae and diatoms.[30] In addition, resuspended river sediments are generally covered by bacteria, which increase the biochemical oxygen demand and community respiration.[31] Both of these circumstances could reduce dissolved oxygen content and lower the pH of the water.

When the river discharge decreases, solids settle to the bottom, the water becomes clearer, photosynthesis increases, and both pH and dissolved-oxygen content increase. (See figures 9, 10, and 11.) The amplitude of the diurnal change in dissolved-oxygen content may have also been increased by additional algal and animal growth causing higher community respiration at night, and more algal photosynthesis in response to increased light penetration during the day.[2]

Although some life stages of many species considered sensitive to low dissolved oxygen concentrations, others can survive at extremely low concentrations of dissolved oxygen,[32] their minimum concentration must be sufficiently high so that fish and macroinvertebrates can complete their life cycles, grow normally, and maintain normal activity.[29] Kansas State water-quality regulations, which apply to perennial drainages, set minimum standards for dissolved oxygen at 4 mg/l during short periods within a 24-hour period, and at, or above, 5 mg/l (except for natural decrease).

*Thompson, Melvin, US Geological Survey, Lawrence Kansas, personal communication.
**Curtis, Russel, US Geological Survey, Lawrence, Kansas, personal communication.
†Kelly, M., Department of Biology, University of Virginia, Charlottesville, Virginia, personal communication.

During one low-flow survey, no dissolved oxygen concentrations were measured below 6.52 mg/l. It is likely that aeration during high-flow maintains a high dissolved oxygen level in the river and creeks. However, during low flow, pooled areas may suffer some anoxia from biological reductions of organic material and community respiration.

Under conditions of high pH and hardness, the toxicity of many substances is reduced because the rates of osmosis, diffusion, and active transport into tissues are decreased.[33] Hardness, which is chiefly attributable to calcium and magnesium ions, contributes substantially to the stability of pH of the water and to the productivity of algae.[31] A large spill of acid or a low-pH waste stream discharged into Kill Creek would upset the stable-pH conditions. Fish kills resulted from acid area discharges into Kill Creek in 1969.[1] The potential for these conditions still exists.

The high filterable (suspended) solids of the creeks and Kansas River is probably a significant limiting factor in the quality of sport fisheries and the diversity of macroinvertebrate communities during periods of high runoff. In a study of fish and macroinvertebrate populations over a 4-year period in a stream receiving sediments from a crushed limestone quarry, Gammon[34] found that inputs that increased the load of suspended solids by less than 40 mg/l resulted in a 35% reduction in macroinvertebrate density in the stream below the quarry. These effects were temporary and were strongly correlated with seasonal precipitation. In Kansas, river-stream fauna are probably well adapted to these seasonal changes in silt load. However, such sediments also tend to absorb toxic chemical substances such as pesticides, heavy metals, and organic compounds.[29] Waters with high turbidity can assimilate some toxic materials through this sorptive capacity. In still backwaters or pools along the main channel, contaminated sediments might settle out, and toxic substances, such as metals and byproducts from the nitroguanidine production facility, could reach high concentrations there. Such deposits could be resuspended during high river discharges, possibly causing fish kills and bioaccumulation. If the proposed nitroguanidine facility discharged pollutants with persistant and toxic properties, concentration in the sediments and in the biota would cause adverse environmental impacts.

Because the calculated impact on the Kansas River of the discharge from the proposed nitroguanidine facility is negligible, the major impacts will most likely come from performances below designed, treatment, malfunctions, discharges from the support facilities (the acid plant and the sewage-treatment plant), and runoff from the solvent area, burning grounds, storage areas, and nitroguanidine area. From results shown in this report, current discharges to Kill Creek are minimal, and they do not cause significant changes in the stream biota. Captain Creek receives runoff from disposal and burning sites, the solvent area, and the proposed nitroguanidine area. It appears that these sources are insignificant at current operation levels when compared with nutrient additions from surrounding farm and pasture lands.

The macroinvertebrate communities in the streams were dominated by riffle beetles, caddisfly larvae, and dipteran larvae. Their distribution in the riffles was extremely variable as shown by the individual sample data (appendix B). This variability between samples from the same riffle requires that a large number of samples be taken to estimate true population means of individual species and to assure that all the species actually present are found. From data of this type, a valid estimate of the numerical relationship between species (relative abundance) can be calculated and the impact of a pollutant that causes the elimination of a species may be determined from biological information about its role in the community indices so that two communities can be separated

because the community measurements are statistically different. Ranson and Dorris[35] emphasize that biological measures of the aquatic environment are superior to chemical measurements alone, because the community structure is influenced by past trends as well as present levels of chemical water quality. They further state that any evaluation of biological conditions is more reliable if the data can be subjected to statistical analysis. Substantial replication of sampling has been conducted here to permit such analysis.

Several different sampling methods were used in the creeks and river. The primary considerations for sampling methods must be (1) the type of habitat and kind of organisms to be sampled, (2) the precision and accuracy of the method, (3) exclusion of specific endemic fauna (determining whether the sample represents the community accurately), (4) the number of replicates required, and (5) the time and cost for taking and processing the sample.

Macroinvertebrates were sampled in the creeks with a PIBS because riffle habitats were selected. This method, designed for use in riffles, is superior to the classical Surber 1-ft^2 sampler for estimating macroinvertebrate abundances. Rock-filled baskets were also used in June, but they were not satisfactory in the creeks because of scouring. Also, grinding of the rocks occurred in the fluctuating currents during the 30-day exposure period. The suspended rock-filled basket samplers were well-suited to sampling in the Kansas River because they provided a substrate for attachment by drifting organisms and scouring was reduced. In the sandy river sediments, macroinvertebrates were found clustered on logs, detritus, and other trapped debris along the shoreline. Hynes[2] says that sand is a desert for macroinvertebrate colonization and a small twig in the sand may become a crowded oasis.

Apparently the basket samplers were the counterpart of a riffle, because the diversities found there were approximately equal to the ones in the Kansas River. The fauna in the samples were typical of hard sediments and fast currents from PIBS samples. Riffle habitats are generally considered very productive areas for collecting macroinvetebrate fauna because food and oxygen are usually abundant. During low flow, all creeks were pooled except KC 1, which was sustained by discharges from the sewage-treatment plant and the acid plant. In September, fewer taxa (33 in June, 18 in September) and more individuals (708 in June, 838 in September) were collected than in June at KC 1. *Stenelmis* spp. was predominant and three times more abundant. The principal difference was that several dipteran, mayfly, stonefly, and crustacean taxa were not collected. The insect disappearance can be correlated with emergence patterns. During low flow the amphipods and isopods tend to concentrate along the shoreline on algae and rooted vegetation.

The decline in abundance of *Oligochaete* sp. is puzzling because many species are well adapted to sedimentation and the nearly anaerobic conditions are typical of low flow.

Comparisons between June and September basket samples from the river are probably not valid because baskets were exposed twice as many days (30) in June as in September (15). During an exposure period, the community composition will gradually change. Grazing caddisflies and snails tend to colonize the substrates first, and these are followed by predatory stonefly and alderfly nymphs. The colonization pattern and rate may be interrupted by scouring the substrates during flooding or by sloughing of organisms when a thick growth accumulates. Further changes in colonization occur; the species performing the grazing and predation functions may change during each season. Their colonization rates are dependent on food, light, and water temperature.

Therefore, it is valid to compare samples collected after an exposure to the same conditions of sunlight, hydrological regime, water temperature, season, and time. We found that in dynamic environments like the Kansas River, artificial substrates provide the best sampling method with which to compare the communities at different locations in the river. These artificial substrated developed a diverse, representative community within 2 weeks during the summer. Macroinvertebrates are considered to be excellent indicators of water quality; however, some organisms are sensitive to water-quality changes, and fluctuations in their numbers collected may only reflect patchy distributions, seasonal variations, or natural population cycles. The aquatic insect fauna are a diverse group of macroinvertebrates, many of which are important indicators of changes in water quality.[36] Bell[37] found that in the Lester River, St. Louis County, Minnesota, most aquatic insects are abundant on rubble substrates, and as the substrate size decreased, fewer insects were present. The large rubble in the basket samplers provides cavities of different sizes, which approximate a rubble substrate described by Bell. Fullner[38] found that basket samplers collected 115 taxa and 19,657 total individuals from five rivers in Ohio and that these results were superior to all other quantitative methods available. During the summer, Mason[7] found as many as 95% of the total number of individuals in basket samplers were aquatic insects. He also found that three replicate baskets estimated the sample mean of a 10-replicate sample within 20% (for 95% confidence limits) and that baskets collected a greater diversity and abundance of macroinvertebrates than multiplate samplers. We found no statistically significant difference between the number of taxa, individuals (adjusted to area), or species diversity for basket versus multiplate samples in our study. There were fewer individuals and the samplers had lower species diversity in Mason's work than for our work in the Kansas River. This may reflect the poor water-quality conditions of the Ohio River, where Mason sampled.

The most abundant organisms collected on baskets resemble those fauna that were collected by hand from logs and detritus along the river banks in September at low flow. This indicates that artificial substrate collections were representative of the endemic taxa. The odonates (dragonfly and damselfly nymphs) were an exception being abundant under woody material and in the mud along the banks. These organisms would not be expected on the artificial substrates because they are mud burrowers. This habit allows them to avoid many short-term changes in water quality. Odonates were also considered to be insensitive to many water-quality changes.

In addition to the damselfly nymph, *Argia moesta*, collected in basket samples, the following odonates were hand picked from debris along the Kansas River banks on 9 September 1975: *Argia apicalis*, *Neurocordulia molesta*, *Gomphus* (*Gomphurus*) *etternus*, *G.* (*Stylurus*) *intricatus*, and *G.* (*Stylurus*) *playiatus*.

Some species of mayflies and stoneflies are not tolerant of the low dissolved-oxygen contents, the low-pH, the high nutrient levels (especially of phosphates and nitrogenous compounds), and the high biochemical oxygen demands typical of organic pollution. The projected loadings of sulfur, nitrogen, and phosphorus from the nitroguanidine production facility and discharges from support facilities may cause some oxygen depletion and enrichment typical of organic pollution, and such changes may eliminate oxygen-sensitive species. These nymphs are very active crawling organisms, and many were probably lost from our samples when the baskets were collected. Because they tend to aggregate on hard substrates and their abundances are important data for water quality assessments, basket samples must be recovered in a rapid and consistent manner to avoid bias between samples. We suspect that changes in these components of the aquatic community will be useful to evaluate the nitroguanidine discharge.

The larvae of the true fly (*Diptera* spp.) and the caddisflies tend to build tubes and encrust on hard substrates. By nature they move more slowly, and most of the individuals that can be retained on the sieve are probably collected.

The *Chironomidae* spp. (midge taxa) have a wide range of environmental requirements that are well documented for *Polypedilum illinoense, Cryptochironomus* sp., *Dicrotendipes* sp., *Procladius* sp., *Strictochironomus* sp., *Glyptotendipes* sp., *Microtendipes* sp., and *Chironomus* spp. These genera can tolerate extremes in dissolved oxygen (<4 ppm), hardness (>300 ppm), higher chloride (>1000 ppm), and biochemical oxygen demand (>5.9 ppm).[36] These species are normally found in conditions of high turbidity, moderate to high biochemical oxygen demand, high sulfate, and high nutrient concentrations.[36, 39]

The biological communities in the Kansas River and the drainages from SAAP have adapted to a long regime of seasonal peaks in flow and nutrients along the heavy sediment loads which they carry. Dissolved oxygen did not reach critical lower limits during our monitoring; however changes in waste discharge, sunlight, flow, siltation, and pH may cause dissolved oxygen concentrations to decrease to a critical level. The normally high nutrient and silt loads now originate from agricultural sources along all drainages and are largely inert particles. The solids loading from manufacturing may contain metallic or toxic particles.

Results from these surveys are valuable in establishing the composition of the aquatic communities and the quality of water in each drainage (chemically and biologically); in identifying what factors to measure, and how to measure them; and in estimating the sample sizes necessary to achieve some level of precision within some statistical confidence level. Substrate sampling methods (PIBS and dip net) were used in the creeks, because the flooding scoured the artificial substrates, and during droughts the fixed artificial substrates were exposed. Comparable sampling locations were standardized by current velocity and substrate size measurements. Artificial substrates worked well in the Kansas River, and only a few replicates were needed to obtain statistically reliable results.

The aquatic environment is a complex system comprising dynamic biological, chemical, and physical factors. Therefore, all surveys of biological communities and water quality should rely more heavily on comparisons between places at the same time than between sampling periods. Studies of temporal variation require extended studies to establish trends and variation. The survey results present sampling locations and methods that should provide reliable data for future work after the construction of the proposed facility.

LITERATURE CITED

1. Pearson, J. G., Taormina, D. J., Asaki, A. E., Hertert, H.D., McBride, J. K., and Russell, W. C. EBSP 76009. Preliminary Environmental Survey Sunflower Army Ammunition Plant, Lawrence, Kansas, August 1974. January 1976. UNCLASSIFIED Report.

2. Hynes, H. B. N. The Ecology of Running Waters. University of Toronto Press, Toronto, Canada. 1972.

3. US Geological Survey, US Department of Interior. Water Resources Data for Kansas. Part 1. Surface Water Records. 1974.

4. American Public Health Association. Standard Methods for the Examination of Waste and Wastewater. 13th ed. New York, New York. 1971.

5. Federal Water Pollution Control Administration. Methods for Chemical Analysis of Water and Wastes. Washington, D.C. 1969.

6. Mason, W. J., Jr., Anderson, J. B., and Morrison, G. E. A Limestone Filled Artificial Substrate Sampler-Float Unit for Collecting Macroinvertebrates in Large Streams. Prog. Fish. Cult. *29*, 74 (1967).

7. Mason, W. T., Weber, C. I., Lewis, P. A., and Julian, E. C. Factors Affecting the Performance of Basket and Multiplate Macroinvertebrate Samplers. Freshwater Biol. *3*, 409-439 (1973).

8. Pennak, R. W. Fresh-Water Invertebrates of the United States. Ronald Press Company, New York, New York. 1973.

9. Ward, H. B., and Whipple, G. C. Fresh Water Biology. 2d Ed. John Wiley and Sons, Inc., New York, New York. 1959.

10. Usinger, L. Aquatic Insects of California. University of California Press, Los Angeles, California. 1973.

11. Parrish, F. K., ed. Keys to Water Quality Indicative Organisms (Southeast United States). Federal Water Pollution Control Administration, Cincinnati, Ohio. 1968.

12. Mason, W. T. An Introduction to the Identification of Chironomid Larvae. US Environmental Protection Agency, Cincinnati, Ohio. 1973.

13. Roback, S. S. The Immature *Tendipedids (Chironomids)* of the Philadelphia Area. Monogr. Acad. Nat. Sci. Phila. *9*, 152 (1957).

14. Johannsen, O. A. *Aquatic Diptera* Parts I-V (Part V by L. C. Thomsen). Second reprinting. Entomological Reprint Specialists, Los Angeles, California. 1970.

15. Ross, H. H. The Caddis Flies or *Trichoptera* of Illinois. Ill. Nat. Hist. Surv. Bull. *23*, 1-326 (1944).

16. Frison, T. H. Studies of North American *Plecoptera*. Ill. Nat. Hist. Surv. Bull. *22*, 232-355 (1942).

17. Burks, B. D. The Mayflies, or *Ephemeroptera*, of Illinois. Ill. Nat. Hist. Surv. Bull. *26*, 1-216 (1953).

18. Shannon, C. E., and Weaver, W. The Mathematical Theory of Communication. Univ. of Illinois Press, Urbana, Illinois. 1963.

19. Wilhm, J. L. Comparison of Some Diversity Indices Applied to Population of Benthic Macroinvertebrates in a Stream Receiving Organic Wastes. J. Water Pollut. Control Fed. *39*(10, 1673-1683 (1967).

20. Sokal, R. R., and Rohlf, F. J. Biometry. W. H. Freeman and Co., San Francisco, California. 1969.

21. Pinkham, C. F. A., and Pearson, J. G. EB-TR 74062. A New Measure of Biotic Similarity Between Samples and Its Applications *With a Cluster Analysis Program*. October 1974. UNCLASSIFIED Report.

22. Pinkham, C. F. A., Pearson, J. G., Clontz, W. L., and Asaki, A. E. EB-TR 75013. A Computer Program for the Calculations of Measures of Biotic Similarity Between Samples and the Plotting of the Relationship Between These Measures. April 1975. UNCLASSIFIED Report.

23. Kaesler, R. L. The Cophenetic Correlation Coefficient in Paleoecology. Geol. Soc. Am. Bull. *81*, 1261-1266 (1970).

24. Sokal, R. R., and Rohlf, F. J. The Comparison of Dendrogram by Objective Methods. Taxon. *11*, 33-40 (1962).

25. Sneath, P. H. A., *and Sokal*, R. R. Numerical Taxonomy—The Principles and Practice of Numerical Classification. W. H. Freeman and Company, San Francisco, California. 1973.

26. Dixon, W. J., and Massey, F. J. Introduction to Statistical Analysis. McGraw-Hill Book Company, Inc., New York, New York. 1969.

27. National Climate Center. Local Climatological Data. Annual Summary With Comparative Data on Topeka and Kansas City, Kansas. National Oceanic and Atmospheric Administration, US Department of Commerce, Asheville, North Carolina. 1973.

28. Gaufin, A. R., and Tarzwell, C. M. Aquatic Macroinvertebrate Communities as Indicators of Organic Pollution in Lytle Creek. Sweage Ind. Wastes. *28*(7), 906-924 (1956).

29. Environmental Protection Agency. Water Quality Criteria. National Environmental Research Center, Cincinnati, Ohio. 1973.

30. Cole, G. A. Textbook of Limnology. The C. V. Moxley Company, St. Louis, Missouri. 1975.

31. Ruttner, F. Fundamentals of Limnology. University of Toronto Press, Toronto, Canada. 1969.

32. Surber, E. L., and Bessey, W. E. Minimum Oxygen Levels Survived by Stream Invertebrates, Va, Water Resour. Res. Cent., Bull. *81*, 1-52 (1974).

33. Brown, V. M. The Calculation of Acute Toxicity of Mixtures of Poisons to Rainbow Trout. Water Res. *2*(10), 723-733 (1968).

34. Gammon, J. R. The Effect of Inorganic Sediment on Stream Biota. Environmental Protection Agency. Water Pollution Control Research Series No. 18050DWC, Government Printing Office, Washington, D.C. 1970.

35. Ranson, J. D., and Dorris, T. C. Analysis of Benthic Community Structure in a Reservoir by Use of Diversity Indices. Am. Midl. Nat. *87*(2), 434-447 (1972).

36. Roback, S. S. Insects (*Arthropoda-Insecta*). Chapter 10. in Pollution Ecology of Freshwater Macroinvertebrates. pp. 353-376. Hart, C. M., Jr., and Fuller, S. L. M., eds. Academic Press, Inc., New York, New York. 1974.

37. Bell, H. L. Effect of Substrate Types on Aquatic Insect Distribution. J. Minn. Acad. Sci. *35*(2-3), 79-81 (1969).

38. Fullner, R. W. A Comparison of Macroinvertebrates Collected by the Basket and Modified Multiple-Plate Samplers. J. Water Pollut. Control Fed. *43*(3), Part 1, pp. 494-499 (1971).

39. Mason, W. T., Jr. *Chironomidae* (*Diptera*) as Biological Indicators of Water Quality. Organisms and Biological Communities as Indicators of Environmental Quality—A Symposium. King, C. E., and Elfner, L. E., eds. Ohio Biological Survey Informative Circular No. 8, pp. 40-54, 1975.

APPENDIX A

WATER-QUALITY DATA

Tables A-1 to A-12 give the summaries of water-quality data from the six creek stations and from the two river stations.

Table A-1. Summary of Water-Quality Data From Kill Creek Station 1, 2-3 June 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,[a] total, mg/l of $CaCO_3$	6	198.5	2.81	193.0	200.0
Chloride, mg/l	6	6.7	.75	6.0	7.5
Conductivity,[b] $\mu S/cm$[c]	554	419.1	71.9	151.0	549.0
Hardness, total, mg/l of $CaCO_3$	6	156.7	27.14	140.0	210.0
Nitrate, NO_3, mg/l of N	6	1.55	.27	1.3	1.9
Nitrite, NO_2, mg/l of N	2	.029	.001	.028	.029
Oxygen, dissolved,[b] mg/l	554	8.13	.56	6.92	9.14
pH,[b] SU[d]	554	7.87	.12	7.53	8.04
Phosphate, PO_4, mg/l of P	6	.08	.01	.05	.08
Residue, mg/l:					
Filterable	11	1,577.6	781.8	620.0	2,580.0
Nonfilterable	10	205.8	60.1	94.0	214.0
Total	11	1,843.6	785.3	840.0	3,040.0
Sulfate, mg/l	6	47.7	1.86	45.0	50.0
Temperature,[b] °C	554	18.78	1.55	15.35	21.35

[a]Titrated to a pH of 5.1.
[b]Continuous monitoring, 1530, 28 May to 1400, 3 June 1975.
[c]1 S = 1 ohm^{-1} = 1 mho.
[d]SU = standard units for pH; i.e., minus the logarithm of the concentration of $[H_3O]^+$

Table A-2. Summary of Water-Quality Data From Kill Creek Station 2, 28-29 May 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,* total, mg/l of $CaCO_3$	2	207.5	3.5	205.0	210.0
Chloride, mg/l	2	7.5	–	7.5	7.5
Conductivity,** $\mu S/cm$	121	343.8	33.22	290.0	410.0
Hardness, total, mg/l of $CaCO_3$	2	137.5	10.6	120.0	145.0
Nitrate, NO_3, mg/l of N	2	1.4	.14	1.3	1.5
Nitrite, NO_2, mg/l of N	2	.022	.001	.021	.023
Oxygen, dissolved,** mg/l	122	7.94	.12	7.60	8.20
Phosphate, PO_4, mg/l of P	2	.04	.00	.04	.05
Residue, mg/l:					
Filterable	10	970.0	414.33	350.0	1,600.0
Nonfilterable	10	122.0	30.48	60.0	160.0
Total	10	1,212.0	174.92	920.0	1,360.0
Sulfate, mg/l	2	33.0	–	33.0	33.0
Temperature,** °C	122	20.1	1.06	18.5	22.0

*Titrated to a pH of 5.1.
**Continuous monitoring, 1720, 28 May to 1400, 30 May 1975.

Table A-3. Summary of Water-Quality Data From Spoon Creek Station 1, 1-2 June 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,* total, mg/l of $CaCO_3$	12	186.5	10.56	175.0	210.0
Chloride, mg/l	12	8.3	1.83	9.0	11.0
Conductivity,** μS/cm	178	495.7	51.16	390.0	578.0
Hardness, total, mg/l of $CaCO_3$	12	210.2	17.22	170.0	230.0
Nitrate, NO_3, mg/l of N	12	2.24	.30	1.8	2.70
Nitrite, NO_2, mg/l of N	12	.08	.01	.07	.10
Oxygen, dissolved,** mg/l	178	7.67	.40	6.80	8.20
Phosphate, PO_4, mg/l of P	12	.10	.02	.07	.11
Sulfate, mg/l	6	56.2	4.83	50.0	60.0
Temperature,** °C	178	16.7	1.32	14.5	19.7

*Titrated to a pH of 5.1.
**Continuous monitoring, 1830, 30 May to 1420, 3 June 1975.

Table A-4. Summary of Water-Quality Data From Captain Creek Station 1, 3-4 June 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,* total, mg/l of $CaCO_3$	4	87.5	6.46	80.0	95.0
Chloride, mg/l	4	6.3	.50	6.0	7.0
Conductivity,** μS/cm	83	269.3	21.68	235.0	326.0
Hardness, total, mg/l of $CaCO_3$	4	113.8	8.54	105.0	125.0
Nitrate, NO_3, mg/l of N	4	1.45	.95	.50	2.50
Nitrite, NO_2, mg/l of N	4	.02	.01	.02	.04
Oxygen, dissolved,** mg/l	83	7.42	.48	6.66	8.62
pH,** SU	83	7.50	.06	7.38	7.60
Phosphate, PO_4, mg/l of P	4	.07	.02	.06	.09
Sulfate, mg/l	4	32.0	3.37	30.0	37.0
Temperature,** °C	83	20.58	.99	19.45	23.0

*Titrated to a pH of 5.
**Continuous monitoring, 1715, 3 June to 1345, 4 June 1975.

Table A-5. Summary of Water-Quality Data From Captain Creek Station 3, 3-4 June 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,* total, mg/l of $CaCO_3$	7	76.4	6.90	65.0	85.0
Chloride, mg/l	7	6.6	.54	6.0	7.0
Conductivity,** μS/cm	59	259.6	60.8	100.0	338.0
Hardness, total, mg/l of $CaCO_3$	7	104.3	11.34	90.0	120.0
Nitrate, NO_3, mg/l of N	6	4.40	.46	4.0	5.3
Nitrite, NO_2, mg/l of N	6	.049	.00	.05	.05
Oxygen, dissolved,** mg/l	59	8.01	.28	7.6	8.6
Phosphate, PO_4, mg/l of P	7	.12	.03	.06	.16
Sulfate, mg/l	7	44.1	6.82	30.0	50.0
Temperature,** °C	59	20.13	.87	19.3	23.0

*Total alkalinity is titrated to a pH of 5.1.
**Continuous monitoring, 1620, 3 June to 1430, 4 June 1975.

Table A-6. Summary of Water-Quality Data From Kill Creek Station 1, 30-31 August 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,[a] total, mg/l of $CaCO_3$	8	134.8	2.12	132.0	138.0
Chloride, mg/l	8	45.2	.96	43.5	46.0
Conductivity,[b] μS/cm	95	1,021.9	13.15	1,000.0	1,050
Hardness, total, mg/l of $CaCO_3$	8	302.0	2.83	298.0	304.0
Nitrate, NO_3, mg/l of N	8	2.36	.32	2.0	2.9
Nitrite, NO_2, mg/l of N	8	.01	.00	.01	.01
Oxygen, dissolved,[b] mg/l	95	8.21	1.57	6.0	10.5
pH,[b] SU	95	7.94	.16	7.50	8.35
Phosphate, PO_4, mg/l of P	8	.08	.00	.07	.08
Residue, mg/l:					
Filterable	7	760.0	109.3	574.0	884.0
Nonfilterable	8	52.0	7.41	38.0	64.0
Total	8	625.3	4.77	620.0	632.0
Sulfate, mg/l	8	204.5	22.19	198.0	240.0
Temperature,[b] °C	95	25.88	1.38	24 0	29.4
Turbidity, FTU[c]	8	5.63	2.56	2.0	9.0

[a]Titrated to a pH of 5.1.
[b]Continuous monitoring, 29-30 August 1975.
[c]FTU = Formazin turbidity units.

Table A-7. Summary of Water-Quality Data From Kill Creek Station 1, 2-3 September 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,* total, mg/l of $CaCO_3$	8	152.8	5.34	144.0	160.0
Chloride, mg/l	8	35.3	.76	34.0	36.5
Conductivity,** μS/cm	358	955.7	39.53	850.0	1,000.0
Hardness, total, mg/l of $CaCO_3$	8	267.0	2.14	266.0	270.0
Nitrate, NO_3, mg/l of N	8	1.54	.32	1.2	1.9
Nitrite, NO_2, mg/l of N	8	.01	.00	.01	.02
Oxygen, dissolved,** mg/l	321	7.66	1.58	5.5	11.80
pH,** SU	358	7.90	.17	7.60	8.30
Phosphate, PO_4, mg/l of P	8	.08	.01	.07	.09
Residue, mg/l:					
Filterable	8	432.8	25.45	384.0	460.0
Nonfilterable	8	7.25	4.98	3.0	16.0
Total	8	541.3	13.65	526.0	562.0
Sulfate, mg/l	8	156.5	10.73	144.0	172.0
Temperature,** °C	358	27.40	1.08	23.8	32.2
Turbidity, FTU	8	6.05	4.88	0	9.0

*Titrated to a pH of 5.1.
**Continuous monitoring, 1500, 29 August to 1100, 4 September.

Table A-8. Summary of Water-Quality Data From Kansas River Station 2, 5 June 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,* total, mg/l of $CaCO_3$	7	130.0	2.89	125.0	135.0
Chloride, mg/l	7	21.29	.76	21.0	22.0
Conductivity,** μS/cm	25	438.8	23.78	396.0	480.0
Hardness, total, mg/l of $CaCO_3$	7	165.0	4.02	160.0	170.0
Nitrate, NO_3, mg/l of N	7	1.40	1.52	.80	4.00
Nitrite, NO_2, mg/l of N	7	.097	.049	.42	.163
Oxygen, dissolved,** mg/l	25	7.18	.07	7.06	7.34
pH,** SU	25	7.73	.02	7.67	7.75
Sulfate, mg/l	7	44.0	14.38	12.0	55.0
Temperature,** °C	25	22.74	.54	21.90	23.45

*Titrated to a pH of 5.1.

**Continuous monitoring, 1050-1650, 5 June 1975.

Table A-9. Summary of Water-Quality Data From Kansas River Station 2, 27-28 August 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,* total, mg/l of $CaCO_3$	8	149.1	3.18	146.0	154.0
Chloride, mg/l	8	56.6	1.95	54.0	60.0
Conductivity,** μS/cm	475	752.5	105.8	565.0	1,010.0
Hardness, total, mg/l of $CaCO_3$	8	209.7	6.55	204.0	218.0
Nitrate, NO_3, mg/l of N	8	2.13	.27	1.8	2.6
Nitrite, NO_2, mg/l of N	8	.04	.01	.04	.06
Oxygen, dissolved,** mg/l	475	7.57	.49	6.52	9.45
pH,** SU	475	7.87	.06	7.74	8.11
Phosphate, PO_4, mg/l of P	8	.22	.01	.20	.23
Residue, mg/l:					
Filterable	8	481.3	33.52	438.0	546.0
Nonfilterable	8	225.8	49.13	118.0	272.0
Total	8	670.8	33.86	626.0	730.0
Sulfate, mg/l	8	112.4	12.06	100.0	130.0
Temperature,** °C	475	26.31	1.33	24.2	29.2
Turbidity, FTU	8	79.1	55.3	29.0	143.0

*Titrated to a pH of 5.1.

**Continuous monitoring, 1100, 27 August to 1030, 1 September 1975.

Table A-10. Summary of Water-Quality Data From Kansas River Station 2, 29-30 August 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity, total, mg/l of $CaCO_3$	8	149.0	1.82	144.0	152.0
Chloride, mg/l	8	69.8	3.16	65.0	74.0
Conductivity,* μS/cm	475	752.5	105.8	565.0	1,010.0
Hardness, total, mg/l of $CaCO_3$	8	207.8	4.06	101.0	212.0
Nitrate, NO_3, mg/l of N	8	1.76	.37	1.30	2.50
Nitrite, NO_2, mg/l of N	8	.029	.003	.026	.033
Oxygen, dissolved,* mg/l	475	7.57	.49	6.52	9.45
pH,* SU	475	7.87	.06	7.74	8.11
Phosphate, PO_4, mg/l of P	8	.20	.02	.18	.15
Residue, mg/l:					
Filterable	8	496.5	13.76	472.0	516.0
Nonfilterable	8	176.3	16.02	154.0	198.0
Total	8	654.3	75.57	588.0	794.0
Sulfate, mg/l	8	118.75	4.43	110.0	125.0
Temperature,* °C	475	26.31	1.33	24.2	29.2
Turbidity, FTU	8	102.3	13.92	81.0	124.0

*Continuous monitoring, 1100, 27 August to 1030, 1 September 1975.

Table A-11. Summary of Water-Quality Data From Kansas River Station 2, 4-5 September 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,* total, mg/l of $CaCO_3$	8	155.8	11.54	138.0	154.0
Chloride, mg/l	8	64.8	.46	64.0	65.0
Conductivity,** μS/cm	380	1,027.0	65.2	880.0	1,150.0
Hardness, total, mg/l of $CaCO_3$	8	218.4	40.97	185.0	282.0
Nitrate, NO_3, mg/l of N	8	1.26	.36	.8	1.9
Nitrite, NO_2, mg/l of N	8	.014	.007	.005	.023
Oxygen, dissolved,** mg/l	380	9.43	2.03	6.73	13.70
pH,** SU	380	8.29	.19	7.94	8.73
Phosphate, PO_4, mg/l of P	8	.17	.02	.14	.21
Residue, mg/l:					
Filterable	8	659.3	45.86	594.0	706.0
Nonfilterable	8	54.8	13.22	42.0	80.0
Total	8	760.5	19.7	730.0	792.0
Sulfate, mg/l	8	171.5	10.24	160.0	186.0
Temperature,** °C	380	28.05	1.67	24.45	31.1
Turbidity, FTU	8	4.63	2.13	2.0	7.0

*Titrated to a pH of 5.1.

**Continuous monitoring, 1050, 1 September to 1030, 5 September 1975.

Table A-12. Summary of Water-Quality Data From Kansas River Station 2, 6-7 September 1975

Parameter	No. of samples	Mean	Standard deviation	Minimum	Maximum
Alkalinity,* total, mg/l of $CaCO_3$	8	151.3	6.41	145.0	160.0
Chloride, mg/l	8	53.5	3.55	50.0	58.0
Conductivity,** μS/cm	191	971.5	98.6	790.0	1,160.0
Hardness, total, mg/l of $CaCO_3$	8	227.5	19.82	200.0	260.0
Nitrate, NO_3, mg/l of N	8	1.35	.421	.70	1.90
Nitrite, NO_2, mg/l of N	8	.014	.001	.013	.017
Oxygen, dissolved,** mg/l	191	9.82	1.94	7.32	13.63
pH,** SU	191	8.54	.15	8.29	8.75
Phosphate, PO_4, mg/l of P	8	.19	.05	.13	.25
Residue, mg/l:					
Filterable	8	685.5	49.21	638.0	762.0
Nonfilterable	8	77.25	15.6	62.0	100.0
Total	8	784.5	52.62	702.0	854.0
Sulfate, mg/l	8	162.0	18.76	146.0	200.0
Temperature,** °C	191	23.89	1.18	2.21	25.5
Turbidity, FTU	8	6.75	2.71	3.0	11.0

*Titrated to a pH of 5.1.

**Continuous monitoring, 1130, 5 September to 1100, 7 September 1975.

APPENDIX B

REPLICATE SAMPLE DATA FOR ALL SIX CREEK STATIONS, MAY TO JUNE 1975

Tables B-1 to B-3 give the replicate sampling data for the six stations, CC 1, CC 2, CC 3, KC 1, KC 2, and SPC 1 for the May-to-June survey. Table B-4 gives the species diversity and the redundancy for these stations, as well as the number of species observed.

Table B-1. Data for CC 1 and CC 2

Taxon	CC 1					CC 2				
	Replicate					Replicate				
	1	2	3	4	5	1	2	3	4	5
Argia moesta	0	1	0	0	0	0	1	0	0	0
Astacidae sp.	1	1	0	0	0	0	1	0	1	0
Atherix sp.	0	0	1	1	0	0	0	0	0	0
Athripsodes sp.	0	0	0	1	0	0	0	0	0	0
Baetis sp.	16	3	14	9	4	9	10	11	5	4
Branchiura sowerbyi	1	19	0	0	1	0	0	0	0	0
Caenis sp.	4	4	0	4	5	6	7	6	7	3
Ceratopogonidae sp.	0	1	1	0	0	0	0	0	0	0
Chaoborus sp.	0	0	0	0	0	0	0	0	0	0
Cheumatopsyche sp.	404	31	218	319	3	83	115	223	148	96
Chironomus sp.	0	0	0	0	1	0	0	0	0	0
Chrysops sp.	0	0	0	0	0	0	0	0	0	0
Collembola sp.	0	0	0	0	0	0	0	0	0	0
Corixidae sp.	0	0	1	0	1	0	0	0	0	0
Corydalus sp.	0	0	0	1	0	0	1	0	0	0
Coryneura sp.	0	0	0	0	0	0	0	0	0	0
Cricotopus sp.	1	0	0	8	0	0	0	0	0	0
Cryptochironomus sp.	1	0	0	2	0	0	0	0	0	0
Dicrotendipes sp.	2	0	2	1	1	0	0	0	0	0
Dubiraphia sp.	5	1	2	4	0	1	2	0	5	0
Eukiefferiella sp.	0	0	0	0	0	0	0	0	0	0
Ferrissia Kirklandi	0	1	0	0	0	1	1	0	0	0
Glyptotendipes sp.	0	0	0	0	0	0	1	0	0	0
Hemiptera unk	0	0	1	0	0	0	0	0	0	0
Hirudinea unk	1	0	2	0	0	0	0	0	0	0
Hyallela azteca	0	0	0	1	1	1	6	2	1	1
Hydrophilus sp.	0	0	0	0	0	0	0	0	0	0
Hydroptila sp.	2	1	2	4	0	0	0	0	0	0
Ischnura sp.	0	0	0	0	0	0	0	0	0	1
Isonychia sp.	41	7	20	35	0	37	33	36	15	7
Licerus sp.	0	0	0	0	0	0	0	0	0	0
Lymnaea sp.	0	0	0	0	0	0	1	0	0	0
Microtendipes sp.	5	2	0	1	1	0	0	0	0	0
Neoperla sp.	1	0	0	0	0	2	0	0	0	0
Oligochaete sp.	2	6	5	0	5	0	2	2	7	2
Parachironomus sp.	0	0	0	0	0	0	0	0	0	0

Table B-1. Data for CC 1 and CC 2–Concluded

Taxon	CC 1					CC 2				
	Replicate					Replicate				
	1	2	3	4	5	1	2	3	4	5
Pentaneura sp.	9	2	4	10	2	2	11	4	6	13
Pericoma sp.	0	0	0	0	0	0	0	0	0	0
Perlesta placida	0	0	2	0	0	0	0	0	0	1
Physa hawnii	2	0	0	4	2	0	1	0	0	0
Plecoptera unk	0	0	1	0	0	0	0	0	0	0
Polypedilum sp.	8	0	7	26	4	9	8	3	3	1
Procladius sp.	0	0	0	0	0	0	2	0	0	0
Psectrocladius sp.	0	0	0	0	0	0	0	0	0	0
Pseudochironomus sp.	5	0	3	2	4	0	0	1	0	0
Rheotanytarsus sp.	1	0	0	5	0	0	0	0	0	0
Simulium sp.	3	1	5	11	0	5	12	6	23	6
Sphaerium sp.	3	0	0	30	0	3	0	0	0	0
Stenelmis sp.	75	15	154	83	1	94	55	167	56	16
Stenonema sp.	7	5	3	2	5	11	7	6	4	3
Strictochironomus sp.	2	0	3	1	0	0	0	0	0	0
Tanytarsus sp.	0	0	1	0	0	0	0	0	0	0
Tricorythodes sp.	3	0	0	6	0	3	0	2	0	0
Total individuals	605	101	452	571	41	267	277	469	281	154

Table B-2. Data for CC 3 and KC 1

Taxon	CC 3					KC 1				
	Replicate					Replicate				
	1	2	3	4	5	1	2	3	4	5
Argia moesta	0	0	1	0	0	0	0	0	0	0
Astacidae sp.	0	0	0	0	0	0	1	0	1	3
Atherix sp.	0	1	1	0	2	0	0	0	0	0
Athripsodes sp.	0	0	0	0	0	0	0	0	0	0
Baetis sp.	3	0	5	0	0	0	5	0	7	0
Branchiura sowerbyi	0	0	0	0	0	0	0	0	14	4
Caenis sp.	1	2	5	6	0	1	0	0	2	0
Ceratopogonidae sp.	0	1	0	0	0	0	1	0	0	0
Chaoborus sp.	0	0	0	0	0	1	1	0	0	0
Cheumatopsyche sp.	45	96	106	86	10	4	12	4	13	24
Chironomus sp.	0	0	0	0	0	0	2	0	1	0
Chrysops sp.	0	2	3	0	0	0	1	0	0	0
Collembola sp.	0	1	0	0	0	0	0	0	0	0
Corixidae sp.	0	0	0	0	0	0	0	0	0	0
Corydalus sp.	0	0	0	0	0	0	0	1	0	0
Coryneura sp.	0	0	0	0	0	0	0	0	0	0
Cricotopus sp.	0	0	3	0	2	3	0	3	1	0
Cryptochironomus sp.	0	0	0	0	0	0	0	0	1	3
Dicrotendipes sp.	0	0	0	0	1	0	1	0	0	1
Dubiraphia sp.	0	13	1	0	3	0	1	0	0	1
Eukiefferiella sp.	0	0	0	0	0	0	1	0	0	0
Ferrissia kirklandi	1	2	0	0	0	0	0	0	0	0

Table B-2. Data for CC 3 and KC 1—Concluded

Taxon	CC 3					KC 1				
	Replicate					Replicate				
	1	2	3	4	5	1	2	3	4	5
Glyptotendipes sp.	0	0	0	1	0	0	0	0	0	0
Hemiptera unk	0	0	0	0	0	0	0	0	0	0
Hirudinea unk	6	1	7	0	1	0	0	0	0	0
Hyallela azteca	0	0	0	1	1	1	1	0	0	0
Hydrophilus sp.	0	0	0	0	0	0	0	0	0	0
Hydroptila sp.	2	1	0	0	0	0	0	0	0	0
Ischnura sp.	0	0	0	0	0	0	0	0	0	0
Isonychia sp.	4	0	6	3	0	0	1	0	0	1
Licerus sp.	0	0	0	0	0	0	0	0	1	3
Lymnaea sp.	0	0	0	0	0	0	0	0	0	0
Microtendipes sp.	3	0	1	4	0	2	8	1	5	41
Neoperla sp.	0	0	0	0	0	0	0	0	0	0
Oligothaeta sp.	7	0	0	1	0	53	31	5	51	3
Parachironomus sp.	0	1	8	2	0	0	0	0	0	0
Pentaneura sp.	0	3	13	2	1	2	17	2	7	7
Pericoma sp.	0	0	0	0	1	0	0	0	0	0
Perlesta placida	0	0	0	0	0	0	0	0	2	0
Physa hawnii	0	5	5	4	2	0	0	0	6	1
Plecoptera unk	0	0	0	0	0	0	0	0	0	0
Polypedilum sp.	2	2	7	9	16	6	11	2	27	5
Procladius sp.	0	0	0	0	0	2	0	0	1	2
Psectrocladius sp.	0	0	0	0	1	0	0	0	0	0
Pseudochironomus sp.	0	0	2	0	0	0	0	0	3	4
Rheotanytarsus sp.	0	2	0	0	4	1	0	0	2	0
Simulium sp.	6	8	11	1	2	1	1	1	0	1
Sphaerium sp.	0	2	0	2	0	0	0	0	0	0
Stenelmis sp.	27	36	32	35	3	7	90	8	40	107
Stenonema sp.	4	0	1	0	0	0	0	0	0	1
Strictochironomus sp.	0	0	0	0	0	3	3	0	6	0
Tanytarsus sp.	0	0	0	0	0	0	0	0	1	0
Tricorythodes sp.	0	0	0	0	0	0	0	0	0	1
Total individuals	111	179	218	157	52	87	189	27	192	213

Table B-3. Data for KC 2 and SPC 1

Taxon	KC 2					SPC 1				
	Replicate					Replicate				
	1	2	3	4	5	1	2	3	4	5
Argia moesta	0	0	0	0	0	0	0	0	1	0
Astacidae sp.	4	2	6	5	3	1	0	0	0	0
Atherix sp.	0	0	0	0	0	1	0	0	0	0
Athripsodes sp.	0	0	0	0	0	0	0	0	0	0
Baetis sp.	0	5	4	1	2	2	0	0	0	0
Branchiura sowerbyi	0	0	0	0	0	0	0	0	0	0
Caenis sp.	1	6	2	1	1	1	6	0	0	0
Ceratopogonidae sp.	0	0	0	0	1	0	1	0	0	0

Table B-3. Data for KC 2 and SPC 1—Concluded

Taxon	KC 2					SPC 1				
	Replicate					Replicate				
	1	2	3	4	5	1	2	3	4	5
Chaoborus sp.	1	3	1	3	5	7	0	2	0	0
Cheumatopsyche sp.	33	191	214	77	173	128	29	31	78	13
Chironomus sp.	0	0	1	0	0	0	0	0	0	0
Chrysops sp.	0	0	0	0	0	0	4	5	0	4
Collembola sp.	0	0	0	0	0	0	0	0	0	0
Corixidae sp.	0	0	0	0	0	0	0	0	0	0
Corydalus sp.	0	0	0	0	0	0	0	0	0	0
Coryneura sp.	0	0	0	1	0	0	0	0	0	0
Cricotopus sp.	8	9	0	4	5	10	17	0	0	0
Cryptochironomus sp.	1	1	4	0	5	0	0	1	0	0
Dicrotendipes sp.	1	1	0	0	1	2	10	0	5	3
Dubiraphia sp.	0	0	0	1	0	0	0	0	0	0
Eukiefferiella sp.	0	0	0	0	0	0	0	0	0	0
Ferrissia kirklandi	0	0	0	0	0	0	0	0	0	0
Glyptotendipes sp.	0	0	0	0	0	0	0	0	0	0
Hemiptera unk	0	0	0	0	0	0	0	0	0	0
Hirudinae unk	0	0	1	0	2	1	0	0	0	0
Hyallela azteca	0	1	0	1	0	0	0	0	0	0
Hydrophilus sp.	0	0	1	0	0	0	0	0	0	1
Hydroptila sp.	0	3	1	0	0	0	0	0	0	0
Ischnura sp.	0	0	0	0	0	0	0	0	0	0
Isonychia sp.	0	2	1	2	0	0	0	0	0	0
Licerus sp.	0	0	0	0	1	0	3	0	0	1
Lymnaea sp.	0	2	4	0	0	0	0	0	0	0
Microtendipes sp.	5	9	37	2	23	2	3	0	2	0
Neoperla sp.	0	0	0	0	0	0	0	0	0	0
Oligochaeta sp.	0	0	0	0	0	17	12	0	4	14
Parachironomus sp.	0	0	0	1	0	0	0	0	0	3
Pentaneura sp.	4	7	7	3	1	8	14	2	7	7
Pericoma sp.	0	0	0	0	0	0	0	0	0	0
Perlesta placida	0	2	0	0	0	0	0	0	0	0
Physa hawnii	1	5	6	1	0	18	7	4	13	1
Plecoptera unk	0	0	0	0	0	0	0	0	0	0
Polypedilum sp.	11	14	13	6	18	50	31	6	9	5
Procladius sp.	0	0	0	1	1	4	1	0	1	0
Psectrocladius sp.	0	0	0	0	0	0	0	0	0	0
Pseudochironomus sp.	0	0	0	0	0	2	1	0	0	1
Rheotanytarsis sp.	0	0	0	0	0	5	6	0	8	3
Simulium sp.	0	4	2	0	7	84	21	131	11	29
Sphaerium sp.	0	2	4	0	3	0	0	0	0	0
Stenelmis sp.	78	291	406	61	257	55	43	11	2	8
Stenonema sp.	1	2	6	1	1	0	0	0	0	0
Strictochironomus sp.	0	3	0	0	0	3	2	0	0	0
Tanytarsus sp.	0	0	0	0	0	0	0	0	0	0
Tricorythodes sp.	0	0	0	0	0	0	0	0	0	0
Total individuals	149	565	721	172	510	401	211	193	141	93

Table B-4. Species Observed, Species Diversity, and Redundancy at All Six Stations

Stations	Replicate	Species present	Species diversity	Redundancy
Captain Creek:				
CC 1	1	26	1.99	0.58
	2	17	3.13	.23
	3	22	2.12	.52
	4	25	2.47	.47
	5	16	3.71	.07
CC 2	1	15	2.54	.35
	2	20	2.80	.35
	3	13	1.92	.48
	4	13	2.28	.38
	5	13	2.08	.48
CC 3	1	13	2.69	.27
	2	18	2.39	.44
	3	19	2.79	.34
	4	14	2.18	.43
	5	15	3.13	.20
Kill Creek:				
KC 1	1	14	2.28	.40
	2	19	2.84	.38
	3	9	2.82	.11
	4	21	3.29	.25
	5	19	2.48	.42
KC 2	1	13	2.21	.40
	2	22	2.01	.55
	3	20	1.84	.57
	4	18	2.23	.46
	5	19	1.95	.54
Spoon Creek: SPC 1	1	20	2.94	.32
	2	18	3.51	.16
	3	9	1.69	.49
	4	12	2.37	.34
	5	14	3.19	.19

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