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Validity of Effluent and Ambient Toxicity Testing for Predicting Biological Impact on Five Mile Creek, Birmingham, Alabama

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Validity of Effluent and Ambient Toxicity Testing for Predicting Biological Impact on Five Mile Creek, Birmingham, Alabama

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Foreword

The Complex Effluent Toxicity Testing Program was initiated to support the developing trend toward water quality-based toxicity control in the National Pollutant Discharge Elimination System (NPDES) permit program. It is designed to investigate, under actual discharge situations, the appropriateness and utility of "whole effluent toxicity" testing in the identification, analysis, and control of adverse water quality impact caused by the discharge of toxic effluents.

The four objectives of the Complex Effluent Testing Program are:

1. To investigate the validity of effluent toxicity tests in predicting adverse impact on receiving waters caused by the discharge of toxic effluents.
2. To determine appropriate testing procedures which will support regulatory agencies as they begin to establish water quality-based toxicity control programs.
3. To serve as a practical case example of how such testing procedures can be applied to a toxic effluent discharge situation involving a single discharge to a receiving water.
4. To field test short-term chronic toxicity tests involving the test organisms, *Ceriodaphnia*[a] and *Pimephales promelas.*

Until recently, NPDES permitting has focused on achieving technology-based control levels for toxic and conventional pollutants in which regulatory authorities set permit limits on the basis of national guidelines. Control levels reflected the best treatment technology available, considering technical and economic achievability. Such limits did not, nor were they designed to, protect water quality on a site-specific basis.

The NPDES permits program, in existence for over 10 years, has achieved the goal of implementing technology-based controls. With these controls largely in place, future controls for toxic pollutants will, of necessity, be based on site-specific water quality considerations.

Setting water quality-based controls for toxicity can be accomplished in two ways. The first is the pollutant-specific approach which involves setting limits for single chemicals, based on laboratory-derived no-effect levels. The second is the "whole effluent" approach which involves setting limits using effluent toxicity as a control parameter. There are advantages and disadvantages to both approaches.

The "whole effluent" approach eliminates the need to specify a limit for each of thousands of substances that may be found in an effluent. It also includes all interactions between constituents as well as biological availability. Such limits determined on fresh effluent may not reflect toxicity after aging in the stream and fate processes change effluent composition. This problem is less important

[a]The species of *Ceriodaphnia* used for this study is not known with certainty. The stocks were thought to be *C. reticulata* but, in November 1983, based on taxonomic verification by Dorothy Berner, Ph.D. (Temple University, PA), a second species, *C. dubia* was also discovered in the stock cultures. The exact determination of the species tested is not critical to this study, and all reference is to the genus in this report. The cultures used for the October study were subsequently identified as *C. dubia*.

since permit limits are normally applied at the edge of the mixing zone where aging has not yet occurred.

This report is based on the third of the eight site studies which consisted of three discharges into a small river near Birmingham, Alabama.

To date, eight sites involving municipal and industrial dischargers have been investigated. They are, in order of investigation:

1. Scippo Creek, Circleville, Ohio
2. Ottawa River, Lima, Ohio
3. Five Mile Creek, Birmingham, Alabama
4. Skeleton Creek, Enid, Oklahoma
5. Naugatuck River, Waterbury, Connecticut
6. Back River, Baltimore Harbor, Maryland
7. Ohio River, Wheeling, West Virginia
8. Kanawha River, Charleston, West Virginia

This project is a research effort only and has not involved either NPDES permit issuance or enforcement activities. The study site was at Birmingham, Alabama, and the study was conducted in February and October 1983.

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Permits Division

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Complex Effluent Toxicity
Testing Program

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EPA personnel from Region IV assisted in selecting site locations, sample collection, obtaining required electrical sources for the mobile laboratory, and providing well water. The assistance provided by William H. Peltier, III, on the October fathead minnow tests is especially appreciated.

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Executive Summary

This report describes an investigation to determine the validity of laboratory toxicity tests to predict biological impact in receiving water. The first site visit in February 1983 was adversely affected by heavy rainfall immediately preceding and during the visit. Two of the treatment plants were discharging at twice their design flows and stream sampling was difficult. The second visit was in October 1983 when flow conditions were acceptable.

The biological survey of the stream revealed a substantial impact near and downstream of the two coke plants and the POTW. The effluent toxicity tests predicted impact at three stations and the survey found approximately one-half or fewer species present at those stations. The ambient toxicity tests also measured toxicity at these stations as well.

Both the toxicity data and the biological survey data show that impacts at different stations affect species differently. No one test species or community group will reveal the impact present at every station.

The results of this study combined with those of previous published studies and ones yet to be completed will be used to recommend the best available way to predict the impacts of discharges on biological communities using effluent and ambient toxicity tests. The data from this study clearly indicate the utility of effluent toxicity tests.

Quality Assurance

Coordination of the various studies was completed by the principal investigator preceding and during the onsite work. A reconnaissance trip was made to the site before the study and necessary details regarding transfer of samples, specific sampling sites, dates of collections, and measurements to be made on each sample were delineated. The evening before the study began, a meeting was held onsite to clarify again specific responsibilities and make last minute adjustments in schedules and measurements. The mobile laboratory was established as the center for resolving problems and adjusting of work schedules as delays or weather affected the completion of the study plans. The principal investigator was responsible for all Quality Assurance-related decisions onsite.

All instruments were calibrated daily by the methods specified by the manufacturers. For sampling and toxicity testing, the protocols described in the referenced published reports were followed. Where identical measurements were made in the field and laboratory, both instruments were cross-calibrated for consistency.

1. Introduction

Future activities in water pollution control will focus, in part, on the control of toxic pollutants that impact water quality. There are two methods used in controlling toxic impact: pollutant-specific controls and "whole effluent toxicity" controls. Because toxicity testing evaluates a living organism's response, it has an advantage over chemical-specific analyses which may not identify all pollutants in a wastewater sample and which cannot detect toxicity interactions. Toxicity information can provide a basis for permit limits based on state water quality standards for toxicity- or technology-based requirements.

This report is organized into sections corresponding to the project tasks. Following an overview of the study design and a summary of the description of the site, the chapters are arranged into toxicity testing, hydrology, and ecological surveys for the two study periods (February and October 1983). An integration of the laboratory and field studies is presented in Chapter 14. All methods and support data are included in the appendix along with the tributary data.

2. Study Design

The site chosen for study was Five Mile Creek at Birmingham, Alabama (Figure 2-1). The study included three discharges: two coke plants and a publicly owned treatment works (POTW). A more complete description of the study area is included in Chapter 3. This study required laboratory tests to measure expected effluent dilutions that would be safe for chronic exposure. In conjunction with these toxicity tests, biological surveys of Five Mile Creek were conducted to identify structural effects on representative biotic communities and selected populations from point-source discharges. Hydrological analyses included effluent configuration studies to define the mixing characteristics of the dischargers. The study was conducted 8-14 February 1983 during very high river flows. A follow-up study was conducted during 4-10 October 1983 which was preceded by several weeks of lower river flows. The methods used in the study are detailed in Appendixes A, B, and C. The respective study designs for the laboratory and field aspects, as well as the data analysis task, are outlined in the following sections.

2.1 Toxicity Testing Study Design

Effluent toxicity tests were performed on each of the three effluents (Coke Plants 1 and 2 and the

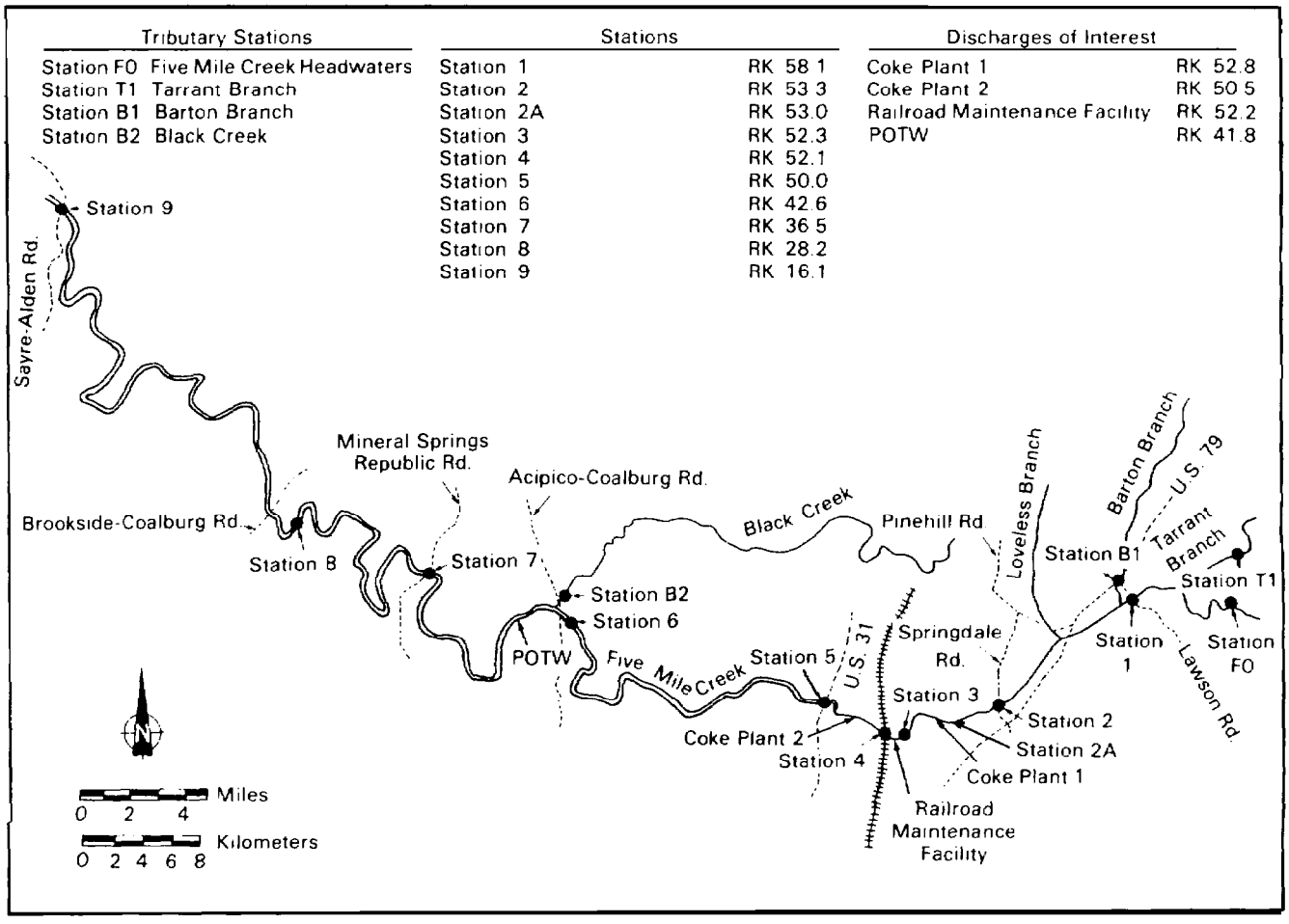

Figure 2-1. Sampling stations, Five Mile Creek, Birmingham, Alabama.

POTW) to measure subchronic effects on growth of larval fathead minnows (*Pimephales promelas*) and chronic reproductive effects on *Ceriodaphnia*. A range of effluent concentrations was used so that acute mortality also could be measured, if it existed. The objective of these tests was to estimate the maximum concentration of each effluent that would result in no chronic effects on growth (fathead minnows) or reproduction (*Ceriodaphnia*).

Resident species from eight different families were also tested for acute toxicity of each effluent during February. This sought to determine if there were any species more or less resistant to the effluents than the fathead minnows and *Ceriodaphnia* used in the chronic tests. However, many problems were encountered in testing indigenous species, resulting in invalid test results, and these data are not presented.

In February 1983, five tests were performed in which each effluent was diluted with a high quality dilution water (well water from the Athens, Georgia, EPA Laboratory) to measure the inherent toxicity of each waste (Chapter 4). Three of those tests were conducted using *Ceriodaphnia* in each of the three effluents using well water as the diluent, and fathead minnows were tested using well water as the diluent only for the two industrial discharges. In addition, fathead minnows were tested with one industrial effluent and a diluent water that was collected much farther upstream above all outfalls. This test was conducted for comparison with acute fathead minnow toxicity tests which Region IV EPA was conducting concurrently. Toxicity tests were also conducted using water taken from locations directly upstream of each discharge as the dilution water in the *Ceriodaphnia* and fathead minnow tests.

In October 1983, the dilution water for the effluent tests was taken from immediately upstream of each discharge. Therefore, the second discharge downstream of the first was diluted with stream water containing the upstream effluent, and the most downstream effluent of the three discharges was diluted with stream water containing some of both upstream effluents. Thus, the inherent toxicity of the two downstream discharges was not measured but rather the combined effects of that effluent and the upstream effluent(s) (Chapter 5). This approach was necessary because the objective was to estimate impact below each discharge.

In addition to the above tests stations were established at locations from above the discharges at river kilometer (RK) 58.1 to below the discharges at RK 28.2 to measure ambient toxicity. The purpose of these tests was to measure the loss of toxicity from the effluents after mixing, dilution from other stream inputs, degradation, and other losses such as sorbtion and settling. The tests would also provide data for predicting ecological impact for comparison with the stream biological survey without having to know the effluent concentration. These tests were done with *Ceriodaphnia* and fathead minnows.

2.2 Field Survey Study Design

The field surveys included a quantitative assessment of the periphytic, zooplanktonic, benthic macroinvertebrate, and fish communities. Periphyton were collected in February, and zooplankton were collected in October. Fish and benthic communities were sampled during both February and October.

The hydrological measurements were conducted using dye studies at each of three sites to identify the individual dilution characteristics of each effluent (Chapters 6 and 7). By modeling downstream dilution contours for each discharger, the exposure concentrations at various ambient stations could be established. Streamflow measurements were performed on several days at biological collection stations to define more accurately the instream and effluent concentrations.

The periphyton study measured chlorophyll *a* and biomass to estimate composition and relative abundance (Chapter 8). The relatively short reproduction time and rapid seasonal fluctuation in growth of periphytic algae make that community indicative of recent exposure conditions.

The benthic survey investigated community response above and below the discharge areas (Chapters 9 and 10). The benthic community measured by the methods used in this report is less mobile than other community groups, such as fish, and therefore is a better indicator of water quality where the community is measured.

The fish survey measured the species present and their relative abundance as a means to discern community changes upstream and downstream of the discharges (Chapters 11 and 12).

In contrast to the more sedentary periphytic and benthic communities, planktonic communities in lotic systems drift downstream and do not necessarily reflect exposure at the collection site. Crustacean zooplankton populations were measured and used as an indicator of planktonic community response (Chapter 13). Incidental catches of net phytoplankton were also examined for trends.

2.3 Comparison of Laboratory Data and Field Data

The final component of this study integrated the toxicity predictions with the measured community

impact. Where the instream waste concentrations are known, results of the effluent dilution tests can be used to predict ambient toxicity. Results of the ambient toxicity tests can be used to predict community impact regardless of whether instream waste concentrations are known. In addition, the ambient test and effluent dilution tests results can be compared.

3. Site Description

Three discharges into Five Mile Creek were investigated in this study—two coke plants with associated chemicals production and a publicly owned treatment works (POTW) (Figure 2-1). The POTW contributed the largest volume of effluent to the creek averaging about 0.42 m^3/sec, whereas Coke Plants 1 and 2 contributed approximately 0.008 and 0.169 m^3/sec, respectively, during February 1983. During the October 1983 study, the POTW and Coke Plant 2 contributed less than half of the above values; the Coke Plant 1 contribution was similar to February. Five Mile Creek also receives runoff from a railroad maintenance facility and from strip mining operations downstream of the City of Birmingham. Five Mile Creek originates within a residential and commercial area of Birmingham and therefore may be subjected to some form of perturbation other than that investigated in this study.

Five Mile Creek experiences a wide range of flows, varying from low runoff periods to storm events. During the February survey, flows were relatively high, averaging 5.6 m^3/sec. The creek was about 15.2 m in width, with depths varying from 0.3 to 1.5 m. During this period of high flow, runs predominated the study areas. Riffles were numerous, but pools were relatively infrequent. During October, flows were generally less than half of those in February. The study area incorporated approximately 48 river kilometers of the creek, and many stations were located where previous biological studies had been conducted (Figure 2-1). Each biological station was selected to include a pool and riffle habitat, if possible, where collections were taken depending on study design requirements. Dimensions of these habitats for each station are given in Tables C-1 (February) and C-2 (October). Station descriptions for both studies, as depicted in Figure 2-1 are

1. Station 1 was located at Lawson Road Bridge (RK 58.1). The pool area was open; riffle was shaded by hardwoods. The substrate was gravel and rubble over sand with rocks (0.1-0.3 m in diameter) prevalent in the riffle area. Water velocity in the run areas during October was about 0.44 m/sec and the water was clear. The surrounding land was open field and forested.
2. Station 2 was an area above Coke Plant 1 at Springdale Road Bridge, downstream from Loveless Branch (RK 53.3). Shore vegetation was hardwoods, although shading of the stream did not occur. The water was quite clear. The substrate was fist-sized rocks imbedded in sand. Water velocity in the run area during October was about 0.76 m/sec. The surrounding land was a mixture of residential, commercial, and parkland.

2A. Station 2A was located immediately above a low head dam and above Coke Plant 1. This station was used only for toxicity testing samples.

3. Station 3 was located 0.5 km downstream of Coke Plant 1 (RK 52.3). The water was turbid and there was no tree cover on the banks. The pool substrate was primarily large rocks with some gravel. The riffle was mostly a torrent over large rocks with some pockets of gravel which were utilized for benthic macroinvertebrate collections. Water velocity in the run area in October approximated 0.28 m/sec.
4. Station 4 was immediately below the confluence of runoff from railroad maintenance facilities with Five Mile Creek (RK 52.1). No pool was present at this station. The substrate was primarily a concrete bed (footing from a bridge located at this station) covered with periphytic growth and some large rocks. This station was sampled only in February.
5. Station 5 was located in the vicinity of the Rt. 31 bridge (RK 50.0). No well-defined pool and riffle were discernible since the reach was essentially a channel with a boulder substrate throughout. Benthic macroinvertebrates were taken from pockets of gravel. The rocks were very slick and the water was turbid. Water velocity was 0.38 m/sec in October. The surrounding area was predominantly hardwood, but no shading occurred.
6. Station 6 was located at the Acipico-Coalburg Bridge (RK 42.6) immediately above the confluence with Black Creek. The stream was wide and shallow with poorly discernible pool and riffle. The velocity was 0.30 m/sec in October. On the bank, hardwoods essentially shaded all of the stream.

The substrate was bedrock with pockets of gravel and a few boulders. The stream was uniformly wide and shallow with no channel. The water was moderately clear.

7. Station 7 was located at the Mineral Springs - Republic Road Bridge downstream of the POTW (RK 36.5). Poorly discernible pool and riffle areas were present because the stream was wide and shallow as at Station 6. The substrate was bedrock with large rocks and pockets of sand. A hardwood canopy was present. Water velocity was about 0.51 m/sec. Forested land surrounded the stream at Station 7.

8. Station 8 was at the Bevins Chapel - Brookside Road (RK 28.2). A water velocity of 0.30 m/sec was measured in October; the water was clear. Hardwoods on the bank provided considerable shading. The substrate in both the riffle and pool was gravel and fist-sized rocks imbedded in sand.

9. Station 9[a] was near Linn Crossing at the US 78 bridge (RK 16.1). A water velocity of 0.44 m/sec was measured in October; the water was turbid. The bank vegetation was hardwoods which provided limited shading. Pool substrate was sand and sediments; the riffle was a slab of bedrock with pockets of gravel and a few rocks.

During the October study, three tributaries to Five Mile Creek were sampled to evaluate the quality of the source water for Five Mile Creek. One Station (F0) was upstream of Station 1 on Five Mile Creek. Tarrant Creek (T1), Barton Branch (B1), and Black Creek (B2) were also sampled.

1. Station F0 was located on Five Mile Creek above Station 1. The station was a channelized section in a residential area. There was no vegetation along the stream; the banks were vertical concrete walls. The substrate in the pool was solid bedrock occasionally overlain with sand and gravel. The riffle substrate was rock and gravel imbedded in sand. The water was clear and had a velocity of about 0.38 m/sec.

2. Station B1 was located on Barton Branch which is an in-town tributary. No discernible pool was found. Velocity was 0.44 m/sec. A few hardwoods overhung part of the stream. The banks were vertical concrete. The substrate was very rough bedrock with occasional rocks or pockets of gravel. The water was clear and the substrate was overgrown with a dense coat of filamentous and amorphous material.

3. Station T1 was located on Tarrant Creek upstream of the city. Bank vegetation was hardwoods on one side and annual plants on the other. The pool substrate was sand and gravel. The riffle substrate was small rocks and gravel with some sand. The water was very clear, with some springs in evidence; water velocity was approximately 0.23 m/sec. Surrounding land was forest and fields.

4. Station B2[a] was in Black Creek prior to the confluence with Five Mile Creek. Black Creek was slow-moving with no distinct riffle area. Substrate was mostly sand with some logs and scattered rocks.

Instream water quality measurements were taken at all biological sampling stations during each collection effort (periphyton, zooplankton, benthos, and fisheries). A Hydrolab Model 4041 *in situ* water quality instrument was used to measure all parameters.

None of the values for any of the water quality parameters appeared limiting to the biotic communities. During February 1983, water temperature remained fairly consistent among stations, ranging from 8.8 to 10.7 C over a 6-day period. No distinct temperature variance was noted at any station. The pH range was 6.7-7.8 and was generally highest at the uppermost stations and lowest in Black Creek. Dissolved oxygen was relatively high at all stations, ranging from 12.0 to 14.2 mg/liter during the week. Conductivity ranged from 255 to 436 μmhos/cm within the study area during the week, and, like the other parameters, showed no variance that might indicate water quality influences due to discharged effluents from any of the point-source dischargers.

During the October 1983 survey, water temperature ranged from 17.1 to 23.7 C. This variation in temperature was due to diel fluctuation in solar radiation. The pH range was 5.6-7.0 with no discernible spatial trend in values among stations. Dissolved oxygen ranged from a low of 6.3 mg/liter to a maximum of 12.4 mg/liter during October. The values were generally higher at stations located upstream of the dischargers. Conductivity ranged from 287 to 632 μmhos/cm during the study period and tended to increase from upstream to downstream. Values of the water quality parameters were consistent between the tributary and mainstem stations.

[a] Station 9 was sampled only during October 1983 because adverse flow conditions during February 1983 prevented selection of habitat in the first survey.

[a] Station B2 was sampled only during February 1983. This station was deleted from the October survey because of dissimilar habitat.

4. Toxicity of Effluents and Receiving Water, February 1983

Toxicity tests were performed on each of the three effluents to measure subchronic effects on growth of larval fathead minnows and chronic reproductive effects of *Ceriodaphnia*. The objective was to estimate the minimum concentration of each effluent that would cause acute mortality and chronic effects on growth (fathead minnows) or reproduction (*Ceriodaphnia*). A range of effluent concentrations was used so that the occurrence of acute mortality could be measured in addition to chronic toxicity. These toxic effect levels would then be compared to the effluent concentrations in Five Mile Creek to predict where impact on resident species should occur. Ambient toxicity tests were also completed and the results compared to biological impact and effluent dilution test predictions. The validity of these predictions could be determined by an examination of the biotic condition of the stream at the locations where such effluent concentrations occurred as determined by the concurrent hydrological studies. The methods used for toxicity testing are described in Appendix A.

4.1 Chemical/Physical Conditions

Temperatures were continuously recorded for the fathead minnow tests and were maintained between 22 and 25 C for the duration of the tests. The *Ceriodaphnia* tests were kept in constant temperature cabinets that were maintained at 25 ± 1°C. Routine water quality measurements included pH, dissolved oxygen (DO), alkalinity, hardness, and conductivity, and are reported for all tests in Appendix D. Alkalinity, for the most part, ranged from 64 to 143 mg/liter. Hardness varied from 64 to 312 mg/liter, and conductivities ranged from 83 to 1,280 µmhos/cm, although most were in the range 310-490 µmhos/cm (Table D-1).

Values of pH and DO were recorded initially before the water samples were divided for testing with *Ceriodaphnia* and fathead minnows, and again before the water was renewed daily. Values of pH observed during the test ranged from 6.9 to 8.1 for fathead minnows (Table D-1) and 7.2 to 8.2 for *Ceriodaphnia* (Table D-2). Initial DO values for both test organisms ranged from 7.0 to 9.1 mg/liter, whereas final DO values were lower, ranging from 2.0 to 7.8 mg/liter for fathead minnows (Table D-1) and 5.4 to 8.4 for *Ceriodaphnia*. Nearly all values are in the acceptable range and no trends are obvious. The low DO values for the fathead minnow tests would be expected to influence growth; however, consistent adverse effects were not observed (Section 4.2). It is likely that the probe measures the DO 1 cm or more beneath the water surface, while the minnows were staying in the oxygen-rich surface layer where DO values would be greater.

4.2 Results of Fathead Minnow Growth Tests

Three dilution waters were used in tests of fathead minnow larvae exposed to various concentrations of three effluents. Coke Plant 1 effluent, when diluted with well water and Station 2A water, was lethal at effluent concentrations of 5 percent or greater. There was a small, but significant ($P \leq 0.05$) difference in survival at 1 percent effluent concentrations in well water but not in Station 2A water (Table 4-1). Three dilution waters (well water,

Table 4-1. Seven-Day Percent Survival of Larval Fathead Minnows Exposed to Various Concentrations of Three Effluents in Different Dilution Waters, Birmingham, Alabama, February 1983

		Percent Effluent (v/v)					
Effluent by Replicate	Dilution Water	50	10	5	1	0.5	Dilution Water
Coke Plant 1	Station 2A						
A		—	0	0	80	90	80
B		—	0	0	90	100	90
C		—	0	0	90	100	90
D		—	0	0	60	80	80
Mean		—[a]	0[a]	0[a]	80	93	85
		50	10	5	1	0.5	Dilution Water[b]
Coke Plant 1	Well Water						
A		—	0	0	80	90	100
B		—	0	0	90	90	100
C		—	0	0	100	100	100
D		—	0	0	70	80	90
Mean		—[a]	0[a]	0[a]	85[a]	90	98
		100[b]	50	10	5	1	Dilution Water
Coke Plant 2	Station 3						
A		40	60	100	90	100	100
B		40	80	90	100	100	100
C		30	90	90	100	100	80
D		50	80	90	80	90	80
Mean		40[a]	78	93	93	98	90

Table 4-1. (Continued)

Effluent by Replicate	Dilution Water	Percent Effluent (v/v) 100[b]	50	10	5	1	Dilution Water[b]
Coke Plant 2	Well Water						
A		40	90	90	60	100	100
B		40	100	100	90	100	100
C		30	100	100	100	100	100
D		50	90	100	100	90	90
Mean		40[a]	95	98	88	98	98
		100[b]	50	10	5	1	Dilution Water
Coke Plant 2	Station 1						
A		40	90	90	100	90	100
B		40	90	100	100	100	100
C		30	100	100	100	70	100
D		50	80	100	100	100	100
Mean		40[a]	90	98	100	90	100
		100	50	10	5	1	Dilution Water
POTW	Station 6						
A		100	80	80	90	100	90
B		90	100	90	90	80	90
C		90	90	70	90	90	100
D		80	90	70	100	80	100
Mean		90	90	78[a]	93	88	95

[a]Significant difference, $P \leq 0.05$.
[b]Data is repeated in table; only one Coke Plant 2 100 percent effluent and one well water control were used.

Station 3, and Station 1) were used in the tests using effluent from Coke Plant 2. Survival was significantly ($P \leq 0.05$) less only at 100 percent effluent but not at lower concentrations. Survival of fathead minnows exposed to POTW effluent in Station 6 water was unaffected even at 100 percent effluent (Table 4-1).

Growth effects occurred at sublethal concentrations in the tests on both coke plant effluents. The weights are actual values for each replicate and the treatment mean is a weighted average of the replicate means. Weight gain over the testing period was significantly less at concentrations of 1 percent Coke Plant 1 effluent than at 0.5 percent effluent in both dilution waters ($P \leq 0.05$) (Table 4-2). The effect level on growth in the tests using effluent from Coke Plant 2 was at concentrations between 5 and 10 percent in Station 3 water ($P \leq 0.05$). For the other two water types, the effect level was between concentrations of 10 and 50 percent (Table 4-3). No growth effects were detected in the fathead minnow tests using effluent from the POTW (Table 4-4). Based on the significant differences in minnow growth, Coke Plant 2 was more toxic when diluted with Station 3 water (collected directly above the discharge and containing Coke Plant 1 effluent) than when diluted with well or Station 1 water.

Results of the ambient toxicity tests indicated no significant differences among stations for either survival or growth of fathead minnows when compared to Station 1 (Table 4-5). Survival was greater than 85 percent at all stations (Table 4-6). Weights of the minnows averaged above 0.5 mg at all stations except Station 3 where the weight averaged 0.469 mg.

4.3 Results of *Ceriodaphnia* Reproductive Potential Tests

Tables 4-7 and 4-8 contain the data for *Ceriodaphnia* production tests for the three effluent and ambient tests. The dilution water (Station 1 water) for the Coke Plant 1 effluent dilution test was toxic, but this toxicity was substantially reduced at the 0.5 percent Coke Plant 1 effluent concentration. The Station 1 and Station 2 data show the upstream toxicity by low young production. The ambient toxicity test data also show the mitigation of toxicity at Station 3 by high young production in the ambient sample, which contained Coke Plant 1 effluent. Coke Plant 2 effluent appeared to reduce young production at concentrations of 5 percent but not at 1 percent when tested with Station 3 water as the diluent, yet was more toxic in well water where the effect level was below the 1 percent effluent concentration. No statistical analyses were performed on the *Ceriodaphnia* data, except to obtain the mean number of young per female and the confidence intervals, because of the problems of upstream toxicity.

The effect level was between 10 and 50 percent in the POTW effluent diluted with Station 6 water. When the POTW effluent was diluted with well water, an unusual response curve was obtained (Table 4-8) which has been observed with other POTW effluents (Mount et al. 1984) and for which the cause is not known.

Ambient toxicity was marked at Stations 1, 2, 2A, and 5 and somewhat less at Stations 7 and 8, while no toxicity was apparent at Stations 3 and 6 (Table 4-8). The effect at Station 5 was mortality in the first 24 hours so the data do not permit a determination as to whether the toxicity was due to a slug of something toxic in the water or was continuously present. At all other stations (except Station 5), the dominant toxic effect was on young production and not on mortality.

4.4 Discussion

Since the hydrological measurements were not designed to measure effluent mixing and final concentrations each day under variable stream-flow conditions, the effluent concentrations in the

Table 4-2. Mean Individual Dry Weights (mg) of Larval Fathead Minnows After Seven Days of Exposure to Various Concentrations of Coke Plant 1 Effluent in Two Dilution Waters, Birmingham, Alabama, Feburary 1983

Effluent by Replicate	Dilution Water	Percent Effluent (v/v) 50	10	5	1.0	0.5	Dilution Water
Coke Plant 1	Station 2A						
A		—	—	—	0.39	0.39	0.52
B		—	—	—	0.44	0.55	0.56
C		—	—	—	0.34	0.47	0.49
D		—	—	—	0.40	0.43	0.54
Weighted mean		—[a]	—[a]	—[a]	0.392[a]	0.464	0.527
SE		—	—	—	0.040	0.025	0.026
Coke Plant 1	Well Water						
A		—	—	—	0.44	0.46	0.50
B		—	—	—	0.40	0.48	0.51
C		—	—	—	0.46	0.48	0.59
D		—	—	—	0.29	0.49	0.48
Weighted mean		—[a]	—[a]	—[a]	0.404[a]	0.477	0.521
SE		—	—	—	0.026	0.025	0.024

[a]Significant difference, $P \leq 0.05$.

Table 4-3. Mean Individual Dry Weights (mg) of Larval Fathead Minnows After Seven Days of Exposure to Various Concentrations of Coke Plant 2 Effluent in Two Dilution Waters, Birmingham, Alabama, February 1983

Effluent by Replicate	Dilution Water	Percent Effluent (v/v) 100	50	10	5	1	Dilution Water
Coke Plant 2	Station 3						
A		0.19	0.26	0.35	0.43	0.44	0.44
B		0.14	0.33	0.40	0.45	0.45	0.45
C		0.09	0.24	0.41	0.42	0.45	0.47
D		0.18	0.25	0.42	0.51	0.44	0.53
Weighted Mean		0.156[a]	0.271[a]	0.394[a]	0.450	0.445	0.469
SE		0.045	0.018	0.016	0.016	0.016	0.016
Coke Plant 2	Well water						
A		—	0.34	0.51	0.58	0.57	0.50[b]
B		—	0.36	0.60	0.67	0.59	0.51
C		—	0.39	0.67	0.66	0.73	0.59
D		—	0.46	0.56	0.57	0.72	0.48
Weighted Mean		—[a]	0.387[b]	0.587	0.623	0.651	0.521
SE		—	0.029	0.029	0.030	0.029	0.029
Coke Plant 2	Station 1						
A		—	0.31	0.46	0.78	0.70	0.56
B		—	0.35	0.71	0.72	0.74	0.76
C		—	0.33	0.59	0.66	0.79	0.62
D		—	0.33	0.60	0.61	0.63	0.63
Weighted Mean		—[a]	0.330[b]	0.593	0.693	0.709	0.643
SE		—	0.038	0.037	0.036	0.038	0.036

[a]Significant difference, $P \leq 0.05$.
[b]These are the same values as in Table 4-2, as only one well water control was used.

stream are not known for several of the days during the testing. Both Coke Plant 2 and the POTW flows were over twice their normal flow, thus effluent quality was probably not typical of the effluent to which the stream community had been exposed for the preceding weeks even if concentrations had been known.

Therefore, the relationship of the effluent tests and the ambient tests to the expected effects in the

Table 4-4. Mean Individual Dry Weights (mg) of Larval Fathead Minnows After Seven Days of Exposure to Various Concentrations of POTW Effluent in River Water, Birmingham, Alabama, February 1983

Effluent by Replicate	Dilution Water	Percent Effluent (v/v) 100	50	10	5	1	Dilution Water
POTW	Station 6						
A		0.46	0.69	0.45	0.53	0.56	0.68
B		0.48	0.74	0.71	0.61	0.65	0.61
C		0.61	0.50	0.66	0.52	0.46	0.60
D		0.50	0.45	0.47	0.50	0.49	0.62
Weighted mean		0.511	0.596	0.577	0.539	0.539	0.627
SE		0.046	0.046	0.050	0.045	0.047	0.045

Table 4-5. Mean Individual Dry Weights (mg) of Larval Fathead Minnows After Seven Days of Exposure to Water From Various Ambient Stations, Birmingham, Alabama, February 1983

Replicate	Sampling Station 1	2	2A[a]	3[a]	5	6[a]	7	8
A	0.56	0.51	0.52	0.44	0.62	0.68	0.61	0.39
B	0.47	0.59	0.56	0.45	0.61	0.61	0.55	0.78
C	0.58	0.60	0.49	0.47	0.50	0.60	0.53	0.65
D	0.51	0.53	0.54	0.53	0.60	0.62	0.60	0.45
Weighted mean	0.544	0.585	0.527	0.469	0.583	0.627	0.572	0.569
SE	0.038	0.036	0.038	0.037	0.036	0.035	0.036	0.037

[a]Water from Stations 2A, 3, and 6 was used as dilution waters for various effluent tests.

Table 4-6. Seven-Day Percent Survival of Larval Fathead Minnows Exposed to Water From Various Ambient Stations, Birmingham, Alabama, February 1983

Replicate	Sampling Station 1	2	2A[a]	3[a]	5	6[a]	7	8
A	80	80	80	100	90	90	100	80
B	90	100	90	100	100	90	90	80
C	90	100	90	80	90	100	100	100
D	80	90	80	80	90	100	90	90
Mean	85	93	85	90	93	95	95	88

[a]Water from Stations 2A, 3, and 6 was used as dilution waters for various effluent tests.

stream cannot be estimated. The data do show, however, that the toxicity observed at Stations 1, 2, and 2A upstream of the discharge was mitigated by the discharge of Coke Plant 1. This occurred when the Coke Plant 1 effluent was added to Station 2A water in the effluent test and by the response of the animals in Station 3 water. The fathead minnows did not display toxic response to any ambient water samples.

Table 4-7. Mean Young Per Female and Percent Survival of *Ceriodaphnia* After Seven Days in Three Effluents at Various Concentrations and Dilution Waters, Birmingham, Alabama, February 1983

Type of Effluent	Dilution Water	Percent Effluent	Mean Number of Young per Female	Confidence Interval	Mean Percent Survival
Coke Plant 1	Station 2A	10	0	—	0
		5	0	—	40
		1	9.9	8.5–11.3	80
		0.5	9.4	5.8–13.1	100
		Dilution water	1.2	0–2.9	80
Coke Plant 1	Well water	10	0	—	0
		5	0.4	0–1.4	78
		1	5.4	2.6–8.3	100
		0.5	3.4	0.4–6.4	100
		Dilution water	12.2	9.4–14.8	80
Coke Plant 2	Station 3	100	0	—	60
		50	0.3	0–1.1	100
		10	2.8	0–9.9	100
		5	11.8	8.4–15.3	90
		1	15.0	13.0–17.0	10
		Dilution water	17.3	15.1–19.5	100
Coke Plant 2	Well water	100	2.0	0–4.1	60
		50	0	—	90
		10	0	—	90
		5	1.5	0–3.4	100
		1	4.3	0.5–7.9	90
		Dilution water	12.2	9.4–14.9	80
POTW	Station 6	100	0	—	0
		50	12.0	7.7–16.2	10
		10	15.6	12.7–18.7	90
		5	13.2	9.6–16.8	100
		1	14.2	12.3–16.1	100
		Dilution water	13.4	11.4–15.4	100
POTW	Well water	100	0	—	0
		50	12.4	10.2–14.7	60
		10	9.5	8.0–11.1	100
		5	5.7	3.9–7.5	100
		1	0	—	0
		Dilution water	12.2	9.5–14.8	80

Table 4-8. Mean Young Per Female and Percent Survival of *Ceriodaphnia* After Seven Days of Exposure to Water From Stream Stations for Ambient Toxicity Tests, Birmingham, Alabama, February 1983

Station	Mean Number of Young per Female	Confidence Interval	Mean Percent Survival
1	2.0	0–4.1	80
2	1.1	0–3.1	90
2A	4.0	2.1–5.9	100
3	15.4	11.6–19.3	100
5	0	—	0
6	16.3	12.0–20.7	100
7	7.0	3.2–10.9	80
8	7.9	5.0–10.8	100

5. Toxicity of Effluents and Receiving Water, October 1983

Because heavy rainfall produced wide variations in stream and effluent flow during the February 1983 study, the site was visited again from 4 to 10 October 1983 when stream flow had been low and stable for several weeks. The sources of dilution water for each effluent test were from the stations immediately upstream of each discharge. Appendix A describes test methods.

5.1 Chemical/Physical Conditions

Routine water quality measurements for the fathead minnow and *Ceriodaphnia* tests included pH, dissolved oxygen, alkalinity, hardness, and conductivity, and are reported in Appendix D. The initial water quality data are the same as for the fathead minnow and *Ceriodaphnia* tests since test solutions for both tests were made as one batch. All values, except one, were within normally prescribed limits for toxicity tests (Tables D-3 and D-4). A DO of 3.5 mg/liter in 100 percent Coke Plant 1 effluent was the only value outside such limits.

5.2 Results of Fathead Minnow Growth Tests

The data for the fathead minnow effluent and ambient tests are given in Tables 5-1 through 5-4. The effect concentration was between 1 and 3 percent for Coke Plant 1 and between 10 and 30 percent for Coke Plant 2, based on reduced weights. For the POTW, no chronic toxicity was found even at 100 percent effluent. The weights (Table 5-2) are actual values for each replicate and the treatment mean is a weighted average of the replicate means. All of the effluent dilution tests gave the typical dose response curves and the performance of the dilution water animals were within normal ranges i.e. 0.3 mg/fish or larger. In the ambient tests (Tables 5-3 and 5-4), Stations 5 and 6 had significantly lower weights ($P \leq 0.05$) compared with Station 2. Survival was significantly lower only with Station 5 ($P \leq 0.05$). Since the interest in the ambient tests is their relative toxicity, the station with the highest mean weight was used as the basis for the statistical comparison.[a] The growth and survival of organisms in natural waters are often better than in laboratory waters and, therefore, it is not always appropriate to use laboratory water test data for the statistical analyses.

5.3 Results of *Ceriodaphnia* Reproductive Potential Tests

The no-effect levels based on young production were between 3 and 10 percent for Coke Plant 1 and between 10 and 30 percent for Coke Plant 2 (Table 5-5). For the POTW, only the 100 percent concentration in which all the adults died prior to producing any young was significantly different ($P \leq 0.05$). The no-effect levels, based on survival data for all effluents tested, were between 30 and 100 percent.

The October ambient toxicity test survival and young production data are quite different from the February data (Tables 5-6 and 4-8). As with the statistical analysis for the fathead minnow growth tests, the ambient station with the highest young production was used as the basis for the statistical analysis. When comparing all of the ambient stations with Station 6, only Station 7 was not significantly different based on young production, but did have significantly lower survival. Less toxicity was observed at Station 5 in October than was seen in February. The upstream toxicity at Stations 1, 2, and 2A is much less pronounced. Only Station 1 showed a noticeable amount. Station 7 showed some toxicity in both studies but Station 8 displayed less in the October study.

Station 9 was added in the October study because there was evidence of some toxicity at Station 8 in February 1983. However, none occurred at Stations 8 or 9 in October 1983. Survival was 80 percent or higher at all stations except at Station 7 where only 20 percent survived. Most of this mortality occurred on Day 5, with some on Day 6. This pattern suggests that a high toxicity of short duration may have occurred causing the effect at Station 7. Since no increase in toxicity was found in the POTW effluent test, and because of the detention in the POTW and the flow time to Station 7, an increase in toxicity in the POTW sufficient to cause the effect on Day 5 at Station 7 should not have been masked by composite sampling of the POTW.

In addition to effluent dilution tests using composite samples, a test series using discrete grab samples was performed to evaluate variation in

[a]For further clarification, see Chapter 14 for interpretation of results and Appendix A for detailed statistical procedures.

Table 5-1. Seven-Day Percent Survival of Larval Fathead Minnows Exposed to Various Concentrations of Three Effluents in Different Dilution Waters, Birmingham, Alabama, October 1983

Type of Effluent	Dilution Water	Replicate	Percent Effluent (v/v) 100	30	10	3	1	Dilution Water
Coke Plant 1	Station 2A	A	0	10	90	90	100	70
		B	0	30	90	90	90	100
		C	0	10	100	100	90	100
		D	0	10	100	89	90	100
		Mean	0[a]	15[a]	95	93	93	93
Coke Plant 2	Station 3	A	0	30	80	100	100	80
		B	0	78	100	90	100	100
		C	0	40	90	90	100	90
		D	0	50	89	100	100	100
		Mean	0[a]	48[a]	90	95	100	93
POTW	Station 6	A	90	100	90	100	100	100
		B	100	90	70	100	100	100
		C	100	80	100	90	100	100
		D	100	100	100	100	70	100
		Mean	98	93	90	98	93	100

[a]Significant difference, P ≤ 0.05.

Table 5-2. Mean Individual Dry Weights (mg) of Larval Fathead Minnows After Seven Days of Exposure to Various Concentrations of Three Effluents in Different Dilution Waters, Birmingham, Alabama, October 1983

Type of Effluent	Dilution Water	Replicate	Percent Effluent (v/v) 100	30	10	3	1	Dilution Water
Coke Plant 1	Station 2A	A	0	0.050	0.144	0.283	0.417	0.408
		B	0	0.057	0.165	0.183	0.281	0.356
		C	0	0.150	0.172	0.295	0.411	0.365
		D	0	0.020	0.285	0.266	0.277	0.325
		Weighted mean	0[a]	0.065[a]	0.193[a]	0.258[a]	0.348	0.360
		SE	--	0.066	0.026	0.027	0.027	0.026
Coke Plant 2	Station 3	A	0	0.200	0.219	0.278	0.414	0.288
		B	0	0.217	0.255	0.306	0.360	0.370
		C	0	0.250	0.337	0.289	0.347	0.356
		D	0	0.160	0.313	0.394	0.295	0.339
		Weighted mean	0[a]	0.206[a]	0.281	0.318	0.354	0.340
		SE	--	0.031	0.023	0.022	0.021	0.022
POTW	Station 6	A	0.333	0.210	0.261	0.260	0.252	0.328
		B	0.370	0.389	0.250	0.195	0.235	0.265
		C	0.418	0.406	0.293	0.233	0.320	0.265
		D	0.345	0.333	0.378	0.261	0.364	0.280
		Weighted mean	0.367	0.329	0.300	0.237	0.287	0.285
		SE	0.027	0.027	0.028	0.027	0.027	0.026

[a]Significantly different from controls (P ≤ 0.05).

toxicity within different effluent parcels over a 24-hour period. The survival of *Ceriodaphnia* retained in 100 percent Coke Plant 2 effluent ranged from 40 to 100 percent for the 96-hour test (Table 5-7). Assuming that a survival of 80 percent or greater suggests no acute toxicity, toxicity occurred in only 21 percent of the tests conducted from samples collected on 10 October compared to 67 percent of the grab samples collected on 8 October. Toxicity was found in approximately 50 percent of the samples collected on the other two days. No consistent day (0600-1700 hours) versus night (1800-0500 hours)

Table 5-3. Percent Survival of Larval Fathead Minnows After Seven Days of Exposure to Water From Various Ambient Stations, Birmingham, Alabama, October 1983

Replicate	Reconstituted Water	Sampling Station 1	2	2A	3	5	6	7	8	9
A	100	100	100	70	80	80	100	100	90	100
B	100	100	100	100	100	60	100	90	90	90
C	100	100	90	100	90	70	100	90	90	100
D	100	100	100	100	100	40	100	70	100	90
Mean	100	100	98	93	93	63[a]	100	88	93	95

[a]Significantly different ($P \leq 0.05$) from Station 2.

Table 5-4. Mean Individual Dry Weights (mg) of Larval Fathead Minnows After Seven Days of Exposure to Water From Various Ambient Stations, Birmingham, Alabama, October 1983

Replicate	Reconstituted Water	Sampling Station 1	2	2A	3	5	6	7	8	9
A	0.405	0.316	0.335	0.408	0.288	0.121	0.328	0.255	0.411	0.375
B	0.415	0.361	0.325	0.356	0.370	0.143	0.265	0.278	0.283	0.378
C	0.335	0.310	0.471	0.365	0.356	0.221	0.265	0.339	0.300	0.394
D	0.345	0.289	0.428	0.325	0.339	0.138	0.280	0.407	0.265	0.339
Weighted mean	0.375	0.319	0.388	0.360	0.340	0.157[a]	0.285[a]	0.313	0.362	0.372
SE	0.025	0.025	0.026	0.026	0.022	0.032	0.025	0.027	0.026	0.026

[a]Significantly different ($P \leq 0.05$) from Station 2.

Table 5-5. Percent Survival and Mean Young Per Female *Ceriodaphnia* After Seven Days of Exposure to Three Effluents at Various Concentrations in Three Dilution Waters, Birmingham, Alabama, October 1983

Effluent	Dilution Water	Percent Effluent (v/v)	Mean Percent Survival	Mean Number of Young per Female	Confidence Intervals
Coke Plant 1	Station 2A	100	0[a]	0[a]	--
		30	80	0[a]	--
		10	100	2.5[a]	1.3-3.7
		3	100	24.4	20.1-28.8
		1	90	23.3	18.7-27.8
		Dilution water	100	23.8	20.3-27.3
Coke Plant 2	Station 3	100	0[a]	0[a]	--
		30	100	11.3[a]	7.6-15.0
		10	100	25.6	21.3-29.9
		3	100	26.4	22.0-30.8
		1	100	22.8	19.0-26.6
		Dilution water	100	22.5	19.9-25.1
POTW	Station 6	100	0[a]	0[a]	--
		30	80	39.8	34.4-45.2
		10	100	36.8	31.2-42.4
		3	100	35.2	30.7-39.7
		1	100	34.6	29.6-39.6
		Dilution water	100	32.7	26.4-39.0

[a]Different from control, $P \leq 0.05$.

differences in toxicity could be discerned. Generally, toxicity occurred in 25-58 percent of the samples collected during the night and in 17-75 percent of the samples collected during the day.

The acceptable effluent concentrations (AEC) for *Ceriodaphnia* and fathead minnows were calculated as the geometric mean of the highest no-effect concentration and the lowest-effect concentration (Table 5-8). The AEC for Coke Plant 1 was 1.7 percent for fathead minnows and 5.5 percent for *Ceriodaphnia*. The AEC for Coke Plant 2 was identical for both species (17.3 percent). The POTW effluent had the highest AEC at concentrations of

Table 5-6. Percent Survival and Mean Young Per Female *Ceriodaphnia* After Seven Days of Exposure to Water From Various Ambient Stations, Birmingham, Alabama, October 1983

Sampling Station	Percent Survival	Mean Number of Young Per Female	Confidence Intervals
1	80	14.4[a]	9.8-19.1
2	100	18.1[a]	16.5-19.7
2A	100	21.3[a]	19.6-23.1
3	100	20.1[a]	17.5-22.7
5	100	22.4[a]	18.7-26.1
6	80	35.6	30.4-41.0
7	20[a]	29.3	24.6-33.1
8	90	22.1[a]	18.8-25.7
9	100	22.5[a]	18.9-26.1

[a]Significantly lower than the reference Station 6 ($P \leq 0.05$).

Table 5-7. 48-Hour Survival of *Ceriodaphnia* Exposed to Discrete Samples of 100 Percent Effluent From Coke Plant 2, Birmingham, Alabama, October 1983

	Date of Sample			
Hour of Sample	8 OCT	9 OCT	10 OCT	11 OCT
1500	90	80	90	70
1600	70	80	80	100
1700	90	100	90	100
1800	70	90	90	60
1900	60	80	90	60
2000	60	80	80	80
2100	50	70	90	90
2200	80	70	80	40
2300	80	90	90	60
2400	90	90	70	100
0100	50	70	100	80
0200	80	80	90	50
0300	50	60	80	80
0400	70	80	60	100
0500	80	80	70	80
0600	80	50	70	60
0700	70	70	90	70
0800	50	70	80	40
0900	60	80	80	80
1000	40	70	90	60
1100	50	50	80	90
1200	70	60	70	60
1300	70	60	80	40
1400	70	70	90	40
Station 3	90	100	100	100
Summary Statistics	Percent Frequency of Toxicity (≤80 percent survival)			
Day	58	33	25	42
Night	75	67	17	67
Mean	67	50	21	54

greater than 100 percent for fathead minnows and 54.8 percent for *Ceriodaphnia*.

5.4 Discussion

None of the dilution water used for effluent toxicity testing displayed toxicity. For the *Ceriodaphnia* tests, additional sets of 10 animals were used for the ambient toxicity test, whereas only one set of fathead minnows was used for both the ambient test and the dilution water for each effluent. For *Ceriodaphnia*, young production showed a 10, 11, and 8 percent difference between the duplicate values for Stations 2A, 3, and 6, respectively. Young production was highest at Station 6 (Table 5-6) suggesting that there were no measurable additive effects of the two coke plants. The abrupt mortality starting on Day 5 at Station 7 is most likely an increase in toxicity due to an unknown upstream source rather than an additive effect of the POTW and coke plant effluents since the flow of Five Mile Creek and of the effluents did not change drastically although there were some increases in discharges of Coke Plant 2.

Station 1 data was noticeably different from Stations 2 and 2A data for *Ceriodaphnia*. During the February study, Stations 1, 2, and 2A were decidedly toxic to *Ceriodaphnia*, much more so than during the October study. In the February study, Station 5 water caused complete mortality in the first 24 hours but little effect was found for daphnids in the October study. Both studies suggested impairment in water from Station 7 and a water quality problem at Station 1. Preliminary testing in February showed measured zinc concentrations high enough (17.9 μg/liter) to cause the observed effect. Rainfall runoff occurring in late January could have increased zinc concentrations above those existing in October.

The fathead minnow ambient toxicity data differs from the *Ceriodaphnia* data. In both study periods, there was no evidence of toxicity to the fathead minnows at Stations 1, 2, or 2A. In the February study, no ambient toxicity to the fathead minnows was found; in the October study, however, Stations 5 and 6 were the only ambient stations that showed significant toxicity. The possibility that this was the result of the coke plant discharges is discussed in Chapter 14.

Acceptable effluent concentrations can be calculated as the geometric mean of the lowest effect concentration (using the most sensitive endpoint of growth, survival or young production) and the highest no effect concentration. The effluent dilution tests predict impacts in the stream where the effluent concentrations equal or exceed approximately 1.7 percent Coke Plant 1 waste, 17 percent Coke Plant 2 waste, and 55 percent POTW effluent (Table 5-8). Average instream waste concentrations based on the dye studies during the site study (Table 7-2) show that these effect levels are exceeded in the stream at some stations. Since the effluents were tested in water taken immediately upstream of each outfall, any positive or negative

Table 5-8. Acceptable Effluent Concentration (AEC) for Three Effluents for Fathead Minnows and *Ceriodaphnia*, Birmingham, Alabama, October 1983

Effluent	AEC Percent Concentration (v v)	
	Fathead Minnows	*Ceriodaphnia*
Coke Plant 1	1 7	5.5
Coke Plant 2	17.3	17.3
POTW	·100	54.8

Source: Tables 5-2 and 5-5.

interactions caused by upstream effluents are incorporated into the estimate of the AEC. Therefore, the AEC estimate should be valid regardless of the amount of upstream effluent present. From Table 7-2 the AEC for Coke Plant 1 was exceeded at Station 3 and the AEC of Coke Plant 2 was exceeded at Stations 5 and 6. The dilution water for the POTW test contained concentrations of Coke Plant 2 effluent in excess of its AEC. The effect is reflected in the mean weights of the fathead test. The dilution water animals were smaller, although not statistically so than the animals in 10 to 100% POTW effluent. The same group of animals, when compared in the ambient test data set, using Station 2 as the reference value, were statistically smaller. The daphnids show no effect at all. In fact the highest young production occurred at Station 6 and that held true for both sets of animals, i.e., the dilution water "controls" and the ones in the ambient tests.

In the February tests, some effluents were tested in more than one water type. Coke Plant 2 was more toxic in Station 3 water than in well water but the reverse was true for *Ceriodaphnia* (Tables 4-3 and 4-7). The response in February is consistent with the response of daphnids and fathead minnows in Station 6 water during the October study. There are other potential sources of toxicity between Coke Plant 2 outfall and Station 5. There was a small tributary draining a railroad facility. In the February study, the fathead minnows were not sensitive to Station 5 water; however *Ceriodaphnia* were dead within 24 hours. In the October study, only the fathead minnows were sensitive, but less than the *Ceriodaphnia* were in February. There were several small tributaries entering through the study reach and these drained watersheds in which strip mining had occurred in the past.

In summary, by combining data from the two species, the effluent tests predict toxicity at Stations 3, 5 and 6 and the ambient tests found toxicity present so on that basis the tests agree. At Stations 5 and 6 the fatheads displayed toxicity but the daphnids did not even though the AEC values were identical for both species. At Station 3, only the fathead AEC was exceeded but only the daphnids "sensed" toxicity in the ambient test. Section 14 of this report discusses why this might be expected to happen.

6. Hydrological Analysis, February 1983

The objective of the hydrology study in Five Mile Creek was to ascertain time-of-travel with relationship to multiple inputs, the dilution characteristics of Coke Plant 1 effluent, and the flow relationships between stream and effluent contributions to estimate instream waste concentrations (IWC) for each of the three inputs. Streamflow measurements were performed on several days at biological collecting stations. A description of the sampling and analytical methods is provided in Appendix B.

6.1 Stream/Discharge Flow Relationships

Flows measured at biological sampling stations and in the vicinity of discharges on Five Mile Creek are shown in Table 6-1. Also included are the reported daily average flows at the USGS gauging station (Station 2457000) located between Stations 1 and 2 and the reported discharges at Coke Plant 1, Coke Plant 2, and the POTW. At Station 3 (below the Coke Plant 1 discharge), the river flow tripled (1.95-5.94 m^3/sec) between 8 and 10 February due to heavy rain, then subsided to twice its initial value (3.56 m^3/sec) on 11 February. On 10 February the measured flow of 5.94 m^3/sec below Coke Plant 1 (RK 52.1) increased to 6.51 m^3/sec below Coke Plant 2 at the confluence with Black Creek (approximately RK 42.9), where an additional 3.14 m^3/sec entered Five Mile Creek. Below the POTW (RK 41.8), the total river flow showed an additional increase due to the combined effects of the high POTW flows and additional runoff.

For 7-9 and 11 February the flows were estimated at the stations not sampled by interpolating between the few known flow measurements on each day and by comparison to the complete set of flow data taken on 10 February. The drainage area between the USGS gauge and Coke Plant 1 discharge and for Black Creek were planimetered from topographical maps of the area and found to be 11.6 and 22.5 km^2, respectively. The reported drainage area above the USGS gauge is 5.90 km^2. On 10 February the difference between the USGS flow and that below Coke Plant 1 (3.85 m^3/sec) and the measured flow for Black Creek (3.14 m^3/sec) are both larger than the 2.06 m^3/sec flow at the USGS station even though the USGS station drainage area is 5 and 2.6 times as large, respectively. Additional stormwater runoff had to be included above Coke Plant 1 and in Black Creek, particularly on 7 and 11 February due to heavy rain on 6 and 10 February. On 11 February the estimated flow of 4.72 m^3/sec was used at Station 6, instead of the measured flow of 6.65 m^3/sec, because the measured value was higher than expected when compared to flows at the USGS station and at Station 3.

Table 6-1. Measured and Estimated Flows at Biological Sampling Stations and Discharges on Five Mile Creek, February 1983

Location	Flow (m^3/sec)				
	7 FEB	8 FEB	9 FEB	10 FEB	11 FEB
USGS gauging station	1.84	1.55	1.98	2.06	1.58
Storm water runoff	(2.83)	0.36[a]	(0.45)	3.85[a]	1.95[a]
Coke Plant 1 discharge	0.0105	0.0076	0.0082	0.0091	0.0093
Station 3 (below Coke Plant 1)	(4.67)	1.95	(2.46)	5.94	3.56
Coke Plant 2 discharge	0.17	0.17	0.24	0.24	0.15
Station 5 (below Coke Plant 2)	(5.26)	(2.40)	(3.00)	6.51	(3.99)
Station 6	(6.08)	(3.11)	(3.90)	6.42	(4.72)[b]
Station B2 (Black Creek)	(2.49)	(1.01)	(1.30)	3.14	(1.89)
Above POTW	8.58	(4.13)	(5.21)	10.25	(6.62)
POTW discharge	0.96	0.88	0.80	0.92	0.89
Station 7	9.54[a]	(5.01)	(6.03)	11.18[a]	(7.53)
Station 8	--	--	--	--	12.91

[a]Value calculated by summation or difference between measured values.
[b]Estimated flow was used rather than measured flow of 6.65 m^3/sec because this measured flow was higher than expected compared to flows at the USGS station and Station 3.

Note: Numbers in parentheses were estimated using drainage area measurements. Station 8 was sampled only on 11 February.

6.2 Time-of-Travel Study

On 8 February a time-of-travel study was conducted by releasing dye at Coke Plant 1 and monitoring its passage at locations 580, 1,158, 1,180, and 3,140 m downstream. The results of the 8 February time-of-travel study are shown in Figure 6-1 for the four downstream stations. The location of the center of mass trailed the peak concentration by 5-7 minutes (Figure 6-1). Average velocities calculated between each station are shown below

Distance Interval (m)	Velocity (m/sec)
0-580	0.32
579-1,158	0.33
1,158-1,880	0.32
1,880-3,140	0.35

The average velocity over the 3.14-km section of the river was 0.4 m/sec. This time-of-travel velocity is equivalent to an exposure time of 1.3 hours for each 1.60 km (1 mi) of downstream movement from the point of discharge for the average water parcel. Water parcels in the leading edge of the distribution would have experienced an exposure time of less than average, whereas parcels in the tail of the distribution would have longer exposure times. The average velocity of the leading edge of the dye distribution over this 3.14-km segment of the river was 0.5 m/sec, which is equivalent to 1.0 hour of exposure time for each 1.60 km (1 mi) of downstream movement.

6.3 Effluent Configuration—Coke Plant 1

The Coke Plant 1 effluent configuration study was performed on 8-9 February 1983. The average dye concentration measured at the point of discharge between 1600 and 1730 hours on 8 February was 113 ppb. The recorded discharge dye concentration slowly decayed overnight because of residue building up inside the flow cell of the fluorometer. From the uniform dye injection rate measured over the course of the study (7.24 g/min), it was determined that the initial 113 ppb value could be used for the entire study period. The average background fluorescence measured in the discharge was 3 ppb, yielding a 110 ppb discharge dye concentration that was corrected to 220 ppb by applying the factor

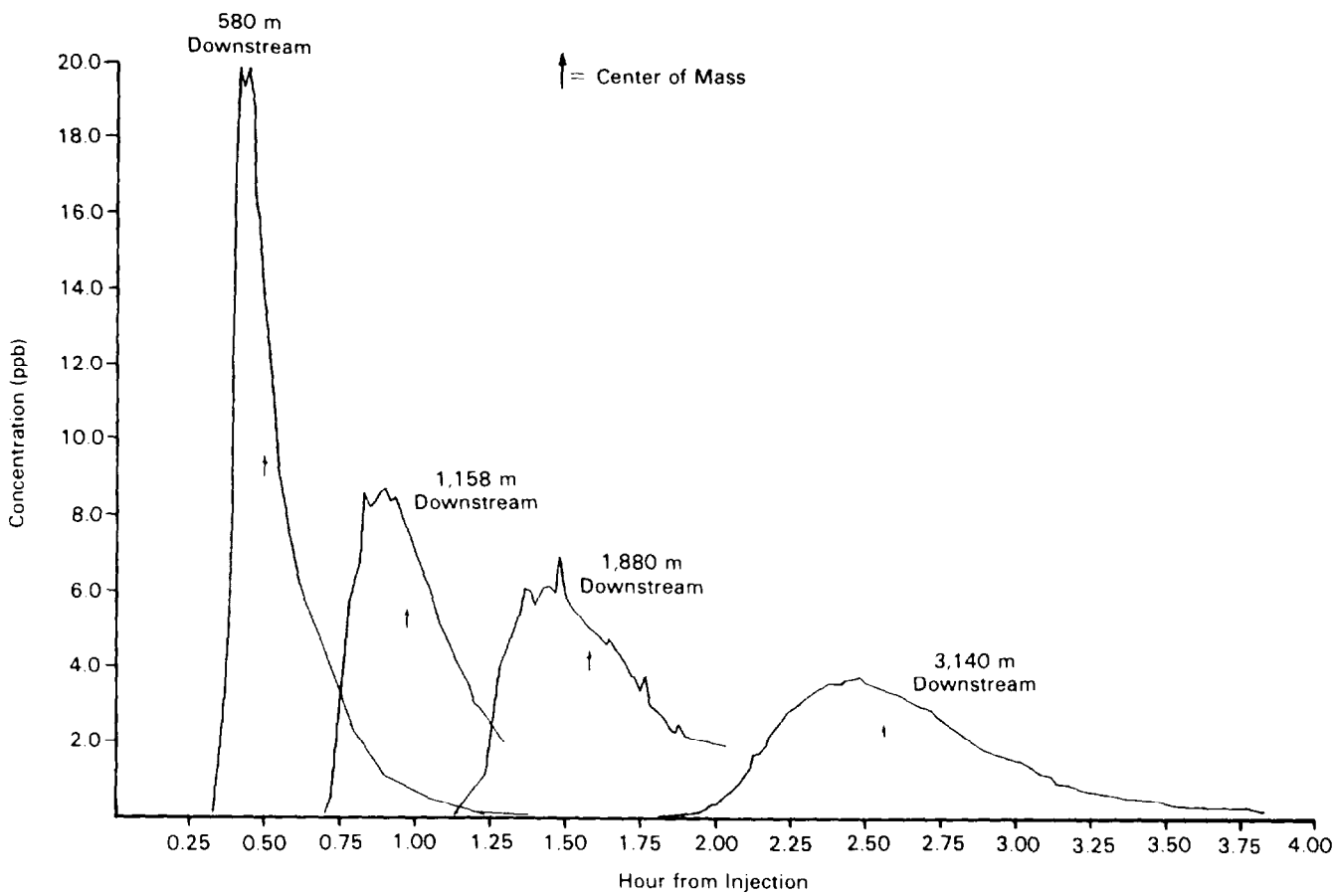

Figure 6-1. Time-of-travel study on Five Mile Creek, February 1983 (injection time 0.0 hour).

determined from the dye integrity study, which accounts for the high color content of the effluent (Appendix B). The instream water samples were collected on 9 February between 1230 and 1630 hours at the 12 transects.

Taking into account the measured background levels of the river water and the effluent, dilution ratios were calculated for all instream samples using the 220 ppb discharge dye concentration. The resulting dilution contours for 9 February downstream of the Coke Plant 1 discharge are shown in Figure 6-2. Where water depths were greater than 0.5 m, the surface and bottom dye concentrations showed so little variation that the mean value was used in preparing Figure 6-2. The rain that caused the daily average flow to increase from 1.95 to 2.46 m^3/sec between 8 and 9 February did not start until after the dye samples had been collected.

Due to the small discharge flow of 0.008 m^3/sec from Coke Plant 1 on 9 February compared to the river flow of approximately 1.95 m^3/sec, large dilution ratios were achieved quickly. At Transect 6, 213 m below the discharge, dilution ratios ranged from 160 to 200 and the river was approximately 90

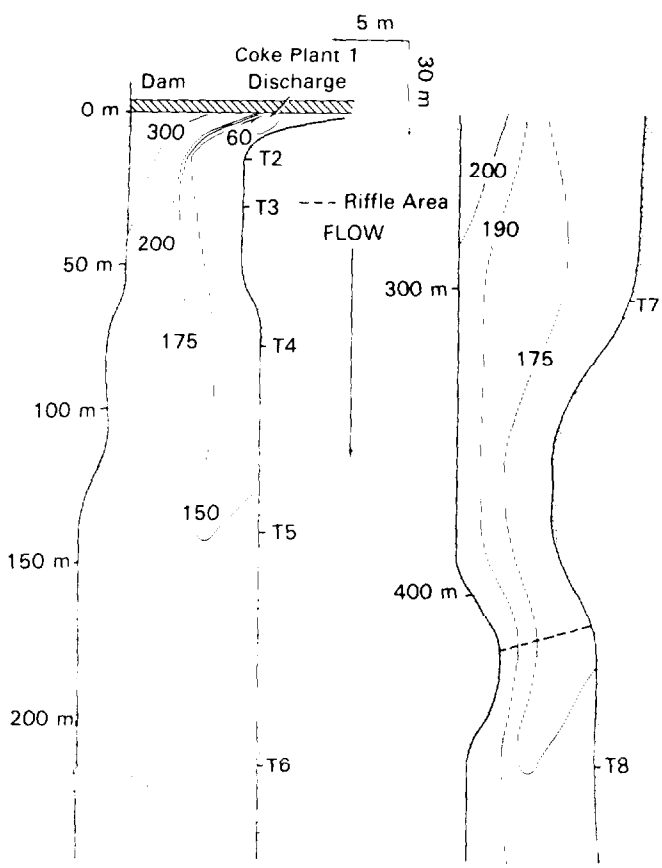

Figure 6-2. Dilution contours in Five Mile Creek downstream from Coke Plant 1, 9 February 1983.

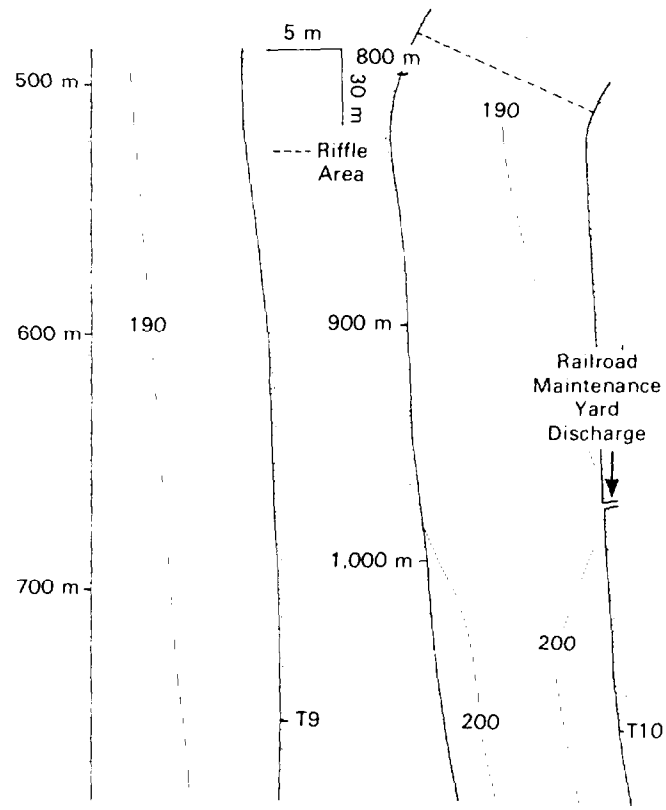

Figure 6-2. (Cont.)

percent fully mixed (Figure 6-2). Additional mixing occurred gradually with the river approaching a fully mixed state (99 percent) at 762 m downstream at Transect 9 with a dilution ratio of 190.

6.4 Evaluation of Dilution Characteristics

The Five Mile Creek flow and the percent fully mixed flow contribution at selected sampling stations from each of the three discharges are summarized in Table 6-2 for the period 7-11 February. Daily differences in the reported flows at the three discharges were very small compared to the effect of the changing river stage on the flow contribution at each station. From 7 February to the afternoon of 9 February, the decreasing river stage resulted in progressively higher flow contribution to each station from the discharges. The rain on 9-10 February increased river flows, but when river flows again decreased on 11 February, flow contributions again increased. The percent flow contribution from both coke plants had a larger incremental decrease between Stations 6 and 7 because of the additional flow from Black Creek.

The contribution of the effluent from Coke Plant 1 varied from a maximum of 0.39 percent of the river flow on 8 February at Station 3 to a minimum of

Table 6-2. Percent Flow Contribution From the Three Discharges at Selected Sampling Stations on Five Mile Creek, February 1983

	River Flow (m^3 sec)	Flow Contribution (%)		
		Coke Plant 1	Coke Plant 2	POTW
7 FEB				
Sta 3	4.67	0.22		
5	5.25	0.20	3.38	
6	6.08	0.17	2.92	
7	9.54	0.11	1.86	10.09
8 FEB				
Sta 3	1.95	0.39		
5	2.40	0.32	7.12	
6	3.11	0.25	5.50	
7	5.01	0.15	3.42	17.63
9 FEB				
Sta 3	2.46	0.33		
5	3.00	0.27	8.01	
6	3.90	0.21	6.15	
7	6.03	0.14	3.99	13.43
10 FEB				
Sta 3	5.94	0.15		
5	6.51	0.14	3.69	
6	6.51	0.14	3.69	
7	11.18	0.08	2.15	8.30
11 FEB				
Sta 3	3.56	0.26		
5	3.99	0.24	3.76	
6	4.72	0.20	3.15	
7	7.53	0.12	1.98	11.88

0.08 percent of Station 7 on 10 February. The flow contribution from Coke Plant 2 varied from 8.01 percent at Station 5 to 1.86 at Station 7. Between 10 and 11 February the decreasing Coke Plant 2 flow of from 0.24 to 0.14 m^3/sec was proportional to the decreasing river flow. The flow contribution from the POTW of 8.30-17.63 percent varied inversely with the river flow.

6.5 Summary

Hydrological measurements were made to estimate the instream waste concentration for each of the three outfalls during February 1983. These measurements were not frequent enough to establish the value of IWC for the outfalls for each day because of heavy rains and highly variable stream flows. An effort was made to estimate flows on days for which measurements were not made by use of the watershed area. These estimates were not reasonable possibly because of storm sewers or other inputs that were not proportional to the drainage area.

7. Hydrological Analysis, October 1983

7.1 Stream/Discharge Flow Measurements

Because flows could not be accurately estimated in February, they were measured frequently at each station so that effluent concentration could be estimated for each day in the event stream flows were variable. Dye studies were also made to determine mixing characteristics.

Flows measured at sampling stations on Five Mile Creek in October 1983 are shown in Table 7-1. Also included are the daily average discharges from Coke Plant 1, Coke Plant 2, and the POTW. At Coke Plant 1 and the POTW, the daily average discharge was calculated from the reported hourly values. At Coke Plant 2, the discharge flow is measured by plant personnel once daily at a flume. Flows from the USGS gauging station (Station 2457000) which were included in the February 1983 study were not available because the gauge was inoperable.

During the week of 3-9 October, the daily average flow at Coke Plant 1 varied from 0.0074 to 0.0093 m^3/sec. During 3-7 October the flows were very uniform, whereas on 8 and 9 October (the dates of the dye study), the hourly flows varied between 0.0076 and 0.0116 m^3/sec. Coke Plant 1 flows observed during this study are comparable to the 0.0076-0.0105 m^3/sec daily average values recorded during the February 1983 study.

During the study, the daily reported flow at Coke Plant 2 ranged from 0.066 to 0.122 m^3/sec and averaged 0.096 m^3/sec. On 5-6 October (the dates of the dye study), reported flows were 0.122 and 0.116 m^3/sec. An additional flow of 0.085 m^3/sec was measured at a current meter transect on 6 October. These flow values are nearly half of the 0.15-0.24 m^3/sec flows reported during the February 1983 study.

At the POTW during the week of 3-9 October, daily average discharges ranged from 0.229 to 0.275 m^3/sec. A minimum flow of 0.14-0.17 m^3/sec was normally reached at 0800 or 0900 hours and a maximum flow of 0.31-0.37 m^3/sec was reached early in the afternoon. On 7 October from 0900 to 1300 hours there was no reported discharge flow while the plant was shut down for back flushing. However, the average discharge from 1400 to 2100 hours increased to 0.445 m^3/sec such that the daily average value of 0.266 m^3/sec was typical of the other days. The POTW flows in October were substantially lower than the 0.80-0.96 m^3/sec flows recorded during the February 1983 study.

Flows in Five Mile Creek slowly receded during the week following a 4 October rain event (Table 7-1). This effect is most noticeable at Station 1 where the flow decreased from 0.286 to 0.221 m^3/sec and at Station 5 where the flow decreased from 0.527 to 0.362 m^3/sec. On 4 October the flow of 0.524 m^3/sec measured at Station 3 was recorded 3.5 hours later than the downstream flow of 0.470 m^3/sec at Station 5 and is evidence of the rising river stage during the rain event. The 0.691 m^3/sec flow measured

Table 7-1. Measured Flows (m^3/sec) at Biological Sampling Stations on Five Mile Creek, October 1983

	October							
Location	3	4	5	6	7	8	9	10
Station 1		0.286		0.249	0.232	0.204	0.215	0.221
Station 2		0.379		0.272		0.258		
Station 2A					0.348		0.275	
Coke Plant 1 discharge	0.0076	0.0079	0.0076	0.0074	0.0076	0.0088	0.0093	
Station 3		0.524		0.371		0.292		
Coke Plant 2 discharge	0.066	0.079	0.122	0.116	0.092	0.101	0.096	0.096
Station 5		0.470		0.527	0.498	0.464	0.297	0.362
Station 6			0.691		0.501		0.394	
Black Creek (Station B2)			0.047		0.021			
POTW discharge	0.258	0.275	0.255	0.263	0.266	0.238	0.229	
Station 7			0.691		0.736		0.586	
Station 8			0.906		0.575		0.586	0.598
Station 9			1.045	0.844	0.810	0.779		

at Station 7 on 5 October is much lower than expected and is regarded as suspect. This is because the flow measured at Station 6 (0.691 m^3 sec) with the addition of a 0.255 m^3 sec discharge from the POTW is consistent with the 0.906 m^3 sec flow measured at Station 8. The 0.575 m^3 sec flow at Station 8 on 7 October is also suspect but it may be related to the POTW discharge being turned off during the back flushing operation.

7.2 Effluent Configuration—POTW

The POTW dye study was performed on 3-4 October. For the period of dye injection, an hourly discharge dye concentration was calculated from the reported plant flows and the 5.27 g min dye injection rate. The calculated values were in good agreement with the four grab samples collected from the discharge. The measured discharge dye concentration on 4 October at the start and end of the instream sampling survey was 114 ppb at 0819 hours and 51 ppb at 1340 hours. The decreasing dye concentration was due to the normal morning increase in discharge at the POTW.

In order to relate the time varying discharge concentrations to observed downstream dye concentrations, a travel time was estimated between the discharge and each transect. An average cross-sectional velocity was calculated at each transect by dividing the Five Mile Creek flow by each transect's cross-sectional area. These velocities were used in conjunction with the transect spacing to calculate a travel time for an "average" water particle between each transect.

For the first 300 m (Transects T2 through T7), which were sampled between 0837 and 1022 hours, the corresponding water particles left the discharge between 0836 and 0943 hours. The farther downstream transects required successively longer travel times such that the average water particles had left the discharge at 0916 hours for Transect T9 (762 m) and before 0830 hours for Transects T10 and T11. Since the discharge times for Transects T2 through T9 were all between 0836 and 0943 hours, a 4-hour average discharge concentration of 103.0 ppb from 0700 to 1000 hours was used in calculating the dilution ratios. The appropriate discharge concentration for use at transects beyond T8 (457 m) is not critical since there was no contourable variation in the observed dye distribution beyond this point.

The resulting dilution contours are shown in Figure 7-1. The discharge plume mixed with the stream flow quickly. During initial mixing, a dilution contour of 10 was 3 m from the far bank at Transect T2 (15 m) and reached the far bank by Transect T6 (213 m). A dilution contour of 5 (20 percent effluent) reached the far bank above Transect T7 (305 m) and

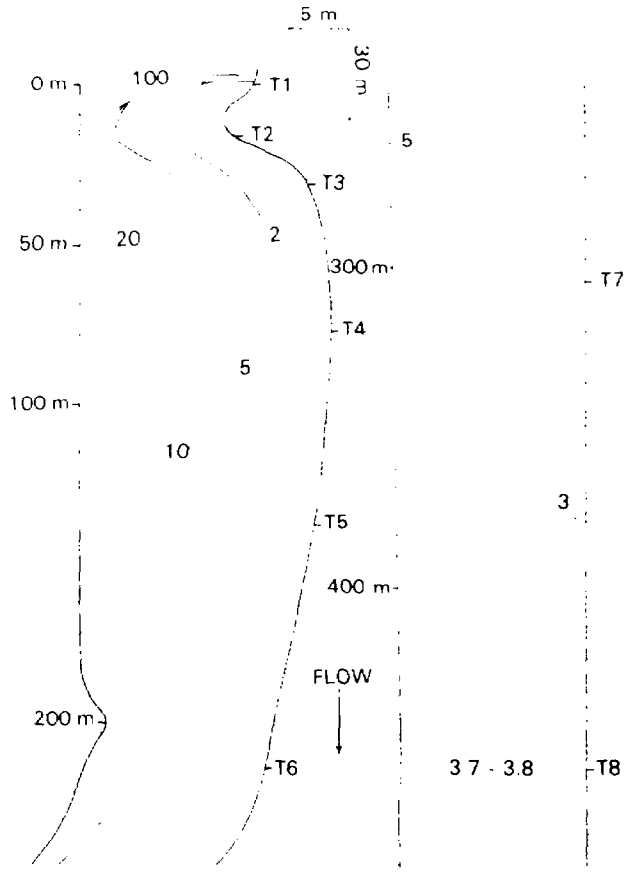

Figure 7-1 Dilution contours in Five Mile Creek downstream from the POTW discharge, 4 October 1983.

a contour of 3 (33 percent effluent) closed back on the near shore below Transect T7. At Transect T8 (457 m) the river was fully mixed and the variation in dye reading along the transect corresponded to the dilution ratio of 3.7-3.8 (26-27 percent effluent).

7.3 Effluent Configuration—Coke Plant 2

The effluent configuration study at Coke Plant 2 was performed on 5-6 October. During this 2-day period, grab samples were taken four times in the discharge to calculate the discharge dye concentration. Additional discharge dye concentrations can be calculated from the three measured discharge flows using the 2.76 g/min dye injection rate. The average discharge dye concentration calculated from these seven values is 77.7 ppb and ranged from 50.5 to 107.5 ppb. (The highest reading corresponds to the flow measurement at 1020 hours on 6 October and the lowest reading corresponds to a grab sample at 1330 hours on 6 October.) The other five values ranged from 74.2 to 80.0 ppb and had a mean of 77.1 ppb. The original value of 77.7 ppb was used as the average discharge dye concentration during the study. This dye concentration corre-

sponds to an average discharge flow of 0.119 m^3/sec which agrees favorably with the flows reported for Coke Plant 2 in Table 7-1.

The instream samples were collected from 0825 to 1150 hours on 6 October. The observed background fluorescence of 0.1 ppb observed at Transect T0 was subtracted from the data. The resulting dilution contours using the 77.7 ppb discharge dye concentration are shown in Figure 7-2.

The effluent from the Coke Plant 2 discharge mixed in fairly quickly. A dilution contour of 8 (12 percent effluent) reached the far shore by Transect T4 (76 m). A dilution contour of 4 (25 percent effluent) enclosed back to the discharge bank at Transect T7 (305 m) and a contour of 5 (20 percent effluent) reached the far bank at approximately 360 m. Downstream from Transect T8 (457 m), there was no contourable variation in the observed dye concentrations. At Transect T8 the stream narrowed down to a 4.5-m width through a riffle and the variation of the dilution contour of 4.3-4.4 corresponds to the fully mixed stream being 23 percent Coke Plant 2 effluent.

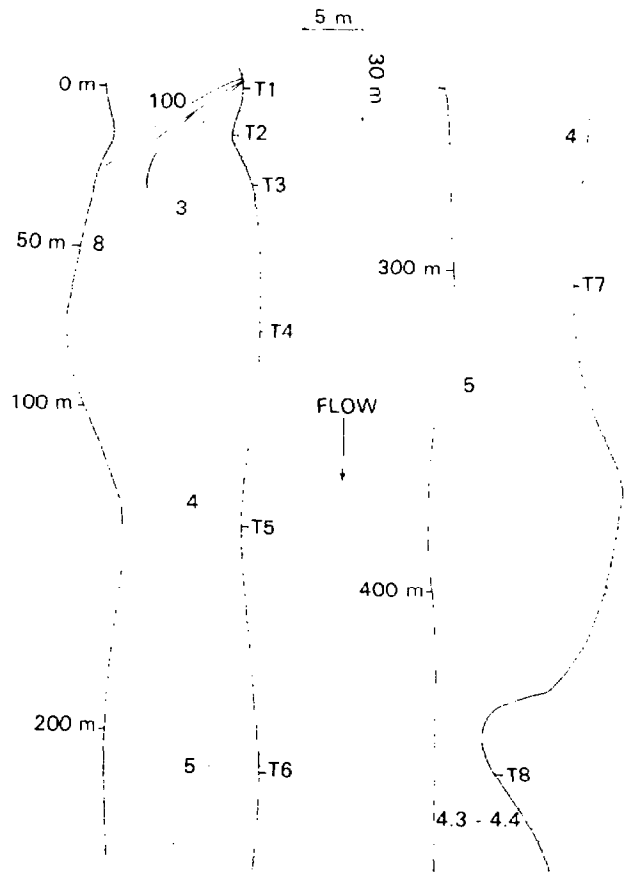

Figure 7-2. Dilution contours in Five Mile Creek downstream from the Coke Plant 2 discharge, 6 October 1983

7.4 Effluent Configuration—Coke Plant 1

The Coke Plant 1 discharge configuration study was performed on 8-9 October 1983. The stream samples were collected on 9 October from 0855 to 1110 hours. The daily average flows on these two dates were 0.0088 and 0.0093 m^3/sec, respectively. The flow variation on these two dates (Saturday, Sunday) was greater than earlier in the week. The flow decreased from a maximum of 0.0116 m^3/sec at 0500 hours on 8 October, reached a minimum of 0.0076 m^3/sec at 0000 and 0100 hours on 9 October, and increased to a second maximum of 0.0105 m^3/sec at 0600 hours. Discharge dye concentrations were calculated from the hourly plant flow data and the 5.48 g/min dye injection over the duration of the study.

On 9 October the calculated discharge dye concentrations decreased from 165 ppb at 0000 hour to 120 ppb at 0600 hours. From 0800 to 1000 hours, during the period when the stream samples were being collected, the discharge concentration had a constant value of 122 ppb (0.0105 m^3/sec). Since the dye concentrations were very uniform (fully mixed) beyond the first few transects, this value of 122 ppb was used in forming the nearfield dilution ratios.

The water level in the pool above the lowhead dam at the Coke Plant 1 site had been drawn down a few days previous to the study. At this time it was observed that cracks in the discharge pipe which passes through the pool would increase the volume discharge on the other side of the dam. During the study, the pressure of the pool prevented effluent from leaking out of the pipe as evidenced by the 0.08 ppb background dye concentration obtained at Transect T0 just above the dam. The undetermined amount of dilution taking place inside the pipe and the optical blocking problem addressed in Appendix B made comparisons of grab samples taken at the end of the pipe to calculated discharge concentrations meaningless.

Taking into account the measured background levels and the concentration adjustment to the stream samples as a function of the sample effluent contribution, dilution ratios were calculated. The resulting dilution contours for the Coke Plant 1 discharge are shown in Figure 7-3. The effluent mixed in very quickly. At Transect T2 (15 m), Five Mile Creek passed through a 3-m wide construction with a horizontal dilution gradient of 20-40 (2.5-5 percent effluent). The variation in dye concentration was too small to contour downstream of Transect T5 (137 m) where the dilution varied from 29 to 37 (2.7-3.4 percent effluent).

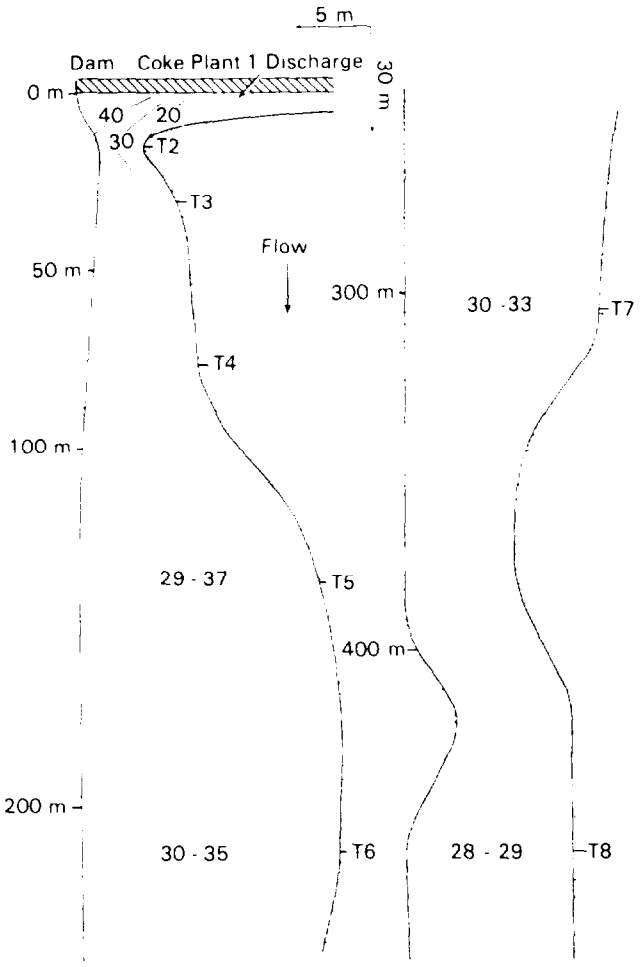

Figure 7-3. Dilution contours in Five Mile Creek downstream from the Coke Plant 1 discharge, 9 October 1983.

The plume from the POTW reached the far bank within 25 m downstream and was fully mixed at Transect T8, 457 m downstream of the discharge. The fully mixed effluent contribution on the day of the dye study was 26.5 percent of the total downstream flow.

The flow contribution of the three discharges are illustrated in Figure 7-4 in relation to the total Five Mile Creek flow between biological Stations 1 and 9. The fully mixed (percent) flow contribution of the three discharges at each biological station is summarized in Table 7-2. The average flows used in the above figure and table were for the period 4-10 October 1983. Average flows used for the three discharges were 0.008, 0.10, and 0.26 m^3/sec for Coke

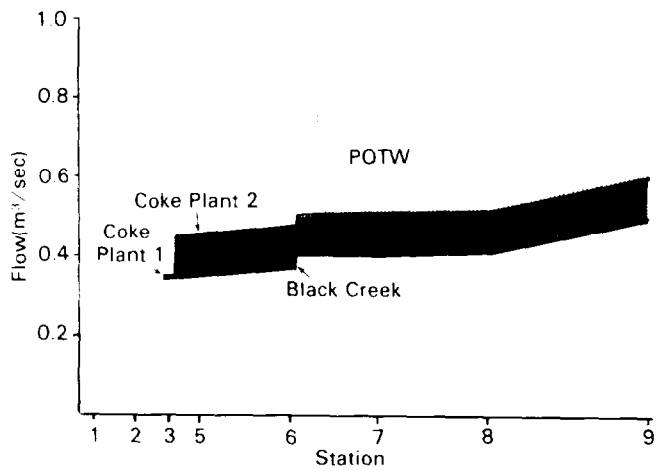

Figure 7-4. Flow contributions to Five Mile Creek from upstream and from three discharges, October 1983.

7.5 Evaluation of Dilution Characteristics

The dye configuration studies showed that the effluent from Coke Plant 1, Coke Plant 2, and the POTW were fully mixed before reaching the next downstream sampling station. The relatively small (0.01 m^3/sec) discharge from Coke Plant 1 mixed very quickly. The plume achieved a large amount of initial mixing by the time it passed through a 3-m wide constriction 15 m below the discharge, and the effluent was fully mixed within 100 m downstream with a 3 percent effluent contribution at the time of the dye study.

The plume from Coke Plant 2 reached the far bank within 50 m downstream of the discharge and was fully mixed at Transect T8, 457 m downstream. The fully mixed effluent contribution on the day of the study was 23.0 percent.

Table 7-2. Average Five Mile Creek Flow and Percent Flow Contribution From Three Discharges for the Period 4-10 October 1983

		Percent Flow Contribution			
Station	Total Flow (m^3/sec)	Upstream	Coke Plant 1	Coke Plant 2	POTW
1	0.24	100			
2	0.29	100			
3	0.35	97.7	2.3		
5	0.46	76.6	1.7	21.7	
6	0.48	77.5	1.7	20.8	
7	0.77	52.2	1.0	13.0	33.8
8	0.78	52.9	1.0	12.8	33.3
9	0.87	57.7	0.9	11.5	29.9
		Worst-Case Condition[a]			
7-9	0.51	27.8	1.6	19.6	51.0

[a]A conservative approximation of 7Q10 conditions.

Plant 1, Coke Plant 2, and the POTW, respectively. Flow contribution from Coke Plant 1 decreased from 2.3 to 0.9 percent between Stations 3 and 9. The flow contribution from Coke Plant 2 decreased from 21.7 to 11.5 percent starting at Station 5, while the POTW decreased from 33.8 to 29.9 percent starting at Station 7.

A 7Q10 flow for Five Mile Creek is not available, making it difficult to address a low-flow condition from a perspective meaningful to the regulations. As a worst-case condition, the minimum observed daily flow at the USGS station located between Stations 1 and 2 was 0.14 m^3/sec on 2 November 1954 based on a gauging record of 1953-1958 and 1972-1976.

Included in Table 7-2 are the flow contributions for the three discharges at stations downstream of the POTW using this worst-case 0.14 m^3/sec flow and assuming that the discharges remain at their current discharge rates.

The resulting flow contributions are 1.6, 19.6, and 51.0 percent for Coke Plant 1, Coke Plant 2, and the POTW, respectively (Table 7-2). It is likely that under actual 7Q10 conditions, the upstream flow may be slightly higher and the discharge rates may decrease, making the above contributions an upper limit.

8. Periphytic Community, February 1983

The periphyton study measured chlorophyll *a* and biomass and determined periphyton abundance and composition. The relatively short reproduction time and rapid seasonal fluctuation in growth of periphytic algae make that community a useful indicator of changes in water quality. Adverse effects on the periphytic community may be seen in either a reduction of an important habitat or food source for invertebrates and fish, or the enhancement or dominance of nuisance species of algae that neither support other trophic levels nor are aesthetically pleasing. A description of sampling and analytical methods is presented in Appendix C; additional data are presented in Appendix E.

8.1 Community Structure

Thirty-four algal taxa (31 genera) representing four major taxonomic divisions were identified in periphyton samples collected from eight stations in Five Mile Creek and one station in Black Creek (Table E-1). Total periphyton densities in Five Mile Creek ranged from 194 to 43,044 units/mm^2, diversity varied from 0.85 to 3.37, and equitability ranged from 0.23 to 0.84 (Table 8-1).

The predominant slate, bedrock streambed at Station 1 near Lawson Road could not be sampled quantitatively, but moderate periphytic growth was observed on these substrates. Qualitative samples from small rocks revealed the community was dominated by the diatom *Achnanthes* and the filamentous green alga *Cladophora* (Table E-1). *Achnanthes* commonly grows on rock substrates in rivers and streams (Round 1964; Hynes 1972), and some species are good indicators of high dissolved oxygen concentrations (Lowe 1974). *Cladophora* usually requires firm rock substrates for maximum development and profuse growth often occurs when nutrient (especially phosphorus) concentrations are high (Whitton 1970). Because *Cladophora* is a large filamentous alga that is readily colonized, its presence can greatly influence periphyton composition, standing crop, and occurrence of smaller algae. In Five Mile Creek, *Achnanthes* was not observed attached to *Cladophora*, and these algae appeared to occupy different microhabitats on the rock substrates.

Diversity and equitability was considered moderate at Station 1 compared to the other stations (Table

Table 8-1. Summary of Periphyton Species Composition and Diversity on Natural Substrates in Five Mile Creek, February 1983

	Sampling Station							
Parameter	1	2	3	4	5	6	7	8
Density (units·mm^2)								
Diatoms	--[a]	32,869	7,733	5,737	750	15,589	111	86
Green algae	--	2,095	4,539	6,035	295	4,592	1,247	77
Blue-green algae	--	8,080	12,868	28,079	740	227	82	31
Total Periphyton	--	43,044	25,140	39,851	1,785	20,408	1,440	194
Percent Composition								
Diatoms	54.11	76.36	30.76	14.40	42.02	76.39	7.71	44.33
Green algae	32.36	4.87	18.05	15.14	16.53	22.50	86.60	39.69
Blue-green algae	13.53	18.77	51.19	70.46	41.45	1.11	5.69	15.98
Taxa (Genus) Diversity ($\bar{d}$)	2.58	2.54	3.37	2.87	2.56	3.04	0.85	2.14
Taxa (Genus) Equitability (e)	0.55	0.47	0.70	0.68	0.62	0.68	0.23	0.84
Total Taxa Identified	15	17	21	15	13	17	9	7

[a]Not sampled quantitatively for periphyton abundance.

8-1). Diversity ranged from 0.85 to 3.39 and equitability from 0.23 to 0.84. The lowest values for both community parameters occurred at Station 7.

Maximum density (43,044 units/mm^2) observed in Five Mile Creek occurred at Station 2 located upstream from the Coke Plant 1 discharge but downstream from the confluence with Loveless Branch (Table 8-1). *Achnanthes* was a dominant diatom downstream to Station 6 (Table E-1). *Cladophora* was an important green algae even though it was variable in abundance. Diatoms that were associated with *Cladophora* (e.g., *Cocconeis, Cymbella,* and *Diatoma*) were abundant at Station 2, as were small species of the blue-green alga *Lyngbya*. Generally, composition at Stations 1 and 2 was similar, and diversity and equitability were only slightly reduced at Station 2.

Compared to Station 2, a fourfold reduction in diatom abundance occurred at Station 3 which is located downstream from the Coke Plant 1 discharge. Both green and blue-green algae were more abundant at Station 3 (Table E-1). Most of the decline of diatoms was caused by a decrease in the density of *Achnanthes*, although *Diatoma* and *Navicula* also were substantially reduced. The abundance of green algae doubled, even though *Cladophora* declined, because another filamentous form, *Stigeoclonium*, became prevalent. Several taxa of blue-green algae were also abundant at Station 3. Diversity and equitability increased when compared to Station 2, probably because the dominance of *Achnanthes* was suppressed.

Diatom abundance declined from Station 3 to Station 4. Green algae increased slightly, whereas blue-green algae increased twofold from Station 3 to Station 4. Total periphyton density at Station 4 was the second highest in Five Mile Creek (39,851 units/mm^2). There was little change in composition within these three major groups between Stations 3 and 4. Diversity declined somewhat at Station 4, but values for equitability were essentially unchanged.

A 20-fold decline in total density occurred at Station 5 (relative to Station 4) which was located downstream from the Coke Plant 2 discharge (Table E-1). Substantial reductions were noted for all three major taxonomic divisions. Although several taxa that were of minor importance at upstream stations were absent at Station 5, the greatest change in composition was the absence of *Cladophora*. Diversity and equitability, although lower than at Station 4, were similar to or slightly greater than respective values at Stations 1 and 2, in spite of the very low densities at Station 5. At Station 6, located approximately 8 km farther downstream, the abundance of diatoms and green algae exhibited substantial increases, but blue-green algae continued to decline in abundance. The maximum density of *Cladophora* occurred at Station 6, and the deposition of large amounts of sediment and detritus at this sampling location may have been facilitated by entrapment of particles in the structural matrix of this large, branched, filamentous alga. The maximum abundance of the diatom *Navicula* (many of which were very small species related to the benthic habitats) and the benthic diatom *Surirella* was probably related to the quantity of sediment present at Station 6. More sediment was included in the periphyton sample at this station than at any other station.

At Station 7, located at least 5 km downstream from both the POTW and the confluence with Black Creek, total periphyton density was slightly lower than that recorded at Station 5. Diatoms and blue-green algae were very sparse at Station 7. In contrast, green algae composed more than 86 percent of total density. *Cladophora* was absent, and *Stigeoclonium* was responsible for the dominance green algae. As a result, diversity and equitability were lowest at Station 7. The minimum density observed in Five Mile Creek occurred at Station 8 (194 units/mm^2). The abundance of each major group was $<$100 units/mm^2. The most abundant taxa were the diatom *Navicula*, the green alga *Stigeoclonium*, and the blue-green alga *Lyngbya*. While diversity remained low, maximum equitability was recorded at Station 8.

The qualitative results for Station B2 in Black Creek could not be compared directly to those for Five Mile Creek because a wood substrate was sampled instead of rock (Table E-2). Although the periphyton were dominated by *Navicula*, several other taxa were either common or abundant. These others included the diatoms *Achnanthes, Frustula, Nitzschia*, and *Surirella*; the green alga *Stigeoclonium;* the blue-green algae *Lyngbya* and *Oscillatoria*; and the filamentous red alga *Audouinella*. Because so many taxa were relatively abundant, diversity and equitability were high at Station 11 (Table E-3).

8.2 Chlorophyll *a* and Biomass

Large variations in chlorophyll *a* and ash-free dry weight (AFDW) measurements were present within and among stations and appeared attributable to habitat differences among stations. In addition, Station B2 had a totally different substrate than the other eight stations and therefore could only be sampled qualitatively. As a result, this station had the lowest chlorophyll *a* and second lowest biomass of any station.

Chlorophyll *a* standing crop in Five Mile Creek ranged from 3.9 to 505.1 mg/m^2; biomass standing

crop (AFDW) varied from 2.0 to 137.0 g/m^2 (Table E-4). Chlorophyll *a* and, to a lesser extent, biomass appeared to be influenced strongly by the abundance of *Cladophora*. At Stations 2, 4, and 6, where *Cladophora* occurred at densities greater than 1,000 units/mm^2, chlorophyll *a* standing crops were greater than 400 mg/m^2. Chlorophyll *a* values of 20 mg/m^2 or less occurred at Stations 5, 7, and 8 where *Cladophora* was absent. These differences were statistically significant at $P \leq 0.05$. Similarly, biomass was greater than 30 g/m^2 at Stations 2, 4, and 6, and less than 8 g/m^2 at Stations 5, 7, and 8. Stations 2 and 4 were the only sampling locations where biomass was not significantly less than that observed at Station 6. Autotrophic Index (AI) values less than approximately 100 appeared to be typical for most of Five Mile Creek in this February survey, indicating periphyton was dominated by autotrophic (photosynthetic) rather than heterotrophic (nonalgal) taxa (APHA 1981).

Chlorophyll *a* and biomass measurements provided the only quantitative data for Station 1 (Table 8-1). These measurements indicated standing crop was much lower at Station 1 than at Station 2, despite the similarity in composition previously noted for those sampling locations. Variations in chlorophyll *a* and biomass at the remaining stations in Five Mile Creek were generally similar to those observed for total density. Standing crops declined at Station 3, returned to Station 2 levels at Station 4, and decreased dramatically at Station 5. Substantial recovery occurred at Station 6, where maximum biomass standing crop probably resulted from the related factors of high *Cladophora* abundance and accumulation of nonliving organic matter. As a result, AI values increased to approximately 300. Chlorophyll *a* and biomass were greatly reduced at Stations 7 and 8. Biomass declined less than chlorophyll *a*, and AI values at Stations 7 and 8 were greater (2,015 and 790, respectively) than at other sampling locations in Five Mile Creek.

The single chlorophyll *a* measurement at Station B2 in Black Creek was collected from a wood substrate and indicated that algal biomass was low (Table E-4). Although biomass appeared low in absolute terms, it was high relative to chlorophyll *a* standing crops, and the resultant AI value was much higher than any observed in Five Mile Creek. However, because wood was the substrate sampled in Black Creek, biomass standing crops may have been increased artificially by the incidental inclusion of wood fibers in the sample.

8.3 Evaluation of Periphytic Community Response

Although Stations 1 and 2 were located upstream from the principal discharges, periphyton chlorophyll *a* and biomass increased significantly between these sampling locations (Table E-4). However, these increases had little effect on the diversity, equitability, and Autotrophic Index or on the relative abundance of important taxa in Five Mile Creek. Standing crop on the prevalent bedrock substrate at Station 1, which could not be sampled, may have been greater than that observed on occasional loose rocks that were sampled. Other studies have shown that the abundance of *Achnanthes* and *Cladophora*, the important components of periphyton at Stations 1 and 2, was less on rocks that could be moved by currents or waves than on larger, more stable substrates (Douglas 1958; Taft and Kishler 1973). In either case, Station 2 appeared to be the most appropriate reference area for assessing effects of the principal discharges being investigated.

Results of an analysis of variance test and Tukey's multiple comparison test indicated that there were statistically different ($P \leq 0.05$) concentrations of chlorophyll *a* and biomass between stations (Table E-4). The chlorophyll *a* and biomass content of periphyton at Station 1 increased at Station 2 ($P \leq 0.05$). However, the abundance of diatoms such as *Achnanthes* and *Nitzschia* decreased at Station 3 and continued to decline at Station 4; only a partial recovery in *Cladophora* density was noted. Conversely, *Stigeoclonium* increased substantially at Station 3 and reached maximum abundance at Station 4; blue-green algae (e.g., *Lyngbya* were also most abundant at Station 4. These changes in composition caused a slight increase in diversity and equitability relative to the reference locations.

Periphyton standing crop was much lower (significantly so for biomass and chlorophyll *a* at $P \leq 0.05$) at Station 5 than at either Stations 2 or 4 (Table E-4). All types and genera of algae were affected negatively. *Achnanthes, Stigeoclonium,* and *Lyngbya* were the only taxa which maintained densities greater than 100 units/mm^2, and *Cladophora* was absent. Substantial recovery was evident at Station 6, where *Cladophora* reached maximum abundance. There was no statistically significant difference in chlorophyll *a* or biomass standing crops between Stations 6 and 2 ($P > 0.05$). Only *Achnanthes, Diatoma,* and *Lyngbya* were much less abundant than at Station 2. Most of the differences between Stations 6 and 2 probably resulted from the large quantities of sediment and detritus entrapped in the profuse *Cladophora* growths.

Chlorophyll *a* standing crop at Stations 7 and 8 was significantly different and lower than those at either Stations 6 or 2 ($P \leq 0.05$); biomass was also significantly different and lower than at Station 6 ($P \leq 0.05$). Diatoms and blue-green algae were nearly absent at Station 7, *Cladophora* was absent,

and the numerical dominance of *Stigeoclonium* caused low diversity. An increase in standing crop was evident at Station 8 even though diversity, equitability, and AI values showed varying degrees of improvement.

9. Benthic Macroinvertebrate Community Survey, February 1983

The benthic macroinvertebrate survey measured instream community composition and abundance. The benthic community is considered to be a good indicator of instream response to water quality because of the lack of extensive mobility. The degree of community stability can be measured by comparing species composition and dominance, and effects would be apparent as alterations in community structure or standing crop beyond the limits of normal fluctuation within the waterbody. Additional data on the composition and relative abundance are presented in Appendix E. Sampling and analytical methods for benthic macroinvertebrate data are discussed in Appendix C.

9.1 Community Composition

The composition of the 38 numerically dominant components of the benthic community showed variations among stations (Tables 9-1 and E-6). Station 1 was dominated by caddisflies and mayflies, whereas the remainder of the stations were dominated by oligochaetes and chironomid larvae, although the relative abundance between the worms and midges varied at downstream stations. The caddisflies *Cheumatopsyche* and *Chimarra* were the predominant macroinvertebrates at Station 1 along with the mayflies *Stenonema* and *Caenis*. *Tubifex tubifex* was the dominant oligochaete at other stations with abundance increases of *Nais bretscheri* and species of *Limnodrilus* at certain stations. *Cricotopus tremulus* was the numerically dominant midge at all stations; *Cricotopus bicinctus* exhibited highest densities at Stations 6 and 8.

9.2 Comparison of Community Indices Among Stations

Community response was summarized by examining an index of diversity and an index of community loss based on reference station benthic composition. Values of the Shannon-Wiener diversity index, with associated values of evenness, redundancy, and the community loss index, are presented for each station (EPA, 1973) (Table 9-2). Station diversity indices reflect a trend of decreasing value from Stations 1 and 2 to a minimum value at Station 4 and then progressively increasing downstream. The lowest diversity value found at Station 4 was primarily due to overwhelming abundance of *T. tubifex* (Table 9-1) which contributed to the highest redundancy value of all stations (Table 9-2). The highest evenness values and corresponding lowest redundancy values were found at Stations 1 and 2 which indicated that the most evenly distributed benthic populations were at these two upstream stations. Evenness and redundancy values approached those of Stations 1 and 2 at the farthest downstream station (Station 8) and in Black Creek at Station B2 (Tables 9-2 and E-6). The spatial distribution in species diversity reflected this trend of recovery of the benthic community.

Community loss index calculations indicated that the greatest loss of reference station community taxa occurred at Station 5 where the least number of species and low abundance were found. The index values at all other stations were similar. The community loss index, which only takes into account the presence or absence of taxa, indicates a different effect from that of species diversity, which is influenced by species richness and density. At Station 5, the least number of taxa were captured and the community loss index was greatest (Table 9-2). Most notable at Station 5 was the absence of the variety of insect larvae found in the reference area.

9.3 Taxa Differences Among Stations

Oligochaete species and chironomid larvae were the numerically dominant taxa, and exerted the major effect on fluctuations in abundance. *Tubifex tubifex* is the dominant oligochaete and was essentially more abundant (1,850 organisms/m^2) than any other organism at Station 4. This density of *T. tubifex* at Station 4 was significantly higher ($P = 0.0066$) than densities found upstream of Station 4 or at Stations 7 and 8 (Table E-7). However, the habitat of Station 4 was not sufficiently different from that at other stations to be an imporatnt factor influencing the density (see Site Description). Abundance of *T. tubifex* decreases to approximately 130/m^2 at Station 5 and was absent from downstream Stations 7 and 8 and from the reference stations as well (Table 9-1).

The dominant midge, *Cricotopus tremulus*, was present in low levels at Stations 1 and 2 (not exceeding 20/m^2), increased to 177 larvae/m^2 at Station 3, decreased to 56/m^2 at Station 5, increased to peak abundance (over 400/m^2) at Station 6, and decreased again at Station 7 (124/m^2) and Station 8

Table 9-1. Average Density (No./m²) of the Most Abundant Macroinvertebrate Species at Each Sampling Station From Five Mile Creek, February 1983

	Station															
	1		2		3		4		5		6		7		8	
Species	Number Indiv	Pct Comp	Number Indiv	Pct Comp	Number Indiv	Pct Comp	Number Indiv.	Pct Comp	Number Indiv	Pct Comp	Number Indiv	Pct Comp	Number Indiv	Pct Comp	Number Indiv	Pct Comp
Imm Tub w cap. chaet	0.00	0.00	0.00	0.00	15.07	3.77	1212.87	53.40	105.47	37.84	37.67	3.69	0.00	0.00	0.00	0.00
Cricot tremulus Grp L	7.53	1.59	18.83	13.51	177.03	44.34	139.37	6.14	56.50	20.27	414.33	40.59	124.30	40.24	52.73	20.90
Tubifex tubifex	0.00	0.00	0.00	0.00	0.00	0.00	644.10	28.36	15.07	5.41	0.00	0.00	0.00	0.00	0.00	0.00
Imm tub w o cap. chaet	0.00	0.00	3.77	2.70	0.00	0.00	30.13	1.33	18.83	6.76	116.77	11.44	41.43	13.41	26.37	10.45
Cricot bicinct Grp L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	1.35	214.70	21.03	15.07	4.88	37.67	14.93
Chironomidae P.	3.77	0.79	11.30	8.11	48.97	12.26	48.97	2.16	15.07	5.41	18.83	1.85	33.90	10.98	26.37	10.45
Hais bretscheri	0.00	0.00	30.13	21.62	52.73	13.21	71.57	3.15	0.00	0.00	3.77	0.37	0.00	0.00	0.00	0.00
Thienemannimyia Grp L	7.53	1.59	0.00	0.00	7.53	1.89	7.53	0.33	7.53	2.70	71.57	7.01	11.30	3.66	15.07	5.97
Limnodrilus hoffmeisteri	0.00	0.00	0.00	0.00	0.00	0.00	7.53	0.33	18.83	6.76	26.37	2.58	22.60	7.32	15.07	5.97
Limnodrilus udekemianus	0.00	0.00	0.00	0.00	3.77	0.94	48.97	2.16	30.13	10.81	18.83	1.85	3.77	1.22	7.53	2.99
Cheumatopsyche I	64.03	13.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	1.22	7.53	2.99
Stenonema H	41.43	8.73	0.00	0.00	26.37	6.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caenis N.	37.67	7.94	11.30	8.11	7.53	1.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cryptochironomous L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.73	5.17	0.00	0.00	0.00	0.00
Baetis N	18.83	3.97	18.83	13.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.53	2.99
Corbicula	15.07	3.17	3.77	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	1.22	15.07	5.97
riciadida	11.30	2.38	11.30	8.11	7.53	1.89	3.77	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniinae H	18.83	3.97	0.00	0.00	15.07	3.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baetidae N	11.30	2.38	7.53	5.41	3.77	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isonychia N	11.30	2.38	3.77	2.70	15.07	3.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemertea	22.60	4.76	3.77	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptagenidae H	22.60	4.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsyche L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.30	1.11	11.30	3.66	3.77	1.49
Polypedilum scalaenum L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.53	0.74	15.07	4.88	0.00	0.00
Chimarra L	26.37	5.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lirceus	11.30	2.38	7.53	5.41	0.00	0.00	0.00	0.00	3.77	1.35	0.00	0.00	0.00	0.00	0.00	0.00
Amphinemura N	15.07	3.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae L	11.30	2.38	3.77	2.70	0.00	0.00	3.77	0.17	3.77	1.35	0.00	0.00	0.00	0.00	0.00	0.00
Psephenus L	15.07	3.17	0.00	0.00	3.77	0.94	0.00	0.00	0.00	0.00	0.00	0.00	3.77	1.22	0.00	0.00
Branchiura sowerbyi	0.00	0.00	0.00	0.00	0.00	0.00	18.83	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Enchytraeidae	0.00	0.00	0.00	0.00	3.77	0.94	0.00	0.00	0.00	0.00	3.77	0.37	7.53	2.44	3.77	1.49
Corydalus L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.07	5.97
Agapetus L	7.53	1.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	1.22	3.77	1.49
Empididae L	3.77	0.79	0.00	0.00	3.77	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turbellaria	3.77	0.79	0.00	0.00	0.00	0.00	7.53	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pristina breviseta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.53	0.74	0.00	0.00	0.00	0.00
Limnio claparedianus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.30	4.48
Acarina	11.30	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other species	75.33	15.87	3.77	2.70	7.53	1.89	26.37	1.16	0.00	0.00	15.07	1.48	7.53	2.44	3.77	1.49
Station Total	474.60		139.37		399.27		2,271.30		278.73		1,020.77		308.87		252.37	

Table 9-2. Shannon-Wiener Diversity Indices, Associated Evenness and Redundance Values, and Community Loss (I) Indices Calculated on Benthic Data From Five Mile Creek, February 1983

	Sampling Station							
Parameter	1	2	3	4	5	6	7	8
Total Densities (No. m²)	1,423	418	1,196	6,815	836	3,063	925	756
Total No. Taxa	36	14	17	18	11	17	16	16
Community Loss Index[a]	--	1.69	1.47	1.50	2.45	1.71	1.56	1.73
Diversity Index[b]	4.68	3.43	2.83	2.00	2.72	2.72	2.98	3.55
Evenness	0.90	0.90	0.69	0.48	0.78	0.67	0.75	0.89
Redundancy	0.10	0.11	0.32	0.53	0.22	0.34	0.27	0.12

[a]Calculated on log base 2.
[b]Calculated using Station 1 as reference station.

(52 m²). Although station densities were significant ($P = 0.0039$), considerable overlap in the transformed (ln count) mean abundance existed among stations (Table E-17).

Abundance data for the major taxonomic groups illustrate a shift in dominance from a mayfly/caddisfly community at Station 1 to a worm/midge community by Station 4 and continuing downstream (Table 9-1). This shift began to disappear at Stations 7 and 8. Although differences in station abundance were significant ($P < 0.01$) for all major benthic groups, no consistency in spatial trends was discerned (Table E-6). Confidence intervals (95 percent) were large for the mean abundance of the major taxa (Table E-18).

9.4 Evaluation of the Benthic Community

In April 1978, EPA Region IV conducted a benthic survey in conjunction with chemical analyses and

toxicity tests on Five Mile Creek (EPA 1978). The benthic survey included four sampling stations, three of which corresponded to sampling stations in the present survey (FMC-004 = Station 1; FMC-002 = Station 5; FMC-001 = Station 7; FMC-000A = Station 8). EPA (1978) found a decrease in the number of species and abundance downstream of Station 3 and some recovery at FMC-000A (Station 8). These population effects were supported by diversity indices and one-way analysis of variance results for the benthic data. In addition, sublethal effects were observed in the form of morphological aberrancies in midge larvae. The greatest proportion of deformities was found at the station downstream of Station 4. These aberrancies were stated as minor compared to deformities noted at other sites (EPA 1978).

Results of the present study generally agreed with the EPA (1978) study, although the present survey did elucidate additional community trends. The benthic community at Station 3 had a different taxonomic composition from that observed at Station 4. It is likely that habitat differences contributed to the dissimilarity among the communities since the habitat at Station 4 was composed mostly of sediment, and the sparsity of rocks made the riffle area almost nonexistent. Diversity was lowest at Station 4 because of the overwhelming dominance of *T. tubifex*. In contrast, Station 3 had a rifle area comparable to Station 1, and a higher diversity value than Station 4 because of the even distribution of individuals among taxa. In addition, Ephemeroptera were relatively abundant at Station 3 compared to the other stations.

Station 1 had the highest diversity and evenness values as a result of the highest number of taxa collected. The community loss index was above 1.0 at all stations, which indicates a relatively high level of dissimilarity among the benthic communities at all stations compared to Station 1. However, the index values were similarly the lowest at Station 2 near Springdale Road and at Stations 3 and 4. Although community dominants differed among those stations, the proportion of number of taxa in common with Station 1 was similarly low among Stations 2, 3, and 4. The benthic community at Station 5 was the least similar to Station 1 in composition.

10. Benthic Macroinvertebrate Community Survey, October 1983

The benthic macroinvertebrate survey measured instream community composition and abundance. The benthic community is considered to be a good indicator of instream response to water quality because of the lack of extensive mobility. The degree of community stability can be measured by comparing species composition and dominance, and effects would be apparent as alterations in community structure, standing crop, or species composition beyond the limits of normal fluctuation within the waterbody. Additional data on the composition and relative abundance are presented in Appendix E. Sampling and analytical methods for benthic macroinvertebrate data are discussed in Appendix C.

Qualitative and quantitative collections were taken during the October 1983 survey, thus increasing the number of habitats sampled at each station. As in the February survey, quantitative collections were taken in riffle areas. Qualitative collections were taken along shore zones and pool areas. In addition to the stations sampled in February, other stations were sampled during the October survey: Station 9, Station F0 located upstream of Station 1, Station T1 on *Tarrant Branch*, and Station B1 on Barton Branch (Chapter 3).

10.1 Comparison of Community Indices Among Stations

The number of taxa collected from the mainstream of Five Mile Creek ranged from 10 to 26 (Table 10-1). The largest variety of taxa taken were the chironomids which were represented at each station by up to 13 genera (Table E-9). The benthic community at one of the tributary stations, B1 (Barton Branch), comprised the most taxa (29) of any station due to the great variety of mayflies, caddisflies, beetles, and midges (Table E-11). The total number of taxa was low at Stations 2 and 3; Station 5, the least diverse community, had only 10 taxa, 8 of which were chironomid larvae. The benthic communities at Stations 6 through 9 were more diverse, with the number of taxa (18-25) approaching the number of taxa at Station 1. The numbers of taxa at Stations 1, 6, 7, 8, and 9 were significantly ($P = 0.001$) higher than that at other stations (Table E-19). However, results of the Tukey's Multiple Comparison Test indicated that there was considerable overlap in the distribution of number of taxa.

A community loss index was calculated for the quantitative collections (Table 10-1) and the total taxa (qualitative and quantitative) (Table E-11). Station dissimilarity to Station 1 was high at Stations 2 and 3 and highest at Station 5 where the fewest number of taxa were collected. Recovery in the degree of similarity with Station 1 began at Station 6 and continued downstream to Station 9. Very little difference in community loss values resulted when the qualitative sampling effort (Table E-14) was included in the calculations except at one of the upstream tributary stations at Tarrant Branch (T1), which was more similar to Station 1 after adding the additional species collected in the qualitative sampling. The other tributary stations, the headwaters of Five Mile Creek (F0) and Barton Branch (B1) were similar to Station 1.

Diversity was lowest at Station 5 which also had the highest community loss value (Table 10-1). Diversity gradually increased downstream to Station 9 which was higher than the observed diversity at Station 1.

10.2 Community Composition and Distribution

Ephemeropterans (mayflies) and trichopterans (caddisflies) were present in high densities at Station 1 (Tables 10-2 and E-19). Both groups essentially disappeared at Station 2, re-established populations occurred at Station 6, and were abundant downstream at levels nearly as high or higher (especially the mayflies) than at the upstream stations. Significant station differences ($P < 0.001$) were detected in the abundances of mayflies and caddisflies, with Stations 1, 8, and 9 having the highest numbers and Stations 2, 3, and 5 having the lowest numbers (Table E-20). Oligochaete densities were highest at Stations 3 and 5, where they and chironomids were co-dominant. Chironomid density was highest at Stations 6, 7, 9, and Barton Branch (B1), and generally low at all other stations. Station differences were significant ($P < 0.001$) for midges and worms (Table E-20), and abundances were highest at Stations 6, 7, and 9 for midges and Station 3 for worms. Corbicula, the Asiatic clam, had significant ($P = 0.0001$) populations only at Stations 8 and 9 (Table E-21). The greatest benthic abundance was at Station 8, with 6,220 organisms/m^2 and was the result of the high density of Corbicula

Table 10-1. Community Data for Benthic Macroinvertebrates From Quantitative Sampling of Five Mile Creek, October 1983

Parameter	Sampling Station 1	2	3	5	6	7	8	9
Total Densities (No. m^2)	4,475	361	1,671	978	3,596	3,521	6,220	5,360
Total No. Taxa[a]	26	11	14	10	24	22	18	25
Community Loss Index[b]		1.55	1.36	2.20	0.46	0.64	0.67	0.40
Diversity Index[c]	2.84	2.36	2.73	2.14	2.92	2.95	2.46	3.53
Evenness	0.58	0.62	0.68	0.60	0.61	0.64	0.56	0.73
Redundancy	0.42	0.39	0.32	0.41	0.39	0.36	0.44	0.27

[a]Multiple life stages, higher taxonomic levels, Oligochaeta and Nematoda not included in number of taxa.
[b]Calculated using Station 1 as reference station.
[c]Calculated on log base 2.

Table 10-2. Average Density (No./m^2) of Benthic Macroinvertebrates Collected From Five Mile Creek, October 1983

Taxa	Sampling Station 1	2	3	5	6	7	8	9
Ephemeroptera								
Isonychia	1,055	7						68
Baetis	359				93	606	2,329	692
Stenonema	388				18	11	524	219
Tricorythodes	4				36	36	858	176
Total	1,806	7			147	653	3,711	1,155
Plecoptera								
Leuctridae	4							
Trichoptera								
Chimarra	65							
Hydropsyche	47	4	4			4	4	126
Cheumatopsyche	1,783				158	165	560	391
Hydropsychidae pupae	4							
Leucotrichia	57				4		18	43
Total	1,956	4	4		162	169	582	560
Coleoptera								
Psephenus	90				4			
Helicus	14							
Stenelmis	133	32	7		7	22	11	50
Dubiraphia								18
Berosus	4		22		29			65
Total	241	32	29		40	22	11	133
Megaloptera								
Corydalis	100				25	50	25	104
Diptera								
Simuliidae	4							
Antocha	22							
Tipula	4							
Hemerodromia		4	4			11		
Probezzia					11			11
Chironomidae pupae	36	11	90	100	215	269	14	176
Ablabesmyia	80		144	93	165	129	28	169
Procladius			133	11		4		4
Tanypus				4	4	11		
Pentaneura				4				
Dicrotendipes								36
Polypedilum			4	29	807	32	25	244
Chironomus			39	32	32	29		
Glyptotendipes					7			
Cryptochironomus					79	4		
Rheotanytarsus	136				32	172	14	
Tanytarsus					47	434	72	248
Corynoneura	14				4		4	4

Table 10-2. (Continued)

Taxa	Sampling Station 1	2	3	5	6	7	8	9
Cricotopus	14	129	233	29	1,478	1,374	36	1,464
Psectrocladius			11	72	54	32		
Trichocladius						18		
Micropsectra								22
Nanocladius								4
Total	310	144	658	374	2,935	2,519	193	2,382
Odonata								
Dromogomphus							7	4
Argia	7	7	54	22		11		14
Total	7	7	54	22		11	7	18
Oligochaeta	7	140	736	578	205	68	54	158
Miscellaneous								
Physa			50				4	
Corbicula	4	4			47		1,611	836
Ferrissia	11	7	133	4	14	22	18	7
Planaria	11	4						
Nematoda		4			7		4	7
Decapoda		4	7			7		
Lirceus	18	4			14			
Total	44	27	190	4	82	29	1,637	850

Source Table E-9.

and ephemeropterans, especially Baetis. Results of an ANOVA and multiple comparison test performed on Baetis abundance indicated that although Station 8 had highest abundance, it was not significantly different from the mean abundance at Stations 1, 7, and 9 (Table E-21).

10.3 Comparison Between February and October Surveys

The level of taxa identification between the two surveys was different, so comparisons of relative abundance are limited. However, the collection techniques for quantitative assessment were similar. High, variable flow conditions during the February survey probably affected the data. Trends observed in the data for each survey may be compared in a relative sense because of consistent sampling efforts and conditions at each station within each collection period.

In the October survey, Station 1 had a high number of taxa which was similar to data from Stations 6, 7, and 9 in contrast to the February data for which the similarity did not occur. In the February survey, Station 5 had the fewest number of taxa, whereas in the October survey, Stations 2, 3, and 5 had similar low numbers of taxa. Correspondingly, the community loss was highest at Station 5 during both surveys, although during October the community loss was also high at Stations 2 and 3.

11. Fish Community Survey, February 1983

The objective of the fish investigation was to collect, identify, and count fishes from locations throughout the Five Mile Creek watershed with special emphasis on the number of taxa present at each station. The sampling and analytical methods are presented in Appendix C. Support data are included in Appendix E. Heavy rains before and during the study resulted in flows which were much greater than normal and made sampling efforts difficult.

11.1 Community Structure

The distribution of the fish catch among sampling stations in February 1983 exhibited a trend of decreasing number of specimens and species from upstream to downstream (Table 11-1). The reference Stations 1A and 1B yielded the greatest number of species and specimens. This was largely due to the relative abundance of stonerollers; had they been absent, the catch would have been much like those farther downstream. The number of fishes collected at Stations 2A and 2B were greatly reduced relative to Stations 1A and 1B, owing to the reduction in stonerollers and, to a lesser extent, the disappearance of the striped shiner and banded sculpin. Catches at Stations 3 through 8 on Five Mile Creek were incidental at best, with no more than 2 species or 11 specimens occurring at any one station. The number of fish captured increased sharply at Station B2 in Black Creek (Table E-23). The number of species and specimens collected at the Black Creek station were similar to those collected at Stations 1A and 1B. Blacktail shiner and green sunfish replaced the stoneroller as dominants at Station B2 (Black Creek).

The species diversity index, which is influenced by number of species and abundance, was zero at Stations 3 and 5 where the lowest abundance and number of species were encountered (Table 11-2). The community loss index was highest at Stations 3 and 5. Recovery, as depicted by both indices, was beginning at Stations 7 and 8.

11.2 Evaluation of Fish Community Response

Heavy rains in the study area produced flows about seven times as high as the average daily discharge. This greatly reduced sampling effectiveness, despite the use of electrofishing gear. Upstream stations consisted primarily of riffle and run habitat, whereas downstream stations were primarily runs and pools (Table C-1). Such differences in habitats will affect the fish species within the community.

The reduction in numbers of stonerollers from upstream to downstream roughly corresponds to the

Table 11-1. Numbers of Fish Collected From Five Mile Creek, Birmingham, Alabama, February 1983

	Sampling Station										
Species	1A	1B	2A	2B	3	4	5	6	7	8A	8B
Stoneroller	29	45	7	5		1		4			
Striped shiner	7	15									
Blacktail shiner									3	3	
Black redhorse	2										
Alabama hog sucker			6	2							
Mosquitofish			7								
Green sunfish		9		1	4	4		7	5	4	3
Bluegill		2							1		
Longear sunfish				1							
Redear sunfish											1
Spotted bass				1							
Blackbanded darter		1									
Banded sculpin	2	5									
Total number of fish	40	77	20	10	4	5	0	11	9	7	4
Total fish species	4	6	4	5	2	2	0	2	3	2	2

Note: A and B in Station designations refer to subareas of the station.

Table 11-2. Shannon-Wiener Diversity Indices, Associated Evenness and Redundancy Values, and Community Loss Index for Fish Data From Five Mile Creek, February 1983

Station	Diversity[a]	Evenness	Redundancy	Number of Species	Number of Individuals[b]	Community Loss Index[c]
1	1.6664	0.5936	0.4096	7	327	--
2	2.0439	0.7907	0.2143	6	83	0.8333
3	0	--	--	1	8	6.0000
4	0.7290	0.7290	0.2924	2	10	2.5000
5	--	--	--	0	0	7.0000
6	0.9337	0.9337	0.0692	2	20	2.5000
7	1.3699	0.8643	0.1447	3	16	1.6667
8	1.2362	0.7800	0.2405	3	11	2.0000

[a]Calculated on a log base 2.
[b]Abundance in number per 1,037.3 m^2 (sampling area).
[c]Calculated using Station 1 as reference station.

reduction in the available riffle habitat; this may be explained by the fact that the stoneroller is primarily a riffle inhabitant (Pflieger 1975; Trautman 1981). The effect of the poor sampling conditions cannot be identified at any one station, but appears to have affected the overall effort. Even at Stations 1A and 1B, catches were lower than would be expected under better conditions, based on previous sampling data.

Even considering potential habitat effects and other influencing factors affecting the fish community, the results of species diversity and community loss indices still suggest some general effects on the fish community downstream from Stations 1A and 1B. Recovery from these effects were noted at Stations 7 and 8, although recovery to the extent observed at the reference stations was not attained. Without the large number of stonerollers collected at Stations 1A and 1B, the number of individuals from Stations 1A and 1B would be similar to that collected at Station 2. However, the number of species collected decreased downstream.

12. Fish Community Survey, October 1983

The fish community of Five Mile Creek was surveyed in October using the same methods and stations as in February. Lower river flows in October allowed for a more effective sampling effort. Sampling and analytical methods are presented in Appendix C. The species list for this fish collection is presented in Appendix E.

12.1 Community Structure

Ninety percent of all fish collected were taken in the two tributary stations and the three upstream stations on Five Mile Creek. The dramatic reduction in the total number of fish at Station 3 and below is primarily due to reductions in stoneroller numbers, and, to a lesser extent, numbers of Alabama hog sucker and banded sculpin. There was little difference in abundance of creek chubs and green sunfish between upstream and downstream areas. One species, the blacktail shiner, occurred almost entirely at the downstream locations. Station 5 was extreme in that it produced only one fish. Although none were abundant, 11 species were collected at Station 9, the most downstream station. This may reflect a hint of recovery, but it is not very strong given the low catches of any given species.

12.2 Evaluation of Fish Community Response

The number of individuals collected at Stations 1 and 2 was at least eight times higher than at other stations (Table 12-1). Without the large number of stonerollers collected at Stations 1 and 2, the number of fish at those two stations is still greater than at downstream stations. The greatest number of species was collected at Stations 1, 2, and 9, whereas collections at Stations 5 through 8 were half of those levels.

To provide the best comparison of the fisheries results among sampling stations, the catch data were converted to total number of fish per 93 m^2 (Figure 12-1). Although a 90-m length of stream was sampled at each station, stream widths differed greatly (Table C-2) and, consequently, the total stream area sampled differed greatly among stations. The total number of fish per 93 m^2 declined sharply from Station 2 to Station 3, by a factor of 7. This reduction continued downstream through Station 9. The reduction in number of fish species downstream of Station 2 was statistically significant ($P \leq 0.05$) at Stations 5, 6, and 7.

12.3 Comparison Between February and October Surveys

The fish survey results presented for October 1983 are consistent with the results of fish sampling in February 1983. Although many fewer fish were captured in February due to high water and resultant poor sampling conditions, the distribution of fishes was similar to that recorded in October. That is, numbers of fish and species were relatively high down to Stations 2 or 3 and much reduced below.

Table 12-1. Numbers of Fish Collected From Five Mile Creek, Birmingham, Alabama, October 1983

Species	Sampling Station 1	2	3	5	6	7	8	9
Stoneroller	716	525	27		6	14	5	1
Creek chub	8	5	6		2	11	5	2
Striped shiner	29	2	3					
Blacktail shiner		1	3	1	16		4	10
Bullhead minnow								11
Alabama hog sucker	32	19						
Black redhorse	3							
Channel catfish								1
Blackspotted topminnow		1						
Mosquitofish		1	16				1	8
Spotted bass	8	2	1					2
Largemouth bass		2						1
Green sunfish	88	15	25		22	13	6	5
Longear sunfish	8	1						22
Bluegill	1					1		1
Hybrid sunfish	1					7	1	
Sunfish sp.						1		2
Banded sculpin	125	72	1					
Total number of fish	1,019	646	82	1	46	47	22	66
Total fish species	10	12	8	1	4	4	5	11

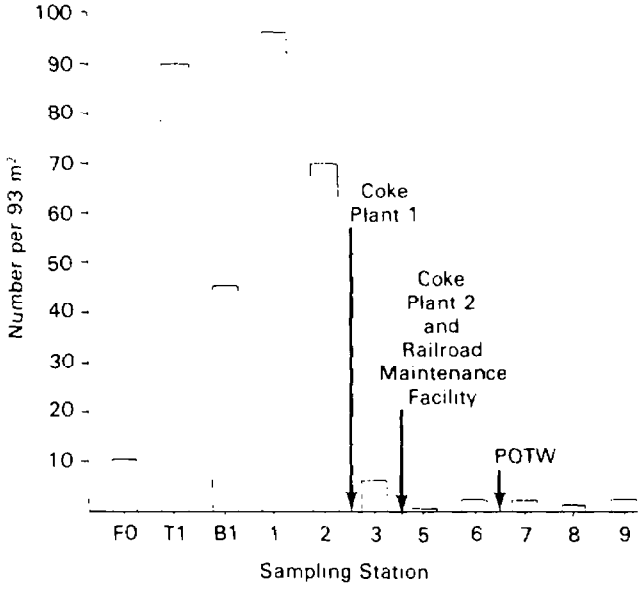

Figure 12-1. Total number of fish captured per 93 m² of stream, Five Mile Creek and tributaries, Birmingham, Alabama, October 1983

13. Plankton Community Survey, October 1983

Plankton were only collected during the October 1983 survey using a Wisconsin stream net with a 80-μm mesh net. The primary emphasis was to collect zooplankton, but those algae collected were enumerated. Measures of the number of taxa and individuals collected are used to determine alteration in composition and/or density.

13.1 Community Structure

Rotifers were the dominant taxa and accounted for the highest zooplankton concentrations taken at Stations 5, 6, and 7 (Table E-28). Crustaceans occurred at all stations except that only nauplii were found at Station 1 and were abundant only at Station 6 with a total density of 6 organisms/liter. Copepod nauplii were the most abundant crustaceans. Both rotifers and crustaceans were least abundant at Stations 1, 2, and 8. The number of taxa ranged from six at Station 9 to 17 at Station 5 (Table 13-1).

Incidental algal components of the plankton community were also recorded. In the algal community, only the noncolonial (solitary) diatoms were consistently abundant at most stations with high densities at Station 6 and the lowest density at Station 8 (Table E-28). The algae *Pediastrum* and the desmids were taken in low densities at all stations.

13.2 Evaluation of the Zooplankton Community

Zooplankton abundance in low numbers at Stations 1 and 2 probably represents normal population levels. However, the substantial density increase at Station 5 is likely attributable to enhanced conditions and represents high population levels for zooplankton. The number of taxa at the most downstream station, Station 9, was significantly lower ($P \leq 0.05$) than the maximum found at Station 5.

Table 13-1. Zooplankton Taxa Present at Ambient Stations, Five Mile Creek, Birmingham, Alabama, October 1983

	Station 1		Station 2		Station 3		Station 5		Station 6		Station 7		Station 8		Station 9	
Taxa	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2
CRUSTACEANS																
Cyclopoid copepod			X	X	X	X	X	X	X	X	X	X			X	X
Bosmina longirostis					X											
Oxyurella tennicardis					X	X							X			
Alona guttata or *A. reticulata*				X	X	X		X	X	X	X	X				
Holina microra						X	X	X	X	X						
Streblocerus serricandatus									X	X		X	X			
ROTIFERS																
Brachionus angularis	X	X		X	X	X	X	X	X	X	X	X	X			
B. calyciflorus	X						X	X	X	X	X					
B. urceolaris							X									
Euchlanis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Kellicottia longispina			X					X								
Keratella sp.																
Keratella cochlearis var. *hispida*	X		X	X	X	X		X	X	X	X	X				
Macrochaetus sp.				X												
Mytilina sp.							X									
Platyas quadricornis															X	
Trichotria sp.	X			X	X											
Lepadella sp.	X		X	X	X	X	X		X		X	X	X		X	
Lecane sp.				X	X	X									X	
Monastyla bulia	X	X	X	X	X	X	X		X	X	X	X	X	X		
Proales sp.											X	X			X	
Cephalodella sp.	X		X	X	X	X	X		X	X	X		X			
Trichocerca sp.	X			X	X	X	X	X	X	X	X					
Ascomorpha sp.								X								
Asplanchna sp.					X			X			X	X				
Filinia sp.																
Testudinella sp.		X							X							
Philodinidae			X	X	X	X	X		X	X	X	X	X	X		
Total number of taxa per station	10		14		16		17		14		14		8		6	

Source: Tables E-29 and E-30

14. Comparison Between Laboratory Toxicity Tests and Instream Biological Response

The comparison between toxicity measured in the laboratory on a few species and the impact occurring in the stream on whole communities must compensate for a very limited database from which to predict. The sensitivity of the test species relative to that of species in the community is almost never known and certainly not in these effluent toxicity tests. Therefore, when toxicity is found, there is no method to predict whether many species in the community, or just a few, will be adversely affected at similar concentrations, since the sensitivity of the species in the community is not known. For example, at a given waste concentration, if the test species has a toxic response and if the test species is very sensitive, then only those species in the community of equal or greater sensitivity would be adversely affected. Conversely, if the test species is tolerant of the waste, then many more species in the community would be affected at the concentration which begins to cause toxic effects to the test species. It is possible that no species in the community is as sensitive as the most sensitive test species, but since there are so many species composing the community, this is unlikely. It is more likely that a number of species in the community will be more sensitive than the test species. The highest probability is that the test species will be near the median sensitivity of organisms in the community if the test species is chosen without knowledge of its sensitivity (as was the case on Five Mile Creek).

In a special case, where toxicants remain the same and the species composing the community remain the same, the number of species in the community having a sensitivity equal to or greater than the test species also will remain the same. As a result, there should be a consistent relationship between the degree of toxicity as measured by the toxicity test and the reduction in the number of species in the community. In this special case, there should be a tight correlation between degree of toxicity and the number of species. If the toxic stress is great enough to diminish the production of offspring by a test species, it should also be severe enough to diminish the reproduction of some species within the community of equal or greater sensitivity. This should ultimately lead to elimination of the more sensitive species. Therefore, a lower number of taxa should be a predictable response of the community. For example, there should be a relationship between the number of young per female *Ceriodaphnia* or the growth of fathead minnows (or other test species) and the number of species in the community. Obviously, the test species must have a sensitivity, such that at ambient concentrations to which the community has responded, a partial effect is produced in the toxicity test. However, unless the special case described above exists, the correlation between toxicity and species richness will not be a tight one.

Effluents differ from single chemicals in some important respects. We know from the literature on single chemicals that there usually are large differences in the relative sensitivity of species to a chemical and that the relative sensitivity changes with different chemicals. For example the fathead may be more sensitive to effluent A and *Ceriodaphnia* more sensitive to effluent B. We also know that effluents vary in their compositon from time to time and often within a few hours. We should not be surprised therefore to find fatheads being more sensitive to an effluent on one day and daphnids more sensitive on another day.

Effluents begin changing in composition as soon as they are discharged. Fate processes such as bacterial decomposition, oxidation and many others change the composition. In addition various components will change at different rates. For example ammonia would be expected to disappear more rapidly than PCBs. If so, then the composition of the effluent is ever changing as it moves through the receiving water. Note that this change is not just a lessening concentration as a result of dilution but also a change in the relative concentrations of the components. In reality the aquatic organisms at some distance from the outfall are exposed to a different toxicant than those near the discharge pont! Therefore it is logical to expect that sometimes one test species would be more sensitive to the effluent as it is discharged and another species more sensitive after fate processes begin altering the effluent. To be sure the source of the effluent is the same but it is certainly not the same "effluent" in regard to its composition. If these statements are true then one should also expect that species in the community in the receiving water will be affected at one place near the discharge and a different group

of species will be affected from the same effluent at another location.

Compound the above described considerations with multiple discharges as well as inputs from tributaries and non-point sources such as agricultural run-off and leachate from landfills and one should logically expect virtually a "random effect" on various components of the community. Reference to Table 14-2 illustrates well this response in Five Mile Creek. The number of zooplankton taxa was most reduced at Stations 1, 8 and 9. Benthic invertebrates were *least* affected at Stations 1 and 9. Fish were nearly eliminated at Station 5. Only one specimen of one species was captured yet Station 5 had the highest number of zooplankton taxa of any station sampled! The field data obtained are consistent with the predicted response described above. So are the data from the toxicity tests. Again examine Table 14-2 which shows that in five of the eight stations the responses of the *Ceriodaphnia* and fish was essentially opposite.

An effluent cannot be viewed as just diluting as it moves away from the outfall. In fact it is a "series of new effluents" with elapsed flow time. If so, there are important implications for interpretation of toxicity and community data. One should not expect the various test species to respond similarly to water collected from various ambient stations. We should expect one species to be more sensitive at one station and another species to be more sensitive at the next. The affected components of the community should vary in a like manner.

An even bigger implication is that the surrogate species concept is invalid in such a situation. As one examines the community data in this report, in the Lima report (Mount et al., 1984) and in the studies yet to be published, it is clear that there is no consistent response of the community. Sometimes the benthic invertebrates and the periphyton have similar responses and both are different from the fish. Sometimes the fish and periphyton have similar responses and these are unlike the benthic invertebrates.

The same is true of the test species. Sometimes the *Ceriodaphnia* respond like the periphyton and other times like the fish. In this study, the fathead minnow response resembled the fish community response and the *Ceriodaphnia* the zooplankton but in other studies such was not the case. The important point is that a careful analyses of our knowledge of toxicology, effluent decay, and relative sensitivity tells us that we *cannot* expect:

1. *Ceriodaphnia* toxicity to always resemble toxicity to benthic invertebrates
2. Fathead minnow toxicity to always resemble toxicity to fish
3. Fathead minnows and fish to resemble each other in sensitivity or to display the same relative sensitivity to different effluents.

Any test species should have a sensitivity representative of some components of the community. The important distinction is that one never can be sure which components they will represent.

In comparing toxicity test results to community response, comparison must be made with the above in mind. Certainly those community components that are most sensitive will be most impacted and/or lost. The response of the most sensitive test species should therefore be used to compare to the response of the most sensitive of the community.

A weakness in using the number of species as the measure of community response is that species may be severely affected yet not be absent. The density of various species is greatly influenced by competition for available habitat, predation, grazing, and/or secondary effects which may result from changing species composition. Density is more subject to confounding causes, other than direct toxicity, and is not as useful as the species richness in the community to compare community response to measured toxicity.

Several measures of community structure are based on number of species, e.g., diversity and community loss index. Since diversity measures are little affected by changes in the number of species (or taxa) that are in very low densities in the community, diversity is an insensitive measure for some perturbations which can be measured by toxicity tests. The community loss index is based only on the presence or absence of specific species relative to a reference station and would be useful except that habitat differences between stations heavily effect this measure. There are several problems when using the number of (taxa) species measured. The foremost is that the mere presence or absence of species is not a comprehensive indicator of community health, especially if the species are ecologically unimportant. Secondly, a toxic stress may not eliminate species but yet have a severe effect on density; presence or absence does not consider such partial reductions. The presence or absence of species as the measure of community impact is influenced by the chance occurrence of one or a few individuals due to either drift, immigration, or some catastrophic event when in fact that species is not actually a part of the community where it is found. Effects other than toxicity, such as habitat, will always confuse such comparisons to toxicity data to some extent. They cannot be eliminated.

The October study of Five Mile Creek was conducted after a period of stable river flow. River flow

had been unstable during the February study because of heavy rainfall which preceded and continued during the sampling of Five Mile Creek. The toxicity data from February are not useful because the coke plants and the POTW were operating at several times their design capacities. These effluents may have different toxicities at high flows and such changes are dependent on whether removal efficiencies or dilution were more important in determining the concentration of toxicants in the effluents. A necessary criteria to complete the validation of toxicity tests is that the exposure in the tests must approximate the one the stream community receives. During the field sampling, the community sampled was the result of the past several months to years of exposure. The effluent being tested during the study, because of rain, would not be expected to be like that to which the community has been exposed for most of the time, therefore one would not expect the effluent test data to correlate well with the community data. In addition, while the instream biological community may not have been changed substantially by the high flows, the sampling effectiveness did change. For these reasons, the February data for Five Mile Creek have not been used for this comparison although they have been presented in this report.

14.1 Prediction of Instream Community Impacts Based on Effluent Dilution Test Results

Table 14-1 lists the AEC for each effluent. The AEC is based on the most sensitive endpoint of the most sensitive species. It is calculated as the geometric mean of the highest concentration not causing a significant effect and the lowest concentration producing the effect. Table 14-1 also contains the average effluent concentrations for each ambient station during the toxicity testing period. The average concentration was selected because the organisms in the tests were exposed to a new and different sample for each day of the seven-day exposure period. Since concentrations did vary due to stream and effluent flow changes, the average would seem to be most valid for chronic effects. If the community is limited by short, high level exposures, then averages are not appropriate.

Table 14-1. **The Lowest Acceptable Effluent Concentration (AEC) and the Average Instream Waste Concentration (IWC) for Three Effluents at Six Stations on Five Mile Creek**

		IWC percent for Station:					
Effluent	AEC (percent)	3	5	6	7	8	9
Coke Plant 1	1.7	2.3	1.7	1.7	1.0	1.0	0.9
Coke Plant 2	17.3	–	21.7	20.8	13	12.8	11.5
POTW	55	–	–	–	33.8	33.3	29.9

Source: Tables 5-8 and 7-2

The effluent dilution tests predict impact at Stations 3, 5 and 6. That is, the AEC is exceeded at these stations. Table 14-2 shows that an increase in toxicity of 26% or more was found at these stations in the ambient tests. Since the IWCs do not exceed the AECs by very much, high toxicity would not be expected. Thus the ambient tests confirm the results of the effluent dilution tests. The reasons for using the most sensitive species response and why the most sensitive species may change from one station to the next are discussed earlier in this section. Since the effluents were diluted with water containing all upstream effluents any interactive effects such as additivity, are already incorporated into the measurement of the AEC.

14.2 Prediction of Instream Community Impacts Based on Ambient Toxicity Test Results

The three effluents tested in this study were certainly not the only potential sources of toxicity. There were old strip mines in the watershed that drained into Five Mile Creek through small streams not shown on Figure 2-1. A portion of the study area contained numerous industries which had no permit to discharge directly but could contribute contaminants through runoff water or spillage. For these reasons, no one station could be considered unimpacted for use as a reference station. An alternative was to select as the reference station, the one with the least toxicity and impact. A glance at Table 14-2 reveals that, as discussed above, the least toxicity/impact occurred at different stations for different species. Therefore a decision was made to use different reference stations for different measures or species. One then gets a measure of relative toxicity and not of absolute toxicity. There is no intent to imply that there is no impact, just that the impact was least compared to the other stations. The reference station was used to calculate the impact at other stations as a percent of the reference station. These values are shown in Table 14-2. Those values that were significantly different using ANOVA, Tukey's test, X^2 test, and Dunnett's test are indicated. The statistical analyses were not intended to identify trends. Thus these analyses do not address the trend in the benthic macroinvertebrate data which shows no impact at Station 1, impact at Stations 2, 3, and 5, and then little or no impact at Station 6, 7, 8, and 9. While Stations 3 and 5 are located below one or both of the coke plant outfalls, Station 2 is not. Therefore, the impact of Stations 3 and 5 cannot be attributed solely to the coke plant's discharges. The observed trend of the benthic invertebrate data might be expected if a

Table 14-2. **Percent Increase in Degree of Toxicity and Percent Reduction in Number of Taxa for the Instream Biological Community[a]**

Station	*Ceriodaphnia* Young Production	Fathead Minnow Weight	Zooplankton Taxa	Benthic Macroinvertebrate Taxa	Fish Taxa
1	60[b]	18	41	0	17
2	49[b]	0	18	58[b]	0
3	44[b]	12	6	46[b]	34
5	37[b]	60[b]	0	62[b]	92[b]
6	0	26	18	8	67[b]
7	18	19	18	15	67[b]
8	38[b]	7	53	31	58
9	37[b]	4	65[b]	4	8

[a] Percent values were obtained by using the highest value for each measurement as having 0 percent impact.
[b] Indicates statistically significant differences.

Source. Tables 5-4, 5-6, 10-1, 12-1, and 13-1.

source of toxicity existed between Stations 1 and 2. The zooplankton data show almost the reverse trend of the benthic data, with the greatest percent reduction at Stations 1, 8, and 9 and least at Stations 2, 3, 5, 6, and 7. The fish data show a trend consistent with an impact due to one or more of the three discharges. Since trends are what is of interest, as discussed above, comparing stations with statistical differences does not accomplish the objective. Furthermore, trends of biological or statistical significance may exist but point to point comparisons (the statistical approach used here) will not show any significant differences.

Since there are not sufficient data for good trend analyses and toxicity (measured in the toxicity tests on ambient samples), was related by comparing percent increase in toxicity and percent reduction in taxa among the various measures a matrix table was prepared (Table 14-3). Twenty, 40, 60, and 80 percent reduction was selected for comparison. An attempt to attribute impact to any or all of the three discharges was not made. Two sets of toxicity data and the three sets of instream biological data were combined into two groups for comparison. The increases in toxicity indicated in Table 14-3 for the combined toxicity data are compared to the percent reduction in taxa for the combined instream biological data. Using the 20 percent increase in toxicity, 87.5 percent or all stations using either 20 or 40 percent reduction levels for the field data are correctly predicted (Table 14-4). However, using the 40 percent increase in toxicity for the laboratory data, a poorer prediction for any level of field impact is obtained. Both 60 and 80 percent levels for toxicity data give 87.5 percent of the stations correctly predicted at the 80 percent level for field data. However, this is all correct prediction of "no impact" since very few values reached 60% and none were 80%.

Any one level of percent impairment is not being proposed as the correct percentage at this time. One study such as Five Mile Creek is not sufficient to judge which impairment of instream biological response data will correspond to a specified level of laboratory toxicity. Similar comparisons for all eight study sites (see Foreword) need to be completed before making decisions or recommendations. Using statistical significance (with the detectable difference variable for each type of measurement) rather than arbitrary levels of impact, agreement of the responses between laboratory and field data occurred at five out of the eight stations (Table 14-2). As discussed above, point to point statistical comparisons are not the cogent ones to use.

One should expect a general but not a point by point correlation between amount of toxicity and number of taxa lost. This expectation is *not* due to error in measurement of toxicity or taxa but is expected because of the varying relative sensitivity of test and community species. Added on top of this variability are the confounding effects of measurement error. In addition, there is the chance collection of a few individuals of a species that does not usually occur in that location and these numbers bias the number of taxa found. Events such as toxic spills before the study period could have residual effects on the community which would not be measured by the toxicity tests. General water quality conditions and physical effects, nontoxic in nature, such as low DO, high temperature, or direct activities of man (like gravel removal or dredging) also might have affected the community in the period preceding the study.

14.3 Summary

The predictions of instream impact based on the ambient toxicity test results correctly predict the community response at 87.5 percent of the stations using a 20 percent toxicity impact and 20 or 40 percent reduction of taxa for field data. The ambient tests measured toxicity where effluent dilution

Table 14-3. Comparison of Ambient Toxicity Test Results and Instream Biological Impact at Four Levels of Percent Difference[a]

Station	*Ceriodaphnia* Young Production	Fathead Minnow Growth	Zooplankton Taxa	Benthic Macroinvertebrate Taxa	Fish Taxa
		20 percent difference			
1	+	0	+	0	0
2	+	0	0	+	0
3	+	0	0	+	+
5	+	+	0	+	+
6	0	+	0	0	+
7	0	0	0	0	+
8	+	0	+	+	+
9	+	0	+	0	0
		40 percent difference			
1	+	0	+	0	0
2	+	0	0	+	0
3	+	0	0	+	0
5	0	+	0	+	+
6	0	0	0	0	+
7	0	0	0	0	+
8	0	0	+	0	+
9	0	0	+	0	0
		60 percent difference			
1	+	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
5	0	+	0	+	+
6	0	0	0	0	+
7	0	0	0	0	+
8	0	0	0	0	0
9	0	0	+	0	0
		80 percent difference			
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0

[a] + indicates a difference the indicated level of percent difference.
0 indicates a difference the indicated level of percent difference.

Source: Table 14-2.

Table 14-4. Percent of Correctly Predicted Impacted Stations Using Four Levels of Defined Impact

Combined Laboratory Toxicity Data	Combined Instream Biological Data			
	20 Percent	40 Percent	60 Percent	80 Percent
20 percent	87.5	87.5	50	25
40 percent	50	50	25	62.5
60 percent	25	25	62.5	87.5
80 percent	0	0	37.5	87.5

tests predicted it would occur. Ambient toxicity was found at other stations as well. This is not surprising in view of other potential sources of toxicity. The need to measure toxicity using more than one species and the need to measure more than one component of the community for comparison is illustrated by the data. Importantly, the responses in the toxicity tests and by the community fit the expected pattern based on our present understanding of toxicology and relative sensitivity.

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Appendix A
Toxicity Test and Analytical Methods

A.1 Toxicity Test Methods, February 1983

For the effluent dilution tests, stream water was collected as a grab sample from just upstream of each outfall in the morning of the day it was used. The well water was hauled to the site and one batch was used for all tests. The effluent was collected as a 24-hour composite sample by continuously pumping a small flow from the discharge flow. Each composite was begun between 0800 and 1000 hours. Samples were not flow proportional because discharge flows varied due to rainfall.

The ambient samples were collected as a daily grab sample from the stations listed in Chapter 3. In addition, dilution water for Coke Plant 1 was collected just above a low dam at the discharge site.

Stream and effluent samples were warmed to 25°C on a gas burner in aluminum pans and then, after dilutions were made, the samples were aerated in 4-liter beakers until dissolved oxygen (DO) was reduced to saturation. Ambient toxicity samples were treated in the same manner. All samples were supersaturated with respect to DO when solutions were made.

The various concentrations were made by measuring effluent and stream water using graduated cylinders of various sizes and mixing each concentration in 4-liter glass beakers. Two liters of each concentration were made; 160 ml were used for the *Ceriodaphnia* tests and the remainder was used for fathead minnow tests.

No chemical measurements for specific chemicals were performed. Routine water chemistry such as DO and pH were measured initially in the 2-liter solutions, while still in the 4-liter beaker. DO and pH were also measured just before changing test solutions to determine the final values as well.

Test solutions were changed daily so that in the ED tests, the fish and *Ceriodaphnia* were exposed to a new 24-hour composite effluent sample each day, which was made up in a new daily grab sample of receiving water. For the ambient toxicity test, the *Ceriodaphnia* and fathead minnows were placed in a new daily grab sample each day. The controls for each of the ED tests in receiving water were in the same water as the animals in the ambient toxicity tests for Stations 2A, 3, and 6.

For the fathead minnow larval tests, a chamber 30- × 15- × 10-cm deep was made and divided by three glass partitions which resulted in four compartments, 13- × 7.6- × 10-cm deep. The partitions stopped 2.5 cm short of one side of the chamber and a piece of stainless steel screen was glued from one chamber end to the other and across the ends of each compartment. This left a narrow sump 2.5- × 30- × 10-cm deep along one side of the chamber to which each of the four compartments was connected by its screen end. In this way, the compartments could be filled and drained by adding to or removing water from the sump, without violent agitation of the fish in the compartments. This design allowed four replicates for each concentration. These are not true replicates in the pure statistical sense because there was a water connection between compartments; however, there was virtually no water movement between compartments as judged by DO measurements where in some cases, there were measurable DO differences between compartments. When the compartments were filled or drained, some water would mix into other chambers.

Each day the compartments were siphoned using a rubber "foot" on a glass tube to remove uneaten brine shrimp. Additional test solution was removed from the sump until about 500 ml remained in the four compartments combined. This amounted to about 1 cm of depth. Then approximately 2,000 ml of new test solution was added slowly into the sump. The larval fish were easily able to maintain their position against the current during filling.

Each day 0.1 ml of newly hatched brine shrimp were fed three times. Live brine shrimp were available during the entire daylight period of 16 hours. Fluorescent lights were mounted over the test chambers and were operated by a timer.

Fish survival was counted daily and at the end of the test, the fish were counted and preserved in 4 percent formalin. Upon return to the home laboratory, they were rinsed in distilled water, oven dried at 98°C for 18 hours, and weighed on an analytical balance. Fish were assigned to compart-

ments one or two at a time in sequential order. They were less than 24-hours hatched at the test beginning and were obtained from the Newtown Fish Toxicology Laboratory culture unit. This method is described in more detail in Norberg and Mount (1985).

Brood animals were not acclimated to the site water but were kept in ERL-D culture water. The *Ceriodaphnia* from the Duluth culture were placed one animal to each of ten 30-ml beakers for each concentration or sample tested. Each treatment received one animal before any treatment received a second animal. Fifteen ml of test water was placed in each beaker and a newly born *Ceriodaphnia*, less than 6 hours old, was used. One drop of yeast containing 250 μg was added daily. Each day, the animal was moved to a new 15-ml volume with an eye dropper and yeast again added. When young were present, they were counted and discarded. Males were readily identified by their smaller size, different shape and rapid swimming. Temperatures were maintained at 24-26°C. For the *Ceriodaphnia* tests, the same concentration and change schedules were used as described for the fathead minnows. For the ambient toxicity tests, 10 animals were used for each station and a new sample was used daily. The culture procedures and test method are delineated in Mount and Norberg (1984).

Light was kept very dim to avoid algal growth and to keep conditions comparable to those used for culturing at Duluth. The high bacterial content of the water and waste samples increased available food and where toxicity was not present, better young production was obtained than where the only food was the yeast as was the case for the tests using well water for dilution.

The data on the four group dry weights for each treatment are statistically analyzed in the following manner. Even though the four compartments were connected, the assumption is made that they behave as replicates. The analysis assumes the variability in mean treatment response is inversely proportional to the number of measurements (or fish) in the treatment. The analysis is performed using MINITAB (copyright Pennsylvania State University 1982) by estimating a t-statistic for comparing mean treatment and control responses using weighted regression with weights equal to the number of measurements in the treatments. The t-statistic is then compared to the critical t-statistic for the standard Dunnett's test (Steel and Torrie 1960). The survival data is arcsine transformed (a variance stabilizing transformation) prior to the regression analysis.

The statistical analysis of the *Ceriodaphnia* results were performed using the procedure described by Hamilton (1984) as modified by John Rodgers (personal communication). The effluent toxicity is analyzed to obtain the mean number of young per female (all data method) and the mean survival. A Dunnett's t-test is then done to compare each treatment to the control to identify significant differences. For the ambient station data, a matrix is made to provide comparisons of any station to any other station using Tukey's Honestly Significant Difference Test.

A.2 Toxicity Test Methods, October 1983

All procedures were the same as for the February study with these exceptions:

1. Coke Plants 1 and 2 were operating at about 30 and 50 percent capacity, respectively.
2. Ambient water temperatures were near test temperatures and required essentially no heating. Effluent temperatures were a few degrees cooler and slight heating was needed. Aeration of the test solutions was not necessary to reduce supersaturation.
3. All three effluents were tested in dilution water taken immediately upstream from each outfall.
4. All testing of *Ceriodaphnia* was done using hard, clear plastic cups instead of 30-ml glass beakers. These cups were not washed but discarded when test solutions were changed.
5. A more downstream station (9) was added below Station 8. Station 9 was located at Littleton Cutoff Road. In addition an ambient toxicity station was established at the mouth of Black Creek (Station B2). Three stations were added—one on each of the three main headwater tributaries of Five Mile Creek. They are designated Barton Branch (B1), Tarrant Branch (T1), and the headwater of Five Mile Creek (F0).
6. Composite samples were taken at all ambient stations except the three headwater stations. Commercially available battery-powered, peristaltic samplers were used which sampled every 15 minutes.
7. A set of acute tests were made to measure variability of acute toxicity on Coke Plant 2. For this aspect, a second sampler was used and a discrete sample was taken each hour. After 24 samples were collected, five animals less than 24 hours old were put in each of two duplicate 15-ml volumes of 100 percent effluent, and mortality was counted at 1, 2, 4, 8, 24, and 48 hours later. Four sets of 24 samples were tested.

8. Concentrations of effluents tested were 100, 30, 10, 3, and 1 percent.

9. Polyethylene beakers and cylinders were used for mixing effluents.

10. *Ceriodaphnia* were from cultures at Athens EPA Laboratory and the University of Wyoming, Laramie. These cultures were subsequently identified as *Ceriodaphnia dubia* by Dr. Dorothy Bemer of Temple University, Pa.

Appendix B
Hydrological Sampling and Analytical Methods

B.1 Flow Measurements

Flow measurements were made at the biological stations during 7-11 February 1983 and 4-10 October 1983. During February, a Model 665 Teledyne Gurley flowmeter was used and during October a Teledyne Gurley Pygmy flowmeter was used. When depths were less than 0.75 m, velocities were recorded at a depth of 0.6 of the water column. When depths were $\geq$0.75 m, a velocity measurement was recorded at 0.2 and 0.8 of the water column, and the average of the two readings was used in the subsequent flow calculation. A minimum of 10 velocity measurements were made along a transect at each station unless fewer measurements were warranted by the width. A discharge was calculated for each velocity measurement by multiplying the velocity times the cross-sectional area associated with the segment. The total flow through the transect is the summation of the flows through each segment along the transect.

The 7-day average flows were calculated from Table 7-1 by interpolating between days and between stations in order to simulate a complete data set. The resulting values were adjusted if necessary so that the flow at each station was greater or equal to the sum of the next upstream station and an intervening outfall if present.

B.2 Time-of-Travel Study

On 8 February 1983, 150 g of 20 percent solution Rhodamine WT dye was released in the Coke Plant 1 effluent prior to its point of discharge into Five Mile Creek. The passage of the dye was monitored at four stations located 580, 1,158, 1,880, and 3,140 m downstream from the point of release. At the first three stations, grab samples were collected in 200-ml plastic bottles. At the 3,140-m station, a Turner Designs fluorometer was set up in the flow-through mode and readings were recorded manually. The sampling interval was initially 2-5 minutes at each station and decreased to 1 minute as the main dye mass approached.

Grab samples were processed in a Turner Designs fluorometer set in the discrete sample mode. All fluorometers used had been calibrated prior to the study over a range of 0-214 ppb dye and the calibration was checked when used in the discrete sample mode with standard dye solutions. Fluorometer data were converted to dye concentration, C(ppb), using the relationship:

$$C(ppb) = SR \exp[0.027(T - T_c)] \qquad \text{(Equation B-1)}$$

where

- S = slope from the calibration regression for the appropriate fluorometer scale
- R = fluorometer reading
- T = temperature of the grab sample at the time it was processed
- T_c = reference temperature from instrument calibration

This relationship includes a correction factor for the temperature dependence of fluorescence. In February a 20°C reference temperature was used, whereas in October a 25°C reference temperature was used. At each station the dye concentration data was plotted against time. The arrival time of the average water particle at each station was taken at the center of mass of the dye distribution. From the intervening times and distances, an average velocity was calculated between each station.

The center of mass of the dye distribution at the four stations was calculated. To calculate the center of mass of the dye distribution at the second and third stations, the shape of the tail of the distribution had to be estimated. The tails were estimated visually from Figure 6-1. The center of mass was calculated by numerically integrating the areas under the 4 curves in Figure 6-1.

B.3 Effluent Configuration Studies

Effluent configuration studies were conducted at Coke Plant 1 in February 1983 and at Coke Plants 1 and 2 and the POTW in October 1983. Dye was injected continuously for approximately 24 hours at each site to establish an equilibrium between the injection-point dye concentration and the downstream dye distribution. On the second day of each study, water samples were collected at 12 transects extending from 30 m above to approximately 1,500 m below the point of discharge. The transect locations with respect to the three discharges are tabu-

lated in Table B-1. The ratio of the dye concentration at the point of discharge to the dye concentration in the water samples collected at the downstream transects represents the dilution undergone by the effluent. By conducting the studies from the downstream to the upstream site, contamination of dye from one study to the next is avoided.

Rhodamine WT dye was injected at each site by a Fluid Metering, Inc. precision metering pump. The injection system was placed at a sufficient distance from the river to allow complete mixing of the dye and effluent prior to the point of discharge. The weight of the dye container was periodically recorded to monitor the dye injection rate. The Rhodamine WT dye used in the study will decay in the presence of chlorine. Sodium thiosulfate, $Na_2S_2O_3$, reduces the chlorine to chloride when present in a concentration approximately six times as great as the chlorine level. At the POTW, a second precision metering pump injected an appropriate solution of $Na_2S_2O_3$. The line from the dye was inserted through the side wall of the larger line from the $Na_2S_2O_3$ such that both solutions were injected at the same point.

A flow-through Turner Designs fluorometer was set up where the discharge enters the river to provide a continuous record of discharge dye concentration. The fluorometer reading was recorded on an Esterline Angus data logger at 5-minute intervals. The temperature at the discharge was measured using a YSI probe and was also recorded because the fluorometer reading is temperature-dependent.

Table B-1. Transect Locations Used During the Dye Studies at Three Sites on Five Mile Creek, February and October 1983

	Distance (m) Downstream of Site		
Transect	POTW	Coke Plant 2	Coke Plant 1
T0	30	-30	20
T1	0	0	0
T2	15	15	15
T3	30	30	30
T4	76	76	76
T5	137	137	137
T6	213	213	213
T7	305	305	305
T8	457	457	457
T9	762	731	762
T10	1,067	1,067	1,067
T11	1,524	1,524	1,524

At Coke Plant 1, the effluent coated the inside of the fluorometer flow cell during the February study, rendering the data obtained after the first few hours useless. As a result, a fluorometer was not installed in October at Coke Plant 1. At Coke Plant 2, the point of discharge is not secured and at the POTW the discharge is located above the water surface with no suitable point to sample continuously at the end of the pipe. Consequently, the discharge dye concentrations during the three October studies were monitored by taking daily grab samples. These samples were compared to predicted discharge dye concentrations based upon dye injection rate and reported plant flow.

During the instream survey on the second day of dye injection, water samples were collected in 200-ml bottles. A sample was taken and the water depth recorded every 3.0 m across the transect, except near a discharge or at a narrow transect where a 1.5-m interval was used for greater resolution. A manual sampler was set to take the water samples 0.2 m from the bottom. When the depth was less than 0.25 m, the sample was taken at middepth. If the water depth was greater than 0.5 m, a second sample was taken 0.1 m from the surface.

Water samples were processed on the same day of the instream survey using a Turner Designs fluorometer in the discrete sample mode. The fluorometer calibration was checked with field standards each day it was used. The fluorometer data was converted to dye concentration, C(ppb), using Equation B-1. The reference temperatures for the fluorometer calibration were 20°C in February and 25°C in October.

The background levels (equivalent dye concentration fluorescence) measured upstream of the discharge and in the effluent prior to dye injection were flow-weighted to determine a background level which was subtracted from the instream data. In a similar fashion, the fluorometer readings from the discharge data logger were reduced every 30 minutes for the duration of the study.

At the time of each of the four dye studies, a dye integrity study was performed. Rhodamine WT dye was added to effluent in order to make 50-ppb dye solutions. The effluent solution for the POTW also contained sodium thiosulfate. Each solution was measured in the fluorometer immediately after mixing and periodically for several hours. No noticeable decay was observed at the POTW or Coke Plant 2 during October.

At Coke Plant 1, both dye integrity studies resulted in fluorometer readings which were approximately 50 percent of the expected value. On 12 and 13 February, a dye integrity study was performed by making a 50-ppb dye solution using an effluent

sample and an upstream river sample. Each of the two solutions were measured six times during a 24-hour period. Although the two solutions were stable over the 24-hour period, effluent measurements were only 48 percent of the expected 50-ppb value, whereas the upstream measurements gave the expected results. The integrity test was repeated in EA's laboratory on 7 March for the effluent sample by making a new 50-ppb solution; the measured concentration was 52 percent of the expected value.

It was determined that the reduced readings were caused by the high color content of the effluent blocking the passage of light through the sample in the fluorometer chamber rather than actual physical decay of the dye present. Further analysis showed that the percentage reduction in fluorometer reading was linearly proportional to the fraction of effluent in the sample, i.e., a 100 percent effluent sample gives a 50 percent reduction in dye reading, a 50 percent efluent sample a 25 percent reduction, and a 1 percent effluent sample a 0.5 percent reduction. Although the discharge fluorometer would only record 50 percent of the actual amount of the dye present, the instream samples, which for all but one value represented as dilution of effluent with river water of greater than 1:100, would have a negligible (<0.5 percent) correction due to the initial effluent color.

At Coke Plant 1 in the February study, a 20 g/kg solution of Rhodamine WT dye was injected from 1500 hours on 8 February to 1600 hours on 9 February. The average injection rate during this period was 7.24 g/min. At the POTW, the injection of a 200 g/kg Rhodamine WT dye solution started at 1025 hours on 3 October and continued until 1340 hours on 4 October. During this period the average dye injection rate was 5.27 g/min. A 400 g/liter solution of $Na_2S_2O_3$ was also injected at the same point at a rate of 200 ml/min. The $Na_2S_2O_3$ injection rate is equivalent to a 4.9 ppm concentration in a discharge flow of 0.27 m^3/sec which would protect the dye from a chlorine residual of 0.8 ppm.

At Coke Plant 2, a 200 g/kg solution of Rhodamine WT dye was injected from 1020 hours on 5 Octoer to 1420 hours on 6 October. The average injection rate during this period was 2.76 g/min. The dye weight data indicates that the injection rate may have decreased from 3.02 to 2.50 g/min during the study.

At Coke Plant 1, the dye injection was initially started on 7 October at 1000 hours. At some time during that night, the dye injection system was turned off by an unknown person. The system was restarted on 8 October at 1530 hours. Between the restart time and 1150 hours on 9 October, a 13.9 g/kg solution of Rhodamine WT dye was injected at an average rate of 5.48 g/min.

Appendix C
Biological Sampling and Analytical Methods

C.1 Periphyton Methods

Natural substrates (rocks) in Five Mile Creek were sampled quantitatively using an epilithic algal bar-clamp sampler. Station 11, located at Black Creek, had insufficient rock habitat for similar quantitative sampling, so scrapings were taken from wood substrates (stationary log and wooden board). All other samples were taken from the lower end of riffle areas and runs located at each station. Suitable substrate also was lacking at Station 1, so a quantitative sample was collected for identification and abundance estimates. Three replicate samples were taken at each station for chlorophyll *a* and biomass measurements. A volumetrically measured aliquot was removed from these samples and filtered using 0.45-μm filters. These filters were stored with desiccant in an ice chest to await laboratory analysis for chlorophyll *a*. The remainder of each sample was stored in a 120-ml glass jar on ice to await laboratory analysis for biomass. One sample consisting of a composite of two bar-clamp collections was taken from each station for cursory identification (genus level) and abundance estimates. These samples were preserved in M3 *preservative* to await analysis.

Ash-free dry weights (AFDW) and chlorophyll *a* were analyzed in the laboratory. For AFDW, samples were dried at 105°C to a constant weight and ashed at 500°C. Distilled water then was added to replace the water of hydration lost from clay and other minerals. Samples were redried at 105°C before final weighing, and standing crop (biomass) was expressed in grams per square meter (g/m^2). Filters for chlorophyll *a* analysis were macerated in a 90 percent acetone solution, centrifuged, and analyzed spectrophotometrically. A chlorophyll *a* standard (Sigma Chemicals) extracted in a 90 percent acetone solution was used for instrument calibration. Chlorophyll *a* standing crop was expressed as milligrams per square meter (mg/m^2). The biomass and chlorophyll *a* data were used to calculate the Autotrophic Index (Weber 1973), which indicates the relative proportion of heterotrophic and autotrophic (photosynthetic) components in the periphyton. The biomass and chlorophyll *a* data were also statistically tested by analysis of variance (Steel and Torrie 1980) and multiple comparison tests to detect significant ($P \leq 0.05$) differences between sampling locations.

Each sample for identification and enumeration was mixed for 30 seconds in a blender to disrupt algal clumps,and sample volume, then was increased to 100 or 250 ml depending on the quantity of material present. Ten percent of each thoroughly mixed sample was removed to prepare Hyrax slides, which were examined at 1,250X magnification to confirm the identity of diatoms encountered during the quantitative analyses. Large quantities of sediment and detritus in the sample from Station 6 required dilution to an effective sample volume of 2,500 ml before further analysis. A 0.2-ml aliquot from each quantitative sample was placed in a settling chamber designed for use on an inverted microscope. The chamber then was filled with de-ionized water, and periphytic forms were allowed to settle to the bottom of the chamber for 24 hours. Samples were examined at 1,000X magnification with an inverted microscope, and algae were identified to genus. For each sample, one to five diameters of the counting chamber were examined, and algae containing protoplasm were enumerated as units. These units were cells except for genera of filamentous blue-green algae and the very large green alga *Cladophora*, which were counted in 10-μm units of length. The actual number of units identified and counted in each sample ranged from 68 to 863 but was greater than 350 in all but one sample. Periphyton abundance was expressed as number units per square millimeter ($units/mm^2$), and taxa diversity and equitability were calculated from raw counts by U.S. EPA methods (EPA 1973).

The chlorophyll *a* and biomass replicate data for each station were analyzed quantitatively by using one-way analysis of variance (ANOVA). A Tukey's Studentized Range Test was performed when a significant station effect was obtained from the ANOVA. Analyses were conducted using SAS PROC GLM.

C.2 Benthic Methods

C.2.1 Benthic Methods, February 1983

Benthic samples were collected from the riffle habitat at nine stations. Three replicate samples were

collected from each of the two habitats at each station. A Hess sampler (881 cm^2) with 500-μm mesh was used to sample the benthos in the riffle habitat. Samples were preserved in 10 percent buffered formalin and returned to the laboratory for analysis. Emphasis on the riffle habitat was believed sufficient to detect effects and discern recovery.

Water quality measurements consisting of temperature, dissolved oxygen, pH, and conductivity were taken at every station. These data are discussed in Chapter 3.

Samples were sorted with the aid of a Wild M-5 dissecting microscope. Organisms were sorted into major taxonomic categories and preserved in 80 percent alcohol to await identification; organisms were identified to the lowest practical taxon using appropriate keys and references. Oligochaetes and chironomid larvae were mounted on microslides prior to identification.

C.2.2 Benthic Methods, October 1983

Triplicate benthic invertebrate samples were obtained at quarter points on a transect across the stream in a riffle area with a Hess sampler with 500-μm mesh. A hand-held net with the same mesh was used for qualitative sampling in additional habitats.

Benthic invertebrate samples were picked after sugar floatation and identified to the lowest convenient taxon, usually genus.

C.2.3 Analytical Methods

A one-way ANOVA was used to test for differences in abundance of key taxa among stations. The data were natural log-transformed to ensure a normal distribution and equal variances at all stations. A Tukey's Studentized Range Test was performed when a significant station effect was obtained from the ANOVA. Analyses were conducted using SAS PROC GLM.

C.3 Fish Survey Methods

C.3.1 Fish Survey Methods, February 1983

Fish collections were made in premeasured sections of the stream at each of the nine Five Mile Creek biological sampling stations. Each sampling area contained pool and riffle habitats with interconnecting runs, although in widely varying proportions (Table C-1). Two sections at selected stations were fished when habitat permitted to obtain a more complete representation of the community.

Fish collections were conducted using a Coffelt VVP-2C electrofisher. This specific gear consisted of two hand-held positive electrodes and negative electrode attached to a small pram which carried the generator and shocking box. Each section of the stream was fished from bank-to-bank in an upstream direction. Fish were held in buckets of stream water until an entire section was completed. Captured fishes were identified and counted. Only those fish of questionable identity and requiring further examination were preserved and returned to the laboratory. All other fish were released alive. Water temperature, dissolved oxygen, specific conductance, and pH were measured during fish collections at each station. A Hydrolab Model 4041 was used for all measurements. These data are discussed in Chapter 3.

Table C-1. Station Lengths and Pool, Run, and Riffle Proportions for Fish Survey, Birmingham, Alabama, February 1983

		Proportion (%)		
Station	Length (m)	Pool	Run	Riffle
1a[a]	100	5	45	50
1b[a]	100	5	65	30
2a[a]	100	30	40	20
2b[a]	100	10	70	20
3	120	5	70	25
4	120	0	75	25
5	120	20	80	0
6	120	10	40	50
7	120	10	90	0
8a[a]	120	15	85	0
8b[a]	83	5	95	0
B2	120	85	10	5

[a]a and b refer to subareas of stations sampled.

C.3.2 Fish Survey Methods, October 1983

Fish collections were made in premeasured sections of the stream at each of the nine Five Mile Creek and two tributary biological sampling stations. All fish sampling stations were 90 m long and included a portion of both riffle and pool habitat (Table C-2).

Most fish collections were made with a Coffelt VVP-2C electroshocker operated out of a towed pram. Pulsed direct current was generated through two, hand-held positive electrodes. At the Five Mile Creek headwater station (F0) and the tributaries, Tarrant Spring Branch (T1) and Barton Branch (B1), a Coffelt BP1C backpack electrofisher was used with one positive and one negative probe. Each section of stream was fished from bank-to-bank in the upstream direction. Captured fishes were held in buckets of stream water until an entire section was completed, and then they were identified and counted. Only those fish of questionable identity and requiring further examination were preserved and returned to the laboratory. Remaining fishes were released alive or, if dead, were properly disposed of.

Table C-2. Dimensions of Pool and Riffle Habitat at Each Station, Birmingham, Alabama, October 1983

Station	Length (m) Pool	Length (m) Riffle	Mean Width (m) Entire Section	Estimated Maximum Depth (m) of Pool
F0	45	45	12.1	0.3
T1	45	45	3.7	0.3
B1	20	71	6.4	0.3
1	55	37	9.4	0.9
2	70	22	11.9	1.2
3	45	45	9.8	0.9
5	45	45	9.2	0.9
6	31	61	17.1	0.6
7	45	45	21.9	0.5
8	61	31	12.8	0.6
9	61	31	24.6	·1.5

In conjunction with fish sampling, stream widths were measured at four approximately equidistant points through the 90-m section. This was used in the computation of number of fish per 93 m^2.

C.3.3 Statistical Methods

The fish data were quantitatively analyzed using the X^2 test on the number of taxa per station. Data for Station 2 were used as the expected values.

C.4 Plankton Methods, October 1983

Duplicate plankton samples were obtained using a Wisconsin-style plankton net with 80-μm mesh. The net was held horizontally as the water flowed into the mouth for 2 minutes. Timing the drift of a float over a measured 10-ft distance allowed calculation of approximate volume of water filtered.

Two 1-ml subsamples were observed from each of the approximately 120-ml plankton samples in a Sedgwick-Rafter counting chamber. The organisms were categorized and enumerated under 100X magnification. Algal components of the plankton community which were retained in the net were also enumerated. For solitary diatoms, one short dimension strip was observed at 100X and the total density was calculated.

A one-way ANOVA was used to test for differences in the number of zooplankton taxa per station. A Tukey's Studentized Range Test was performed when a significant station effect was obtained from the ANOVA. Analyses were conducted using SAS PROC GLM.

Appendix D
Toxicological Test Data

Table D-1. Routine Chemistry Data for Three Effluents in Various Waters for Fathead Minnow Tests, Birmingham, Alabama, February 1983

% Effluent Concentration (v/v)	x̄ pH (Range)	Dissolved Oxygen (mg/l) x̄ Daily Initial (Range)	Dissolved Oxygen (mg/l) x̄ Daily Final (Range)	Alkalinity (mg/l)	Hardness (mg/l)	Conductivity (µmhos/cm)
Coke Plant 1 in Station 2A Water						
Dilution water	7.7 (7.4-8.1)	8.5 (8.3-8.7)	6.0 (4.4-7.7)	143	162	310
0.5	7.7 (7.4-8.1)	8.5 (8.3-8.7)	5.9 (3.3-7.8)	--	--	310
1.0	7.7 (7.4-8.0)	8.5 (8.3-8.7)	6.0 (3.5-7.7)	141	168	350
5.0	7.5 (7.4-7.7)	8.4 (8.1-8.8)	4.7 (3.5-5.4)	--	--	490
Coke Plant 1 in Well Water						
Dilution water[a]	7.5 (7.2-7.8)	8.5 (8.2-8.8)	6.0 (4.2-7.1)	64	64	--
0.5	7.5 (7.3-7.8)	8.3 (8.1-8.7)	5.9 (3.5-6.7)	--	--	--
1.0	7.5 (7.3-7.8)	8.3 (8.0-8.7)	5.5 (3.5-6.5)	66	70	--
5.0	7.4 (7.3-7.5)	8.1 (7.0-8.8)	5.0 (4.3-6.1)	--	--	--
Coke Plant 2 in Station 3 Water						
Dilution water	7.5 (7.4-7.8)	8.5 (8.3-8.8)	5.0 (4.1-7.1)	141	166	350
1.0	7.6 (7.4-7.8)	8.5 (8.1-8.8)	5.4 (4.0-7.1)	--	--	350
5.0	7.5 (7.4-7.7)	8.5 (8.1-8.8)	5.4 (4.5-7.1)	140	182	400
10.0	7.5 (7.3-7.7)	8.5 (8.1-8.8)	5.0 (4.1-6.2)	--	--	480
50.0	7.5 (7.3-7.6)	8.5 (8.1-8.8)	4.2 (2.3-5.1)	117	312	83
100.0	7.3 (6.9-7.5)	8.5 (8.1-9.0)	4.1 (2.6-5.1)	--	--	1,280
Coke Plant 2 in Well Water						
1.0	7.4 (7.2-7.7)	8.6 (8.2-8.8)	5.4 (4.2-6.8)	--	--	--
5.0	7.4 (7.2-7.7)	8.5 (8.2-9.0)	4.5 (2.7-5.8)	--	--	--
10.0	7.4 (7.2-7.7)	8.5 (8.4-8.6)	4.6 (2.0-5.2)	6	104	--
50.0	7.3 (7.2-7.7)	8.5 (8.2-8.7)	4.5 (3.8-5.6)	--	--	--

Table D-1. (Continued)

% Effluent Concentration (v v)	x̄ pH (Range)	Dissolved Oxygen (mg/l) x̄ Daily Initial (Range)	Dissolved Oxygen (mg/l) x̄ Daily Final (Range)	Alkalinity (mg/l)	Hardness (mg/l)	Conductivity (µmohs/cm)
Coke Plant 2 in Station 1 Water						
Dilution water	7.7 (7.5-8.0)	8.5 (8.0-8.7)	5.2 (4.4-6.3)	--	--	--
1.0	7.7 (7.5-8.0)	8.4 (8.0-8.7)	5.3 (4.4-6.2)	--	--	--
5.0	7.7 (7.5-8.0)	8.4 (8.1-8.7)	5.0 (4.1-6.2)	--	--	--
10.0	7.7 (7.4-8.0)	8.4 (8.1-8.7)	4.8 (3.5-6.3)	--	--	--
50.0	7.5 (7.3-7.9)	8.3 (8.1-8.6)	4.1 (2.2-5.9)	--	--	--
POTW in Station 6 Water						
Dilution water	7.8 (7.7-8.0)	8.4 (8.0-8.8)	6.3 (4.7-7.3)	138	172	--
1.0	7.9 (7.7-8.1)	8.4 (8.1-9.1)	6.0 (4.7-7.2)	--	--	--
5.0	7.9 (7.7-8.1)	8.3 (8.1-8.6)	6.0 (4.4-7.1)	138	172	--
10.0	7.8 (7.7-8.0)	8.4 (8.1-8.7)	4.8 (4.1-6.3)	--	--	--
50.0	7.7 (7.6-7.9)	8.3 (8.1-8.8)	5.7 (3.9-6.7)	137	166	--
100.0	7.6 (7.5-7.8)	8.2 (8.0-8.7)	5.9 (4.6-6.8)			
Sampling Stations						
1	7.7 (7.3-8.0)	8.2 (8.0-8.6)	6.7 (4.8-7.6)	--	--	--
2	7.7 (7.4-8.0)	8.2 (7.9-8.6)	6.0 (4.6-7.3)	140	154	--
5	7.4 (7.2-7.6)	8.2 (7.9-8.3)	5.9 (4.7-6.8)	84	212	--
7	7.6 (7.3-7.8)	8.3 (8.1-8.6)	5.8 (4.2-7.1)	--	--	--
8	7.6 (7.3-7.8)	8.4 (8.0-8.6)	5.7 (3.6-7.2)	--	--	--

[a] Well water control was used for the two effluent well water dilution tests.

Table D-2. Final Water Chemistry Data for *Ceriodaphnia* Tests, Birmingham, Alabama, February 1983

% Effluent Concentration (v v)	x̄ pH (Range)	Dissolved Oxygen (mg/l) x̄ Daily Final (Range)
Coke Plant 1 in Station 2A Water		
Dilution water	7.8 (7.6-8.1)	7.6 (7.3-8.0)
0.5	7.8 (7.6-8.1)	7.7 (7.4-8.2)
1.0	7.8 (7.6-8.1)	7.7 (7.4-8.2)
5.0	7.8 (7.6-8.1)	7.5 (7.0-7.8)
Coke Plant 1 in Well Water		
Dilution water	7.6 (7.5-7.7)	7.3 (7.3-8.0)
0.5	7.6 (7.5-7.7)	7.5 (7.3-7.8)

Table D-2. (Continued)

% Effluent Concentration (v/v)	x̄ pH (Range)	Dissolved Oxygen (mg/l) x̄ Daily Final (Range)
1.0	7.6 (7.5-7.7)	7.4 (7.2-7.7)
5.0	7.6 (7.5-7.7)	7.3 (7.0-7.7)
Coke Plant 2 in Station 3 Water		
Dilution water	7.9 (7.7-8.2)	7.9 (7.6-8.4)
1.0	8.0 (7.9-8.1)	7.8 (7.4-8.1)
6.0	7.9 (7.8-8.0)	7.6 (7.4-8.0)
10.0	7.8 (7.8-7.9)	7.4 (7.2-7.7)
50.0	7.7 (7.6-7.7)	7.1 (6.9-7.7)
100.0	7.5 (7.4-7.5)	6.9 (6.3-7.5)
Coke Plant 2 in Well Water		
Dilution water	(See Coke Plant 1 in Well Water)	
4.0	7.5 (7.3-7.7)	7.5 (6.9-8.1)
5.0	7.5 (7.3-7.7)	7.2 (6.6-7.8)
10.0	7.4 (7.3-7.6)	7.2 (6.6-7.6)
50.0	7.4 (7.2-7.5)	6.8 (5.4-7.4)
POTW in Station 3 Water		
Dilution water	7.9 (7.7-8.1)	7.3 (6.9-8.0)
1.0	7.8 (7.7-8.1)	7.3 (6.8-7.5)
5.0	7.8 (7.7-8.1)	7.3 (6.5-8.0)
10.0	7.8 (7.7-8.1)	7.0 (6.5-7.6)
50.0	7.8 (7.7-8.0)	7.0 (6.7-7.3)
Sampling Stations		
1	7.8 (7.8-7.9)	7.6 (7.1-8.1)
2	7.9 (7.8-8.0)	7.7 (7.2-8.1)
2A	7.8 (7.7-8.0)	7.2 (7.0-7.6)
3	7.9 (7.7-8.1)	7.4 (6.6-8.2)
5	--	7.4 (1 value)
6	7.9 (7.7-8.1)	7.7 (7.3-8.0)
7	7.8 (7.7-7.9)	7.5 (6.8-8.0)
8	7.8 (7.7-8.0)	7.5 (7.2-7.8)

Table D-3. Routine Chemistry Data for Three Effluents and Various Stream Stations for Fathead Minnow Tests, Birmingham, Alabama, October 1983

% Effluent Concentration (v v)	x̄ Initial pH (Range)	Dissolved Oxygen (mg l) x̄ Daily Initial (Range)	Dissolved Oxygen (mg l) x̄ Daily Final (Range)	Alkalinity[a] (mg l)	Hardness[d] (mg l)	Initial Conductivity (μmohs cm)
Coke Plant 1 in Station 2A Water						
Dilution water	7.7 (7.5-7.9)	8.5 (7.5-9.3)	6.4 (5.6-6.8)	145	158	309
1	7.8 (7.8-7.8)	7.6 (7.3-7.8)	6.5 (5.9-6.9)			330
3	7.8 (7.7-7.8)	7.6 (7.4-7.7)	6.5 (5.9-6.8)			385
10	7.8 (7.7-7.8)	7.5 (7.3-7.6)	6.4 (5.9-7.0)			600
30	7.6 (7.5-7.7)	7.3 (7.0-7.5)	6.0 (5.3-7.0)			1,215
100	7.6 (7.3-7.9)	6.5 (5.2-7.1)	3.5 --	365	98	3,329
Coke Plant 2 in Station 3 Water						
Dilution water	7.6 (7.4-7.8)	8.4 (7.5-9.0)	6.6 (5.9-7.2)	153	158	394
1	7.7 (7.6-7.7)	7.7 (7.5-7.9)	6.8 (6.5-7.3)			378
3	7.7 (7.6-7.7)	7.8 (7.6-8.0)	6.3 (4.7-7.3)			400
10	7.7 (7.6-7.7)	7.8 (7.6-8.0)	6.4 (5.5-7.3)			421
30	7.7 (7.7-7.7)	7.9 (7.8-8.0)	6.6 (6.2-7.8)			738
100	7.7 (7.5-8.0)	8.6 (7.9-9.1)	6.4 (6.2-6.6)	104	552	1,346
POTW in Section 6 Water						
Dilution water	7.5 (7.2-7.7)	8.5 (7.8-9.3)	6.8 (6.2-7.2)	146	230	688
1	7.6 (7.5-7.6)	7.9 (7.8-7.9)	6.8 (6.4-7.4)			725
3	7.6 (7.5-7.6)	7.8 (7.7-7.8)	6.8 (6.2-7.2)			675
10	7.5 (7.5-7.5)	7.8 (7.7-7.8)	6.9 (6.0-7.7)			660
30	7.4 (7.4-7.4)	7.7 (7.7-7.7)	6.7 (6.0-7.5)			613
100	7.0 (6.9-7.1)	7.7 (7.2-8.1)	6.4 (5.9-6.8)	91	122	448
Sampling Stations						
1	7.5 --	8.0 --	6.7 (6.3-7.3)	160	180	320
2	7.5 --	7.5 --	6.6 (6.3-7.2)	162	166	300
5	7.3 --	7.3 --	6.4 (5.7-7.1)	256	135	600
7	7.5 --	7.7 --	7.1 (6.5-7.4)	140	200	650
8	7.5 --	7.5 --	6.6 (6.1-7.2)	144	208	650
9	7.9 --	8.6 --	6.8 (6.1-7.5)	136	210	600
B-1	7.5 --	7.9 --	6.9 (6.5-7.1)	204	290	1,152

Table D-3. (Continued)

% Effluent Concentration (v/v)	x̄ Initial pH (Range)	Dissolved Oxygen (mg/l) x̄ Daily Initial (Range)	Dissolved Oxygen (mg/l) x̄ Daily Final (Range)	Alkalinity[a] (mg/l)	Hardness[a] (mg/l)	Initial Conductivity (µmohs/cm)
Reconstituted water	7.8 --	7.8 --	6.4 (6.1-6.9)			460
F0	7.3 --	6.8 --	6.7 (6.2-7.2)	151	158	235
B1	7.5 --	7.8 --	6.7 (6.3-7.2)	172	182	315
T1	7.8 --	8.0 --	6.6 (5.9-7.3)	156	164	335

[a]Alkalinity and hardness were done only once on 10 October 1983

Table D-4. Final Water Chemistry Data for Ceriodaphnia Tests, Birmingham, Alabama, October 1983

% Effluent Concentration (v/v)	x̄ pH (Range)	Dissolved Oxygen (mg/l) x̄ Daily Final (Range)
Coke Plant 1 in Station 2A Water		
Dilution	--	7.4 (7.1-7.8)
1	--	7.5 (7.2-7.8)
3	--	7.3 (7.1-7.6)
10	--	7.3 (7.1-7.5)
30	--	7.2 (6.6-7.6)
100	--	6.9 (6.2-7.4)
Coke Plant 2 in Station 3 Water		
Dilution water	--	7.2 (7.1-7.3)
1	--	7.3 (7.1-7.8)
3	--	7.3 (7.1-7.6)
10	--	7.3 (7.1-7.4)
30	--	7.3 (7.1-7.6)
100	--	7.2 (7.0-7.3)
POTW in Station 6		
Dilution water	7.7	7.4 (6.8-8.1)
1	7.7	7.3 (7.1-7.8)
3	7.8	7.3 (6.8-7.8)
10	7.8	7.4 (7.2-7.7)
30	7.8	7.3 (7.1-7.5)
100	--	7.0 --

Table D-4. (Continued)

% Effluent Concentration (v/v)	x̄ pH (Range)	Dissolved Oxygen (mg/l) x̄ Daily Final (Range)
Sampling Stations		
1	--	7.6 (7.3-7.8)
2	--	7.5 (7.2-7.6)
2A	--	7.5 (7.1-7.6)
3	--	7.5 (7.1-7.7)
5	--	7.3 (7.2-7.6)
6	--	7.4 (7.2-7.8)
7	--	7.3 (7.0-7.7)
8	--	7.3 (7.0-7.5)
9	--	7.2 (6.9-7.5)
11	--	7.4 (7.1-7.9)
Reconstituted water-1	--	7.5 (7.1-7.9)
Reconstituted water-2	--	7.5 (7.3-7.9)
Reconstituted water-3	--	7.6 (7.3-7.8)
B1	--	7.6 (7.4-7.8)
T1	--	7.5 (7.3-7.8)
F0	--	7.5 (7.2-7.8)

Table D-5. Seven-Day Percent Survival of Larval Fathead Minnows Exposed to Water From Various Ambient Stations, Birmingham, Alabama, October 1983

	Tributary Stations			
Replicate	B2	F0	B1	T1
A	100	100	100	100
B	100	100	100	100
C	100	90	100	100
D	100	90	100	100
Mean	100	95	100	100

Table D-6. Mean Individual Weights (mg) of Larval Fathead Minnows After Seven Days of Exposure to Water From Various Tributary Ambient Stations, Birmingham, Alabama, October 1983

	Tributary Stations			
Replicate	B2	F0	B1	T1
A	0.380	0.390	0.400	0.400
B	0.360	0.420	0.350	0.385
C	0.289	0.328	0.435	0.405
D	0.380	0.367	0.355	0.428
Weighted mean	0.352	0.378	0.384	0.405
SE	0.018	0.019	0.019	0.018

Table D-7. Percent Survival and Young Production of *Ceriodaphnia* Exposed to Water From Ambient Stations, Birmingham, Alabama, October 1983

Tributary Station	Percent Survival	Mean Number of Young Per Female	Confidence Intervals
B2	100	28.3	22.2-34.4
F0	100	15.0	13.2-16.8
B1	100	17.7	14.6-20.8
T1	90	18.6	16.5-20.5

Appendix E
Biological Data

Table E-1. Abundance (units/mm²) of Periphytic Algae on Natural Substrates in Five Mile Creek, February 1983

Taxa	Sampling Station 1	2	3	4	5	6	7	8
Bacillariophyta (Diatoms)								
Achnanthes	D[a]	20,599	2,943	1,197	600	1,417	14	3
Amphipleura	--	0	0	0	0	0	0	0
Amphora	R	50	0	0	0	57	6	0
Asterionella	--	0	0	0	0	57	0	0
Caloneis	--	100	0	0	0	0	0	0
Cocconeis	R	200	150	0	0	0	0	0
Cyclotella	--	0	100	0	0	113	0	0
Cymbella	R	1,796	1,347	948	48	1,871	6	6
Denticula	--	0	0	0	0	57	0	0
Diatoma	R	3,491	0	150	14	340	0	0
Frustulia	--	0	0	0	0	0	0	0
Gomphonema	R	299	100	299	17	850	3	0
Gyrosigma	--	0	50	0	0	0	0	0
Melosira	--	0	0	0	0	113	0	0
Meridion	R	100	50	0	3	57	0	0
Navicula	R	1,895	1,047	2,095	31	4,648	65	57
Nitzschia	R	3,940	1,397	599	20	3,798	14	14
Pinnularia	--	0	50	0	0	0	0	0
Rhoicosphenia	R	50	50	200	3	0	0	0
Rhopalodia	--	0	0	0	0	0	0	0
Surirella	--	349	449	249	14	1,644	0	0
Synedra	--	0	0	0	0	567	3	6
Total Bacillariophyta	D	32,869	7,733	5,737	750	15,589	111	86
Chlorophyta (Green Algae)								
Ankistrodesmus	--	0	50	0	0	0	0	0
Cladophora	D	1,995	748	1,147	0	4,365	0	0
Stigeoclonium	C	100	3,541	4,888	295	227	1,247	77
Tetrastrum	--	0	200	0	0	0	0	0
Total Chlorophyta	D	2,095	4,539	6,035	295	4,592	1,247	77
Cyanophyta (Blue-green Algae)								
Chroococcus	C	0	898	1,197	0	0	0	0
Lyngbya	R	6,833	5,985	13,466	465	0	82	31
Oscillatoria	--	648	848	299	91	227	0	0
Phormidium	--	599	0	0	0	0	0	0
Unidentified #1	R	0	1,197	5,536	65	0	0	0
Unidentified #2	--	0	3,940	0	0	0	0	0
Unidentified #3	--	0	0	7,581	0	0	0	0
Total Cyanophyta	A	8,080	12,868	28,079	740	227	82	31
Total Periphyton		43,044	25,140	39,851	1,785	20,408	1,440	194

[a]Not sampled quantitatively for periphyton abundance. D = dominant (>20 percent of total units counted), A abundant (10-20 percent); C = common (5-10 percent); R = rare (<5 percent); dashes indicate not observed.

Table E-2. Abundance (units/mm²) of Periphytic Algae on Natural Substrates in Black Creek, February 1983

Taxa	Station B2[a]
Bacillariophyta (Diatoms)	
Achnanthes	A
Amphipleura	R
Amphora	--
Asterionella	--
Caloneis	--
Cocconeis	--
Cyclotella	--
Cymbella	R
Denticula	--
Diatoma	R
Frustulia	C
Gomphonema	R
Gyrosigma	--
Melosira	R
Meridion	--
Navicula	D
Nitzchia	C
Pinnularia	--
Rhoicosphenia	R
Rhopalodia	R
Surirella	C
Synedra	R
Total Bacillariophyta	D
Chlorophyta (Green Algae)	
Ankistrodesmus	--
Cladophora	--
Stigeoclonium	A
Tetrastrum	--
Total Chlorophyta	A
Cyanophyta (Blue-green Algae)	--
Chroococcus	--
Lyngbya	C
Oscillatoria	C
Phormidium	--
Unidentified #1	--
Unidentified #2	--
Unidentified #3	--
Total Cyanophyta	A
Rhodophyta (Red Algae)	
Audouinella	C
Total Rhodophyta	C

[a] Not sampled quantitatively for periphyton abundance.
D = dominant (>20 percent of total units counted),
A = abundant (10-20 percent); C = common (5-10 percent);
R = rare (<5 percent),
Dashes indicate not observed.

Note: Wood substrates rather than rocks were sampled in Black Creek.

Table E-3. Summary of Periphyton Species Composition and Diversity on Natural Substrates in Black Creek, February 1983

Parameter	Station B2[a]
Density (units mm²)	
Diatoms	--[a]
Green algae	--
Blue-green algae	--
Total Periphyton	--
Percent Composition	
Diatoms	58.02
Green algae	18.18
Blue-green algae	14.17
Red algae	9.63
Taxa (Genus) Diversity ($\bar{d}$)	3.30
Taxa (Genus) Equitability (e)	0.82
Total Taxa Identified	17

[a] Not sampled quantitatively for periphyton abundance.

Note: Wood substrates rather than rocks were sampled in Black Creek.

Table E-4. Chlorophyll *a* and Biomass Data and Statistical Results for Periphyton Collected From Natural Substrates in Five Mile Creek, February 1983

Parameter	Sampling Station 1	2	3	4	5	6	7	8
Chlorophyll *a* (mg m^2)								
Rep 1	84.6	207.6	230.8	546.2	11.9	150.8	1.0	3.6
Rep 2	5.4	253.8	115.4	707.6	30.8	630.8	9.2	13.5
Rep 3	12.7	907.6	70.0	261.6	17.3	538.4	1.6	8.2
Mean	34.2	436.3	138.7	505.1	20.0	440.0	3.9	8.4
Biomass (g m^2)								
Rep 1	7.2	22.1	33.3	45.8	2.3	92.3	6.7	8.4
Rep 2	0.2	37.0	6.1	37.9	2.1	110.2	10.4	5.7
Rep 3	2.9	33.2	7.8	8.1	1.4	208.5	6.5	5.8
Mean	3.4	30.8	15.8	30.6	2.0	137.0	7.9	6.6
Autotrophic Index (Weber 1973)	99	71	114	61	98	311	2,015	790
Statistical Results:[a]								
Chlorophyll *a*								
F = 17.52 Station[b]	7	8	1	5	3	2	6	4
P = 0.001 Mean[c]	1,324	2,140	2,974	2,975	4,822	5,898	5,920	6,146
Biomass								
F = 13.28 Station	5	1	8	7	3	4	2	6
P = 0.001 Mean	1,076	1,210	2,021	1,162	2,558	3,240	3,437	4,864

[a]Results based on analysis of variance and Tukey multiple comparison test performed on data transformed with natural logarithms [ln(x + 1)]. Stations underscored by a continuous line were not significantly different (P = 0.05) according to Tukey's test.
[b]Stations are listed in order of increasing mean values.
[c]Means of transformed data.

Table E-5. Chlorophyll *a* and Biomass Data for Periphyton Collected From Natural Substrates in Black Creek, February 1983

Parameter	Station B2
Chlorophyll *a* (mg m^2)	
Rep 1	1.6
Rep 2	--
Rep 3	--
Mean	1.6
Biomass (g m^2)	
Rep 1	5.2
Rep 2	--
Rep 3	--
Mean	5.2
Autotrophic Index (Weber 1973)	3,219

Table E-6. Ranked Abundance Listing of all Macroinvertebrates Collected From Five Mile Creek, February 1983

Species Name	Number	Percent	Cumulative Percent
Imm. tub. w cap. chaet.	152.341	25.852	25.852
Cricotopus tremulus Grp. L.	112.163	19.034	44.886
Tubifex tubifex	73.241	12.429	57.315
Imm. tub. w o cap. chaet.	30.970	5.256	62.571
Cricotopus bicinctus Grp. L.	30.552	5.185	67.756
Chironomidae P.	23.019	3.906	71.662

Table E-6. (Continued)

Species Name	Number	Percent	Cumulative Percent
Nais bretscheri	17.578	2.983	74.645
Thienemannimyia Grp. L.	14.230	2.415	77.060
Limnodrilus hoffmeisteri	12.974	2.202	79.261
Limnodrilus udekemianus	12.556	2.131	81.392
Cheumatopsyche L.	8.370	1.420	82.813
Stenonema N.	7.952	1.349	84.162
Caenis N.	7.115	1.207	85.369
Cryptochironomus L.	5.859	0.994	86.364
Baetis N.	5.022	0.852	87.216
Corbicula	4.604	0.781	87.997
Tricladida	3.767	0.639	88.636
Heptageniinae N.	3.767	0.639	89.276
Baetidae N.	3.348	0.568	89.844
Isonychia N.	3.348	0.568	90.412
Nemertea	2.930	0.497	90.909
Heptageniidae N.	2.930	0.497	91.406
Hydropsyche L.	2.930	0.497	91.903
Polypedilum scalaenum L.	2.930	0.497	92.401
Chimarra L.	2.930	0.497	92.898
Lirceus	2.511	0.426	93.324
Amphinemura N.	2.511	0.426	93.750
Elmidae	2.511	0.426	94.176
Psephenus L.	2.511	0.426	94.602
Branchiura sowerbyi	2.093	0.355	94.957
Enchytraeidae	2.093	0.355	95.313
Corydalus L.	1.674	0.284	95.597
Agapetus L.	1.674	0.284	95.881
Empididae L.	1.674	0.284	96.165
Turbellaria	1.256	0.213	96.378
Pristina breviseta	1.256	0.213	96.591
Limno. claparedianus	1.256	0.213	96.804
Acarina	1.256	0.213	97.017
Ephemeroptera N.	1.256	0.213	97.230
Symphitopsyche L.	1.256	0.213	97.443
Simulium L.	1.256	0.213	97.656
Nais pardalis	0.837	0.142	97.798
Argia N.	0.837	0.142	97.940
Micrasema L.	0.837	0.142	98.082
Stenelmis A.	0.837	0.142	98.224
Natarsia L.	0.837	0.142	98.367
Cricotopus cylindricus Grp. L.	0.837	0.142	98.509
Grastropoda	0.837	0.142	98.651
Nais variabilis	0.419	0.071	98.722
Pristina longiseta leidy	0.419	0.071	98.793
Bothrio. vejdovskyanum	0.419	0.071	98.864
Plecoptera N.	0.419	0.071	98.935
Acroneuria N.	0.419	0.071	99.006
Dolophilodes L.	0.419	0.071	99.077
Diplectrona L.	0.419	0.071	99.148
Glossoma L.	0.419	0.071	99.219
Coleoptera L.	0.419	0.071	99.290
Optioservus L.	0.419	0.071	99.361
Stenelmis L.	0.419	0.071	99.432
Ablabesmyia L.	0.419	0.071	99.503
Pseudodiamesa L.	0.419	0.071	99.574
Parakiefferiella L.	0.419	0.071	99.645
Rheocricotopus L.	0.419	0.071	99.716
Smittia L.	0.419	0.071	99.787
Simuliidae L.	0.419	0.071	99.858
Tipula L.	0.419	0.071	99.929
Ancylidae	0.419	0.071	100.000

Note: L. larva
P. pupa
N. nymph
A. adult

Table E-7. Density (No. m²) of Benthic Macroinvertebrates from Replicate Samples Collected in Five Mile Creek, Birmingham, Alabama, February 1983

	Station 1		Station 1		Station 1		Station 2		Station 2		Station 2		Station 3	
	Rep 1		Rep 2		Rep 3		Rep 1		Rep 2		Rep 3		Rep 1	
Species	Number m²/div	Pct Comp	Number m²/div	Pct Comp	Number m²/div	Pct Comp	Number m²/div	Pct Comp	Number m²/div	Pct Comp	Number m²/div	Pct Comp	Number m²/div	Pct Comp
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	22.60	2.99	0.00	0.00	0.00	0.00	56.50	27.78	192.10	44.74
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.30	5.56	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	11.30	1.49	0.00	0.00	0.00	0.00	33.90	16.67	67.80	15.79
Nais [illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	79.10	53.85	11.30	5.56	45.20	10.53
[illegible]	0.00	0.00	11.30	2.70	11.30	1.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chironomatonsyche	45.20	18.18	56.50	13.51	90.40	11.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stenonema N	22.60	9.09	11.30	2.70	90.40	11.94	0.00	0.00	0.00	0.00	0.00	0.00	56.50	13.16
Caenis N	33.90	13.64	22.60	5.41	56.50	7.46	22.60	33.33	0.00	0.00	11.30	5.56	11.30	2.63
Cryptochironomus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baetis N	0.00	0.00	0.00	0.00	56.50	7.46	22.60	33.33	22.60	15.38	11.30	5.56	0.00	0.00
Corbicula	0.00	0.00	45.20	10.81	0.00	0.00	11.30	16.67	0.00	0.00	0.00	0.00	0.00	0.00
Tricladida	0.00	0.00	0.00	0.00	33.90	4.48	0.00	0.00	11.30	7.69	22.60	11.11	11.30	2.63
Heptageniidae N	0.00	0.00	0.00	0.00	56.50	7.46	0.00	0.00	0.00	0.00	0.00	0.00	22.60	5.26
Baetidae N	0.00	0.00	33.90	8.11	0.00	0.00	0.00	0.00	0.00	0.00	22.60	11.11	0.00	0.00
Isonychia N	22.60	9.09	0.00	0.00	11.30	1.49	0.00	0.00	11.30	7.69	0.00	0.00	11.30	2.63
Nemertea	0.00	0.00	56.50	13.51	11.30	1.49	0.00	0.00	0.00	0.00	11.30	5.56	0.00	0.00
Heptageniidae N	22.60	9.09	45.20	10.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsyche L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polypedilum scalaenum L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cricotopus L	0.00	0.00	22.60	5.41	56.50	7.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lirceus	0.00	0.00	22.60	5.41	11.30	1.49	11.30	16.67	11.30	7.69	0.00	0.00	0.00	0.00
Amphinemura N	11.30	4.55	0.00	0.00	33.90	4.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae L	22.60	9.09	11.30	2.70	0.00	0.00	0.00	0.00	0.00	0.00	11.30	5.56	0.00	0.00
Psephenus L	11.30	4.55	11.30	2.70	22.60	2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Branchiura sowerbyi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Enchytraeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corydalus L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agapetus L	11.30	4.55	11.30	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Empididae L	0.00	0.00	0.00	0.00	11.30	1.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turbellaria	0.00	0.00	11.30	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pristina breviseta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnodriloides claparedianus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acarina	0.00	0.00	11.30	2.70	22.60	2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other species	45.20	18.18	33.90	8.11	146.90	19.40	0.00	0.00	11.30	7.69	0.00	0.00	11.30	2.63
Station Total	248.60		418.10		757.10		67.80		146.90		203.40		429.40	

Table E-7. (Extended)

Species	Station 3 Rep 3 Number Indiv	Station 3 Rep 3 Pct Comp	Station 3 Rep 3 Number Indiv	Station 3 Rep 3 Pct Comp	Station 4 Rep 1 Number Indiv	Station 4 Rep 1 Pct Comp	Station 4 Rep 2 Number Indiv	Station 4 Rep 2 Pct Comp	Station 4 Rep 3 Number Indiv	Station 4 Rep 3 Pct Comp	Station 5 Rep 1 Number Indiv	Station 5 Rep 1 Pct Comp	Station 5 Rep 2 Number Indiv	Station 5 Rep 2 Pct Comp
Imm Tub w cap chaet	45 20	13 79	0 00	0 00	1412 50	55 56	2214 80	54 75	11 30	5 00	11 30	11 11	293 80	44 07
Cricot tremulus Grp L	124 30	37 93	214 70	48 72	293 80	11 56	56 50	1 40	67 80	30 00	56 50	55 56	79 10	11 86
Tubifex tubifex	0 00	0 00	0 00	0 00	452 00	17 78	1469 00	36 31	11 30	5 00	11 30	11 11	33 90	5 08
Imm Tub w o cap chaet	0 00	0 00	0 00	0 00	33 90	1 33	33 90	0 84	22 60	10 00	0 00	0 00	56 50	8 47
Cricot pictet Grp L	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	11 30	1 69
Chironomidae P	11 30	3 45	67 80	15 38	56 50	2 22	67 80	1 68	22 60	10 00	0 00	0 00	33 90	5 08
Nais bretscheri	22 60	6 90	90 40	20 51	113 00	4 44	22 60	0 56	79 10	35 00	0 00	0 00	0 00	0 00
Thienemannimyia Grp L	22 60	6 90	0 00	0 00	22 60	0 89	0 00	0 00	0 00	0 00	11 30	11 11	11 30	1 69
Limnodrilus hoffmeisteri	0 00	0 00	0 00	0 00	0 00	0 00	22 60	0 56	0 00	0 00	0 00	0 00	56 50	8 47
Limnodrilus udekemianus	11 30	3 45	0 00	0 00	90 40	3 56	56 50	1 40	0 00	0 00	11 30	11 11	79 10	11 86
Cheumatopsyche L	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Stenonema N	22 60	6 90	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Caenis N	0 00	0 00	11 30	2 56	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Cryptochironomus L	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Baetis N	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Corbicula	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Tricladida	11 30	3 45	0 00	0 00	11 30	0 44	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Heptageniidae N	11 30	3 45	11 30	2 56	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Baetidae N	0 00	0 00	11 30	2 56	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Isonychia N	33 90	10 34	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Nemertea	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Heptageniidae N	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Hydropsyche L	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Polycedilum scalaenum L	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Chimarra L	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Lepidus	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Amphinemura N	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Elmidae L	0 00	0 00	0 00	0 00	0 00	0 00	11 30	0 28	0 00	0 00	0 00	0 00	11 30	1 69
Psephenus L	11 30	3 45	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Branchiura sowerbyi	0 00	0 00	0 00	0 00	11 30	0 44	45 20	1 12	0 00	0 00	0 00	0 00	0 00	0 00
Enchytraeidae	0 00	0 00	11 30	2 56	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Corydalus L	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Agapetus L	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Empididae L	0 00	0 00	11 30	2 56	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Turbellaria	0 00	0 00	0 00	0 00	0 00	0 00	22 60	0 56	0 00	0 00	0 00	0 00	0 00	0 00
Pristina breviseta	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Limnodrilus claparedianus	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Acarina	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Other species	0 00	0 00	11 30	2 56	45 20	1 78	22 60	0 56	11 30	5 00	0 00	0 00	0 00	0 00
Station Total	327 70		440 70		2542 50		4045 40		226 00		101 70		666 70	

Table E-7. (Extended)

Species	Station 5 Rep 3 Number Indiv.	Station 5 Rep 3 Pct Comp.	Station 6 Rep 1 Number Indiv.	Station 6 Rep 1 Pct. Comp.	Station 6 Rep 2 Number Indiv.	Station 6 Rep 2 Pct. Comp.	Station 6 Rep 3 Number Indiv.	Station 6 Rep 3 Pct Comp.	Station 7 Rep 1 Number Indiv.	Station 7 Rep 1 Pct. Comp.	Station 7 Rep 2 Number Indiv.	Station 7 Rep 2 Pct Comp.	Station 7 Rep 3 Number Indiv.	Station 7 Rep 3 Pct Comp.
Imm. Tub. w. cap. chaet.	11.30	16.67	90.40	5.00	0.00	0.00	22.60	2.27	0.00	0.00	0.00	0.00	0.00	0.00
Cricot. tremulus Grp. L.	33.90	50.00	655.40	36.25	67.80	26.09	519.80	52.27	158.20	41.18	124.30	33.33	90.40	53.33
Tubifex tubifex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Imm. Tub. w.o cap. chaet.	0.00	0.00	237.30	13.12	11.30	4.35	101.70	10.23	33.90	8.82	45.20	12.12	45.20	26.67
Cricot. bicinct. Grp. L.	0.00	0.00	293.80	16.25	113.00	43.48	237.30	23.86	22.60	5.88	22.60	6.06	0.00	0.00
Chironomidae P.	11.30	16.67	33.90	1.87	22.60	8.70	0.00	0.00	56.50	14.71	33.90	9.09	11.30	6.67
Nais bretscheri	0.00	0.00	0.00	0.00	0.00	0.00	11.30	1.14	0.00	0.00	0.00	0.00	0.00	0.00
Thienemannimyia Grp. L.	0.00	0.00	169.50	9.37	11.30	4.35	33.90	3.41	11.30	2.94	22.60	6.06	0.00	0.00
Limnodrilus hoffmeisteri	0.00	0.00	56.50	3.12	22.60	8.70	0.00	0.00	0.00	0.00	56.50	15.15	11.30	6.67
Limnodrilus udekemianus	0.00	0.00	33.90	1.87	11.30	4.35	11.30	1.14	11.30	2.94	0.00	0.00	0.00	0.00
Cheumatopsyche L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.30	2.94	0.00	0.00	0.00	0.00
Stenonema N.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caenis N.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cryptochironomus L.	0.00	0.00	146.90	8.12	0.00	0.00	11.30	1.14	0.00	0.00	0.00	0.00	0.00	0.00
Baetis N.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corbicula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.30	2.94	0.00	0.00	0.00	0.00
Tricladida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniinae N.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baetidae N.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isonychia N.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nemertea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniidae N.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsyche L.	0.00	0.00	33.90	1.87	0.00	0.00	0.00	0.00	11.30	2.94	22.60	6.06	0.00	0.00
Polypedilum scalaenum L.	0.00	0.00	22.60	1.25	0.00	0.00	0.00	0.00	33.90	8.82	11.30	3.03	0.00	0.00
Chimarra L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lirceus	11.30	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphinemura N.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Psephenus L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.30	3.03	0.00	0.00
Branchiura sowerbyi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Enchytraeidae	0.00	0.00	11.30	0.62	0.00	0.00	0.00	0.00	22.60	5.88	0.00	0.00	0.00	0.00
Corydalus L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agapetus L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.30	6.67
Empididae L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turbellaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pristina breviseta	0.00	0.00	11.30	0.62	0.00	0.00	11.30	1.14	0.00	0.00	0.00	0.00	0.00	0.00
Limno. claparedianus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acarina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other species	0.00	0.00	11.30	0.62	0.00	0.00	33.90	3.41	0.00	0.00	22.60	6.06	0.00	0.00
Station Total	67.80		1808.00		259.90		994.40		384.20		372.90		169.50	

Table E-7. (Extended)

Species	Station 8 Rep 1 Number Indiv.	Station 8 Rep 1 Pct Comp	Station 8 Rep 2 Number Indiv.	Station 8 Rep 2 Pct. Comp.	Station 8 Rep 3 Number Indiv.	Station 8 Rep 3 Pct. Comp.
Imm. Tub. w. cap. chaet.	0.00	0.00	0.00	0.00	0.00	0.00
Cricot. tremulus Grp. L.	0.00	0.00	45.20	16.00	113.00	28.57
Tubifex tubifex	0.00	0.00	0.00	0.00	0.00	0.00
Imm. Tub. w.o cap. chaet.	0.00	0.00	56.50	20.00	22.60	5.71
Cricot. bicinct. Grp. L.	22.60	28.57	33.90	12.00	56.50	14.29
Cheumatopsyche L.	0.00	0.00	0.00	0.00	79.10	20.00
Nais bretscheri	0.00	0.00	0.00	0.00	0.00	0.00
Thienemannimyia Grp. L.	11.30	14.29	11.30	4.00	22.60	5.71
Limnodrilus hoffmeisteri	0.00	0.00	33.90	12.00	11.30	2.86
Limnodrilus udekemianus	0.00	0.00	0.00	0.00	22.60	5.71
Cheumatopsyche L.	11.30	14.29	0.00	0.00	11.30	2.86
Stenonema N.	0.00	0.00	0.00	0.00	0.00	0.00
Caenis N.	0.00	0.00	0.00	0.00	0.00	0.00
Cryptochironomus L.	0.00	0.00	0.00	0.00	0.00	0.00
Baetis N.	22.60	28.57	0.00	0.00	0.00	0.00
Corbicula	0.00	0.00	33.90	12.00	11.30	2.86
Tricladida	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniinae N.	0.00	0.00	0.00	0.00	0.00	0.00
Baetidae N.	0.00	0.00	0.00	0.00	0.00	0.00
Isonychia N.	0.00	0.00	0.00	0.00	0.00	0.00
Nemertea	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniidae N.	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsyche L.	0.00	0.00	0.00	0.00	11.30	2.86
Polypedilum scalaenum L.	0.00	0.00	0.00	0.00	0.00	0.00
Chimarra L.	0.00	0.00	0.00	0.00	0.00	0.00
Lirceus	0.00	0.00	0.00	0.00	0.00	0.00
Amphinemura N.	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae L.	0.00	0.00	0.00	0.00	0.00	0.00
Psephenus L.	0.00	0.00	0.00	0.00	0.00	0.00
Branchiura sowerbyi	0.00	0.00	0.00	0.00	0.00	0.00
Enchytraeidae	0.00	0.00	0.00	0.00	11.30	2.86
Corydalus L.	0.00	0.00	22.60	8.00	22.60	5.71
Agapetus L.	11.30	14.29	0.00	0.00	0.00	0.00
Empididae L.	0.00	0.00	0.00	0.00	0.00	0.00
Turbellaria	0.00	0.00	0.00	0.00	0.00	0.00
Pristina breviseta	0.00	0.00	0.00	0.00	0.00	0.00
Limno. claparedianus	0.00	0.00	33.90	12.00	0.00	0.00
Acarina	0.00	0.00	0.00	0.00	0.00	0.00
Other species	0.00	0.00	11.30	4.00	0.00	0.00
Station Total	79.10		282.50		395.50	

Table E-8. **Density (No./m²) of Benthic Macroinvertebrates From Replicate Samples Collected in Black Creek, Birmingham, Alabama, February 1983**

	Station B2					
Species	Number Indiv.	Pct. Comp.	Number Indiv	Pct Comp.	Number Indiv.	Pct Comp.
Imm. Tub. w cap. chaet.	0.00	0.00	0.00	0.00	0.00	0.00
Cricot. tremulus Grp. L.	33.90	12.50	0.00	0.00	22.60	28.57
Tubifex tubifex	0.00	0.00	0.00	0.00	0.00	0.00
Imm. Tub. w o cap. chaet.	90.40	33.33	11.30	9.09	22.60	28.57
Cricot. bicinct. Grp. L.	0.00	0.00	11.30	9.09	0.00	0.00
Chironomidae P.	0.00	0.00	0.00	0.00	0.00	0.00
Nais bretscheri	0.00	0.00	0.00	0.00	0.00	0.00
Thienemannimyia Grp. L.	0.00	0.00	0.00	0.00	0.00	0.00
Limnodrilus hoffmeisteri	79.10	29.17	0.00	0.00	0.00	0.00
Limnodrilus udekemianus	0.00	0.00	0.00	0.00	0.00	0.00
Cheumatopsyche L.	0.00	0.00	0.00	0.00	0.00	0.00
Stenonema N.	0.00	0.00	11.30	9.09	0.00	0.00
Caenis N.	0.00	0.00	11.30	9.09	11.30	14.29
Cryptochironomus L.	0.00	0.00	0.00	0.00	0.00	0.00
Baetis N.	0.00	0.00	0.00	0.00	0.00	0.00
Corbicula	0.00	0.00	11.30	9.09	0.00	0.00
Tricladida	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniinae N.	0.00	0.00	0.00	0.00	0.00	0.00
Baetidae N.	11.30	4.17	11.30	9.09	0.00	0.00
Isonychia N.	0.00	0.00	0.00	0.00	0.00	0.00
Nemertea	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniidae N.	0.00	0.00	11.30	9.09	0.00	0.00
Hydropsyche L.	0.00	0.00	0.00	0.00	0.00	0.00
Polypedilum scalaenum L.	11.30	4.17	0.00	0.00	0.00	0.00
Chimarra L.	0.00	0.00	0.00	0.00	0.00	0.00
Lirceus	0.00	0.00	0.00	0.00	0.00	0.00
Amphinemura N.	11.30	4.17	11.30	9.09	0.00	0.00
Elmidae L.	0.00	0.00	0.00	0.00	0.00	0.00
Psephenus L.	0.00	0.00	0.00	0.00	0.00	0.00
Branchuira sowerbyi	0.00	0.00	0.00	0.00	0.00	0.00
Enchytraeidae	0.00	0.00	0.00	0.00	0.00	0.00
Corydalus L.	0.00	0.00	0.00	0.00	0.00	0.00
Agapetus L.	0.00	0.00	0.00	0.00	0.00	0.00
Empididae L.	11.30	4.17	11.30	9.09	0.00	0.00
Turbellaria	0.00	0.00	0.00	0.00	0.00	0.00
Pristina breviseta	11.30	4.17	0.00	0.00	0.00	0.00
Limno. claparedianus	0.00	0.00	0.00	0.00	0.00	0.00
Acarina	0.00	0.00	0.00	0.00	0.00	0.00
Other species	11.30	4.17	22.60	18.18	22.60	28.57
Station Total	271.20		124.30		79.10	

Table E-9. Density of Benthic Macroinvertebrates in Replicate Samples From Five Mile Creek, Birmingham, Alabama, October 1983

	Station 1				Station 2				Station 3				Station 5			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Ephemeroptera																
Isonychia	1,475	1,163	527	1,055		11	11	7								
Baetis	323	527	226	359												
Stenonema	409	388	366	388												
Tricorythodes			11	4												
Plecoptera																
Leuctridae		11		4												
Trichoptera																
Chimarra	183	11		65												
Hydropsyche	86	22	32	47	11			4			11	4				
Cheumatopsyche	3,186	1,270	893	1,783												
Hydropsychidae P.	11			4												
Leucotrichia		75	97	57												
Coleoptera																
Psephenus	54	118	97	90												
Helicus	11	11	22	14												
Stenelmis	151	183	65	133	43		54	32		22		7				
Dubiraphia																
Berosus	11			4					22		43	22				
Megaloptera																
Corydalis	161	43	97	100												
Diptera																
Simulidae	11			4												
Antocha		22	43	22												
Tipula		11		4												
Hemerodromia						11		4	11			4				
Probezzia																
Chironomidae P.	32	65	11	36	32			11	97	97	75	90	172	75	54	100
Ablabesmyia	11	108	118	80					75	183	172	144	151	32	97	93
Procladius									32	129	237	133		11	22	11
Tanypus															11	4
Pentaneura															11	4
Dicrotendipes									11			4	32	54		
Polypedilum																29
Chironomus										11	108	39	54	22	22	32
Glyptotendipes																
Cryptochironomus																
Rheotanytarsus	86	215	108	136												
Tanytarsus																
Corynoneura		43		14												
Cricoptopus		22	22	14	183	118	86	129	161	215	323	233		86		29
Psectrocladius									11		22	11	151	11	54	72
Trichocladius																
Micropsectra																
Nanocladius																
Odonata																
Dromogomphus																
Argia		22		7	22			7	54	75	32	54	32	11	22	22
Other																
Physa									86	66		50				
Corbicula		11		4		1		4								
Ferrissima			32	11			22	7	97	151	151	133	11			4
Planaria	32			11	11			4								
Oligochaete		11	11	7	75		344	140	581	1,162	463	736	603	592	538	578
Nematoda						11		4								
Decapoda					11			4			22	7				
Lirceus	32	22		18	11			4								

Table E-9. (Continued)

	Station 6				Station 7				Station 8				Station 9			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Ephemeroptera																
Isonychia														32	172	68
Baetis	140	118	22	93	1,001	560	258	606	1,528	2,207	3,251	2,329		1,195	883	692
Stenonema	11	32	11	18	11	22		11	301	538	732	524	161	183	312	219
Tricorythodes	75	22	11	36			108	36	592	1,442	538	858	452	75		176
Plecoptera																
Leuctridae																
Trichoptera																
Chimarra																
Hydropsyche					11			4		11		4			377	126
Cheumatopsyche	248	226		158	409	54	32	165	22	592	1,066	560	11	474	689	391
Hydropsychidae P.																
Leucotrichia		11		4					11	44		18			129	43
Coleoptera																
Psephenus	1			4												
Helicus																
Stenelmis	22			7	32		32	22		22	11	11	43	43	65	50
Dubiraphia														54		18
Berosus	11	54	22	29									11	118	65	65
Megaloptera																
Corydalis	54	11	11	25	75		75	50		32	43	25	22	118	172	104
Diptera																
Simulidae																
Antocha																
Tipula																
Hemerodromia					22		11	11								
Probezzia			32	11									32			11
Chironomidae P.	355	205	86	215	151	301	355	269		22	22	14	258	118	151	176
Ablabesmyia	140	75	280	165	22		366	129	32	32	22	28	463	11	32	169
Procladius							11	4					11			4
Tanypus			11	4			32	11								
Pentaneura																
Dicrotendipes													108			36
Polypedilum	1,033	936	452	807	43	32	22	32	11	54	11	25	248	161	323	244
Chironomus	54	22	22	32	22		65	29								
Glyptotendipes		11	11	7												
Cryptochironomus	54	75	108	79			11	4								
Tribelos																
Rheotanytarsus	11	86		32	43	151	323	172	11		32	14				
Tanytarsus	86	22	32	47	474	431	398	434	32	22	161	72	710		32	248
Corynoneura		11		4							11	4		1		4
Cricoptopus	2,110	1,765	560	1,478	1,152	1,733	1,238	1,374	43	43	22	36	1,808	1,324	1,259	1,464
Psectrocladius	65		97	54	65	11	22	32								
Trichocladius					22	22	11	18								
Microspectra													65			22
Nanocladius														11		4
Odonata																
Dromogomphus									22			7		1		4
Argia								32	11				22	22		14
Other																
Physa											11	4				
Corbicula	75	65		47					86	377	4,370	1,611	464	1,389	657	836
Ferrissima	11	11	22	14	22		43	22			54	18	22			7
Planaria																
Oligochaete	118	140	355	205	54	11	140	68	65	43	54	54	258	65	151	158
Nematoda		22		7					11			4	11	11		7
Decapoda					11			7								
Lirceus		43		14												

Table E-10. Density (No./m²) of Benthic Macroinvertebrates From Replicate Samples of the Tributaries to Five Mile Creek, Birmingham, Alabama, October 1983

	Head Waters (F0)				Barton Branch (B1)				Tarrant Creek (T1)			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Ephemeroptera												
Isonychia	32	11	97	47	32	11	22	22				
Baetis	592	732	2,293	1,206	97	108	75	93	1,033	969	420	807
Stenonema	129	140	237	169	43	11	108	54				
Caenis	22	22	43	29	172	118	75	122				
Tricorythodes	22	32	43	32	22	22	11	18				
Total				1,483				309				807
Plecoptera												
Leuctridae												
Trichoptera												
Chimarra												
Hydropsyche	43	43	151	93	11	11		7		75	32	36
Cheumatopsyche		366	1,195	520	161	172	65	133	54	1,281	151	495
Hydropsychidae P.		11	11	7						108	54	54
Leucotrichia							22	7				
Anagepetus									32			11
Total				620				147				596
Coleoptera												
Psephenus	11			4	22		11	11				
Helicus		11		4	11	22	11	14				
Stenelmis	22	43	11	25	54	11	43	36	11		32	14
Dubiraphia					11			4				
Berosus	22	118	151	97	22	11	11	14				
Peltodytes												
Laccobius												
Total				130				79				14
Megaloptera												
Corydalis					11	11	22	14				
Diptera												
Limnophora						11		4				
Simulidae												
Antocha					54	11	65	43	22	75	32	43
Tipula												
Hemerodromia												
Probezzia												
Chironomidae P.		11	22	11	291	366	226	298	75	86	32	65
Ablabesmyia	75	32	97	68	420	549	581	517	86	161	65	104
Procladius												
Tanypus												
Pentaneura												
Dicrotendipes		11		4	108	194	118	140	22			7
Polypedilum		22		7	22		11	11				
Chironomus												
Glyptotendipes												
Cryptochironomus		11		4								
Tribelos					194	140	97	144				
Rheotanytarsus												
Tanytarsus		1	11	7	118	495	624	413	75	11	32	39
Corynoneura												
Cricoptopus	54	32	97	61	1,109	1,119	893	1,041	1,022	291	151	488
Psectrocladius		32		11	54	86	118	86				
Trichocladius												
Micropsectra												
Nanocladius					151	54	65	90				
Total				173				2,787				746

Table E-10. (Continued)

	Head Waters (F0)				Barton Branch (B1)				Tarrant Creek (T1)			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Odonata												
Dromogomphus												
Boyeria												
Argia	11		11	7	65			22				
Hetaerina											11	4
Other												
Physa						11		4				
Corbicula												
Ferrissima						22	11	11				
Planaria	420	280	291	330					388	549	22	319
Oligochaete		32	43	25	312	237	603	384	54	301	388	248
Nematoda					11	11	22	14		11		4
Decapoda												
Lirceus					323	549	183	352	398	452	258	370
Hyalella												

Table E-11. Occurrence of Benthic Macroinvertebrates of Five Mile Creek From Quantitative and Qualitative Samples, October 1983

	Sampling Station										
Taxa	1	2	3	5	6	7	8	9	F0	B1	T1
Ephemeroptera											
Isonychia	x	x						x	x	o	x
Baetis	x				x	x	x	x	x	x	x
Stenonema	x				o	x	x	x	x	x	x
Caenis							x		x	x	
Tricorythodes	o				x	x	x	x	x	o	
Plecoptera											
Leuctridae	o										
Trichoptera											
Chimarra	o									x	
Hydropsyche	o	x	o			o	x	x	x	o	x
Cheumatopsyche	x				o	x	x	x	x	x	x
Hydropsychidae pupae	o							x	o		o
Leucotrichia	o				o	x	o	o		x	
Anogapetus											o
Coleoptera											
Psephenus	x				o				o	o	
Helicus	o								x	o	
Stenelmis	x	x	o		o	o	x	x	x	x	x
Dubiraphia							x	o		x	
Berosus	o		x		x			o	x	x	x
Peltodytes			x								
Laccobius									x		
Megaloptera											
Corydalis	o				o	x	x	x		o	x
Diptera											
Limnophora										o	
Simuliidae	o								x		
Antocha	o									x	x
Tipula	o										
Hemerodromia		o	o			x					
Probezzia					x			o			
Chironomidae pupae	x	o	x	x	x	x	x	x	o	x	x
Ablabesmyia	o	x	o	o	x	x	x	o	o	o	x
Procladius			o	o		o	x	o			
Tanypus				o	x	o					
Pentaneura				o							
Dicrotendipes								o	o	o	o
Polypedilum			o	o	o	x	x	x	o	x	x
Chironomus			o	o	o	x					
Glyptotendipes					o						
Cryptochironomus					o	o			o		

Table E-11. (Continued)

Taxa	Sampling Station 1	2	3	5	6	7	8	9	F0	B1	T1
Tribelos										x	
Rheotanytarsus	x				x	x	x				
Tanytarsus					o	x	x	x	o	x	x
Corynoneura	o				o		x	o			
Cricotopus	x	x	x	o	x	x	o	x	o	x	x
Psectrocladius			o	o	x	o			o	o	
Trichocladius						o					
Micropsectra								o			
Nanocladius								o		o	x
Odonata											
Dromogomphus							x	o			
Boyeria							x				
Argia	x	x	o	o		x		o	x	o	
Hetaerina						x			x		o
Oligochaeta	o	x	x	x	x	x	x	o	o	x	x
Miscellaneous											
Physa			o	x	x	x	o			o	
Corbicula	o	o			x		x	x			
Ferrissia	o	o	o	o	x	x	x	o		o	
Tricladida	o	o			x				x		x
Nematoda		o			o		o	o		o	o
Decapoda		o	o		x	x	x				
Lirceus	x	o			o	x			x	x	x
Hyalella											x
Total No. Taxa[a] w Qual.	26	12	15	11	27	26	23	25	24	29	20
Community Loss Index (Qual. & Quant.)		1.33	1.27	2.00	0.33	0.46	0.52	0.40	0.42	0.24	0.60

[a]Multiple life stages, higher taxonomic levels, Oligochaeta and Nematoda not included in number of taxa.

Note: o = presence of species in quantitative samples only.
x = presence of species in qualitative samples (may include quantitative samples).

Table E-12. Community Data for Benthic Macroinvertebrates From Tributaries to Five Mile Creek, October 1983

Parameter	Sampling Station F0	B1	T1	B2
Total Densities (No. m^2)	2,768	4,123	3,108	473
Total No. Taxa[a]	20	28	13	18
Community Loss Index[b]	0.60	0.29	1.31	1.73
Diversity Index[c]	2.75	3.68	3.07	3.54
Evenness	0.61	0.74	0.75	0.85
Redundancy	0.40	0.26	0.25	0.17

[a]Multiple life stages, higher taxonomic levels, Oligochaeta, and Nematoda not included in number of taxa.
[b]Calculated using Station 1 as reference station.
[c]Calculated on log base 2.

Table E-13. Qualitative Sampling of Benthic Macroinvertebrates From Five Mile Creek, Birmingham, Alabama, October 1983

	Sampling Station							
	1	2	3	5	6	7	8	9
Ephemeroptera								
Isonychia	7	3						6
Baetis	11				1	114	193	13
Stenonema	17					1	115	6
Caenis							1	
Tricorythodes					1	7	90	2
Trichoptera								
Hydropsyche		1					1	14
Cheumatopsyche	6					26	53	1
Hydropsychidae pupae								1
Leucotrichia						1		
Coleoptera								
Psephenus	1							
Stenelmis	10	1					1	1
Dubiraphia							20	
Berosus			4	2				
Peltodytes			6					
Megaloptera								
Corydalis						8	13	2
Diptera								
Hemerodromia						1		
Probezzia				1				
Chironomidae pupae	1		3	1	14	10	3	3
Ablabesmyia		9			1	2	5	
Procladius							4	
Tanypus					1			
Dicrotendipes						10	2	1
Polypedilum						1		
Rheotanytarsus	10				4	1	2	
Tanytarsus						17	6	2
Corynoneura							2	
Cricotopus	1	2	1		26	7		2
Psectrocladius					1			
Odonata								
Dromogomphus							2	
Boyeria							2	
Argia	4	3				9		
Hetaerina						3		
Other								
Physa				1	1	1		
Corbicula					1		218	52
Ferrissia					2	1	2	
Planaria					1			
Oligochaete		1	7	2	3	3	5	
Decapoda					1	1	1	
Lirceus	1					1		

Table E-14. Qualitative Sampling of Benthic Macroinvertebrates From Tributaries to Five Mile Creek, Birmingham, Alabama, October 1983

	Station		
	F0	B1	T1
Ephemeroptera			
Isonychia	7		1
Baetis	126	4	96
Stenonema	39	2	1
Caenis	3	2	
Tricorythodes	5		
Trichoptera			
Chimarra		1	
Hydropsyche	12		1
Cheumatopsyche	33	1	12
Leucotrichia		1	
Coleoptera			
Helicus	1		
Stenelmis	2	1	2
Dubiraphia		1	
Berosus	36	1	1
Laccobius	1		
Megaloptera			
Corydalis			1
Diptera			
Simuliidae	1		
Antocha		1	1
Chironomidae pupae		3	1
Ablabesmyia			1
Dicrotendipes		1	2
Tanytarsus		5	2
Cricotopus		2	6
Nanocladius			1
Odonata			
Argia	2		
Hetaerina	1		
Other			
Planaria	11		10
Oligochaete		1	10
Lirceus	1	31	61
Hyalella			2

Table E-15. Synopsis of Benthic Invertebrate Data From Five Mile Creek, Birmingham, Alabama, October 1983 (No./m²)

	Station										
Parameters	1	2	3	5	6	7	8	9	F0	B1	T1
Density organisms	4,475	361	1,671	978	3,598	3,521	6,220	5,380	2,768	4,132	3,108
No. taxa	28	12	16	11	26	23	20	27	22	30	16
Density mayflies	1,806	7			147	653	3,711	1,155	1,483	309	807
Percent mayflies	40.36	1.94			4.09	18.55	59.66	21.47	53.58	7.49	25.97
Density caddisflies	1,956	4	4		162	169	582	560	620	147	596
Percent caddisflies	43.71	1.11	0.24		4.50	4.80	9.36	10.41	22.40	3.56	19.18
Density chironomids	280	140	654	374	2,922	2,508	193	2,391	162	2,740	638
No. chironomids genera	4	1	6	8	11	11	6	9	7	8	4
Percent chironomids	6.26	38.78	39.14	38.24	81.21	71.23	3.10	44.44	5.85	66.46	20.53
No. oligochaetes	7	140	736	578	205	68	54	158	25	384	248
Percent oligochaetes	0.16	38.78	44.05	59.10	5.70	1.93	0.88	2.94	0.90	9.29	7.98
No. Corbicula	4	4			47		1,611	836			
Percent Corbicula	0.09	1.11			1.31		25.90	15.54			
Taxa in qual. only	1	1	3	1	2	5	6	0	4	1	7
Total taxa	29	13	19	12	29	28	26	27	26	31	23
Additional chironomid taxa from qual.	1	1				1	1				2

Table E-16. Analysis of Variance and Tukey's Studentized Range Test Results for Major Groups of Benthic Macroinvertebrates, Five Mile Creek, February 1983

Chironomidae

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	25.07	3.58	5.52	0.0023
Error	16	10.37	0.65		
Corrected total	23	35.44			

Tukey's Studentized Range Test

Station	6	3	7	4	8	5	1	2
(mean ln count)	(4.0)	(3.0)	(2.9)	(2.7)	(2.3)	(2.0)	(1.0)	(0.7)

Ephemeroptera

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	22.57	3.22	21.58	0.0001
Error	16	2.39	0.15		
Corrected total	23	24.96			

Tukey's Studentized Range Test

Station	1	3	2	4	8	6	7	5
(mean ln count)	(2.6)	(1.9)	(1.5)	(0.4)	(0.4)	(0)	(0)	(0)

Oligochaeta

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	36.31	5.19	4.20	0.0083
Error	16	19.77	1.24		
Corrected total	23	56.08			

Tukey's Studentized Range Test

Station	4	6	3	7	5	8	2	1
(mean ln count)	(4.5)	(2.7)	(2.1)	(2.0)	(2.0)	(1.5)	(1.1)	(0)

Trichoptera

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	14.69	2.10	12.14	0.0001
Error	16	2.77	0.17		
Corrected total	23	17.45			

Tukey's Studentized Range Test

Station	1	7	8	6	2	3	4	5
(mean ln count)	(2.4)	(1.0)	(0.7)	(0.5)	(0)	(0)	(0)	(0)

Table E-17. Analysis of Variance and Tukey's Studentized Range Test Results for Key Species of Benthic Macroinvertebrates, Five Mile Creek, February 1983

Cricotopus tremulus

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	22.87	3.27	4.95	0.0039
Error	16	10.56	0.66		
Corrected total	23	33.43			

Tukey's Studentized Range Test

Station	6	3	4	7	5	8	2	1
(mean ln count)	(36.7)	(15.7)	(12.3)	(11.0)	(5.0)	(4.7)	(1.7)	(0.7)

Tubifex tubifex

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	41.13	5.88	4.42	0.0066
Error	16	21.27	1.33		
Corrected total	23	62.40			

Tukey's Studentized Range Test

Station	4	5	6	3	1	2	7	8
(mean ln count)	(4.0)	(1.7)	(1.1)	(0.5)	(0)	(0)	(0)	(0)

Table E-18. Abundance Statistics for Major Benthic Taxa, Five Mile Creek, February 1983

Taxa	Station	Mean	Standard Deviation	Standard Error	95% Confidence Interval Lower C.I.	95% Confidence Interval Upper C.I.
Ephemeroptera (mayflies)	1	161.97	94.77	54.71	73.47	397.40
	2	41.43	6.52	3.77	25.23	57.64
	3	71.57	13.05	7.53	24.88	39.95
	4	7.53	13.05	7.53	-24.88	39.95
	5	0.00	0.00	0.00	0.00	0.00
	6	0.00	0.00	0.00	0.00	0.00
	7	0.00	0.00	0.00	0.00	0.00
	8	7.53	13.05	7.53	-24.88	39.95
Trichoptera (caddisflies)	1	128.07	76.92	44.41	-63.02	319.16
	2	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
	6	11.30	19.57	11.30	37.32	59.92
	7	18.83	6.52	3.77	2.63	35.04
	8	15.07	13.05	7.53	17.35	47.48
Chironomidae (midges)	1	26.37	28.44	16.42	-44.28	97.02
	2	30.13	52.19	30.13	-99.53	159.80
	3	233.53	66.21	38.23	69.04	398.03
	4	195.87	154.25	89.06	-187.34	579.07
	5	82.87	47.05	27.16	-34.01	199.74
	6	791.00	560.12	323.39	-600.53	2,182.53
	7	203.40	92.49	53.40	-26.39	433.19
	8	131.83	123.96	71.57	-176.12	439.78
Oligochaeta (worms)	1	0.00	0.00	0.00	0.00	0.00
	2	33.90	40.74	23.52	-67.32	135.12
	3	79.10	22.60	13.05	22.95	135.25
	4	2,041.53	1,865.88	1,077.27	-2,593.9	6,677.01
	5	188.33	287.28	165.86	-525.37	902.04
	6	218.47	202.25	116.77	-283.98	720.91
	7	75.33	23.52	13.58	16.89	133.77
	8	67.80	67.80	39.14	-100.64	236.24

Table E-19. Abundance Statistics for Major Benthic Taxa, Five Mile Creek, October 1983

Taxa	Station	Mean	Standard Deviation	Standard Error	95% Confidence Interval Lower C.I.	95% Confidence Interval Upper C.I.
Ephemeroptera (mayflies)	1	1,805.00	588.11	339.55	343.92	3,266.08
	2	7.33	6.35	3.67	8.44	23.11
	3	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00
	6	147.33	93.47	53.97	84.89	379.55
	7	653.33	328.85	189.86	163.65	1,470.32
	8	3,709.67	1,128.44	651.51	906.23	6,513.10
	9	1,155.00	473.08	273.13	20.29	2,330.29
Trichoptera (caddisflies)	1	1,955.33	1,320.33	762.29	1,324.8	5,235.48
	2	3.67	6.35	3.67	12.11	19.44
	3	3.67	6.35	3.67	-12.11	19.44
	5	0.00	0.00	0.00	0.00	0.00
	6	161.67	140.12	80.90	186.43	509.76
	7	168.67	217.94	125.83	-372.77	710.10
	8	582.00	519.56	299.97	-708.76	1,872.76
	9	560.00	596.67	344.49	-922.32	2,042.32
Chironomidae (midges)	1	280.33	163.05	94.14	-124.74	685.40
	2	139.67	67.17	38.78	-27.22	306.55
	3	653.00	280.57	161.98	-44.02	1,350.02
	5	356.00	177.49	102.47	84.93	796.93
	6	2,925.00	1,150.90	664.47	65.78	5,784.22
	7	2,509.67	454.88	262.63	1,379.59	3,639.74
	8	194.33	78.21	45.16	0.02	388.64
	9	2,368.00	1,131.30	653.16	-442.53	5,178.53
Oligochaeta (worms)	1	7.33	6.35	3.67	8.44	23.11
	2	139.67	180.89	104.44	309.72	589.05
	3	735.33	374.18	216.04	-194.27	1,664.94
	5	577.67	34.79	20.09	491.24	664.10
	6	204.33	130.94	75.60	-120.98	529.64
	7	68.33	65.68	37.92	-94.85	231.51
	8	54.00	11.00	6.35	26.67	81.33
	9	158.00	96.69	55.82	-82.21	398.21

Table E-20. Analysis of Variance and Tukey's Studentized Range Test Results for Major Groups of Benthic Macroinvertebrates, Five Mile Creek, October 1983

Chironomidae

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	31.21	4.46	23.53	0.0001
Error	16	3.03	0.19		
Corrected total	23	34.24			

Tukey's Studentized Range Test

Station	6	7	9	3	5	1	8	2
(mean ln count)	(5.5)	(5.4)	(5.3)	(4.1)	(3.5)	(3.2)	(2.9)	(2.6)

Ephemeroptera

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	120.93	17.28	91.02	0.0001
Error	16	3.04	0.19		
Corrected total	23	123.97			

Tukey's Studentized Range Test

Station	8	1	9	7	6	2	3	5
(mean ln count)	(5.8)	(5.1)	(4.6)	(4.0)	(2.5)	(0.5)	(0)	(0)

Oligochaeta

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	32.53	4.65	7.17	0.0006
Error	16	10.37	0.65		
Corrected total	23	42.91			

Tukey's Studentized Range Test

Station	3	5	6	9	2	8	7	1
(mean ln count)	(4.2)	(4.0)	(2.9)	(2.6)	(1.9)	(1.8)	(1.7)	(0.5)

Trichoptera

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	68.28	9.75	6.00	0.0015
Error	16	26.02	1.63		
Corrected total	23	94.30			

Tukey's Studentized Range Test

Station	1	8	9	7	6	3	2	5
(mean ln count)	(5.1)	(3.4)	(3.1)	(2.3)	(2.1)	(0.2)	(0.2)	(0)

Table E-20. (Continued)

Benthic Number of Taxa

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	535.62	76.52	11.62	0.0001
Error	16	105.33	6.58		
Corrected total	23	640.96			

Tukey's Studentized Range Test

Station	6	1	9	7	8	3	5	2
(mean)	(19.0)	(18.3)	(17.7)	(16.0)	(14.7)	(10.3)	(7.7)	(6.0)

Table E-21. Analysis of Variance and Tukey's Studentized Range Test Results for Key Species of Benthic Macroinvertebrates, Five Mile Creek, October 1983

Argia spp.

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	7.21	1.03	3.94	0.0109
Error	16	4.18	0.26		
Corrected total	23	11.39			

Tukey's Studentized Range Test

Station	3	5	9	7	2	1	8	6
(mean ln count)	(1.8)	(1.1)	(0.7)	(0.5)	(0.4)	(0.4)	(0)	(0)

Baetis spp.

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	88.81	12.69	12.01	0.0001
Error	16	16.91	1.06		
Corrected total	23	105.71			

Tukey's Studentized Range Test

Station	8	7	1	9	6	3	5	2
(mean ln count)	(5.3)	(3.9)	(3.5)	(3.0)	(2.1)	(0)	(0)	(0)

Corbicula spp.

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	69.02	9.86	13.84	0.0001
Error	16	11.40	0.71		
Corrected total	23	80.42			

Table E-21. (Continued)

Tukey's Studentized Range Test

Station (mean ln count)	9 (4.3)	8 (3.9)	6 (1.3)	2 (0.2)	1 (0.2)	3 (0)	7 (0)	5 (0)

Cricotopus spp.

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	7	69.08	9.87	27.08	0.0001
Error	16	5.83	0.36		
Corrected total	23	74.91			

Tukey's Studentized Range Test

Station (mean ln count)	9 (4.9)	7 (4.8)	6 (4.8)	3 (3.1)	2 (2.5)	8 (1.4)	5 (0.7)	1 (0.7)

Table E-22. List of Fish Species and Families Collected From Five Mile Creek, Birmingham, Alabama, February 1983

Family	Scientific Name	Common Name
Cyprinidae (minnow)	*Notemigonus crysoleucas*	Golden shiner
	Semotilis atromaculatus	Creek chub
	Campostoma anomalum	Stoneroller
	Notropis chrysocephalus	Striped shiner
	N. venustus	Blacktail shiner
Castostomidae (sucker)	*Hypentelium etowanum*	Alabama hog sucker
	Moxostoma duquesnei	Black redhorse
Poeciliidae (livebearers)	*Gambusia affinis*	Mosquitofish
Centrarchidae (sunfish)	*Lepomis cyanellus*	Green sunfish
	L. macrochirus	Bluegill
	L. megalotis	Longear sunfish
	L. microlophus	Redear sunfish
	Micropterus punctulatus	Spotted bass
	Lepomis × *Lepomis*	Hybrid sunfish
Percidae (perches)	*Percina nigrofasciata*	Blackbanded darter
Cottidae (sculpins)	*Cottus carolinae*	Banded sculpin

Table E-23. Numbers of Fish Collected From Black Creek Near Birmingham, Alabama, February 1983

Species	Station B2
Golden shiner	1
Creek chub	5
Blacktail shiner	20
Mosquitofish	5
Green sunfish	26
Bluegill	1
Hybrid sunfish	1
Total number of fish	59
Total fish species	7

Table E-24. Shannon-Wiener Diversity Indices, Associated Evenness and Redundancy Values, and Community Loss Index for Fish Data From Black Creek, February 1983

Station	Diversity[a]	Evenness	Redundancy	Number of Species	Number of Individuals[b]	Community Loss Index[c]
B2	1.9733	0.7029	0.3015	7	157	0.7143

[a] Calculated on a log base 2.
[b] Abundance in number per 1,037.3 m^2 (sampling area).
[c] Calculated using Station 1 as a reference station.

Table E-25. Numbers of Fish Collected From Tributaries to Five Mile Creek, Birmingham, Alabama, October 1983

	Sampling Station		
Species	F0	T1	B1
Stoneroller	101	254	220
Creek chub	1	21	10
Alabama hog sucker	4		8
Mosquitofish	4		
Spotted bass	7		4
Largemouth bass	1		
Green sunfish	1		19
Longear sunfish			1
Hybrid sunfish		1	
Sunfish sp.	1		
Redfin darter	2	1	3
Banded sculpin		48	27
Total number of fish	122	325	292
Total fish species	8	4	8

Table E-26. List of Fish Species and Families Collected From Five Mile Creek and Tributaries, Birmingham, Alabama, October 1983

Family	Scientific Name	Common Name
Cyprinidae (minnows)	*Campostoma anomalum*	Stonerollier
	Semotilus atromaculatus	Creek chub
	Notropis chrysocephalus	Striped shiner
	Notropis venustus	Blacktail shiner
	Pimephales vigilax	Bullhead minnow
Catostomidae (suckers)	*Hypentelium etowanum*	Alabama hog sucker
	Moxostoma duquesnei	Black redhorse
Ictaluridae (catfishes)	*Ictalurus punctatus*	Channel catfish
Cyprinodontidae (killifishes)	*Fundulus olivaceus*	Blackspotted topminnow
Poeciliidae (livebearers)	*Gambusia affinis*	Mosquitofish
Centrarchidae (sunfishes)	*Micropterus punctulatus*	Spotted bass
	Micropterus salmoides	Largemouth bass
	Lepomis cyanellus	Green sunfish
	Lepomis megalotis	Longear sunfish
	Lepomis macrochirus	Bluegill
Percidae (perches)	*Etheostoma whipplei*	Redfin darter
Cottidae (sculpins)	*Cottus carolinae*	Banded sculpin

Table E-27. Mean Densities (No./liter) of Plankton From Tributaries to Five Mile Creek, Birmingham, Alabama, October 1983

Organisms	F0	B1	T1
Crustaceans			
Copepods		0.04	
Nauplii	0.09		0.07
Cladocerans	0.09	0.04	
Rotifers			
Large Brachionidae	4.05	1.90	0.53
Small Brachionidae	0.64	0.47	
Philodina		1.05	0.07
Algae			
Desmids	1.64	0.76	0.08
Pediastrum	9.72	0.65	0.61
Ceratium	0.73		
Solitary diatoms	6,397	2,066	359
Filamentous green	1.36	1.57	
Other			
Chironomidae		0.16	
Nematoda		0.34	
Tardigrada	0.54		
Total organisms minus algae	6.87	3.02	0.60
Total crustaceans	0.18	0.08	0.07
Total rotifers	5.74	2.44	0.53

Table E-28. Mean Densities (No./liter) of Plankton From Five Mile Creek, Birmingham, Alabama, October 1983

Organisms	Sampling Station 1	2	3	5	6	7	8	9
Crustaceans[a]								
Copepods		0.02	0.17	0.09	0.12			
Nauplii	0.15	0.05	1.18	1.39	4.58	2.30	0.17	0.18
Cladocerans		0.02	0.40	0.40	1.73	0.14	0.11	
Rotifers[b]								
Proima	1.27	2.17	4.69	36.96	44.46	45.65	0.40	13.37
Floscularlacea	0.02		0.05		0.12			
Bdelloida		0.12	0.54	0.62	0.24	1.51	0.10	
Algae								
Desmids	1.00	0.36	1.75	1.67	2.96	2.14	0.29	2.23
Pediastrum	0.12	1.87	8.69	1.49	4.14	1.90	0.46	0.68
Ceratium		0.05						
Staurastrum			1.07	0.23				
Solitary diatoms	298.60	272.16	406.44	218.67	1,606	128.1	24.48	235.3
Filamentous diatoms								360.9
Filamentous green	1.93	2.84	6.25	2.27	12.33			
Other								
Chironomidae	0.27	0.02	0.33		0.06	0.11		0.39
Nematoda	0.08	0.04				0.18		
Tardiagrada	0.04							0.04
Total organisms minus algae	1.83	2.44	7.36	39.64	51.31	50.22	0.78	13.98
Total crustaceans	0.15	0.09	1.75	1.88	6.43	2.44	0.28	0.18
Total rotifers	1.29	2.29	5.28	37.58	44.82	47.16	0.50	13.37

[a] Species identifications of crustaceans are listed in Table 13-1.
[b] Species identifications of rotifers are listed in Tables 13-1 and E-29.

Table E-29. Densities (No./liter) of Rotifers From Five Mile Creek, Birmingham, Alabama, October 1983

Taxa	Station 1		Station 2		Station 3		Station 5		Station 6		Station 7	
	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2
Brachionus angularis	0.48	0.34		0.21	0.40	0.32	29.89	22.3	22.92	23.28	0.85	2.71
B. calyciflorus	0.05						10.31	6.03	12.65	13.16	0.42	
B. urceolaris							0.18					
Euchlanis	0.79	0.34	1.47	1.32	1.60	1.30	0.35	1.10	5.01	5.06	0.28	0.27
Kellicottia longispina								0.18				
Keratella sp.			0.02									
Keratella cochlearis var. *hispida*	0.02		0.02	0.01	1.66	0.87		0.18	0.24	1.26	0.14	0.14
Macrochaetus sp.				0.03								
Mytilina sp.							0.35					
Platyas quadricornis												
Trichotria sp.	0.02			0.03	0.10							
Lepadella sp.	0.15		0.02	0.22	0.37	0.25	0.35		0.24		0.71	1.36
Lecane sp.				0.18	0.07	0.04						
Monastyla buila	0.08	0.05	0.19	0.30	0.20	0.32	0.53		0.24	0.25	28.22	20.47
Proales sp.											13.75	20.88
Cephalodella sp.	0.08		0.08	0.19	0.23	0.18	0.53		1.90	1.01	0.14	
Trichocerca sp.	0.13			0.04	0.86	0.61	0.18	0.55	1.19	0.50	0.28	
Ascomorpha sp.								0.55				
Asplanchna sp.								0.36			0.14	0.54
Filinia sp.					0.10							
Testudinella sp.		0.03							0.24			
Philodinidae			0.03	0.22	0.53	0.54	1.24		0.24	0.25	0.99	2.03
Total Taxa	9	4	7	10	11	9	10	8	10	8	11	8

Table E-29. (Extended)

Taxa	Station 8		Station 9		Station F0		Station B1		Station T1	
	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep 2	Rep. 1	Rep. 2
Brachionus angularis	0.11								0.06	0.15
B. calyciflorus										
B. urceolaris										
Euchlanis	0.11	0.04	13.06	13.18	3.68	2.49	3.45	2.58	0.38	0.66
Kellicottia longispina										
Keratella sp.										
Keratella cochlearis var. *hispida*						0.09				
Macrochaetus sp										
Mytilina sp.						0.06				
Platyas quadricornis			0.07							
Trichotria sp.					0.09	0.21				
Lepadella sp.	0.04		0.14	0.15	1.03	0.77	0.34	0.37		
Lecane sp.			0.07		1.21	0.77	0.49	0.95		
Monastyla bulla	0.31	0.15			0.58	0.18	0.20	0.63		0.15
Proales sp.			0.07							
Cephalodella sp.	0.04				0.36	0.37	0.34	0.16		
Trichocerca sp.					0.04	0.15	0.34			
Ascomorpha sp.										
Asplanchna sp.										
Filinia sp.					0.04	0.21				
Testudinella sp.							0.02			
Philodinidae	0.15	0.04			2.38	1.51	0.02	0.26		
Total Taxa	6	3	5	2						

Table E-30. Presence of Crustacean Taxa in Five Mile Creek and Tributaries, Birmingham, Alabama, October 1983

Taxa	Station 1		Station 2		Station 3		Station 5		Station 6		Station 7	
	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2
Cyclopoid copepod			X	X	X	X	X	X	X	X	X	X
Bosmina longirostis					X							
Oxyurella tennicardis					X	X						
Alona guttata or *A. reticulata*				X	X	X		X	X	X	X	X
Moina micrura						X	X	X	X	X		
Streblocerus serricandatus									X	X		X
Total Taxa	0	0	1	2	4	4	2	3	4	4	2	3

Table E-30. (Extended)

Taxa	Station 8		Station 9		Station F0		Station B1		Station T1		
	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Total
Cyclopoid copepod			X	X							12
Bosmina longirostis											1
Oxyurella tennicardis	X										3
Alona guttata or *A. reticulata*											8
Moina micrura											4
Streblocerus serricandatus	X										4
Total	2	0	1	1							33

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