Missouri Department of Natural Resources

Biological Assessment and Sediment Study

Flat River
(Flat River Creek)
St. Francois County

2001

Prepared for:

Missouri Department of Natural Resources
Water Protection and Soil Conservation Division
Water Pollution Control Program

Prepared by:

Missouri Department of Natural Resources
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1.0 Introduction

At the request of the Missouri Department of Natural Resources (MDNR) Water Pollution Control Program (WPCP), the Environmental Services Program (ESP) Water Quality Monitoring Section (WQMS) conducted a macroinvertebrate bioassessment and sediment study of Flat River in St. Francois County at Park Hills, Missouri. A lower five-mile segment of Flat River that is 303(d) listed for lead, zinc, and excessive sediment was compared with a control segment of Flat River and five regional reference streams of similar size within the Ozark/Meramec Ecological Drainage Unit (EDU).

1.1 Study Area/Justification

Flat River (also referred to as Flat River Creek in the Missouri Water Quality Standards and as listed on 2002 303(d) list) is a tributary of Big River and is located approximately 70 miles south of St. Louis, entirely within St. Francois County, Missouri. Flat River originates near Bismarck, Missouri and flows northeasterly approximately twelve miles, mostly next to US Highway 32, through Park Hills, Missouri. It confluences with the Big River east of Desloge, Missouri. Flat River drains approximately 40 square miles, has a mean depth of about 0.7 feet and an average width of about 15 feet (Kramer, 1976). Upstream from Park Hills, Flat River is a typical small Ozark stream of riffles and pools with gravel, cobble, and bedrock substrate predominant. From Park Hills to the Big River, Flat River flows through a mostly urban watershed which contains three large lead mine tailings piles from the Old Lead Belt of Southeast Missouri.

The lower nine miles of Flat River are listed in the Missouri Water Quality Standards as a class “C” stream. Use designations are “warm water aquatic life protection, human health/fish consumption, and livestock and wildlife watering.” Flat River was 303(d) listed because studies in the past have revealed threats to Flat River. Flat River is contained in what was called the Old Lead Belt. The area was mined for lead deposits on a large scale from 1890 to 1972. Large “tailings piles” of fine particles (<2.0 mm) with the character (composition) of lead and zinc remain in the watershed of Flat River.

Once fine particles are eroded into streams in large quantities they may homogenize and embed substrate making it unsuitable for macroinvertebrate communities (Zweig 2000; many others in Zweig). Filter feeders may be eliminated with large inputs of sediment (Zweig 2000). Ryck (1974) investigated Flat River macroinvertebrate communities for the Missouri Department of Conservation (MDC) during the 1960’s and 1970’s. Riffle kicknet samples were collected from Flat River upstream and downstream from the Federal Division Mine and Mill, still active during that time. Downstream mayfly and stonefly taxa richness ranged from zero to four and averaged one taxon within nine samples collected from 1965 to 1971. The cause of downstream impairment was attributed to excessive mine tailings that embedded riffles and blanketed pools. Zwieg (2000) notes that little is known about the amount of sediment required to alter communities and the types of responses.

The character of fine sediment may reveal its source from past mining activities. Kramer (1976) and Jennet et al. (1981) reported elevated levels of lead and zinc in Flat River. Concentrations of lead and zinc were elevated within algae, crayfish, and minnows from lower Flat River. They believed the sources were brought to Flat River via tributaries that drained Elvins and Federal tailings piles. Erosion of tailings into the stream and seepage of water through the tailings were thought to be the primary means of delivering lead, zinc, and other metals to Flat River. Besser et al. (1987) said aquatic organisms in tributaries of Big River located downstream from tailings piles contained concentrations of lead, cadmium, and other heavy metals.

Metals may influence the macroinvertebrate communities. Clements (1991) found a lowered percent composition or elimination of Ephemeroptera and increased abundances of Chironomidae (especially Orthocladiinae) and Hydropsychidae (net-spinning caddisflies) downstream from metals impacts in the absence of organic pollution. The replacement of intolerant taxa by tolerant taxa suggests that the health of the aquatic community was affected at a basic level.

In 2001, a study plan for a bioassessment and sediment study was submitted to the MDNR WPCP. The study plan was subsequently modified. The ESP WQMS was responsible for the proposed bioassessment and sediment study on Flat River, St. Francois County (Appendix A).

1.2 Purpose

The purpose of the study was to determine if Flat River is impaired by mine-influences.

1.3 Objectives

1) Determine if the macroinvertebrate community and water quality is affected by mining influences.

2) Determine if fine sediment and heavy metals are present in Flat River and determine their origin.

3) Define habitat influences on Flat River.

1.4 Tasks

1) Conduct a bioassessment of the macroinvertebrate community of Flat River, St. Francois County.

2) Conduct a fine sediment assessment and characterization study on Flat River.

3) Conduct a habitat assessment on Flat River.

1.5 Null Hypotheses

The macroinvertebrate communities of the 303(d) listed segment of Flat River, St. Francois County are similar between control and test stations, as well as between Flat River and the reference streams.

Water quality is similar between control and test stations, as well as with five reference streams.

There is no significant difference in the amount and character of the fine sediment between upstream controls and downstream test stations.

Habitat assessments are similar between control and test stations.

2.0 Methods

This project was conducted by the Water Quality Monitoring Section of the Missouri Department of Natural Resources, Air and Land Protection Division, Environmental Services Program. Steve Humphrey, Ken Lister, and other staff of the Water Quality Monitoring Section conducted the study.

2.1 Study Timing

Sampling was conducted during the spring, summer, and fall of 2001. Spring sampling was conducted March 22, 2001, and consisted of macroinvertebrate and water quality samples at two Flat River stations. Samples were collected upstream and downstream from lead mine tailings piles. Summer samples were collected for water quality and sediment on July 12, 2001, from several locations along Flat River. Fall macroinvertebrate samples were collected during the weeks of September 18 and 25, 2001.

2.2 Station Descriptions

Stations were positioned to provide controls upstream from all known mining influences and test stations which bracketed potential mine influences (Figure 1). Stations #5 and #4 were chosen as control stations, while three Flat River test stations (e.g. stations #3, #2, and #1) bracketed three lead-mine tailings piles within the catchment. Elvins Tailings Pile west of Park Hills, Federal Tailings Pile south of Park Hills, and the National Tailings Pile northeast of Park Hills were the tailings piles of interest. Results throughout this report are shown from upstream to downstream (e.g. stations 5, 4, 3, 2, 1).

In addition to the two control stations on Flat River, five unimpaired, small streams from within the Ozark/Meramec EDU were chosen to provide a regional reference database for comparison with Flat River. Table 1 provides station number, legal and descriptive information for Flat River and regional reference streams.

Table 1
Station Number, Legal and Descriptive Information for Flat River and Regional Reference Streams, September 2001.

Station Number	Location ¼ Section, Township Range	Description	County
Station #5	NE Sec. 22, T36N, R04E	Control-Hwy. 32 bridge, farthest upstream	St. Francois
Station #4	SE Sec. 13, T36N, R04E	Control-Hwy. B. Downstream from Bannister Branch	St. Francois
Station #3	Sec. 7/18, T36N, R05E	Test-Downstream Elvins Tailing Pile discharge point	St. Francois
Station #2	NE Sec. 7, T36N, R05E	Test-Downstream Shaw Branch = Federal TP	St. Francois
Station #1	SE Sec. 29, T37N, R05E	Test-Downstream National Tailings Pile	St. Francois
Courtois Creek #3	NW Sec. 8, T35N, R01W	Reference	Washington
Cub Creek #1	SE Sec. 32, T36N, R01W	Reference	Washington
East Fork Huzzah #1	SE Sec. 6, T34N, R02W	Reference	Dent
West Fork Huzzah #1	SE Sec. 2, T34N, R03W	Reference	Dent
Shoal Creek #1	SE Sec. 15, T36N, R02W	Reference	Crawford

2.2.1 Ecological Drainage Unit

An EDU is a region in which biological communities and habitat conditions can be expected to be similar. A map of the Ozark/Meramec EDU is included in Figure 1. Table 2 compares the land cover percentages from the Ozark/Meramec EDU and the 14-digit Hydrologic Units (HU), #07140104010005 and #07140104010006, which contain the Flat River study reach. Flat River stations #5 through #2 are within HU-005 and Flat River station #1 is within HU-006. Land cover data were derived from Thematic Mapper (TM) satellite data from 1991 to 1993 and interpreted by the Missouri Resource Assessment Partnership (MoRAP).

Table 2
Percent Land Cover

Land Cover	Urban	Crops	Grassland	Forest	Swamp
EDU	1.3	1.7	28.5	67.1	0
Flat River (HU-005)	3.5	1.6	32.0	60.0	0
Flat River (HU-006)	1.2	1.5	47.9	44.9	0

2.3 Habitat Assessment

A standardized assessment procedure was followed as described for Riffle/Pool Habitat in the Stream Habitat Assessment Project Procedure (SHAPP). The habitat assessment was conducted on Flat River during the September 2001 sample season and in reference streams during March 2001.

2.4 Biological Assessment

Biological assessments consist of macroinvertebrate and physicochemical water analyses. Two stations, one above and one below mining influences, were sampled in March 2001. In September 2001 complete biological assessments were conducted on five stations in Flat River and in five regional reference streams.

2.4.1 Macroinvertebrate Collection and Analysis

A standardized macroinvertebrate sample collection and analysis procedure was followed as described in the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP). Three standard habitats (e.g. flowing water over coarse substrates, depositional substrates in non-flowing water, and root-mat) were sampled at all locations.

Macroinvertebrate data were evaluated by using three methods. The first analysis was metric evaluation as per the SMSBPP. (Refer to the SMSBPP for biological criteria calculation and scoring procedures). The following four metrics were used in the SMSBPP evaluation: 1) Total Taxa (TT), 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (EPTT), 3) Biotic Index (BI), and 4)

Shannon Diversity Index (SDI). The second analysis of the biological data was an evaluation of macroinvertebrate community composition using percent composition of predominant macroinvertebrate taxa and metal sensitivity tolerances of macroinvertebrate taxa. The third data analysis was a comparison of Flat River fine sediment data with EPT taxa.

2.4.2 Physicochemical Collection and Analysis

Results are shown from physicochemical and/or sediment analyses from three visits to Flat River during 2001. The first visit was a reconnaissance during March 2001. The second was a follow-up in July 2001. The final sampling was the most comprehensive and took place in September 2001. Results are reported in physicochemical water or sediment sections in chronological order. Comparisons were made between upstream (i.e. controls) and downstream (i.e. test) stations, as well as between Flat River and reference stream stations.

In March and July, water was collected and analyzed for total recoverable metals (TRM) as a general scan for possible influences. In September, water was collected and analyzed for dissolved metals for more precise evaluation of available water column concentrations and to compare with water quality standards.

March 2001 physicochemical variables collected were pH, temperature (C^0), conductivity (uS/cm), dissolved oxygen (mg/L), discharge (cfs), turbidity (NTU), hardness ($CaCO_3$), total recoverable calcium, cadmium, magnesium, lead, and zinc. Temperature, pH, conductivity, dissolved oxygen, and discharge were conducted in the field. Metals analyses, hardness, and turbidity were conducted by the ESP laboratory.

July 2001 physicochemical variables collected were pH, temperature (C^0), conductivity (uS/cm), hardness (CaCO3), calcium, cadmium, magnesium, lead, and zinc. Metals water samples are reported as total recoverable mg/L or ug/L. Temperature, pH, and conductivity were conducted in the field and the remaining analyses were conducted by the ESP laboratory.

September 2001 physicochemical variables collected were pH, temperature, conductivity, dissolved oxygen, discharge, turbidity, hardness, ammonia-N, nitrate/nitrite-N, Total Kjeldahl Nitrogen (TKN), sulfate, chloride, total phosphorus, dissolved barium, calcium, cadmium, copper, iron, magnesium, lead, and zinc. These were collected at five stations on Flat River, as well as five stations in reference streams. Samples were collected per MDNR-FSS-001: Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations. Samples were analyzed as before, either in the field or at the ESP laboratory using previously described methods.

All samples were kept on ice until they were delivered to the ESP laboratory. The WQMS measured turbidity in the WQMS Biology Laboratory. All other samples were delivered to the ESP Chemical Analysis Section (CAS) in Jefferson City, Missouri for analyses.

Results of water quality analyses were compared to limits in the MDNR (1994) Water Quality Standards. In order to identify the applicable limits, Flat River was placed into a “fishery-use” category (i.e. cold-water fishery, general warm-water fishery, limited warm-water fishery). Criteria for designation into a use category include the presence of recreationally important fish species, or to be classified as a Class C stream. A species list provided by Steve Fischer, MDC Fisheries Biologist (Appendix: B), shows that Flat River includes recreationally important fish species. Flat River is also a Class C stream. Both qualify Flat River to be interpreted as a General Warm-Water Fishery (GWWF).

Two other criteria were included to identify limits. The first criterion was the reason for protection. In this case, values were identified for the “Protection of Aquatic Life”. The second was the rate of exposure, such as chronic or acute exposure. This was important to determine limits for pollutants that could be tolerated by aquatic life over a given amount of time. The rate of exposure is noted if the variable is beyond the applicable limits.

2.4.3 Discharge

Stream flow and discharge were measured using a Marsh-McBirney Flow Meter at each station. Measurements were taken and interpreted as cubic feet per second (cfs). Methodology was in accordance with SOP, MDNR-WQMS 113, Flow Measurement in Open Channels.

2.5 Fine Sediment Collection and Analysis

In-stream deposits of fine sediment (i.e. less than particle size ca. 2mm= coarse sand) were estimated for percent coverage per area and characterized for composition by chemical analysis for total recoverable metals (TRM, ug/kg).

2.5.1 Fine Sediment Percentage and Characterization

To ensure sampling method uniformity, areas estimated for fine-sediment percent coverage and characterization were located at the upper margins of pools and lower margins of riffle/run (coarse substrate) habitat. Depths of the sample areas did not exceed two (2.0) feet and water velocity was less than 0.5 feet per second (fps). A Marsh McBirney flow meter was used to ensure that water velocity of the sample area was within this range.

A visual method was used to estimate the percentage coverage per area of fine sediment. Each sampling station was composed of three sample areas (i.e. grids). Each grid consisted of six contiguous transects that traversed the stream. A tape measure was stretched from bank to bank at each transect. One sample quadrat (ca. 10 x 10 inches) was placed directly on the substrate within each of the six transects. Placement of the quadrat within each transect was determined by using a random number that equated to one foot increments. The trailing edge of the quadrat was placed on the random foot increment. Two investigators estimated the percentage of the stream bottom covered by fine sediment within each quadrat. The estimates were accepted if the two observations were within a ten percent margin of error. If estimates diverged more than ten percent, the investigators repeated the process until the estimates were within the acceptable margin of error. An average of these two estimates was recorded and used for analysis.

Substrate fine sediment was characterized by determining its content of TRM (ug/kg) within each of the transect grids. Specifically, sediments were analyzed for lead and zinc content. One composite sample was collected at each grid. If fine sediment was not found in sufficient quantities within the grid, a representative composite collection was taken from an area near the study grid. Each composite consisted of three (3) two-ounce samples of fine sediment sized particles dredged from the substrate to a depth of no more than two-inches. The lid of the two-ounce jar was used to retain the fine sediment while raising the sample through the water column. The three samples were then placed in a single eight-ounce jar. Samples were kept on ice and delivered to the ESP CAS in Jefferson City, Missouri for analyses.

Sediments were collected for total recoverable cadmium, lead, and zinc (ug/kg) analysis at one location in July 2001, downstream of National tailings pile, and at all stations in September 2001. Microtox™ analysis was conducted on the July sample to determine its toxicity.

2.5.2 Data Analysis

The statistics program used for this project was Sigmastat, Version 2.03 (1997). Kruskal-Wallis, Non-parametric ANOVA on Ranks, and Tukey's Test, All Pairwise Multiple Comparison Procedures were used to determine possible differences between stations for fine sediment percent coverage, as well as for comparisons with the character composition of lead and zinc. ANOVA on Ranks and Tukey's Test were conducted for a more conservative identification of similarities or differences.

Kruskal-Wallis ANOVA on Ranks and Tukey's Test were used to identify differences in percentage of fine sediment between stations. Raw percentages of fine sediment observations are shown in Table 16. There were six observations (quadrats) per grid and three grids per station. This generated 18 observations for each of five stations or 90 observations.

Kruskal-Wallis and Tukey's Test were also used to identify differences between stations in the quantities of total recoverable lead and zinc in the sediment. Values for lead and zinc in the sediment are shown in Appendix C. There is one value per grid and three grids per station. This generated three values for each of five stations for a total of 15 values.

2.6 Quality Control

Quality control was used as stated in the various MDNR Project Procedures and Standard Operating Procedures.

3.0 Results and Analysis

Results are shown for the habitat assessment, biological assessment, physicochemical water, fine sediment coverage estimation, and fine sediment character.

3.1 Habitat Assessment

Table 3 provides habitat assessment scores for the five Flat River locations and five minimally impaired small reference streams. Flat River stations #5 and #4 were upstream control stations and stations #3, #2, and #1 were downstream test stations. Data were collected in the fall of 2001 and all scoring was done by the same personnel. According to the SHAPP, for a study site to fully support a biological community, the total score of the study site should be 75 to 100 percent similar to the total score of the reference site. According to the table, Flat River station #5 had the highest habitat score, which was 83 percent of the mean reference value. With the exception of a marginally supportive score (76%) for station #1, the three remaining stations (#4, #3, and #2) had low scores and may not be able to support a macroinvertebrate community comparable to the reference stations.

Table 3
Reference Streams and Flat River Habitat Assessment Scores, September 2001

Ref. Streams	Habitat Score	Flat River	Habitat Score	% of Mean Ref.
Cub Creek #1	140	(Sta. #1)	107	76 %
Shoal Creek #1	167	(Sta. #2)	89	63 %
Courtois Cr. #3	136	(Sta. #3)	89	63 %
E. Fk. Huzzah Cr.#1	133	(Sta. #4)	98	70 %
W. Fk. Huzzah Cr.#1	127	(Sta. #5)	117	83 %
Mean Ref. Stream Score	**141**			

3.2 Biological Assessment

As outlined in the methods, macroinvertebrate data were evaluated by three methods. The first analysis was metric evaluation per the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP). The second analysis of the biological data was an evaluation of macroinvertebrate community composition using percent composition of predominant macroinvertebrate taxa and metal sensitivity tolerances of macroinvertebrate taxa. The third analysis is later shown in the fine sediment section where sediment results are examined, such as a comparison of Flat River fine sediment data with EPT taxa and percent Ephemerpotera.

3.2.1 Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP)

The SMSBPP metric evaluation used numeric biocriteria that were calculated from two sources. The first source was from biocriteria reference streams within the Ozark/Meramec EDU. These criteria are listed for the spring and fall sampling seasons, respectively, in Tables 4 and 5. The second set of bioassessment data were derived from fall samples collected from five small minimally impacted reference streams, also within the Ozark/Meramec EDU. This data set was chosen to ensure stream size comparability with Flat River. The five small streams and Flat River are all second to third order streams while the biocriteria reference streams are generally fourth to fifth order. Larger streams may have more available habitat and higher numbers of macroinvertebrate taxa and diversity than smaller streams. Table 6 provides criteria that are calculated for the four metrics for these five streams from the fall sampling period.

Table 4
Biological Criteria for Warm Water Reference Streams Database in the Ozark/Meramec EDU
Spring Season

	Score = 5	Score = 3	Score = 1
TT	>90	90-45	44-0
EPTT	>28	28-14	13-0
BI	<5.90	5.90-7.95	7.96-10
SI	>3.29	3.29-1.65	1.64-0

Table 5
Biological Criteria for Warm Water Reference Streams Database in the Ozark/Meramec EDU
Fall Season

	Score = 5	Score = 3	Score = 1
TT	>78	78-39	38-0
EPTT	>20	20-10	9-0
BI	<5.86	5.86-7.93	7.94-10
SI	>3.06	3.06-1.53	1.52-0

Table 6
Biological Assessment Criteria for Five Small Reference Streams in the Ozark/Meramec EDU
September 2001

	Score = 5	Score = 3	Score = 1
TT	> 67	67-34	33-0
EPTT	>19	19-10	9-0
BI	<5.11	5.11-7.56	7.57-10
SI	>3.29	1.64-3.29	1.63-0

The metric values and scores for Flat River spring samples are presented in Table 7. The values for each metric are scored using the spring biocriteria scores from Table 4. For the spring sampling season, station #4 is the upstream control station, above the three tailings piles, and station #1 is the downstream station, below the three tailings piles. Station #4 scored 16 = full sustainability and station #1 scored 12 = partial sustainability. There were large differences in the numbers of total taxa and EPT taxa between the stations. Station #4 had 95 total taxa and 22 EPT taxa whereas station #1 recorded 68 total taxa and only 6 EPT taxa. However, the Shannon Diversity Index (SDI) and Biotic Index (BI) indices were very similar at each station (Table 7). There is a possibility that these two metrics were not sensitive measures of Flat River macroinvertebrate community impairment. Please see Discussion Section 5.0 for consideration and recommendations regarding metric sensitivity.

Table 7
Flat River Metric Values and Scores, Spring Season, Using Ozark/Meramec Biocriteria Reference Database

Sample #	01-19506		01-19505	
Date	3/22/2001		3/22/2001	
	Sta. #4 Value	Sta. #4 Score	Sta. #1 Value	Sta. #1 Score
TT	95	5	68	3
EPTT	22	3	6	1
BI	6.52	3	6.58	3
SDI	3.34	5	3.32	5
Total Score		16		12
Sustainability		**Full**		**Partial**

Tables 8 and 9 provide metric values for five Flat River stations from fall macroinvertebrate samples. Table 8 data is computed from Ozark/Meramec biocriteria reference streams while Table 9 data is derived from five smaller reference streams within the same EDU. Data from both tables show that upstream control stations #5 and #4 had full sustainability, based on these metric scores against biocriteria reference streams and against minimally impaired smaller streams.

Table 8
Flat River Metric Values and Scores, Fall Season, Using Ozark/Meramec Biocriteria Reference Database

Sample #	TT	EPTT	BI	SDI	T-Score	Sustain.
01-37074						
#5 Value	87	22	6.38	3.13		
#5 Score	5	5	3	5	18	**Full**
01-37073						
#4 Value	100	24	6.82	3.04		
#4 Score	5	5	3	3	16	**Full**
01-37072						
#3 Value	69	7	6.76	3.34		
#3 Score	3	1	3	5	12	**Partial**
01-37071						
#2 Value	67	9	7.7	3.10		
#2 Score	3	1	3	5	12	**Partial**
01-37070						
#1 Value	75	11	6.7	3.18		
#1 Score	3	3	3	5	14	**Partial**

Stations #3, #2, and #1 downstream from the tailings piles all had only partial sustainability or were non-sustainable (station #2, Table 9). Table 8, using the biocriteria reference values, shows that the lower total scores at the impacted stations were due to low total taxa, and especially, low EPT taxa scores. For example, all downstream stations scored 3 in total taxa, compared to 5 for the upstream control segments, and two of the three impacted stations scored only 1 for EPT taxa, compared to 5 for the controls. As with the spring data, biotic index and diversity scores showed only slight differences between upstream and downstream stations.

Table 9
Flat River Metric Values and Scores, September 2001, Using Small Ozark/Meramec Reference Streams Data

Sample #	TT	EPTT	BI	SDI	T-Score	Sustain.
01-37074						
#5 Value	87	22	6.38	3.13		
#5 Score	5	5	3	3	16	**Full**
01-37073						
#4 Value	100	24	6.82	3.04		
#4 Score	5	5	3	3	16	**Full**
01-37072						
#3 Value	69	7	6.76	3.34		
#3 Score	5	1	3	5	14	**Partial**
01-37071						
#2 Value	67	9	7.7	3.10		
#2 Score	3	1	1	3	8	**Non**
01-37070						
#1 Value	75	11	6.7	3.18		
#1 Score	5	3	3	3	14	**Partial**

3.2.2 Macroinvertebrate Percent and Community Composition

The number of macroinvertebrate total taxa, EPT taxa, and percent EPT are presented in Tables 10 and 11. These tables also provide percent composition data for the five dominant macroinvertebrate families at each Flat River and small regional reference station. The percent of relative abundance data were averaged from the sum of the three macroinvertebrate habitats (coarse substrate, non-flow, and rootmat) sampled at each station.

March macroinvertebrate samples from Flat River upstream control station #4 contained 95 total taxa and 22 EPT taxa (Table 10). Test station #1, downstream from all tailings piles had 68 total taxa and only 6 EPT taxa. No Ephemeroptera (mayflies) families were among the predominant families at either station. However, eight mayfly taxa made up 3.1 percent of the control samples while only two mayfly taxa composed of three individuals were found in the downstream samples. Plecoptera (stoneflies) are usually common in spring samples from Ozark streams. Seven stonefly taxa comprised 4.2 percent of station #4 samples while no stoneflies were found at station #1. Most taxa within the orders Ephemeroptera and Plecoptera are among the more sensitive of macroinvertebrates to pollution and habitat impairment.

March Flat River macroinvertebrate samples were predominantly composed of Chironomidae at control station #4 (61.5 %, Chironomidae) and at test station #1 (41.5 %, Chironomidae). At station #4, Asellidae (isopods), elmid beetles (mostly Stenelmis sp.), planarians, and tubificids collectively made up most of the remaining abundant families. At station #1, Ceratopogonidae (biting midges), Coenagrionidae (damselflies), elmid beetles, and leptocerid caddisflies were the most abundant families after Chironomidae (Table 10).

September macroinvertebrate samples (Table 10) exhibited marked differences in the numbers of EPT taxa, percent Ephemeroptera, and percent composition of predominant macroinvertebrate families between control stations (stations #5 and #4) and the three impacted test stations (stations #3, #2, and #1). EPT taxa accounted for 22 taxa at station #5 and 24 taxa at station #4. Ephemeroptera made up approximately 39 percent of the organisms at each control station. At station #5, two mayfly families, Caenidae and Tricorythidae, collectively made up 31 percent of the macroinvertebrates and at station #4, caenid mayflies were the most abundant organisms and composed nearly 36 percent of the sample. Chironomidae were the second most abundant family at each control station and made up 15 percent of station #5 organisms and 20 percent of the station #4 organisms. Remaining predominant macroinvertebrate families at the upstream control stations were Elmidae (elmid beetles), Hyalellidae (amphipods), and Coenagrionidae (damselflies).

Downstream stations #3, #2, and #1 September kicknet samples contained 11 or fewer EPT taxa (Table 10). Mayflies were nearly absent from stations #2 and #3, where the percent Ephemeroptera made up, respectively, 0.5 and 0.1 percent of the samples. Mayflies composed 10.8 percent of the station #1 samples and they were distributed among six taxa. This indicates that environmental conditions were not as harsh at station #1, compared to stations #2 and #3, where, respectively, four individuals within three mayfly taxa and a single mayfly were found. Chironomidae predominated at each downstream station and comprised from 30 to almost 48 percent of the macroinvertebrates from each sample (Table 10). Coenagrionidae was the second most common family at each station and made up 10.7 to 30.0 percent of the samples. Hydropsychid caddisflies were the third most abundant organisms at station #1 and fourth most common taxon at station #2. Tolerant tubificid oligochaetes comprised 11.4 percent of the station #2 samples and 5.6 percent of the station #3 samples.

Macroinvertebrate data for the five small reference streams sampled in September 2001 are presented in Table 11. Total taxa ranged from 64 to 86 and total EPT taxa ranged from 18 to 27. Percent Ephemeroptera comprised 25.7 to 35.7 percent of the organisms at each station. All five streams had a macroinvertebrate fall fauna typical of unimpaired Ozark streams. Heptageniidae (flat-headed mayflies) were one of the predominant families at each station. At Shoal Creek heptageniid mayflies were the most abundant family and accounted for 16 percent of the macroinvertebrates. Elmid beetles, mostly the typical Ozark genus, Optioservus, were the most abundant family of macroinvertebrates at four of the five reference streams. Percent composition of this family ranged from 16.6 percent at the East Fork of Huzzah Creek to 32 percent at Courtois Creek. Chironomidae, although a predominant family at all stations, accounted for a much smaller percentage of the fauna at these stations in comparison to Flat River control stations #4 and #5. Chironomid percent occurrence ranged from roughly 10 to 16 percent of the organisms. Most of the remaining predominant families were representatives of Hyalellidae, Tricorythidae, Caenidae, and Hydropsychidae (Table 11).

3.2.3 Physicochemical Water

Results given are arranged by groups in chronological order for physicochemical water sample analysis. Comparisons are made between upstream and downstream or between Flat River and reference streams.

In March 2001, general water physicochemistry was slightly different upstream to downstream (Table 12). The control station #4 variables were low and many non-detected. However, the downstream test station #1 increased in conductivity, hardness, and total recoverable lead and zinc. None of the metals exceeded recommended water quality standards because no standards are given for total recoverable. However, the lead levels were the highest in the water samples collected in this project. Further sampling was planned to identify the sources of impairment because the March samples indicated substantial impact.

An area of interest was identified from the July 2001 sampling of Flat River (Table 13). Physicochemical variables such as total recoverable lead and zinc were very high in the water. Total recoverable lead levels followed an increasing trend starting at the Elvins influence and were highest downstream of the National tailings pile. Zinc was extremely high compared to other total recoverable zinc levels at the Elvins influence (Table 13). Levels then decreased further downstream near Shaw Branch (September 2001, station #2).

September 2001 samples indicated that most physicochemical water measurements were similar between stations and did not exceed acceptable levels (i.e. MDNR 1994) on Flat River (Table 14). A trend was found in high conductivity and hardness, which increased at station #3. Turbidity increased upstream to downstream but remained below six (6) NTUs at all sites.

Dissolved zinc in the water exceeded acceptable water quality standards (MDNR 1994) for the protection of aquatic life (Table 14; Figure 2). While control stations #5 and #4 showed levels of zinc below detection limits, levels increased greatly downstream. Dissolved zinc concentrations increased abruptly at station #3 to a high for all samples (754 mg/L). The second highest concentration (622 mg/L) of zinc was found at station #2, which is the next station downstream from the influence. Both stations' values were above the water quality standards for General Warm Water Fisheries (GWWF) of 440 mg/L for chronic exposure and 490 mg/L for acute exposure (MDNR 1994). Zinc declined below problem levels at station #1.

In September, water samples were collected from reference streams (Table 15). Physicochemical variables were similar between streams. Most were below detection limits and none exceeded water quality standards. Nutrient levels were consistently low at all sites. Sulfates and chloride were similar and consistently low at all sites. Dissolved heavy metals were not at high levels at any of the reference stations. Turbidity was less than one NTU at all sites. A comparison of Flat River physiochemical water quality with the reference streams was then done (Tables 14 and 15).

Several differences were noted between Flat River and the reference stream stations. Conductivity and hardness were higher at the downstream Flat River stations (e.g. #2 and #1) than at reference stations. Dissolved lead was higher in the water at station #1. Dissolved zinc was much higher at Flat River station #3, station #2, and station #1 than at all reference stations. Clearly, a difference was found from representative EDU streams.

3.3 Fine Sediment Percentage

The percentage of fine sediment ranged from as low as one percent in the upstream control quadrats to as much as 90 to 98 percent in station #1 quadrats (Table 16). The averages for controls #5 and #4 were approximately 20 percent and approximately 35, 70, and 85 consecutively in the downstream test stations grids (Table 16).

The percent of fine sediment increased from controls to test stations (Figure 3, Table 16). The amount of fine sediment sharply increased at the first test station (station #3) and continued to rise through the last test station (station #1). Kruskal-Wallis ANOVA on Ranks (Sigmastat 2.0, 1997) showed a significant difference ($H = 37.468$, d.f. = 4; $p=<0.001$) between stations (Appendix D). Furthermore, Tukey's Test method of multiple comparisons revealed significant differences ($p<0.05$) between control stations and most test stations. Control stations #5 and station #4 were not significantly different from each other. The first test station #3 was similar to the controls. However, the controls were significantly lower ($p<0.05$) in fine sediment levels than station #2 and station #1.

The third macroinvertebrate analysis, mentioned earlier, was a general comparison of Flat River fine sediment data with EPT taxa (Figure 4). Both the reference streams and the controls are similar in the number of EPT taxa and percent Ephemeroptera. Although fine sediment observations were not done on the reference streams, the Flat River controls clearly had consistently low percentages. At station #3, fine sediment increased and the scores decreased.

The number of EPT taxa, especially percent Ephemeroptera, declined severely at the downstream station #3. Reference and control stations had over 20 EPT taxa per station while test station samples contained 11 or fewer EPT taxa. Similarly, the percent Ephemeroptera decreased from approximately 30 percent upstream to only a very few organisms and less than 1 percent occurrence at stations #3 and #2, followed by an increase to about 11 percent at station #1. The actual number of mayflies removed from samples (not shown in Figure 3) averaged over 500 organisms among the reference and control stations. At station #3, only a single mayfly specimen was found and only four individuals were present in the station #2 sample. Total numbers of mayflies then increased to 120 at station #1.

3.4 Fine Sediment Character

The July 2001 sediment sampling revealed an interesting trend (Table 13). Sediment samples revealed a high lead content (ca. 6,000,000 ug/kg). This far exceeds Probable Effect Levels (PELs) suggested by Ingersoll et al. (1996), which is 82,000 ug/kg. Furthermore, Microtox™ results on the sediment below National tailings pile revealed that the sediment downstream of the pile was toxic, with a 30 minute EC20 of 26.5 percent.

September 2001 analyses for fine sediment composition in the substrate revealed a change in the character from upstream to downstream (Figure 3, Appendix C). Control stations were lower in composition of lead and zinc than test stations downstream. Lead averaged approximately 43,733 ug/kg in station #5, and increased to nearly 8,000,000 ug/kg in station #1. Lead values ranged from 36,100 ug/kg at station #5 to 15,400,000 ug/kg at station #1. Zinc averaged from 37,000 ug/kg in station #5 to nearly 2,000,000 ug/kg at station #3, before declining at station #2 and #1 (Figure 2, Appendix C). Zinc values ranged from 26,000 ug/kg at a control station to 2,660,000 at station #3. Lead increased from upstream to downstream stations while zinc rose and declined from upstream to downstream stations.

Using Kruskal-Wallis ANOVA on Ranks and Tukey's Test, significant differences ($p<0.05$) were found between stations for concentrations of lead and zinc in the sediment. A significant difference ($H=10.800$, d.f. = 4; $p=0.029$) was found between station #5 and station #1 for lead. No other stations were significantly different using this conservative comparison method. Zinc levels also showed a significant difference ($H=11.767$, d.f. = 4; $p=0.019$) between stations. Control stations were significantly lower ($p<0.05$) in dissolved zinc than station #3. Zinc levels in the sediment dropped downstream of station #3 to levels similar to the controls (Appendix D).

4.0 Discussion

The discussion is arranged in the order of habitat assessment, mining-influences, macroinvertebrate metric response, and potential threats.

4.1 Habitat Assessment

Based on habitat assessments, Flat River potentially has had some level of impairment for some time. Only control station #5 was clearly comparable to regional reference stream stations based on SHAPP. Mining in the area from the 1800's may be just one cause for habitat degradation. Location of the stream, with urban runoff and construction such as bridge crossings and numerous sewage line crossings, may have contributed to low downstream scores. Upstream control station #4 also had a low habitat score of 70 percent due to excessive bedrock substrate. However, it was found to be fully biologically supporting.

4.2 Mine Influences

Flat River test stations revealed sources for high levels of potential threats from upstream to downstream. Two potential sources were identified for impairment of the physicochemical water and sediment influences related to the health of the aquatic community. These influences are Elvins tailings pile and National tailings pile. Federal tailings pile did not obviously influence potential threats during this project.

4.2.1 Elvins Tailings Pile

Physicochemical water and fine sediment results suggest that Elvins tailings pile influences the macroinvertebrate community and the quality of the stream. July 2001 (Table 13) sampling identified a total recoverable zinc influence at the Elvins influence. Furthermore, the September 2001 (Table 14) data suggest that the two stations downstream of the Elvins influence were above acceptable levels for dissolved zinc in the water. It also appears that a large amount of fine sediment and total recoverable lead and zinc were added to the stream above station #3, which is immediately downstream from the Elvins tailings pile. The lead values in the sediment were also above PELs. Total recoverable lead in the sediment increased abruptly, while dissolved levels of zinc increased to levels above acceptable chronic or acute water quality standards. At the same station, the number of EPT taxa and the percent Ephemeroptera declined precipitously, as shown by Figure 4 and by lowered metrics scores. Some taxa replaced were silt intolerant and others were metals intolerant.

Other researchers have observed similar water quality and sediment trends at this location on Flat River. Observations of water chemistry by MDNR personnel from St. Joe State Park (Appendix E) revealed dissolved zinc levels above acceptable limits for chronic and acute exposure on numerous occasions over a two-year period between 1997 and 1999. Dissolved lead concentrations exceeded chronic exposure levels below Elvins tailings pile and below the confluence with Shaw Branch. Similarly, Jennet et al. (1981) observed elevated levels of dissolved zinc at the same location. Jennet et al. (1981) suggested that Elvins tailings pile sediments and metals were washed into Flat River. The amounts of metals observed by Jennet followed a pattern similar to ours from higher near Elvins to lower further downstream. They also noted effects on the macroinvertebrate community downstream from the pile.

4.2.2 National Tailings Pile

It appears that National tailings pile contributes to the total recoverable lead and possibly dissolved lead levels in the water. The July 2001 sample below National was the highest of all samples for total recoverable lead in effluent from the tailings pile after a runoff event. If the entire sample consisted of lead as its dissolved components, it would exceed water quality standards for chronic, although not acute, limits. The September 2001 dissolved lead value at the station downstream of National was slightly higher than all stations upstream, again suggesting that National was the contributor. While National may be the contributor of dissolved lead in the water in small amounts, it may also be that lead is leaching from the sediment either from National or from the upstream tailings piles. An accurate determination cannot be made as to how much National contributes without more work.

Sediment and its components increase downstream of National. However, the increase in fine sediment is not as great as was observed upstream. The fine sediment percentage increased only slightly (i.e. from 70 to 77 percent), as compared to the doubling from upstream stations #3 to #2 (i.e. from 37 to 70 percent). This suggests that National is not as much a contributor relative to other test stations. Lead and zinc in the sediment were above PELs at the station below National. However, it may be due to the accumulation from upstream stations.

This reduction in the fine sediment percent may have enabled somewhat of a recovery in silt-tolerant species in the coarse substrate habitat at station #1. Coarse substrate habitat (i.e. riffles) would be the first habitat to recover from excess fine sediment deposits, which suggests that the system was recovering from a large input upstream. However, it appears that the National tailings pile may contribute fine sediment but apparently not continuous and not as much as upstream.

4.2.3 Federal Tailings Pile

The Federal Tailings Pile ephemeral runoff confluences with Flat River at the intermittent stream, Shaw Branch. Shaw Branch was dry during the March, July, and September samplings. Therefore, the water column values found below Shaw Branch are likely explained by high water column values from Elvins. Fine sediment may have been deposited from Federal at some time in the past, however, it is more likely that sediment is supplied by Elvins.

Personnel from St. Joe State Park observed similar values that could be explained by upstream influences. Federal tailings pile apparently did not contribute to the water impairment, sediment, or metals load during this project. Nor does it seem that it contributes during normal flow conditions. However, it may contribute in pulses during large rain events.

4.3 Macroinvertebrate Metric Response

Total taxa and EPT taxa metrics effectively revealed the impact of lead mine tailings on macroinvertebrate community composition. March 2001 Flat River control station #4 contained 95 total taxa and 22 EPT taxa. Downstream test station #1 samples had 68 total taxa and only six EPT taxa (Table 7). September Flat River samples averaged nearly 94 total taxa and 23 EPT taxa at the upstream control stations #5 and #4. The three downstream test stations #3, #2, and #1 averaged 70 total taxa and nine EPT taxa (Table 8). The percentage decline of EPT taxa from control to test stations was much larger than the decline of total taxa from control to test stations. EPT taxa at the test stations declined approximately 61 to 73%, but total taxa declined about 26 to 28%.

The larger percentage drop in EPT taxa was due to two factors. First, as a group, EPT taxa are more sensitive to various pollutants and habitat impairment than most macroinvertebrates and Ephemeroptera are generally the most sensitive of the EPT. Several species of Ephemeroptera are intolerant of excessive sediment and mayflies of the family Heptageniidae have been shown to be sensitive to metals (Clements et al. 1992), including lead and zinc. Therefore, a sharp decline in EPT taxa was expected. Second, the phenomenon of taxa replacement also was a factor in the changes of total taxa from control to test stations. Not only were most EPT taxa eliminated, but tolerant taxa replaced less tolerant taxa and thus the percentage decline of total taxa from control to test stations was not as severe as was the change in EPT taxa. For example, in the spring, station #4 had 73 non-EPT taxa (95 TT-22 EPT) and station #1 had 62 non-EPT taxa (68 TT-6 EPT), or roughly similar numbers. However, the two stations had only 42 non-EPT taxa in common, because of the replacement of presumably more sensitive non-EPT control taxa by more tolerant taxa downstream.

The analysis of the macroinvertebrate community using the SMSBPP showed that two of the metrics, the Shannon Diversity Index (SDI) and the Biotic Index (BI), were not sensitive to changes in the macroinvertebrate community between control and test stations. Values for both were similar to their test stations as well as to reference streams.

The SDI is computed from two elements: the number of taxa and the distribution of the individuals among the taxa, which is called evenness or equitability. If neither element of the index varies greatly among samples, then the SDI remains similar. Flat River control and test stations had similar SDI values because the components of the SDI remained proportionately similar between upstream control and downstream test stations for at least three reasons.

The SDI may have been affected by replacement of species from upstream to downstream. First, this study revealed that sensitive taxa, especially Ephemeroptera, were replaced by less sensitive chironomids, Coenagrionidae (damselflies), hydropsychid caddisflies, and Tubificidae (aquatic worms). Taxa replacement allowed the number of test station taxa to average about 75 percent of the control taxa number instead of a drastic drop of 50 percent or greater. Second, although the number of taxa decreased 25 percent from upstream to downstream, the number of individuals per sample also decreased from control to test stations. Control stations #5 and #4 averaged 1460 organisms and 94 taxa per sample, while test stations #3, #2, and #1 averaged 925 organisms and 70 taxa per sample. Third, none of the downstream replacement taxa made up a very large proportion of the sample. Unlike a stressor such as organic pollution that usually results in excessive dominance of the macroinvertebrate community by a few tolerant species, the impact of the tailings and heavy metals did not result in strong taxa dominance. Thus the relative diversity downstream was very similar to upstream values.

The Biotic Index (BI) metric was not sensitive to Flat River tailings and heavy metal impacts. The BI developed for Missouri assigns tolerance values to taxa based on their response to organic contaminants. In this study, organics were not prevalent, whereas, fine sediment and heavy metals were widespread. The BI, therefore, did not respond well to the faunal changes between control and test stations on Flat River based on fine sediment or metals contamination.

Flat River control stations had a somewhat tolerant macroinvertebrate community in comparison to the reference streams. For example, the station #5 and #4 control mean BI averaged 6.6, while the average BI of the small reference streams was 5.1. Because of this difference, the control station BI values were each 3 instead of 5. A change in the fauna severe enough to drop the test station BI values to a value of 1 would have required a more severe impact, such as an untreated sewage input. Therefore, the Flat River controls may be impaired by influences such as urbanization that was not found at reference streams.

Tolerance values are being developed that reflect taxa sensitivity to fine sediment and metals. For example, Zweig (2000) has developed sediment tolerance values for 30 macroinvertebrate taxa found in Missouri streams. Also, Clements, (et. al. 1992) developed an index of macroinvertebrate community sensitivity (ICC) to metals and provides suggestions for ICC development. Tolerance values for macroinvertebrate response to fine sediment and metals should be incorporated in future studies to more fully understand their response.

4.4 Biases

As was found by Zwieg (2000), estimating the percentage of substrate particle sizes per given area was efficient and effective. With modifications, a potential bias was observed in this study in relating macroinvertebrate communities with fine sediment percentages. Percentage of fine sediment was not estimated in the exact habitat where macroinvertebrates were collected. A compromise location was chosen in between coarse substrate and non-flow habitats much the same as Zwieg (2000). The location was chosen to avoid overestimating or underestimating the percentage of sediment in the stream. It appears that this location is acceptable.

The grid locations were placed to attain a dynamic measurement of fine sediment loading. Locations had to be less than a maximum velocity of less than 0.5 fps in an area downstream from coarse substrates (i.e. riffles) and upstream from pools. Coarse substrates usually are above that minimum velocity so not much sediment is deposited under normal flow or sediment that is deposited would quickly be removed. Fine sediments for the entire stream station would then be underestimated. Evidence of quick removal was found in the coarse substrate at our farthest downstream station (#1). It appeared that fine sediment decreased, while silt sensitive species returned to the coarse substrate habitat in station #1. Conversely, sediment would be overestimated in non-flow habitats where the stream would deposit inordinate quantities of sediment for longer periods of time. Evidence of this is that silt sensitive species were not present in the non-flow habitat of station #1 where fine sediments were present in high amounts and where macroinvertebrates were making a come back. It appears that to estimate at either habitat would have biased the estimate for the entire stream either too high or too low.

However, the question remains, is it effective in estimating the percentage of fine sediment per square feet for the stream that can be interpreted with other variables? The percentage of fine sediment increased and the silt sensitive macroinvertebrates decreased at station #3. It appears that fine sediment levels went up while silt sensitive taxa declined in at least the Elvins confluence. Conversely, silt sensitive species may have recovered somewhat in the coarse substrate habitat of the final station as fine sediment decreased in that habitat (pers. obs.). The rate of increase of fine sediment is less between station #2 and station #1 indicating that the rate of input is decreasing. Thus, the amount of sediment observed in this stream is dynamic and does respond with increasing or decreasing amounts of fine sediment collected using our method. Macroinvertebrates responded to the percentage of fine sediment through changes in abundance and composition. Therefore, the method and chosen location for sampling is apparently sufficient to be related to taxa response.

Lastly, a large-scale threshold effect was observed at station #3, where water and sediment variable measurements increased and taxa decreased. This sudden effect could not be correlated because it was sudden and nearly complete. We could not correlate potentially threatening variables with the indicator species of EPT taxa or Ephemeroptera. On the stream-sized scale, the input occurred and all of the intolerant taxa were removed. Thus, what exactly and how much caused their removal is not known because of a nearly complete decline between stations. A small-scale study should be conducted to allow for correlations between the three variables (i.e. fine sediments, lead, zinc) and the macroinvertebrate communities within station #3, where the major input occurred. Also, in order to determine specific contributors that may be harmful, metal concentrations in the macroinvertebrates should be identified. These recommendations may identify tolerance levels and toxic agents responsible for removal of intolerant taxa from Flat River. This will also help assign numeric metals tolerance values for use in a metal index.

5.0 Conclusions

Three potential threats to Flat River were positively identified during this study. The percentage of fine sediments, amounts of total recoverable lead in the water and sediment, as well as dissolved zinc in the water column were identified as threats and contributing causes for poor water quality in Flat River. It appeared that Elvins and National tailings piles may be contributors to that impairment. Furthermore, some element within a fine sediment sample was toxic to aquatic life according to Microtox^{TM} results. Despite the strong suggestion that any one or combination of these variables is responsible for impairment and that it is toxic, cause-effect relationships cannot absolutely be established without more work.

The purpose of this study was to determine if Flat River is impaired by mining influences. The objectives were fulfilled with a strong suggestion that the macroinvertebrate communities and water quality were affected by influences of mining practices. We determined that fine sediment and certain heavy metals were present in Flat River and their origin was apparently Elvins tailings pile and intermittently from the National tailings pile. We defined habitat influences on Flat River. Habitat was impaired by fine sediment, urban influences, and bedrock to a level below regional reference streams.

None of the null hypotheses was supported by this study. Macroinvertebrate communities were not similar between control and test stations or the reference streams. Water quality was considerably impaired between control and test stations, as well as between Flat River and the reference streams. The amount of fine sediment was much greater downstream of the controls and the character of the sediment was different from controls to test stations. Habitat assessment scores were dissimilar between control and test stations and between control and reference stations.

6.0 Recommendations

Prevent fine sediments from Elvins and National tailings piles from entering Flat River.

Monitor percent and character (composition) of fine sediment downstream of two major tailings piles after remediation.

Monitor dissolved lead and zinc levels downstream from two major tailings piles.

Conduct a small-scale correlation study downstream of station #3 to determine how much toxic input affects the community.

Conduct metals content analysis on macroinvertebrates in the stream.

Assign tolerance values to macroinvertebrates for use in fine sediment and metals indices.

7.0 Summary

1. Flat River macroinvertebrate habitat was impaired at one of two upstream control stations and two of three downstream test stations. Habitat impairment was caused by bedrock substrate at the upstream site. Lead mine tailings and an urban environment were largely responsible for downstream habitat impairment.

2. The Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP) found that the macroinvertebrate community of test stations was only partially sustainable or non-sustainable in comparison to Flat River controls and reference stations. The Biotic Index (BI) and Shannon Diversity Index (SDI) were not sensitive measurements of changes in the macroinvertebrate community between control and test stations.

3. Flat River was impaired by lead mine tailings piles. Erosion of tailings caused excessive fine sediment deposits and embeddedness of Flat River macroinvertebrate habitats. Lead concentrations in the sediment were above acceptable levels. Leaching of zinc from tailings likely caused toxic levels of this metal and contributed to the elimination of sensitive macroinvertebrate taxa.

4. The impact of the lead mine tailings piles caused marked differences in macroinvertebrate composition and abundance between control and test stations. Three major changes in the macroinvertebrate fauna at test stations were:
a. Numbers of EPT taxa declined 50% or more at test stations compared to control stations.

b. Ephemeroptera taxa and abundance declined drastically at test stations, especially below the Elvins Tailings Pile.
c. Metal sensitive macroinvertebrates at control stations were replaced by more tolerant taxa at test stations.

5. Physicochemical and sediment results show dissolved zinc concentrations in the water column above acute and chronic Water Quality Standards at two stations below Elvins tailings pile. The percentage of fine sediment per area increased downstream from Elvins and National tailings piles and lead increased or accumulated downstream in the fine sediment at concentrations above Probable Effects Levels (PELs).

6. Elvins tailings pile apparently contributes fine sediment and total recoverable lead and zinc to the substrate and dissolved zinc to the water column. National tailings pile contributes fine sediment and total recoverable lead intermittently during rain events. Federal tailings pile did not obviously contribute pollutants during the three sampling events, although it may during extreme runoff events.

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Table 10
Flat River Control and Test Stations for Macroinvertebrate Composition per Station, March and September 2001. Upstream to Downstream per Season.

Variable-Station	Flat River #4 Control Station-March 2001	Flat River #1, Test Station-March 2001	Flat River #5, Control Station-September 2001	Flat River #4, Control Station-September 2001	Flat River #3, Test Station-September 2001	Flat River #2, Test Station-September 2001	Flat River #1, Test Station-September 2001
Macro Sample Number	01-19506	01-19505	01-37074	01-37073	01-37072	01-37071	01-37070
Total Taxa	95	68	87	100	69	67	75
Number EPT Taxa	22	6	22	24	7	9	11
% Ephemeroptera	3.1	0.7	38.9	39.5	0.1	0.5	10.8
% Plecoptera	4.2	-	-	-	-	-	0.1
% Trichoptera	0.7	6.4	5.4	9.7	7.2	8.6	10.4
% Dominant Macro Fam							
Chironomidae	61.5	41.5	15.3	20.3	29.5	35.9	47.6
Asellidae	6.8	-	-	-	-	-	-
Elmidae	4.8	8.5	11.4	5.2	-	-	5.8
Planariidae	4.0	-	-	-	-	-	-
Tubificidae	2.5	-	-	-	5.6	11.4	-
Ceratopogonidae	-	10.8	-	-	-	-	-
Coenagrionidae	-	8.7	-	4.7	14.9	30.0	10.7
Leptoceridae	-	4.7	-	-	-	-	-
Tricorythidae	-	-	16.1	-	-	-	7.5
Caenidae	-	-	15.1	35.7	-	-	-
Hyalellidae	-	-	10.8	6.9	-	-	-
Empididae	-	-	-	-	12.5	-	
Hydropsychidae	-	-	-	-	-	6.2	9.4
“Hydracarina”	-	-	-	-	6.0	3.9	-

Table 11
Small Reference Streams. Macroinvertebrate Composition per Station, September 2001.

Variable-Station	Courtois Creek #3	Cub Creek #1	Shoal Creek #1	East Fork Huzzah Creek #1	West Fork Huzzah Creek #1
Macro Sample Number	01-37065	01-37063	01-37067	01-37068	01-37069
Total Taxa	64	83	67	85	86
Number EPT Taxa	18	27	19	21	26
% Ephemeroptera	35.7	30.1	33.1	28.7	25.7
% Plecoptera	0.1	0.2	-	0.3	-
% Trichoptera	7.6	3.7	2.6	6.9	6.8
% Dominant Macro Families					
Elmidae	32.8	30.0	14.4	10.6	21.8
Caenidae	20.0	6.8	-	-	-
Heptageniidae	10.9	18.4	16.2	13.0	12.1
Chironomidae	9.7	16.0	13.3	12.1	14.8
Psephenidae	7.8	7.5	10.9	15.2	-
Hyalellidae	-	-	12.1	10.1	7.3
Hydropsychidae	-	-	-	-	5.3

Table 12
Flat River Physicochemical Water Variables per Station, March 2001. Units mg/L unless otherwise noted.

Variable-Station	Station #4 At Hwy 32/Bus 32, Control Station- March 2001	Station #1 Above Big River Confluence, Test Station- March 2001
Phys/Chem Sample Number	01-16969	01-16968
pH (Units)	8.45	7.94
Temperature (C^0)	9	11
Conductivity (uS)	358	656
Dissolved O_2	13.2	12.0
Discharge (cfs)	4.19	11.50
Turbidity (NTUs)	<1.00	<1.00
Hardness $CaCO_3$	160	320
Ammonia-N	--	--
Nitrate/Nitrite-N	--	--
TKN	--	--
Sulfate	--	--
Chloride	--	--
Total Phosphorus	--	--
Barium, Total Recoverable (TR) ug/L	--	--
Calcium, TR	31.0	65.5
Cadmium, TR ug/L	<1.00	<1.00
Copper, TR ug/L	--	--
Iron, TR ug/L	--	--
Magnesium, TR	20.0	37.2
Lead, TR ug/L	<3.4	23.2
Zinc, TR ug/L	<5.00	106

Table 13
Flat River Physicochemical Water and Sediment Variables, July 2001. Bold exceeds Probable Effects Levels (Ingersoll et al. 1996).
Units mg/L unless otherwise noted; Sediment (Sed.); Total Recoverable Metals, (TR).

Variable-Station	Station #5 @ Hwy 32 Bridge July 2001	Station #4 @ Hwy 32/ Bus 32 July 2001	Elvins TP Influence- July 2001	Station #3 Down Shaw Branch- July 2001	Natl. TP, Upstream July 2001	Natl. TP, downstream July 2001
Phys/Chem Sample Number	01-26790	01-26789	01-26788	01-26784	01-26787	01-26785
pH (Units)	8.30	8.70	8.20	8.20	8.30	8.30
Temperature (C^0)	21	24	23	21	23	23
Conductivity (uS)	415	367	1,470	847	610	750
Hardness $CaCO_3$	180	170	860	460	290	390
Calcium, TR	35.5	32.2	222	99.4	64.0	81.9
Cadmium, TR ug/L	<2.00	<2.00	14.6	<2.00	<2.00	<2.00
Magnesium, TR	22.2	21.0	74.5	52.4	32.7	43.9
Lead, TR ug/L	<3.4	<3.4	45.7	24.4	52.2	105
Zinc, TR ug/L	<5.00	<5.00	4,020	261	106	81.5
Sediment Sample Number	--	--	--	--	--	01-26786
Cadmium, Sed.TR ug/kg	--	--	--	--	--	3,390
Lead, Sed. TR ug/kg	--	--	--	--	--	**5,870,000***
Zinc, Sed. TR ug/kg	--	--	--	--	--	193,000

* Ingersoll 1996- >Probable Effects Levels (PEL)

Table 14
Flat River Physicochemical Water Variables per Station, September 2001. Bold value exceeds minimum Water Quality Standards 10 CSR 20-7. Units mg/L unless otherwise noted;
c = chronic exposure limit, a = acute exposure limit.

Variable-Station	Flat River #5, Control Station-September 2001	Flat River #4, Control Station-September 2001	Flat River #3, Test Station-September 2001	Flat River #2, Test Station-September 2001	Flat River #1, Test Station-September 2001
Phys/Chem Sample Number	01-39367	01-39366	01-39365	01-39364	01-39360
pH (Units)	8.30	8.50	7.90	8.00	8.10
Temperature (C^0)	19	19	17	17	20
Conductivity (uS)	502	484	555	1300	879
Dissolved O_2	9.8	9.8	6.0	7.3	8.9
Discharge (cfs)	0.40	0.70	0.30	0.80	3.10
Turbidity (NTUs)	<1.00	1.07	2.38	2.12	5.19
Hardness $CaCO_3$	220	210	360	740	470
Ammonia-N	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrate/Nitrite-N	<0.05	<0.05	0.08	<0.05	0.10
TKN	0.30	0.20	0.35	<0.20	<0.20
Sulfate	47.5	41.0	131	575	262
Chloride	31.1	27.8	21.8	12.5	21.5
Total Phosphorus	0.10	<0.05	<0.05	<0.05	<0.05
Barium, Dissolved ug/L	120	95.1	71.4	75.4	50.2
Calcium, Dissolved	42.6	39.0	77.9	182.0	95.4
Cadmium, Dissolved ug/L	<1.00	<1.00	1.84	<1.00	<1.00
Copper, Dissolved ug/L	<10.0	<10.0	<10.0	<10.0	<10.0
Iron, Dissolved ug/L	11.9	43.3	8.81	5.64	<5.0
Magnesium, Dissolved	27.3	26.7	39.4	70.1	55.2
Lead, Dissolved ug/L	<2.5	<2.5	<2.5	<2.5	11.0
Zinc, Dissolved ug/L	<5.00	<5.00	**754 c, a**	**622 c, a**	34.4

Table 15
Reference Streams Physicochemical Water Variables per Station, September 2001. Units mg/L unless otherwise noted.

Variable-Station	Courtois Creek #3, September 2001	Cub Creek #1, September 2001	Shoal Creek #1, September 2001	East Fork Huzzah #1, September 2001	West Fork Huzzah #1, September 2001
Phys/Chem Sample Number	01-39355	01-39351	01-39359	01-39357	01-39356
pH (Units)	8.00	8.10	8.30	8.10	8.20
Temperature (C^0)	20	20	21	19	17
Conductivity (uS)	359	419	420	412	389
Dissolved O_2	8.3	6.8	9.4	6.8	8.8
Discharge (cfs)	1.20	0.50	1.50	3.60	4.70
Turbidity (NTUs)	<1.00	<1.00	<1.00	<1.00	<1.00
Hardness $CaCO_3$	190	220	240	220	220
Ammonia-N	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrate/Nitrite-N	<0.05	0.13	<0.05	0.13	0.08
TKN	<0.20	<0.20	<0.20	<0.20	<0.20
Sulfate	<5.00	<5.00	<5.00	<5.00	<5.00
Chloride	<5.00	<5.00	<5.00	<5.00	<5.00
Total Phosphorus	<0.05	<0.05	<0.05	<0.05	<0.05
Barium, Dissolved ug/L	53.0	84.9	50.0	44.9	41.7
Calcium, Dissolved	39.4	45.3	44.8	44.0	44.4
Cadmium, Dissolved ug/L	<1.00	<1.00	<1.00	<1.00	<1.00
Copper, Dissolved ug/L	<10.0	<10.0	<10.0	<10.00	<10.0
Iron, Dissolved ug/L	<5.00	<5.00	11.2	<5.00	<5.00
Magnesium, Dissolved	23	26.3	30.0	26.4	25.7
Lead, Dissolved ug/L	<2.5	<2.5	<2.5	<2.5	<2.5
Zinc, Dissolved ug/L	<5.00	<5.00	<5.00	<5.00	<5.00

Table 16

Percentage of Sediment Values Observed per Grid-Quadrat and Station in September 2001 on Flat River. Stations-Upstream to Downstream (left to right). Six Quadrats per Grid, 18 per Station.

Grid-Quadrat	Flat River #5, Control Station- September 2001	Flat River #4, Control Station- September 2001	Flat River #3, Test Station- September 2001	Flat River #2, Test Station- September 2001	Flat River #1, Test Station- September 2001
1-1	17	16	10	55	70
1-2	19	48	05	99	92
1-3	04	27	19	85	79
1-4	22	07	03	96	95
1-5	04	04	08	89	63
1-6	01	31	05	98	10
2-1	12	05	07	72	95
2-2	03	02	89	87	90
2-3	03	03	17	96	83
2-4	03	08	02	85	98
2-5	30	02	24	81	80
2-6	24	04	14	58	91
3-1	88	28	95	70	85
3-2	88	25	90	51	33
3-3	18	04	75	48	75
3-4	03	06	30	14	94
3-5	50	12	96	54	88
3-6	37	85	75	25	75
Average	23.67	17.61	36.89	70.17	77.56

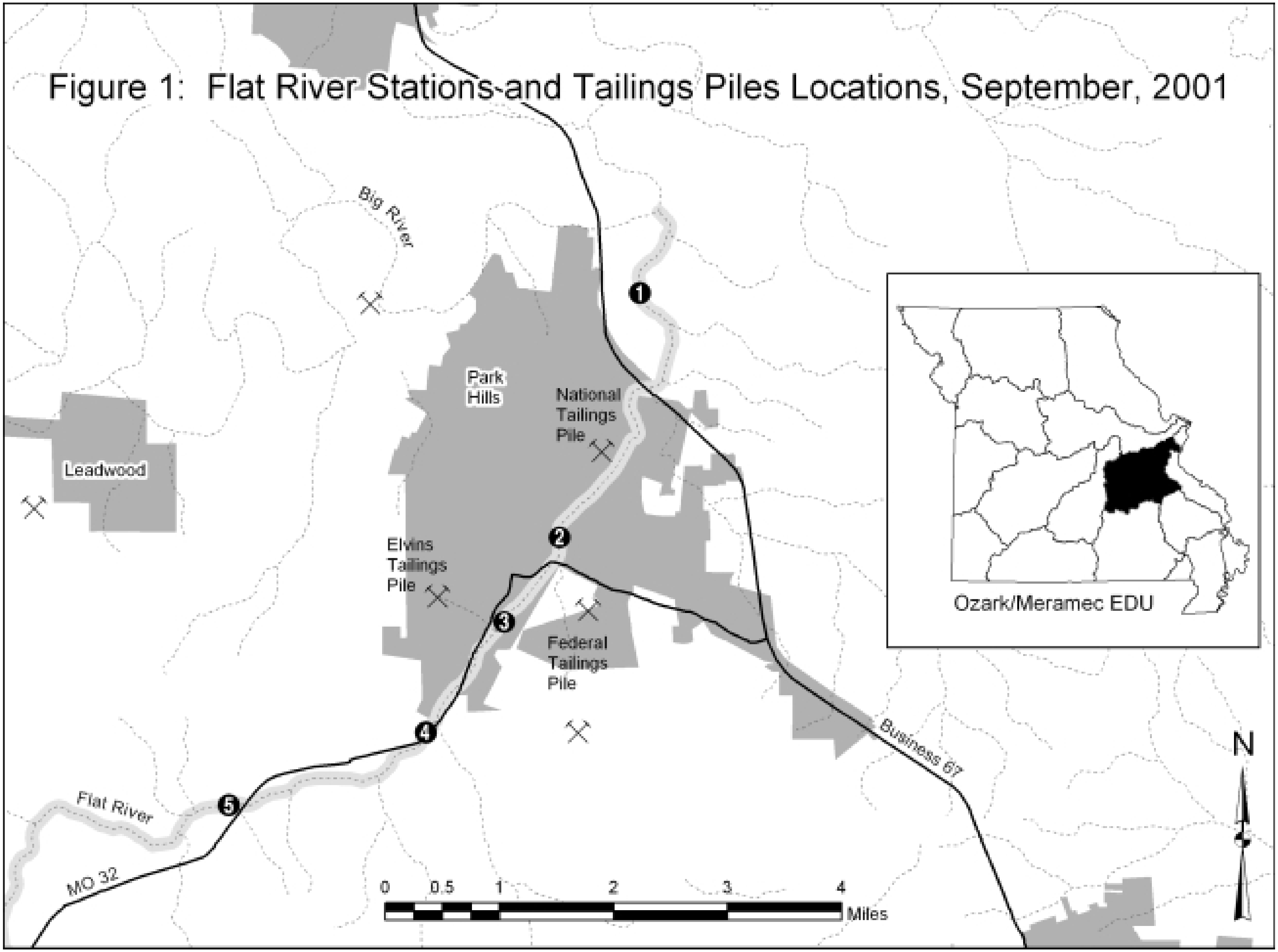


Figure 1: Flat River Stations and Tailings Piles Locations, September, 2001
Big River
Park Hills
National Tailings Pile
Leadwood
Elvins Tailings Pile
Federal Tailings Pile
Business 67
Flat River
MO 32
0 0.5 1 2 3 4
Miles
N
Ozark/Meramec EDU

Figure 2: Flat River Dissolved Zinc (ug/L) Levels per Station, September 2001

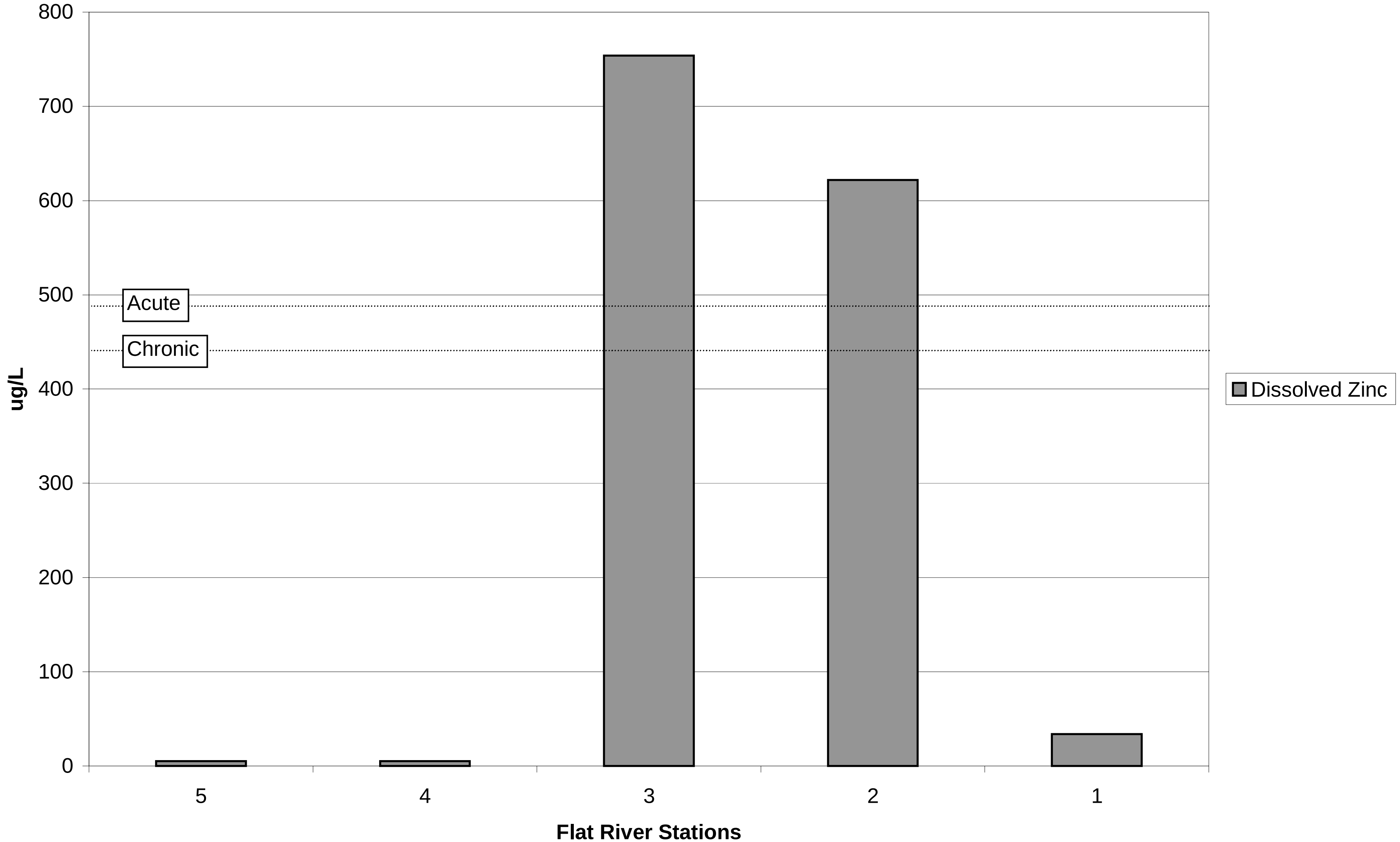


Figure 3: Flat River Average Sediment Percentage, with Lead and Zinc Values per Station, September 2001

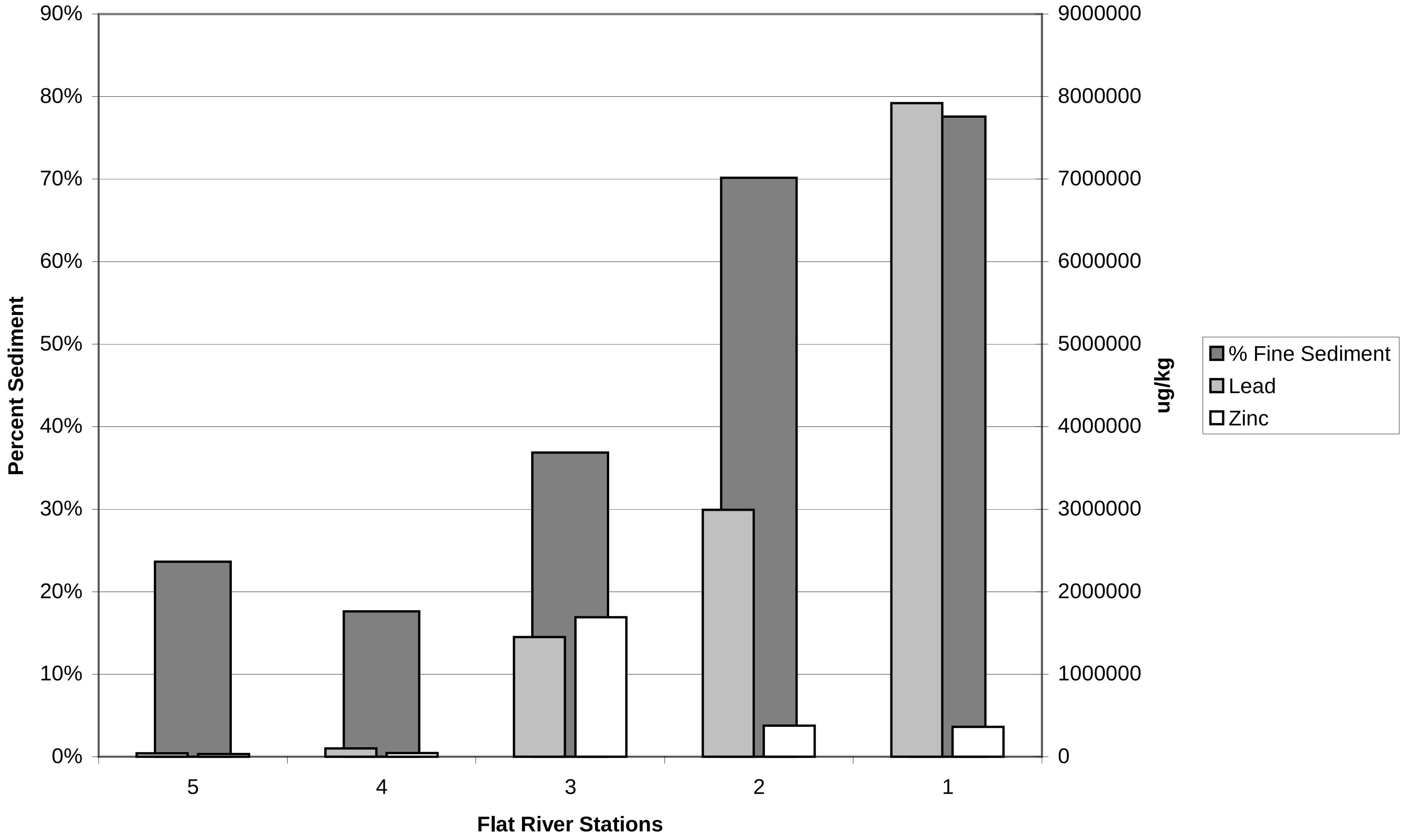
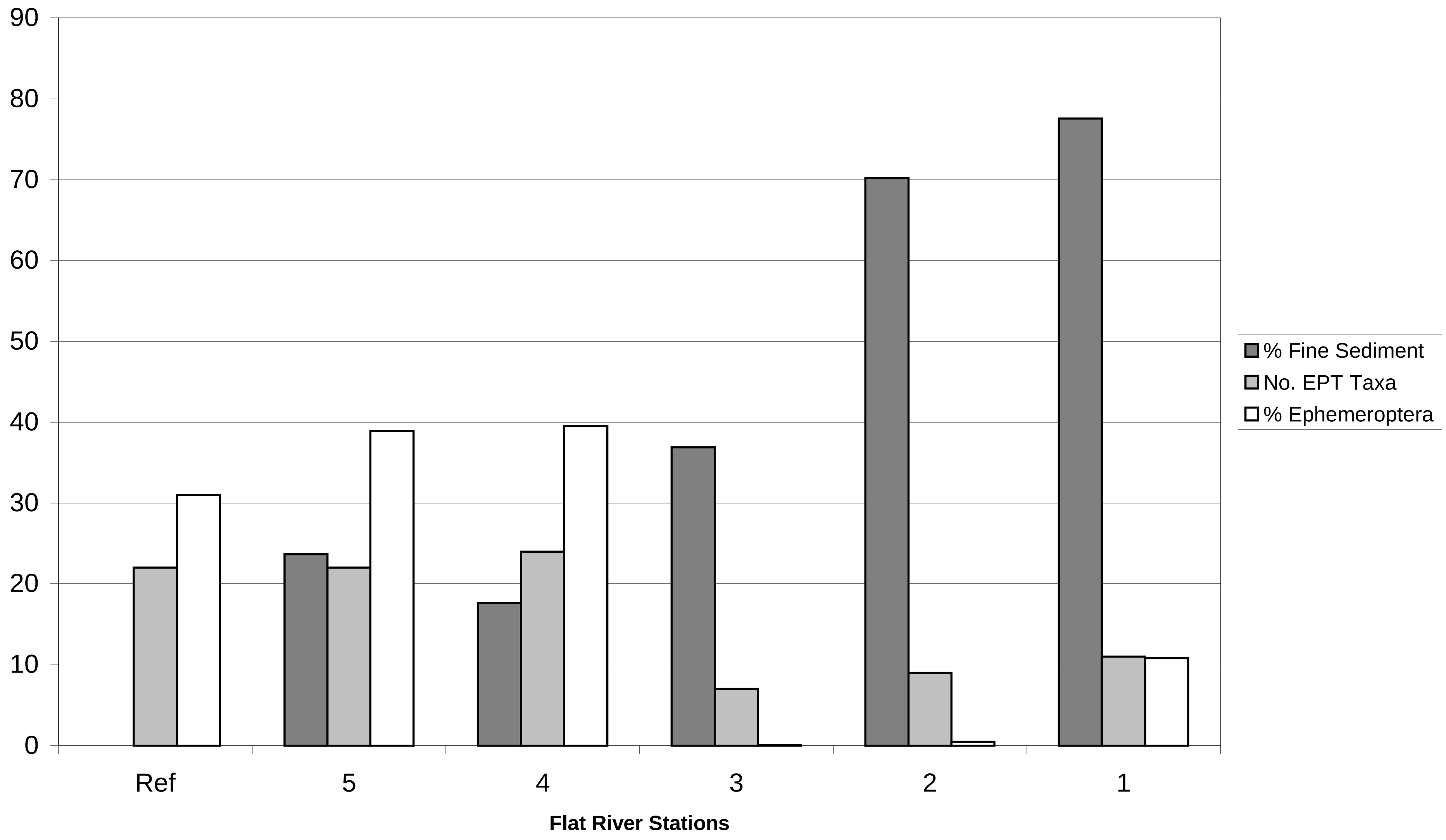


Figure 4: Flat River Percent Fine Sediment, EPT Taxa, and Percent Ephemeroptera per Station, September 2001



Submitted by: ____

Steve Humphrey and Kenneth B. Lister
Environmental Specialists III
Environmental Services Program
Water Quality Monitoring Section

Date: ____

Approved by: ____

Earl Pabst
Director
Environmental Services Program

EP:sh:klt

c: Gary Gaines, Regional Director, SERO
John Ford, QAPP Project Manager, WPCP
Becky Shannon, Acting Section Chief, WPCP

Appendix A

Missouri Department of Natural Resources
Bioassessment and Sediment Study Proposal
Flat River, St. Francois County
Revised June 7, 2002

Missouri Department of Natural Resources
Bioassessment and Sediment Study Proposal
Flat River, St. Francois County

Revised
June 7, 2002

Objectives

1) Conduct a bioassessment of the macroinvertebrate community of Flat River, St. Francois County.

2) Conduct a sediment study of Flat River. Determine if sediments are derived from lead mine tailings.

Null Hypotheses

The macroinvertebrate communities of the 303d listed segment of Flat River and the control segments or streams, are similar.

The extent of stream bottom occupied by fine sediments within the 303d listed segment of Flat River and the control segments or streams, are similar. Lead mine tailings are not a significant source of sediment.

Background

The old Lead Belt area within St.Francois County contains several large lead mine tailings piles. During significant rainfall events the tailings piles erode and discharge substantial quantities of sediment into Flat River. Previous sampling and observations by DNR personnel have shown (1) tailings piles discharging sediment into Flat River,(2) significant concentrations of lead and zinc within water and sediment samples from Flat River and (3) indications of an impaired macroinvertebrate community within Flat River down stream from the tailings piles. The mine tailings may impair the macroinvertebrate community by sedimentation and/or toxic effects of metals on sensitive taxa. In addition, Flat River below the tailings piles flows largely through the urban watershed of Park Hills, Missouri, and the stream may also be impacted by urban runoff and watershed alterations.

Study Design

General: Three Flat River stations, each downstream from one of three tailings piles, will serve as impacted sites. Two Flat River stations upstream from all tailings piles will be used as controls (Figure 1). In addition, several minimally impaired streams of similar size within the Meramec/Ozark Ecological Drainage Unit (EDU) will serve as references for Flat River.

Stream reaches of twenty average stream widths will define each sampling station as per the MDNR Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP). In order to assess variability among sampling stations, stream discharge, habitat assessment, and water chemistry will be determined during macroinvertebrate sampling.

Sampling will be conducted during the Fall of 2001.

Biological Sampling Methods: The macroinvertebrate community of a five-mile segment of Flat River that is 303d listed for lead, zinc and sediment (proposed to be changed to total suspended solids), will be compared with a control segment of Flat River and other streams not impaired by lead, zinc and sediment. The MDNR (SMSBPP) will be used within riffle-run, pool, and root-mat habitats. Each macroinvertebrate sample will be a composite of six subsamples within each habitat as per the procedure.

Habitat Sampling Methods: The MDNR Stream Habitat Assessment Project Procedure (SHAPP) will be utilized at all stations on Flat River and the reference streams. Stream discharge will be measured upstream and downstream from the potentially impacted segment (stations #1, #2, and #3), the control segment (stations #4 and #5), and at each reference stream.

Water Quality Sampling Methods: Water samples from all stream stations will be analyzed at the ESP laboratory for dissolved metals (barium, cadmium, copper, iron, lead, zinc, calcium and magnesium). Additional samples will be analyzed for sulfate, chloride, TKN, ammonia nitrogen, nitrite plus nitrate nitrogen, total phosphorus turbidity, and hardness. Field analyses will include pH, conductivity, temperature and dissolved oxygen.

Sediment Percentage and Characterization: To ensure sampling method uniformity, depositional areas sampled will be in-stream at the upper margins of pools and lower margins of riffle/run habitat. Depths of the sample areas will not exceed two (2.0) feet and water velocity will be less than 0.5 feet per second (fps). A Marsh McBirney flow meter will be used to ensure that water velocity of the sample area is within this range.

In-stream deposits of fine sediment (i.e. less than particle size ca. 2mm= coarse sand) will be (1) estimated for percent coverage per area and (2) characterized by chemical analysis for total recoverable metals (TRM).

A visual method will be used to estimate the percentage of fine sediment. Each sampling station shall be composed of three sample areas (i.e. grids) each consisting of six contiguous transects across the stream. A tape measure will be stretched from bank to bank at each transect. One sample quadrat (ca. 10 x 10 inches) will be placed directly on the substrate within each of the six transects using a random number that equates to one foot increments. The trailing edge of the quadrat will be placed on the random foot increment. Two investigators will estimate the percentage of the stream bottom covered by fine sediment within each quadrat. If the estimated percentages are within ten percent between investigators, it will be accepted. If estimates diverge more than ten percent, the investigators will repeat the process until the estimates are within the acceptable margin of error. An average of these two estimates will be recorded and used for analysis.

Sediment will be characterized by determining the content of total recoverable metals (TRM) at each of the transect-grids. Specifically, sediments will be analyzed for lead and zinc content. Composite collections will be taken within each transect-grid of sediments that are similar in appearance to the sediment estimated earlier for percentage. If amounts of sediment are too small within the grid, a representative composite collection will be taken from an area near the study grid. Each composite will consist of three (3) two-ounce grab samples of sediment. One (1) two-ounce glass jar will be used as a collection device to dredge the bottom to a depth, within the sediment, of no more than two inches. In order to retain the fine sediment, the sediment sample will be held inside the jar for removal from the water column by covering the opening with the back of the cap. Each sample will be deposited into an eight-ounce glass jar comprising a composite for each transect-grid. There will be three transect-grids per station in order to more accurately characterize and lessen potential bias. Each composite jar will be placed on ice for transport to the ESP Lab according to SOP, MDNR-FSS-001.

The lead and zinc TRM concentration within the composite sediment sample will be compared to grab samples collected from the nearest tailings pile. These comparisons may also determine if stream sediments are derived from lead mine tailings.

Laboratory Methods: Analyses of biological and chemical samples will be conducted at the MDNR Environmental Laboratory (ESP) in Jefferson City, Missouri. Biological samples will be processed and identified according to MDNR-FSS-209 Taxonomic Levels for Macroinvertebrate Identifications. The MDNR Environmental Laboratory-ESP will conduct water quality analysis for dissolved metals, as well as for Total Recoverable Metals (TRM) analysis on the sediment samples. Turbidity will be quantified in the Biology/Toxicology Lab at ESP.

Data Recording and Analyses: Macroinvertebrate data will be entered in a Microsoft Access database according to the MDNR Standard Operating Procedure MDNR-WQMS-214, Quality Control Procedures for Data Processing. Data analysis is automated within the Access database. Four standard metrics are calculated according to the SMSBPP: Total Taxa (TT); Ephemeroptera, Plecoptera, Trichoptera Taxa (EPTT); Biotic Index (BI); and the Shannon Index (SI) will be calculated for each reach. Additional metrics, such as Quantitative Similarity Index for Taxa (QSI-T), or Percent

Scrapers (PS) may be employed to discern differences in taxa between control and impacted stations. Macroinvertebrate data from five regional reference streams within the Meramec/Ozark EDU will allow for the calculation of a 25th percentile for the four metrics in the SMSBPP. Flat River will be scored against these calculations and a composite score of 16 or greater will determine non-impairment. The percentage of sediment deposition will be compared between stations, sites, or grids. This will be done by parametric comparisons of means, correlation, or non-parametric methods, at a significant probability level ($p < 0.05$).

Ordination of the communities with multiple linear regression will be used in conjunction with water chemistry, sediment chemistry, sedimentation, and habitat assessment to analyze and correlate with environmental variables.

Data Reporting: Results of the study will be written in report format.

Quality Control: As stated in the various MDNR Project Procedures and Standard Operating Procedures.

Attachments:
Figure 1: Map with sampling stations on Flat River, St. Francois County.

List of sampling stations with GPS location data.

Flat River Bioassessment and Sediment Study

Sampling Stations

Flat River Stations

Flat River #1, St. Francois Co. - SE ¼; S29; T37N; R5E, downstream from confluence with National Tailings Pile breakout discharge point (upstream from the Park Hills WWTF = Mineral Belt WWTF). Contact: Randy Hulsey (plant op.) (573) 431-3024. GPS (at confluence of Flat River and tailings pile discharge): Lat. – N 37° 51' 30.9" Long . - W 90° 30' 27.5"

Flat River #2, St. Francois Co. - NE ¼; S7; T36N; R5E, downstream from confluence with Shaw Branch = Federal Tailings Pile discharge point (upstream from National Tailings Pile). Contact: none. GPS (at confluence of Flat River and Shaw Branch): Lat. – N 37° 50' 51.5" Long. – W 90° 31' 2.0"

Flat River #3, St. Francois Co. - near Sec. Line 7/18; T36N; R5E, downstream from confluence with Elvins Tailings Pile breakout discharge point (upstream from Shaw Branch). Contact: none. GPS (at confluence of Flat River and tailings pile discharge): Lat. – N 37° 50' 21.3" Long. – W 90° 31' 37.3"

Flat River #4, St. Francois Co. – SE ¼; S13; T36N; R4E, @ Hwy. B crossing (downstream of crossing and downstream from confluence of Flat River with Bannister Branch) Contact: none GPS (~40 yards downstream from crossing): Lat. – N 37° 49' 33.7" Long. – W 90° 32' 22.3"

Flat River #5, St. Francois Co. – NE ¼; S22; T36N; R4E, @ Hwy. 32 crossing (upstream). Contact: none GPS: Lat. – N 37° 49' 05.0" Long. – W 90° 34' 14.6"

Regional Reference Stations

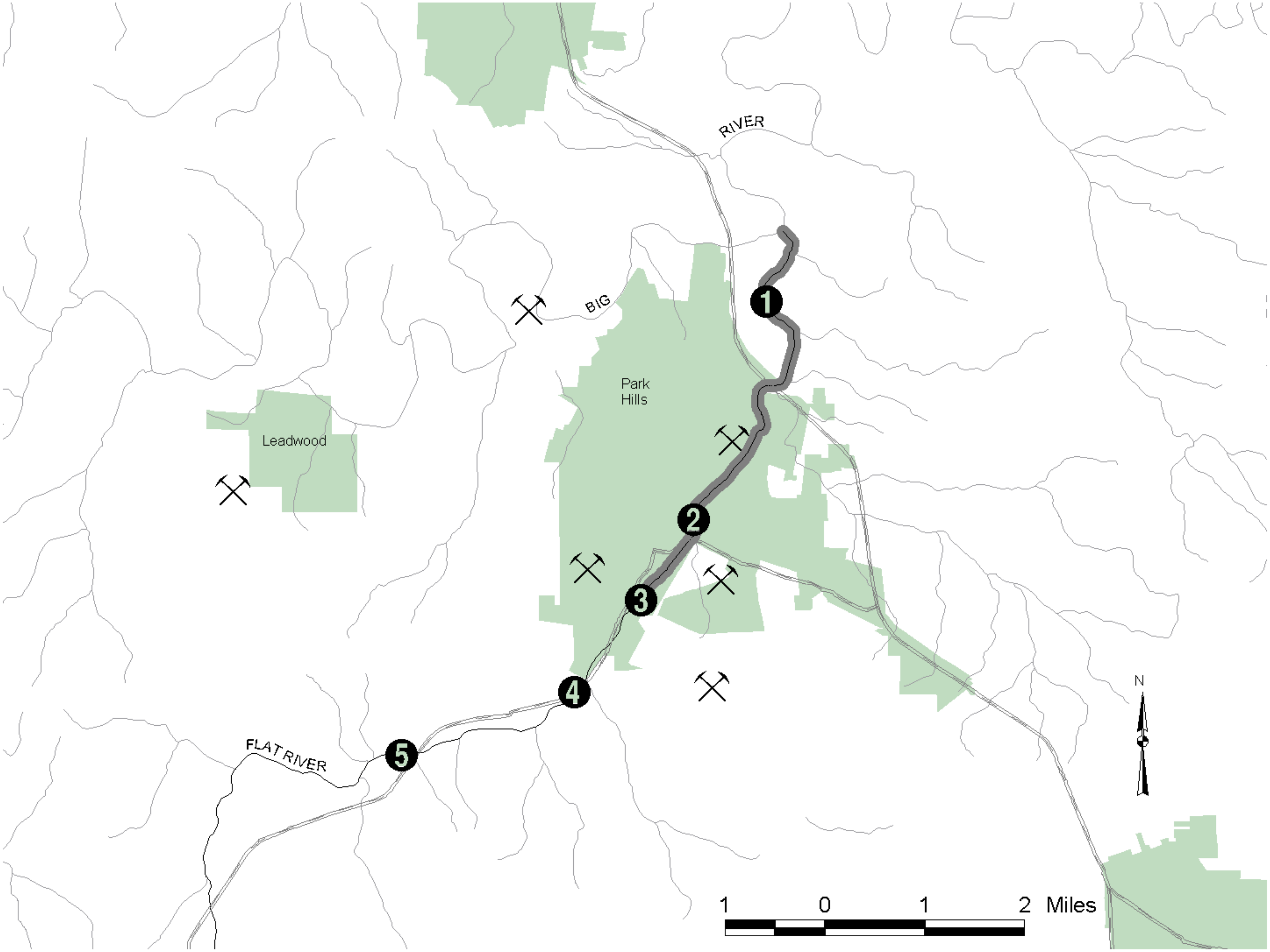
Courtois Creek #3, Washington Co. – SE ¼; S8; T35N; R1W, upstream from Indian Creek.

West Fork Huzzah Creek #1, Dent Co.

East Fork Huzzah Creek #1, Dent Co.

Shoal Creek #1, Crawford Co.

Cub Creek #1, Washington Co.


RIVER
BIG
Park
Hills
Leadwood
FLAT RIVER
1
2
3
4
5
N
1 0 1 2 Miles

Appendix B

Fish Species Collected by Steve Fischer, Missouri Department of Conservation

MISSOURI DEPARTMENT OF CONSERVATION

Headquarters

2901 West Truman Boulevard, P.O. Box 180, Jefferson City, Missouri 65102-0180

Telephone: 573/751-4115 ▲ Missouri Relay Center: 1-800-735-2966 (TDD)

JERRY M. CONLEY, Director

RECEIVED

01 DEC -5 AM 10: 22

DEPT. OF NAT. RESOURCES
ENVIRONMENTAL SERVICES

Reply to: Conservation Research Center
1110 South College Ave.
Columbia, MO 65201
Telephone: 573/882-9880
FAX:573/882-4517

December 3, 2001

Ken Lister
Missouri DNR
Environmental Services Program
PO Box 176
Jefferson City, MO 65102-0176

Ken,

Below is a list of fish species collected (number and sizes) during a stream visit to Flat River (St Francois County) on 9 August 2000. This particular site began upstream of the bridge crossing on State Steet / St Joe Dr; the site extends 240 m upstream of the pipe crossing. Fish were collected with both backpack electrofishing gear and seine. I have included basic water quality data recorded during this visit (T = 24.8°C, DO = 7.5 ppm, pH = 7.2, Cond = 930, turbidity = 5.03 NTU, Chl A =); stream discharge was 0.02 m^3/sec. Attached are 2 site photographs.

ℓ 4.01

Species	number	size range (mm)
Central Stoneroller	179	
Longear sunfish	35	84 - 147
Bleeding shiner	29	
Greenside darter	20	
Northern hogsucker	10	89 - 200
Smallmouth bass	8	177 - 276
Rainbow darter	7	
Green sunfish	6	81 - 141

Species	number	size range (mm)
Orangethroat darter	6	
Yellow bullhead	3	164 - 257
Mimic Shiner	2	
Rock bass	3	96 - 119
Blackspotted topminnow	2	
Hornyhead chub	1	
Slender madtom	1	

If you have any questions regarding this information, please contact me at either 573/882-9880, x-3271 or fischsa@mail.conservation.state.mo.us.

Sincerely,

Steve

Steve Fischer
Fisheries Research Biologist
Missouri Dept of Conservation
Conservation Research Center
1110 S College Ave
Columbia, MO 65201

Flat River - lower end of site

Flat River - upper-end of site

Appendix C

Lead and Zinc Sediment Analyses

September, 2001

Lead and Zinc Sediment Analyses: Values per Station and Grid; Sample Numbers 01-39386 through 01-39372 from Upstream to Downstream. Units ug/kg Total Recoverable. Probable Effects Levels (PELs) Ingersoll et al. 1996 Shown in Gray.

Station- Grid		Lead		Station Average		Zinc		Station Average
	1	2	3	PEL 82,000	1	2	3	PEL 540,000
Flat River #5	36,100	50,900	44,200	43,700	32,900	50,300	27,800	37,000
Flat River #4	166,000	94,400	50,100	103,500	64,300	48,100	26,400	46,267
Flat River #3	2,560,000	1,650,000	142,000	1,450,000	2,660,000	1,870,000	548,000	1,692,667
Flat River #2	3,970,000	1,410,000	3,600,000	2,993,333	282,000	257,000	594,000	377,667
Flat River #1	15,400,000	763,000	7,600,000	7,921,000	547,000	160,000	387,000	364,667

Appendix D

Kruskal-Wallis ANOVA on Ranks, and Tukey's Test, All Pairwise Multiple Comparison Procedure Results: Comparisons Between Stations for Fine Sediment, Lead, and Zinc Levels

September 2001

Kruskal-Wallis One Way Analysis of Variance on Ranks   Friday, July 19, 2002, 14:38:39

Data source: Flat in Notebook: Stations with Fine Sediment

Normality Test: Passed (P = 0.179)

Equal Variance Test: Passed (P = 0.197)

Group	N	Missing	Median	25%	75%
1.000	18	0	0.840	0.750	0.920
2.000	18	0	0.765	0.540	0.890
3.000	18	0	0.180	0.0700	0.750
4.000	18	0	0.0750	0.0400	0.270
5.000	18	0	0.175	0.0300	0.300

H = 37.468 with 4 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
1 vs. 4	737.000	6.649	Yes
1 vs. 5	667.000	6.018	Yes
1 vs. 3	479.000	4.322	Yes
1 vs. 2	69.500	0.627	No
2 vs. 4	667.500	6.022	Yes
2 vs. 5	597.500	5.391	Yes
2 vs. 3	409.500	3.695	No
3 vs. 4	258.000	2.328	No
3 vs. 5	188.000	1.696	Do Not Test
5 vs. 4	70.000	0.632	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Kruskal-Wallis One Way Analysis of Variance on Ranks   Friday, July 19, 2002, 14:22:54

Data source: Flat in Notebook: Stations with Sediment Lead

Normality Test: Failed (P = <0.001)

Group	N	Missing	Median	25%	75%
1.000	3	0	7600000.000	2472250.000	13450000.000
2.000	3	0	3600000.000	1957500.000	3877500.000
3.000	3	0	1650000.000	519000.000	2332500.000
4.000	3	0	94400.000	61175.000	148100.000
5.000	3	0	44200.000	38125.000	49225.000

H = 10.800 with 4 degrees of freedom. (P = 0.029)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.029)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
1 vs. 5	30.000	3.873	Yes
1 vs. 4	22.000	2.840	No
1 vs. 3	10.000	1.291	Do Not Test
1 vs. 2	3.000	0.387	Do Not Test
2 vs. 5	27.000	3.486	No
2 vs. 4	19.000	2.453	Do Not Test
2 vs. 3	7.000	0.904	Do Not Test
3 vs. 5	20.000	2.582	Do Not Test
3 vs. 4	12.000	1.549	Do Not Test
4 vs. 5	8.000	1.033	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Kruskal-Wallis One Way Analysis of Variance on Ranks   Friday, July 19, 2002, 14:25:25

Data source: Flat in Notebook: Stations with Sediment Zinc

Normality Test: Failed (P = 0.004)

Group	N	Missing	Median	25%	75%
1.000	3	0	387000.000	216750.000	507000.000
2.000	3	0	282000.000	263250.000	516000.000
3.000	3	0	1870000.000	878500.000	2462500.000
4.000	3	0	48100.000	31825.000	60250.000
5.000	3	0	32900.000	29075.000	45950.000

H = 11.767 with 4 degrees of freedom. (P = 0.019)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.019)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
3 vs. 5	31.000	4.002	Yes
3 vs. 4	30.000	3.873	Yes
3 vs. 1	13.000	1.678	No
3 vs. 2	11.000	1.420	Do Not Test
2 vs. 5	20.000	2.582	No
2 vs. 4	19.000	2.453	Do Not Test
2 vs. 1	2.000	0.258	Do Not Test
1 vs. 5	18.000	2.324	Do Not Test
1 vs. 4	17.000	2.195	Do Not Test
4 vs. 5	1.000	0.129	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Appendix E

Missouri St. Joe State Park Flat River Data

Jim Yancey

03/16/2001 11:19 AM

To: Steve Humphrey/ESP/DEQ/MODNR@MODNR
cc:
Subject: Flat River data

The monitoring data we have gathered is attached as an Excel file. The data is compiled through July 2000. Sandy Turner, Assistant Superintendent at St. Joe State Park, (573) 431-1069, performed the sampling. Larron Laboratory, 529 Broadway, Cape Girardeau, MO 63701, (573) 334-8910, performed the analyses.

Each sampling point has its own worksheet, with a labeled tab. "Shaw Branch" was sampled at our property line on Shaw Branch, "Flat River below [confluence]" is just downstream of the mouth of Shaw Branch, "Flat River above" is just upstream of the mouth of Shaw Branch, and "Flat River B Hwy" is just above the Route B highway bridge on Flat River. If you need specific directions for the locations please contact Sandy Turner.

If you need anything else or have questions please let me know.

sjspdata-sum.xls

FLAT RIVER (Highway B)

Quarter	Water					Total metals			Dissolved metals			Dissolved to total ratio			Sediment		
	Flow	TSS	TDS	pH	Hard	Cd	Pb	Zn	Cd	Pb	Zn	Cd	Pb	Zn	Cd Tot	Pb Tot	Zn Tot
	gpd	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L				mg/kg	mg/kg	mg/kg
Apr-97																	
Jun-97	1000000	<1.0	110	7.94	99.2	<0.0050	0.0050	0.0610	<0.005	<0.00200	0.01900	0.00	0.00	0.31	0.289	25.8	18.7
Jul-97	450000	<1.0	200	8.34	279.0	<0.0020	0.0020	0.0320	<0.002	0.00200	<0.02000	0.00	1.00	0.00	0.290	41.4	36.8
Oct-97	4320000	<1.0	244	8.17	305.0	<0.0150	0.0129	0.0460	<0.015	<0.00200	<0.01500	0.00	0.00	0.00	5.690	295.0	183.0
Mar-98	17280000	5.5	96	7.54	96.6	<0.0150	<0.0100	0.0192	<0.015	<0.01000	0.01440	0.00	0.00	0.75	0.710	795.0	37.5
Jun-98	2880000	22.0	113	6.67	104.0	<0.0100	0.0259	0.0226	<0.010	0.00316	0.00445	0.00	0.12	0.20	0.722	74.0	20.3
Jul-98	72000	<1.0	189	8.50	188.0	<0.0100	0.0036	<0.1000	<0.010	0.00190	<0.10000	0.00	0.53	0.00	1.340	28.6	160.0
Oct-98	72000	23.3	256	8.28	219.0	<0.0500	<0.5000	<0.1000	<0.050	<0.50000	<0.10000	0.00	0.00	0.00	0.377	21.4	16.6
Mar-99	50400	1.0	82	8.85	422.0	<0.0100	<0.0100	<0.1000	<0.010	<0.01000	<0.10000	0.00	0.00	0.00	1.270	81.6	43.4
Jun-99	30000	<1.0	214	8.32	185.0	<0.0170	0.0101	0.0868	<0.017	0.00384	<0.05000	0.00	0.38	0.00	1.770	31.4	16.2
Jul-99	1440	<1.0	230	8.43	202.0	0.0125	0.0105	0.0114	<0.010	<0.00500	<0.01000	0.00	0.00	0.00	0.480	31.7	21.3
Oct-99	345600	<1.0	276	7.89	238.0	<0.0100	0.0613	<0.1000	<0.010	0.00995	<0.10000	0.00	0.16	0.00	1.430	162.0	43.1
Mar-00	43200000	4.0	110	7.63	75.6	<0.0170	0.1540	0.0493	<0.017	<0.00200	0.01930	0.00	0.00	0.39	2.020	270.0	82.2
Jun-00	2592000	<1.0	292	8.12	144.0	<0.0150	<0.0100	<0.1000	<0.015	<0.01000	<0.10000	0.00	0.00	0.00	2.870	287.0	107.0
Jul-00	115200	2.0	220	7.99	221.0	<0.0150	0.0290	0.2530	<0.015	<0.02900	<0.10000	0.00	0.00	0.00	2.550	114.0	139.0

FLAT RIVER (above confluence)

Quarter	Water					Total metals			Dissolved metals			Dissolved to total ratio			Sediment		
	Flow	TSS	TDS	pH	Hard	Cd	Pb	Zn	Cd	Pb	Zn	Cd	Pb	Zn	Cd Tot	Pb Tot	Zn Tot
	gpd	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L				mg/kg	mg/kg	mg/kg
Apr-97	51000	<1.0	164	8.69	450.0	<0.020	0.02600	0.3490	<0.020	<0.00500	0.0690	0.00	0.00	0.20	28.900	1260.0	2210.0
Jun-97	1000000	5.0	158	8.03	126.0	<0.005	0.05500	0.2790	<0.005	0.00500	0.1640	0.00	0.09	0.59	0.914	273.0	64.3
Jul-97	450000	1.2	340	7.70	376.0	0.003	0.02500	0.7680	<0.002	0.00500	0.5250	0.00	0.20	0.68	3.140	352.0	315.0
Oct-97	1728000	<1.0	438	8.03	389.0	<0.015	0.02450	1.6500	<0.015	0.00460	1.4200	0.00	0.19	0.86	27.700	2990.0	3010.0
Mar-98	86400000	13.5	162	7.85	138.0	<0.015	0.09710	0.8050	<0.015	0.01510	0.6340	0.00	0.16	0.79	10.400	1830.0	1440.0
Jun-98	5760000	36.0	108	7.65	95.3	<0.010	0.04910	0.0226	<0.010	0.00379	0.0082	0.00	0.08	0.36	1.370	257.0	45.7
Jul-98	72000	<1.0	176	8.50	171.0	<0.050	0.00550	<0.1000	<0.050	0.00210	<0.1000	0.00	0.38	0.00	<1.000	18.1	8.6
Oct-98	2160000	4.7	256	8.38	239.0	<0.050	<0.50000	<0.1000	<0.050	<0.50000	<0.1000	0.00	0.00	0.00	2.210	133.0	101.0
Mar-99	64800	<1.0	82	9.19	1030.0	<0.010	0.58600	0.3260	<0.010	<0.01000	<0.1000	0.00	0.00	0.00	1.050	110.0	31.7
Jun-99	36000	1.3	232	8.36	203.0	<0.017	0.00724	0.0705	<0.017	0.00296	<0.0500	0.00	0.41	0.00	2.260	584.0	64.7
Jul-99	1440	1.3	236	8.62	189.0	<0.010	0.02140	0.0114	<0.010	<0.00500	<0.0100	0.00	0.00	0.00	2.020	583.0	74.1
Oct-99	432000	<1.0	870	7.59	705.0	<0.010	0.06210	1.9200	<0.010	0.00578	0.8190	0.00	0.09	0.43	4.090	604.0	415.0
Mar-00	51840000	6.0	138	7.69	82.9	<0.017	0.15400	0.1060	<0.017	<0.00200	0.0606	0.00	0.00	0.57	3.060	457.0	356.0
Jun-00	2592000	2.0	522	7.84	276.0	<0.015	<0.01000	0.6430	<0.015	<0.01000	0.4550	0.00	0.00	0.71	2.700	126.0	272.0
Jul-00	144000	1.6	342	7.80	330.0	<0.015	0.06060	0.2930	<0.015	<0.02900	0.2180	0.00	0.00	0.74	5.940	450.0	706.0

SHAW BRANCH

Quarter	Water Flow	TSS	TDS	pH	Hard	Total metals (mg/L) Cd	Pb	Zn	Dissolved metals (mg/L) Cd	Pb	Zn	Dissolved to total ratio Cd	Pb	Zn	Sediment Cd Tot	Pb Tot	Zn Tot
	gpd	mg/L	mg/L	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L				mg/kg	mg/kg	mg/kg
Apr-97	7000	18.4	235	6.50	330	<0.020	0.0390	0.1600	<0.0200	<0.0050	<0.0100				11.1	7770	467.0
Jun-97	200000	53.0	228	8.25	206	<0.005	0.3550	0.2850	<0.0030	0.0110	0.0560		0.03	0.20	10.6	6560	562.0
Jul-97	172000	1.2	460	6.90	426	0.009	0.1400	0.5630	0.0030	0.0230	0.4190	0.33	0.16	0.74	7.9	2610	277.0
Oct-97	25920	16.4	448	8.17	412	<0.015	0.1510	0.1240	<0.0150	0.0071	<0.0150		0.05		9.4	6400	347.0
Mar-98	17280000	260.0	133	7.98	135	0.016	0.8840	0.4450	<0.0150	0.0503	0.0768		0.06	0.17	6.1	2800	250.0
Jun-98	43200	105.0	210	8.18	184	<0.010	0.5020	0.0331	<0.0100	0.0139	0.0267		0.03	0.81	8.8	1014	24.3
Jul-98	7200	4.4	310	9.37	281	<0.050	0.0402	<0.1000	<0.0500	0.0066	<0.1000		0.16		20.3	21700	378.0
Oct-98	ND	na	na	na	na	na	na	na	na	na	na				10.0	6035	377.0
Mar-99	50400	93.0	142	8.89	885	<0.010	0.5270	0.2840	<0.0100	0.0243	<0.1000		0.05		12.4	8230	403.0
Jun-99	ND	na	na	na	na	na	na	na	na	na	na				15.4	13500	825.0
Jul-99	ND	na	na	na	na	na	na	na	na	na	na				11.7	28900	576.0
Oct-99	ND	na	na	na	na	na	na	na	na	na	na				11.0	6980	478.0
Mar-00	432000	61.0	354	7.81	237	<0.017	0.4090	0.2180	<0.0170	0.0158	0.0981		0.04	0.45	9.2	5770	415.0
Jun-00	ND	na	na	na	na	na	na	na	na	na	na				11.7	5620	574.0
Jul-00	518400	51.0	250	7.35	236	<0.015	0.4210	0.2450	<0.0150	<0.0290	<0.1000				9.3	4965	487.0

FLAT RIVER (below confluence)

Quarter	Water Flow	TSS	TDS	pH	Hard	Total metals Cd	Pb	Zn	Dissolved metals Cd	Pb	Zn	Dissolved to total ratio Cd	Pb	Zn	Sediment Cd Tot	Pb Tot	Zn Tot
	gpd	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L				mg/kg	mg/kg	mg/kg
Apr-97	15000	<1.0	168	8.37	316	<0.0200	0.0180	0.3060	<0.020	<0.00500	0.1940	0.00	0.00	0.63	2.870	377.0	253.0
Jun-97	1000000	54	156	7.65	133	<0.0050	0.0420	0.1920	<0.005	0.00400	0.1240	0.00	0.10	0.65	0.878	73.2	182.0
Jul-97	450000	1.6	342	7.4	359	0.0030	0.0250	0.7860	<0.002	0.00600	0.5430	0.00	0.24	0.69	6.800	1460.0	439.0
Oct-97	432000	<1.0	338	8.2	307	<0.0150	0.0299	0.7300	<0.015	0.00200	0.4820	0.00	0.07	0.66	8.090	6090.0	441.0
Mar-98	69120000	6.5	118	8.08	101	<0.0150	<0.0100	0.1080	<0.015	0.01090	0.0576	0.00	0.00	0.53	3.650	630.0	280.0
Jun-98	5760000	37	128	6.95	122	<0.0100	0.0857	0.0114	<0.010	0.00472	0.0119	0.00	0.06	1.04	3.760	124.0	27.8
Jul-98	17200	10.4	430	8.4	385	<0.0500	0.0305	0.7400	<0.050	0.00240	0.2120	0.00	0.08	0.29	2.690	311.0	299.0
Oct-98	141120	<1.0	389	8.2	319	<0.0500	<0.5000	0.6860	<0.050	<0.50000	0.3540	0.00	0.00	0.52	5.930	1802.0	388.0
Mar-99	57600	81	160	8.75	540	<0.0100	0.0102	<0.1000	<0.010	0.02520	<0.1000	0.00	2.47	0.00	4.830	1380.0	264.0
Jun-99	36000	<1.0	548	8.11	495	<0.0170	0.0409	0.5060	<0.017	0.07240	<0.0500	0.00	1.77	0.00	5.470	1640.0	631.0
Jul-99	2880	37.3	814	8.14	686	0.0205	0.0351	0.3060	<0.010	0.05570	0.2330	0.00	1.59	0.76	9.890	3610.0	435.0
Oct-99	604800	<1.0	1050	7.78	789	<0.0100	0.1150	4.0000	<0.010	0.00319	1.5800	0.00	0.03	0.40	6.100	6430.0	424.0
Mar-00	432000	18	184	7.73	95.4	<.01700	0.2050	0.1320	<.0170	0.01090	0.0568	0.00	0.05	0.43	7.300	2980.0	292.0
Jun-00	1728000	3	494	8.09	259	<0.0150	<0.0100	0.4470	<0.015	<0.01000	0.2210	0.00	0.00	0.49	6.710	3170.0	294.0
Jul-00	720000	4.7	338	7.88	321	<0.0150	0.0526	0.3010	<0.015	<0.02900	0.1900	0.00	0.00	0.63	8.790	4468.0	492.0

Appendix F

Flat River and Reference Streams Macroinvertebrate Bench Sheets

Flat River, Station #1: Spring 2001

Taxa	CS	NF	RM
Branchiobdellida			3
Acarina	1	5	1
Gammarus			1
Hyalella azteca			3
Berosus	2	1	4
Dubiraphia			12
Macronychus glabratus			2
Microcylloepus pusillus	2		2
Oreodytes			2
Stenelmis	15		3
Orconectes luteus	-99		
Orconectes virilis			1
Ablabesmyia	1		2
Ceratopogoninae	4	7	35
Chironomus		2	
Cladopelma		4	
Cladotanytarsus		3	
Clinocera	1		
Clinotanypus		1	
Corynoneura		1	1
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	68	2	10
Cryptochironomus		1	
Dicrotendipes	2		
Hemerodromia	8		1
Hydrobaenus	2		2
Labrundinia			3
Larsia			4
Nanocladius		2	3
Parakiefferiella		1	
Parametriocnemus	1		
Paratanytarsus	1		5
Paratendipes		1	
Polypedilum	2		
Polypedilum convictum grp	2		
Polypedilum illinoense grp			1
Procladius		3	
Prosimulium	13		
Psectrocladius			2
Rheocricotopus	2		
Rheotanytarsus	3	1	
Simulium	16		
Sympotthastia	1		
Tanytarsus	13	5	7
Tipula	1		
Caenis latipennis	2		
Tricorythodes	1		
Physa			1

Lumbricidae	1		
Lumbriculidae	1		
Corydalus	1		
Argia	2	3	15
Dromogomphus		-99	
Enallagma		1	16
Libellulidae			1
Macromia			2
Cheumatopsyche	5		
Hydroptila	1		
Nectopsyche			20
Rhyacophila	1		
Planariidae			1
Branchiura sowerbyi		1	
Enchytraeidae	9	2	8
Imm. Tub. w/ cap. Chaetae	1		2
Imm. Tub. w/o cap. Chaetae	1	6	1
Limnodrilus claparedianus		1	
Limnodrilus hoffmeisteri	1	1	
Sphaerium	1		

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Rootmat Habitat
-99 = Present

Flat River, Station #2: Spring 2001

Taxa	CS	NF	RM
Acarina		1	
Hyalella azteca		2	6
Erpobdellidae		-99	
Agabus			1
Dubiraphia		5	2
Haliplus		1	
Hydroporus		2	1
Microcylloepus pusillus	4		
Oreodytes		9	
Peltodytes			2
Psephenus herricki	1		
Stenelmis	43	1	2
Tropisternus			1
Orconectes hylas	-99		
Orconectes luteus		1	
Ablabesmyia		3	3
Ceratopogoninae		7	
Chironomus		8	
Chrysops		1	
Cladotanytarsus		3	
Clinocera	12		
Corynoneura	7		21
Cricotopus/Orthocladius	70	18	61
Cryptochironomus		1	
Dicrotendipes		4	2
Eukiefferiella brevicalcar grp	120	1	7
Hemerodromia	1		
Hydrobaenus	7	38	55
Larsia	1	4	3
Micropsectra	1		
Nanocladius	11	1	23
Natarsia		3	
Orthocladius (Euorthocladius)	140	1	3
Parakiefferiella		5	2
Parametriocnemus	2		
Paratanytarsus		4	14
Paratendipes		5	
Polypedilum illinoense grp	1		
Procladius		5	1
Prosimulium	13		
Psectrocladius			1
Pseudochironomus	2		
Rheocricotopus	1		
Simulium	10		
Stempellinella	2	2	1
Stictochironomus		3	
Tanypus		2	
Tanytarsus	2	41	7

Thienemanniella	3		
Tipula	-99		
Tvetenia bavarica grp	2		
Acentrella	1		
Caenis latipennis	4	5	3
Caenis punctata		1	1
Leptophlebia			-99
Paraleptophlebia	1		2
Procloeon		8	8
Siphlonurus			1
Stenonema femoratum	1	1	
Lirceus	36	12	33
Noctuidae			1
Ferrissia		1	
Fossaria	-99	10	
Helisoma		1	1
Menetus		2	5
Physa	1	7	9
Lumbricidae		1	
Lumbriculidae		9	
Elimia			-99
Argia			2
Enallagma			3
Epitheca (Tetragoneuria)		1	-99
Erythemis			2
Ischnura		3	2
Libellulidae			1
Allocapnia	1		
Amphinemura	5		1
Clioperla clio	1		-99
Hydroperla crosbyi	2		
Isoperla	15		
Perlesta	18		1
Prostoia	6		-99
Chimarra			1
Hydroptila	1		
Oxyethira		1	
Ptilostomis		1	
Pycnopsyche			1
Rhyacophila	2		
Triaenodes		1	
Planariidae	36	10	1
Enchytraeidae	6	2	2
Imm. Tub. w/ cap. Chaetae		1	
Imm. Tub. w/o cap. Chaetae		24	1
Limnodrilus hoffmeisteri		4	
Sphaerium		1	1

CS = Coarse Substrate Habitat   RM = Rootmat Habitat
NF = Non-flow Habitat   -99 = Present

Flat River, Station #1: Fall 2001

Taxa	CS	NF	RM
Acarina	8	4	18
Hyalella azteca		2	23
Ancyronyx variegatus		1	
Berosus	2		1
Dubiraphia		25	29
Lutrochus	1		
Psephenus herricki	-99		
Stenelmis	9		
Orconectes luteus	-99		
Orconectes medius	-99	1	
Orconectes virilis			-99
Ablabesmyia		5	2
Ceratopogoninae	2	1	16
Cladopelma		4	
Cladotanytarsus	2	36	1
Clinotanypus		1	1
Corynoneura	8	1	
Cricotopus bicinctus	3	2	1
Cricotopus/Orthocladius	24	5	4
Cryptochironomus		6	
Dicrotendipes		8	6
Hemerodromia	9		
Labrundinia		2	9
Nanocladius		1	1
Nilotanypus	1		
Parakiefferiella		2	
Parametriocnemus	1		
Paratanytarsus		10	15
Polypedilum convictum grp	3		
Polypedilum halterale grp		1	12
Polypedilum illinoense grp	9	1	6
Procladius		3	
Rheocricotopus	1		
Rheotanytarsus	206	1	
Simulium	14		
Stempellinella	1	3	
Stictochironomus		2	
Tabanus	1		
Tanytarsus	27	70	4
Thienemanniella	10		
Thienemannimyia grp.	3		
Tipula	1		
Tribelos			3
Apobaetis		1	
Caenis latipennis	2	5	2
Procloeon		22	1
Stenacron		2	
Stenonema femoratum		1	1

Tricorythodes	75	8	
Caecidotea			1
Ancylidae			1
Menetus			2
Physa			2
Lumbricidae	1		
Lumbriculidae	6		
Corydalus	1		
Sialis		1	4
Argia	7	4	53
Calopteryx		1	
Enallagma		4	51
Epitheca (Tetragoneuria)			-99
Gomphus			-99
Libellulidae		1	
Macromia			-99
Acroneuria	1		
Glossiphoniidae			1
Cheumatopsyche	103		1
Chimarra	6		
Oecetis			1
Triaenodes			5
Aulodrilus		1	1
Branchiura sowerbyi	3	7	3
Imm. Tub. w/ cap. Chaetae			1
Imm. Tub. w/o cap. Chaetae		9	9
Corbicula		1	

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Rootmat Habitat
-99 = Present

Flat River, Station #2: Fall 2001

Taxa	CS	NF	RM
Acarina	2	6	25
Hyalella azteca		1	
Berosus	1	3	5
Dubiraphia	1	5	2
Helichus lithophilus			1
Stenelmis	6		2
Orconectes virilis	1		
Ablabesmyia		15	1
Anopheles			1
Apedilum		2	
Ceratopogoninae	3	6	
Cladopelma		2	
Cladotanytarsus	1	6	1
Clinotanypus		1	
Corynoneura	2		
Cricotopus bicinctus	6		
Cricotopus/Orthocladius	38	8	
Dasyheleinae	3		
Dicrotendipes	2	10	1
Diptera		1	
Forcipomyiinae	8		
Goeldichironomus		1	
Hemerodromia	7		
Labrundinia	1	5	4
Limonia	4	2	
Nilotanypus	6		
Parachironomus			1
Paratanytarsus	5	49	43
Phaenopsectra			1
Polypedilum convictum grp	1		
Polypedilum halterale grp		2	
Polypedilum illinoense grp	3	1	1
Procladius		8	
Psectrocladius		1	
Pseudochironomus	1	4	1
Rheotanytarsus	26		
Stratiomys			1
Tanytarsus	29	7	2
Thienemanniella	1		
Caenis latipennis		1	
Procloeon		2	
Tricorythodes			1
Rhagovelia	7		
Steinovelia	1		
Physa	1	1	20
Lumbriculidae	1		
Argia	3	9	41
Enallagma	11	33	118

Epitheca (Tetragoneuria)			1
Erythemis		1	
Gomphidae			1
Gomphus	1		1
Hagenius brevistylus		-99	
Hetaerina	8		
Ischnura			2
Libellulidae		4	1
Macromia	1		1
Cheumatopsyche	52		
Chimarra	3		
Oecetis	2		1
Oxyethira		11	1
Polycentropus			1
Triaenodes		1	
Aulodrilus		3	
Imm. Tub. w/ cap. Chaetae		2	1
Imm. Tub. w/o cap. Chaetae		85	
Limnodrilus hoffmeisteri		4	

CS = Coarse Substrate Habitat
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Flat River, Station #3: Fall 2001

Taxa	CS	NF	RM
Acarina	41	5	4
Ancyronyx variegatus			1
Berosus	1	2	
Dubiraphia	1	1	2
Hydroporus		1	2
Microcylloepus pusillus	2		
Peltodytes			24
Psephenus herricki	19	7	
Stenelmis	16	7	2
Anopheles		1	
Ceratopogoninae	5	19	1
Cladotanytarsus		8	
Cricotopus/Orthocladius	46	24	
Dicrotendipes	4	23	
Ephydridae	1		
Forcipomyiinae	2		
Goeldichironomus		2	
Hemerodromia	99	5	
Labrundinia		1	2
Limonia	4		
Natarsia		2	
Nilotanypus	3		
Parakiefferiella	3	37	
Parametriocnemus	5		
Paratanytarsus		2	
Paratendipes	1	1	
Phaenopsectra		2	
Procladius		2	
Psectrocladius	1	12	
Simulium	3		
Tabanus	3		
Tanytarsus	26	29	2
Thienemannimyia grp.	1	3	
Tipula	8		
Tribelos		3	
Caenis latipennis		1	
Microvelia	2		
Rhagovelia	10		
Rheumatobates			10
Trepobates			4
Caecidotea	1		
Petrophila	1		
Fossaria			1
Physa	2		2
Lumbricidae		1	
Lumbriculidae	1		
Nigronia serricornis	5		
Sialis		3	

Argia	31	23	8
Boyeria		1	
Enallagma		10	50
Epitheca (Tetragoneuria)		4	2
Erythemis		3	1
Ischnura		2	
Libellulidae		2	
Macromia		1	
Stylogomphus albistylus	4		
Acroneuria		1	
Cheumatopsyche	17		
Chimarra	4		
Oecetis	27	2	1
Oxyethira		6	2
Polycentropodidae	1		
Planariidae	1		
Aulodrilus		2	
Imm. Tub. w/ cap. Chaetae		9	
Imm. Tub. w/o cap. Chaetae		36	
Corbicula	1		
Sphaerium			1

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Rootmat Habitat
-99 = Present

Flat River, Station #4: Fall 2001

Taxa	CS	NF	RM
Acarina	7	10	4
Hyalella azteca	6	30	73
Erpobdellidae	-99	-99	
Berosus	1	6	
Dubiraphia		22	7
Ectopria nervosa	1	1	
Macronychus glabratus	1		
Microcylloepus pusillus	6	1	1
Optioservus sandersoni	1		
Psephenus herricki	3		
Scirtes	1		3
Stenelmis	37	3	3
Tropisternus	-99		
Orconectes virilis			-99
Ablabesmyia	3	5	
Anopheles			2
Ceratopogoninae		6	12
Chrysops		1	
Cladotanytarsus		1	
Clinotanypus		2	1
Corynoneura	1		
Cricotopus bicinctus	7		
Cricotopus/Orthocladius	10	1	
Cryptochironomus	1		
Culex			2
Dicrotendipes	1	11	
Hemerodromia	27		
Hydrobaenus		1	
Labrundinia	1	4	6
Larsia		1	
Nanocladius	1	1	3
Natarsia		2	
Paratanytarsus		28	13
Pentaneura	3		1
Phaenopsectra		1	1
Polypedilum convictum grp	4		
Polypedilum illinoense grp	2	1	12
Polypedilum scalaenum grp	5		
Procladius			1
Pseudochironomus		5	2
Rheotanytarsus	84	2	14
Simulium	2		
Stempellinella	2	1	2
Stictochironomus		6	
Tanypus			1
Tanytarsus	13	20	9
Thienemanniella	8		1
Thienemannimyia grp.	8		3

Tipula	-99		1
Zavreliella		2	
Baetis	8		
Caenis anceps	1	2	
Caenis latipennis	242	286	30
Callibaetis		1	
Centroptilum	1	1	
Eurylophella		1	
Fallceon	15		4
Heptageniidae	2	1	1
Stenacron	4		
Stenonema femoratum	2	1	
Stenonema pulchellum	6		
Tricorythodes	9	1	1
Trepobates		1	
Lirceus	29	1	
Noctuidae	1		
Ancylidae	1	1	
Helisoma	-99		4
Menetus			9
Physa	15	10	2
Corydalus	-99		
Sialis		-99	
Elimia	1		
Argia			18
Basiaeschna janata	-99		
Coenagrionidae	2	9	2
Didymops		1	
Enallagma		14	24
Epitheca (Tetragoneuria)		-99	
Erythemis		-99	1
Hetaerina	1		
Ischnura		2	3
Libellulidae		1	
Acroneuria	-99		
Glossiphoniidae			1
Cheumatopsyche	23		
Chimarra	7		
Helicopsyche	70		3
Hydropsyche	15		
Hydroptila	3		
Mystacides		3	
Nectopsyche			2
Oecetis	4	1	2
Orthotrichia		7	
Oxyethira		1	
Triaenodes		7	4
Planariidae	16	2	4
Aulodrilus	1		
Imm. Tub. w/ cap. Chaetae			1

Imm. Tub. w/o cap. Chaetae	4	16	
Corbicula		-99	1

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Flat River, Station #5: Fall 2001

Taxa	CS	NF	RM
Acarina	2		7
Hyalella azteca	2	10	134
Erpobdellidae	-99		
Berosus	1		
Dubiraphia	1	25	30
Ectopria nervosa		2	
Hydroporus			4
Microcylloepus pusillus	3		
Optioservus sandersoni	1		
Peltodytes			1
Psephenus herricki	37	6	
Stenelmis	77	13	4
Orconectes medius	-99		
Ablabesmyia	1	6	1
Ceratopogoninae		1	
Cladotanytarsus		1	
Clinotanypus		1	1
Corynoneura	2		
Cricotopus/Orthocladius			1
Cryptochironomus		3	
Dicrotendipes		2	
Hemerodromia	3		
Labrundinia		1	2
Nilotanypus	2		
Parametriocnemus	2		
Paratanytarsus	2		8
Paratendipes		11	
Phaenopsectra	1	3	
Polypedilum convictum grp	5		
Polypedilum illinoense grp		1	1
Polypedilum scalaenum grp	2	1	
Rheotanytarsus	92	5	4
Simulium	1		
Stempellinella		2	1
Stictochironomus		3	
Tabanus	-99		
Tanytarsus	12	9	6
Thienemannimyia grp.	7	1	
Tipula	-99	-99	
Tribelos		3	
Baetis	20		
Caenis latipennis	47	129	27
Centroptilum		2	
Eurylophella		1	4
Fallceon	5		
Heptageniidae	21		
Isonychia	1		
Leptophlebiidae			1

Procloeon		1	
Stenacron	9	9	
Stenonema femoratum	1	8	
Stenonema pulchellum	21	1	
Tricorythodes	202	13	2
Rhagovelia	3		
Rheumatobates			1
Lirceus	1	3	
Ancylidae	1		
Helisoma	-99	4	4
Menetus	1		4
Physa	2	2	
Lumbriculidae	4		
Corydalus	-99		
Elimia	3	4	4
Argia	6	3	23
Calopteryx			2
Coenagrionidae			2
Enallagma		1	22
Epitheca (Tetragoneuria)		1	-99
Gomphus		-99	
Hagenius brevistylus		-99	
Hetaerina	13		
Libellulidae		1	1
Stylogomphus albistylus		-99	
Glossiphoniidae	1		
Cheumatopsyche	41		1
Chimarra	11		
Helicopsyche	3	1	
Hydropsyche			1
Hydroptila	5	1	
Mystacides			1
Nectopsyche			1
Oecetis		1	
Triaenodes			7
Planariidae	46	1	
Imm. Tub. w/o cap. Chaetae		7	1
Corbicula		-99	-99
Sphaerium		6	

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Courtois Creek, Station #3: Fall 2001

Taxa	CS	NF	RM
Acarina	8		
Ancyronyx variegatus			2
Dubiraphia		9	61
Ectopria nervosa	1		
Helichus basalis			1
Macronychus glabratus			11
Optioservus sandersoni	344	19	6
Psephenus herricki	98	10	
Stenelmis	3		
Orconectes medius	2	2	
Orconectes virilis		1	
Ablabesmyia		1	
Chironomus		1	
Corynoneura	1		2
Cricotopus/Orthocladius	7		21
Dicrotendipes	1		
Forcipomyiinae	1	1	
Hemerodromia	1		
Labrundinia			5
Microtendipes		3	1
Nilotanypus	1		1
Polypedilum convictum grp			1
Polypedilum illinoense grp			1
Rheotanytarsus	24		35
Simulium	1		1
Tanytarsus			2
Thienemanniella	4		1
Thienemannimyia grp.	2	1	6
Tribelos		12	1
Baetis	3		1
Caenis anceps	9	1	
Caenis latipennis	2	258	8
Eurylophella	19	2	
Heptageniidae	72		
Isonychia	33		1
Leptophlebiidae		1	
Stenacron		9	
Stenonema femoratum	30	11	
Stenonema mediopunctatum	28		1
Tricorythodes	5	1	
Caecidotea			4
Pyralidae			2
Ferrissia		1	1
Physa		1	1
Lumbricidae	-99		
Lumbriculidae		5	
Corydalus	-99		
Sialis		1	

Elimia	11	1	-99
Argia	7	4	3
Calopteryx			13
Enallagma			1
Gomphidae	5	1	1
Gomphus		-99	
Hagenius brevistylus	3		
Leuctra	1		
Pteronarcys pictetii	-99		
Glossiphoniidae		1	
Cheumatopsyche	60		
Helicopsyche	1		
Oecetis			1
Polycentropus	5		2
Triaenodes			36
Planariidae		1	

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Cub Creek, Station #1: Fall 2001

Taxa	CS	NF	RM
Branchiobdellida		3	
Acarina	10	4	2
Hyalella azteca			15
Stygobromus		1	
Dubiraphia	1	9	75
Ectopria nervosa	3	1	
Gyrinus			1
Macronychus glabratus			26
Optioservus sandersoni	217	5	5
Psephenus herricki	55	26	5
Scirtes			1
Stenelmis	10		2
Orconectes luteus		2	
Orconectes medius	6	-99	1
Ablabesmyia		5	
Anopheles			5
Ceratopogoninae			1
Chironomus		1	
Corynoneura	6	2	9
Cricotopus/Orthocladius	13	2	5
Dicrotendipes		7	1
Dixella			30
Labrundinia	1		6
Microtendipes	1	7	1
Parakiefferiella	1	2	1
Paralauterborniella		1	
Paratanytarsus		2	1
Polypedilum convictum grp	3		
Polypedilum halterale grp		2	
Polypedilum illinoense grp		3	7
Procladius		1	
Pseudochironomus	1	1	
Rheotanytarsus	22	3	31
Simulium	1	1	
Stenochironomus	1	1	2
Tanytarsus	1	6	2
Thienemanniella	2	1	1
Thienemannimyia grp.	2	1	
Tribelos	4	20	
Baetis	9		
Baetiscidae	1	1	
Caenidae	2		
Caenis	2		6
Caenis anceps	7		
Caenis latipennis		62	3
Ephemera		1	
Eurylophella	3		1
Heptageniidae	99	19	13

Isonychia bicolor	33		1
Leptophlebiidae			5
Procloeon		2	
Stenacron	8	10	
Stenonema femoratum	3	30	2
Stenonema mediopunctatum	32		
Stenonema pulchellum	5		
Tricorythodes	3		
Rhagovelia	2		1
Trepobates	1		
Ancylidae	2	9	
Lumbricidae	2	2	
Lumbriculidae		1	
Nigronia serricornis	4		
Sialis		1	
Elimia		-99	1
Argia	6	13	
Basiaeschna janata			1
Boyeria			3
Calopteryx			5
Gomphidae	16		2
Hagenius brevistylus	1	-99	
Progomphus obscurus		-99	
Pteronarcys pictetii	-99		
Zealeuctra	1	1	1
Cheumatopsyche	15		
Chimarra	1	1	
Helicopsyche	3	1	
Hydropsychidae	2		2
Polycentropodidae		1	1
Polycentropus	14		
Pycnopsyche			2
Triaenodes			2
Planariidae	2		
Imm. Tub. w/o cap. Chaetae		1	

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East Fork Huzzah Creek, Station #1: Fall 2001

Taxa	CS	NF	RM
Branchiobdellida	1		
Acarina	7	9	4
Hyalella azteca		5	133
Dubiraphia		6	44
Ectopria nervosa		2	2
Optioservus sandersoni	60	10	10
Psephenus herricki	137	41	25
Stenelmis	1	13	1
Orconectes luteus	-99	-99	
Orconectes medius	2		
Orconectes virilis			1
Ablabesmyia		9	
Anopheles			1
Ceratopogoninae		1	
Chironomus		1	
Clinotanypus			1
Corynoneura	2		1
Cricotopus/Orthocladius	23	3	6
Cryptochironomus			1
Dixella			8
Ephydridae	1		
Forcipomyiinae			1
Hemerodromia	1		
Labrundinia			3
Microtendipes		3	1
Myxosargus			1
Nilotanypus	2		
Paralauterborniella			1
Paratanytarsus		2	2
Polypedilum convictum grp	10		
Polypedilum halterale grp	1		
Polypedilum illinoense grp	1		2
Procladius			1
Rheotanytarsus	35	1	2
Simulium	10		
Stempellinella	1	5	1
Stenochironomus		1	
Tabanus		-99	
Tanytarsus		10	
Thienemanniella	4		1
Thienemannimyia grp.	1	1	3
Tribelos		21	2
Baetis	21		
Caenis anceps	3		1
Caenis latipennis		53	27
Ephemerella	15		
Eurylophella	1	6	1
Heptageniidae	40	8	1

Isonychia bicolor	81		2
Leptophlebiidae			1
Procloeon			2
Stenacron	1	1	1
Stenonema femoratum		64	1
Stenonema mediopunctatum	42		3
Stenonema pulchellum	13		3
Microvelia			1
Petrophila	1		
Ancylidae	2	9	1
Menetus			1
Physa			2
Lumbricidae		3	3
Corydalus	3		
Nigronia serricornis	1	-99	
Sialis	1	5	
Elimia	25	6	39
Argia	15	10	6
Calopteryx	1		6
Enallagma			3
Gomphidae	2	2	2
Hagenius brevistylus	1	-99	1
Hetaerina			1
Libellulidae		1	
Stylogomphus albistylus		-99	1
Leuctra	3		1
Ceratopsyche morosa grp	4		
Cheumatopsyche	76		4
Chimarra	2		
Helicopsyche	1		
Oecetis	1	1	1
Polycentropus	1	1	
Triaenodes			2
Planariidae	1	1	
Imm. Tub. w/o cap. Chaetae			11
Pisidium			1
Sphaeriidae			2

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West Fork Huzzah Creek, Station #1: Fall 2001

Taxa	CS	NF	RM
Branchiobdellida			5
Acarina	14		6
Gammarus	18		
Hyalella azteca		1	88
Dubiraphia		40	30
Ectopria nervosa	1	1	
Helichus lithophilus			1
Optioservus sandersoni	173	16	5
Psephenus herricki	10		
Stenelmis	1	2	
Orconectes medius	-99	1	
Orconectes virilis			-99
Ablabesmyia		8	4
Atherix	-99		
Ceratopogoninae	1		8
Cricotopus bicinctus	3		3
Cricotopus/Orthocladius	23	3	15
Cryptochironomus		2	
Dicrotendipes		6	8
Dixella			1
Forcipomyiinae			1
Hemerodromia	1	1	
Labrundinia		1	8
Microtendipes		3	10
Parakiefferiella			4
Paramerina			2
Paratanytarsus		5	21
Polypedilum convictum grp	2		2
Polypedilum illinoense grp			9
Pseudochironomus			2
Rheocricotopus	1		
Rheotanytarsus	4		
Simulium	5		
Stempellinella		3	
Stenochironomus			1
Tanytarsus	1	4	5
Thienemannimyia grp.	5	2	4
Tipulidae			1
Tribelos		5	1
Tvetenia	1		
Acentrella	6		
Baetis	7		
Caenis anceps	6		
Caenis latipennis		27	7
Centroptilum		1	3
Ephemerellidae	18		
Eurylophella	10	2	1
Heptageniidae	25	2	2

Isonychia bicolor	64		
Leptophlebiidae		5	3
Leucrocuta	1		
Procloeon		3	1
Stenacron	7	5	1
Stenonema bednariki	25		
Stenonema femoratum		30	
Stenonema mediopunctatum	28		
Stenonema pulchellum	22		
Tricorythodes	3		
Metrobates	1		
Veliidae			2
Ancylidae	1	17	7
Menetus		1	
Physa	1	3	6
Lumbricidae	2	-99	
Lumbriculidae		1	
Corydalus	2		
Nigronia serricornis			1
Elimia	34	32	8
Argia	9	9	13
Calopteryx			2
Enallagma			8
Gomphidae	10	9	1
Hagenius brevistylus	3	14	
Helocordulia			-99
Stylogomphus albistylus		1	
Pteronarcys pictetii	-99		
Ceratopsyche morosa grp	5		
Cheumatopsyche	60		
Helicopsyche	6		
Oecetis		1	
Polycentropus	1		2
Pycnopsyche			1
Triaenodes			7
Planariidae	1	1	1
Imm. Tub. w/o cap. Chaetae		5	
Sphaeriidae		9	

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-99 = Present

Shoal Creek, Station #1: Fall 2001

Taxa	CS	NF	RM
Acarina	7	2	5
Hyalella azteca		8	143
Dubiraphia		31	34
Ectopria nervosa	1	1	
Macronychus glabratus			1
Optioservus sandersoni	77		1
Psephenus herricki	95	36	3
Stenelmis	31	1	3
Orconectes medius	3		
Orconectes punctimanus			2
Orconectes virilis		-99	
Ablabesmyia		9	
Ceratopogoninae	1	2	
Corynoneura	1		
Cricotopus/Orthocladius	7		3
Cryptochironomus	1	1	
Cryptotendipes		1	
Dicrotendipes		1	6
Microtendipes		3	1
Nilotanypus	1	1	
Paralauterborniella		2	
Paratanytarsus			2
Polypedilum convictum grp	2		
Polypedilum illinoense grp			1
Rheotanytarsus	22	2	
Simulium	5		
Stempellinella		2	
Tabanus	2		
Tanytarsus		7	2
Thienemannimyia grp.	1	1	
Tribelos		85	
Baetis	9		
Caenis anceps	51	4	1
Caenis latipennis	2	59	2
Centroptilum			3
Eurylophella	4	3	
Heptageniidae	22		2
Isonychia bicolor	41		
Leptophlebiidae		10	11
Procloeon		1	4
Stenacron	27	12	
Stenonema femoratum		22	5
Stenonema mediopunctatum	21		1
Stenonema pulchellum	89		
Tricorythodes	4	1	
Trepobates			1
Ancylidae		1	2
Menetus			5

Lumbricidae	2		
Lumbriculidae	1		
Corydalus	3		
Sialis		2	
Elimia	5	1	-99
Argia	17	2	9
Enallagma			1
Gomphidae	55		
Hagenius brevistylus		-99	4
Cheumatopsyche	14		
Chimarra	13		2
Leptoceridae	1		
Nyctiophylax			1
Polycentropodidae	2		
Ilyodrilus templetoni		2	
Imm. Tub. w/ cap. Chaetae		17	1
Imm. Tub. w/o cap. Chaetae		4	
Corbicula			1
Sphaeriidae		3	

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Root-mat Habitat
-99 = Present