Missouri Department of Natural Resources

Biological Assessment Report

Beef Branch and Jacobs Branch
Newton County

2010 – 2011

Prepared for:

Missouri Department of Natural Resources
Division of Environmental Quality
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Attachments

Appendix A Statistical Analysis Comparing Benthic Sediment Between Sampling Stations. One Way ANOVA and Tukeys Multiple Comparison Test was used to Test Differences in the Percent of the Stream Bottom covered by Benthic Sediment between the Sampling Stations

Appendix B Beef Branch and Jacobs Branch Macroinvertebrate Taxa Lists

1.0 Introduction

At the request of the Water Protection Program (**WPP**), the Environmental Services Program (**ESP**) Water Quality Monitoring Section (**WQMS**) conducted a biological assessment of Beef Branch and Jacobs Branch. Beef and Jacobs branches, small tributaries of Shoal Creek, are located just south of Joplin in the Ozark/Neosho Ecological Drainage Unit (**EDU**). The lower 2.5 miles of Beef Branch (WBID 3224) and the lower 1.0 mile of Jacobs Branch (WBID 3223) are designated as Class P stream segments in the Missouri Water Quality Standards (MDNR 2012a). Designated uses for Beef and Jacobs branches are "warm water aquatic life protection, human health/fish consumption, livestock and wildlife watering, and class B whole body contact" (MDNR 2012a).

1.1 Study Area/Justification

Beef and Jacobs branches are not currently on the Missouri 303(d) List of Impaired Waters, but are located within the historic tri-state mining district in which surface and underground mining for lead and zinc was common. Stream sediment samples collected by Brian Nodine of the Environmental Services Program, Missouri Department of Natural Resources on July 23, 2009 showed elevated levels for cadmium, lead, and zinc compared to Probable Effects Concentrations (**PEC**), Probable Effects Quotients (**PEQ**), ∑PEQ, and average PEQ as described in MacDonald et al. (2000) and MacDonald et al. (2009). Results from the sediment samples collected in Beef and Jacobs branches are shown in Tables 1 and 2.

The PEC is the concentration at which adverse effects to aquatic biota are expected to occur more often than not. Probable Effects Quotients (**PEQ**), ∑PEQ, and average PEQ, as described in MacDonald et al. (2009), were determined to show the possible cumulative toxicity effect of cadmium, lead, and zinc levels in the sediment. Probable Effects Quotient was determined by dividing the individual metal concentration found in the sediment by the PEC value. MacDonald et al. (2009) determined that ∑PEQ values greater than 7.92 and average PEQ values greater than 1.11 are considered to be toxic to the aquatic biological community. The results from the sediment samples showed that ∑PEQ and average PEQ were much higher than the threshold values for ∑PEQ and average PEQ in both streams (Table 2).

The primary goal of this study is to determine whether the macroinvertebrate community is impaired in Beef and Jacobs branches. If the macroinvertebrate community is impaired, a secondary goal is to determine the source of impairment. The macroinvertebrate samples collected from Beef and Jacobs branches will be assessed using two sets of criteria since they are headwater streams that are much smaller than the reference stream segments used to determine the riffle/pool Ozark/Neosho EDU biological criteria. The macroinvertebrate samples will first be compared to the Ozark/Neosho EDU biological criteria for perennial wadeable streams. The samples will then be compared to small candidate reference stream criteria calculated from the highest

quality streams that were sampled as part of a Headwater Stream Human Threat Index (**HTI**) Evaluation Study.

1.2 Objectives

1) Assess the biological (macroinvertebrate) integrity Beef and Jacobs branches.

2) Document nutrient and dissolved metals levels and assess water quality.

3) Identify the relative quantity of fine sediment per area.

4) Quantify the sediment and pore water metals content.

5) Assess the quality of stream habitat.

Table 1
Stream Sediment Results and PEC Values (mg/kg) for Cadmium, Lead, and Zinc for Samples Collected on July 23, 2009

Variable-Station	Beef Branch	Jacobs Branch	PEC Value
Sample Number	09-14666	09-14665	
Cadmium	30.4	117	4.98
Lead	869	1,670	128
Zinc	5,840	14,500	459

Table 2
Probable Effects Quotients (PEQ), ∑PEQ, and mean PEQ for Total Recoverable Metals for Cadmium, Lead, and Zinc for sediment samples collected on July 23, 2009

Variable-Station	Beef Branch	Jacobs Branch
Sample Number	09-14666	09-14665
Cadmium	6.1	23.49
Lead	6.8	13.05
Zinc	12.7	31.59
∑PEQ	25.6	68.1
Average PEQ	8.5	22.7

1.3 Tasks

1) Conduct a biological assessment on Beef and Jacobs branches.

2) Visually estimate the percentage of the stream bottom that is covered by fine sediment.

3) Collect stream sediment and pore water to quantify metals content in the sediment.

4) Collect water samples and water quality field measurements.

5) Conduct a stream habitat assessment at each sampling station.

1.4 Null Hypotheses

1) The macroinvertebrate assemblages in Beef and Jacobs branches will be similar to the Ozark/Neosho EDU wadeable/perennial stream biological criteria.

2) The macroinvertebrate assemblages in Beef and Jacobs branches will be similar to the Ozark/Neosho EDU small candidate reference stream criteria.

3) Physicochemical water quality at Beef and Jacobs branches will meet the Water Quality Standards (WQS) of Missouri (MDNR 2012a).

4) The metals content in the stream sediment in Beef and Jacobs branches will be less than PEC values.

5) The relative percent coverage of fine sediment observed in Beef and Jacobs branches will be similar to that of Mikes Creek, a small candidate reference stream.

6) The stream habitat assessment scores at Beef and Jacobs branches will not differ from Mikes Creek, a biological criteria reference stream in the Ozark/Neosho EDU.

2.0 Methods

Carl Wakefield and Mike Irwin of the Missouri Department of Natural Resources, Division of Environmental Quality, Environmental Services Program, Water Quality Monitoring Section, Biological Assessment Unit conducted this study.

2.1 Study Timing

Macroinvertebrate and discrete water quality samples were collected at Beef Branch and Jacobs Branch once during both the fall 2010 and spring 2011 sampling seasons. The small candidate reference stream samples used to calculate small stream criteria were collected during the fall 2009 and spring 2010 sampling seasons. For this study fall 2010 sampling was conducted on October 6-7, 2010, and spring 2011 sampling was conducted on March 30, 2011.

2.2 Station Descriptions

The study area and sampling locations for the Beef Branch and Jacobs Branch bioassessment study are shown in Figure 1. The physical characteristics of test stations and the small candidate reference stations are described in Table 3. One station on each test stream was surveyed for macroinvertebrate bioassessment, sediment, pore water, and water quality.

2.2.1 Beef Branch and Jacobs Branch Bioassessment Sampling Stations

Beef Branch #1 – Newton County: Legal description was NE¼ Sec. 2, T26N, R33W. Geographic coordinates were UTM zone 15, 0366450 Easting, 4096733 Northing. Station located downstream of Cedar Road.

Jacobs Branch #1 – Newton County: Legal description was NE¼ Sec. 2, T26N, R33W. Geographic coordinates were UTM zone 15, 0366182 Easting, 4096742 Northing. Station located downstream of Cedar Road.

2.2.2 Small Candidate Reference Bioassessment Sampling Stations

Mikes Creek #1 – McDonald County: Legal description was SW¼ Sec. 29, T23N, R29W. Geographic coordinates were UTM zone 15, 0402207 Easting, 4060345 Northing. Station located downstream of Highway U.

Thomas Hollow #1 – Barry County: Legal description was NW¼ Sec. 1, T22N, R29W. Geographic coordinates were UTM zone 15, 0408262 Easting, 4057216 Northing. Station located upstream of County Road 1025.

Kings Valley #1 – McDonald County: Legal description was SW¼ Sec. 27, T23N, R30W. Geographic coordinates were UTM zone 15, 0396386 Easting, 4060245 Northing. Station located east of Highway JJ.

Bentonville Hollow #1 – McDonald County: Legal description was NW¼ Sec. 28, T22N, R30W. Geographic coordinates were UTM zone 15, 0394268 Easting, 4051857 Northing. Station located west of Highway E.

South Fork Capps Creek #1 – Barry County: Legal description was NE¼ Sec. 20, T25N, R28W. Geographic coordinates were UTM zone 15, 0409261 Easting, 4081212 Northing. Station located upstream of County Road 2040.

Figure 1
Map of Beef Branch, Jacobs Branch, and Sampling Stations

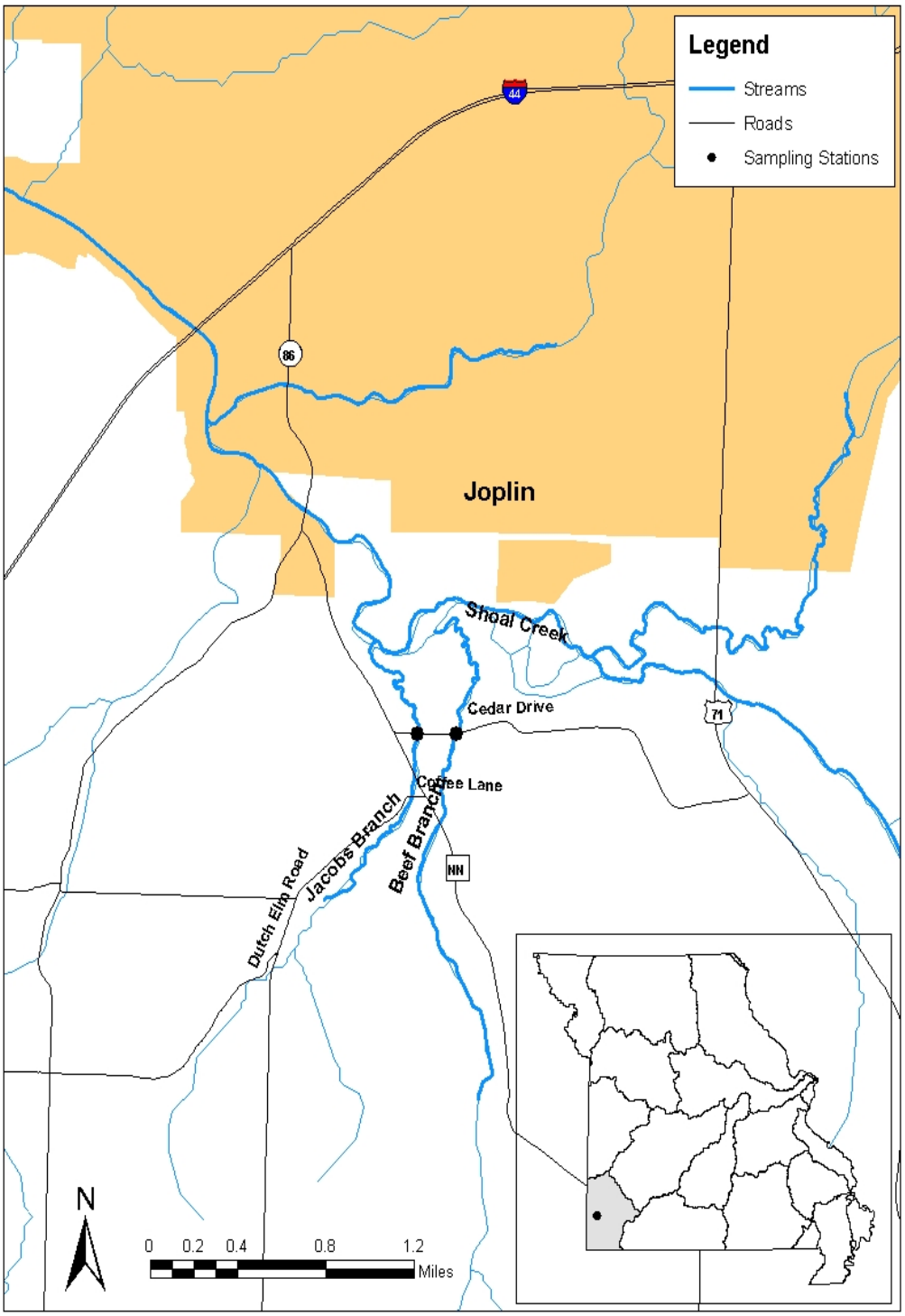

Table 3
Physical Characteristics of the Beef Branch and Jacobs Branch Bioassessment Sampling Reaches Based on Values from the MORAP Valley Segment Types (VST) Geographic Information Systems (GIS) Layer

	Beef Branch #1	Jacobs Branch #1	Mikes Creek #1	Thomas Hollow #1	Kings Valley #1	Bentonville Hollow #1	S. Fork Capps Creek #1
Watershed Area (mi^2)	5.53	2.71	12.10	7.42	4.71	9.55	14.48
Strahler Order	2	2	3	3	2	2	2
Link Magnitude	2	2	7	6	5	5	7
Stream Gradient (feet/mile)	37.43	41.01	36.23	38.01	42.68	39.51	23.16
Relative Gradient	Low	Low	High	High	High	High	Medium
Sinuosity (mile/mile)	1.15	1.30	1.21	1.10	1.12	1.13	1.13
Temperature Regime	Warm	Warm	Warm	Warm	Warm	Warm	Warm
Stream Size	Headwater	Headwater	Creek	Creek	Creek	Creek	Creek
Flow Regime	Permanent	Intermittent	Permanent	Permanent	Permanent	Permanent	Intermittent
Geology	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone

2.3 MoRap Aquatic Ecological Classification

The aquatic ecological classification developed by the Missouri Resource Assessment Partnership (**MoRAP**) is a classification system that divides the aquatic resources of Missouri into distinct regions. It has seven levels of classification starting at large regions and then dividing into smaller sub-regions (Sowa et al. 2004). The following are the seven levels of classification in hierarchical order: zone, subzone, region, aquatic sub regions, EDU, Aquatic Ecological Systems (**AES**), and Valley Segment types (**VST**). The levels of classification are based on biology, zoogeography, taxonomic composition, geology, soils, and groundwater connection. Some levels of the hierarchical system use geology and soils to classify and other levels use biology and taxonomic composition of aquatic communities. Ecological Drainage Units and AES are the two levels of the classification that will be assessed in detail for this study.

2.3.1 Ecological Drainage Unit

The EDU is level five of the classification hierarchy and is based on geographical variation of the taxonomic composition of the level 4 sub regions. An EDU is a region in which aquatic biological communities and habitat conditions can be expected to be similar. Table 4 compares the land cover percentages from the Ozark/Neosho EDU, the Mikes Creek biological criteria reference station watershed, and the watersheds of the Beef Branch and Jacobs Branch sampling stations. Land cover data were derived from Thematic Mapper satellite data from 2000 to 2004 for the entire EDU and from the 2001 national land cover database for the sampling station watersheds. The land use for Beef and Jacobs branches were very similar to Mikes Creek with almost 70 percent of the land use made up of forest, about 25 percent made up of grassland, and very little or no cropland (Figure 2 and Table 4). These values were much higher for forest and much lower for cropland and grassland compared to values for the entire Ozark/Neosho EDU.

2.3.2 Aquatic Ecological Systems

Aquatic Ecological Systems are level six of the classification hierarchy and classify aquatic systems into AES types based on geology, soils, landform, and groundwater influence. Beef and Jacobs branches are located in the Upper Spring River of the Neosho AES type (Sowa and Diamond 2006). The Upper Spring River of the Neosho AES type has local relief that is generally less than 100 feet and is made up of Mississippian period cherty limestone that is covered with loess. Surface soil textures consist of loams and silty loams with slow to moderate infiltration rates. Karst features are prominent with large numbers of springs and sinkholes in this AES type. Streams in this AES generally carry bed loads of cherty gravel and sand. Coldwater streams are a very common and important ecological feature in this AES type.

Table 4
Percent Land Cover

Land Cover	Urban	Crops	Grassland	Forest	Wetland
Ozark/Neosho EDU	4	15	52	25	0
Mikes Creek #1	4	0	27	69	1
Beef Branch #1	3	0	27	68	0
Jacobs Branch #2	4	2	22	70	1

2.4 Stream Habitat Assessment

A standardized assessment procedure was followed as described for Riffle/Pool Habitat in the Stream Habitat Assessment Project Procedure (**SHAPP**) (MDNR 2010a). The habitat assessment was conducted on all stations during October of 2010.

2.5 Visual Estimation of Benthic Sediment

Benthic sediment covering the stream bottom was visually estimated using the methods described in the draft standard operating procedure MDNR-ESP-115, Percent Estimation of Fine Sediment Substrate in Streams (MDNR 2007). Percent fine sediment (particle size less than 2 mm) covering the stream bottom was visually estimated within a metal quadrat (25 cm X 25 cm) at Beef Branch, Jacobs Branch, and Mikes Creek, a small candidate reference stream. The estimates were made at three sample grids within each sample reach and located at the upper end of pools just downstream of riffle/run habitat where stream velocity was less than or equal to 0.5 cubic feet per second (**cfs**) (Figure 3). A sample grid consisted of six contiguous transects across the stream. A transect was established by stretching a tape measure from bank to bank and sampled in a downstream to upstream direction. A sample quadrat was placed directly on the substrate within each of the six transects using a random number that equated to one-foot increments (Figure 3). Two investigators visually estimated the percentage of the stream bottom covered by fine sediment within each quadrat. If the sediment estimates by the two investigators were within ten percent of each other, the estimate was accepted. If the estimates differed by more than ten percent, the investigators repeated the process until the estimates were within ten percent of each other. An average of the two estimates was then recorded and used for analysis.

Figure 2
Land Use of the Beef Branch and Jacobs Branch Watersheds

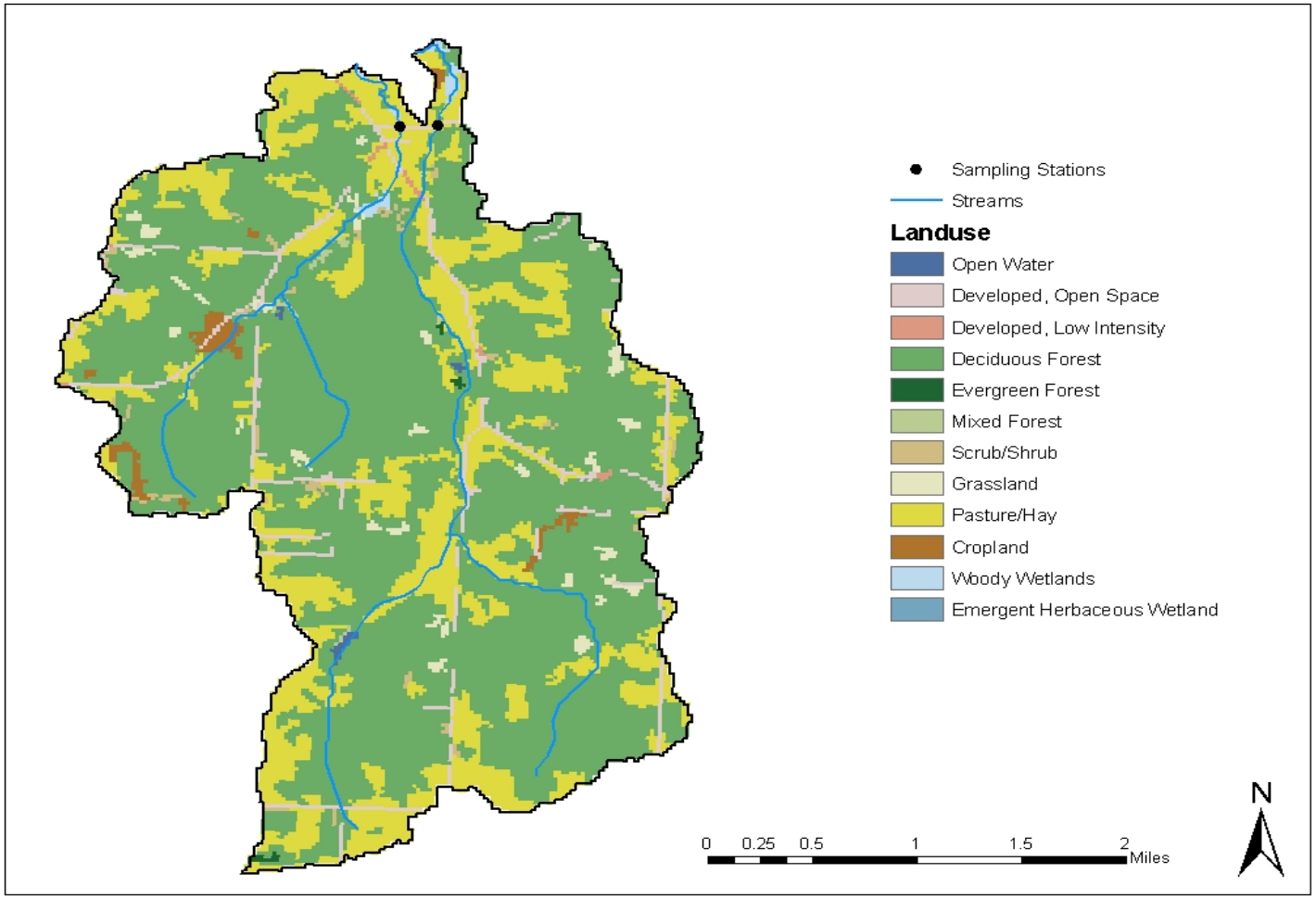

Figure 3
Grid of transects (T) and quadrats (in gray, numbered) used in estimating percent fine sediment; Example: stream 20’ wide; quadrat placement based on random numbers (e.g. 18, 9, 4, 17, 8, and 2).

T6		2																		
T5								8												
T4																	17			
T3				4																
T2									9											
T1																		18		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

The benthic sediment data were assessed using a One-Way Analysis of Variance (**ANOVA**) and Tukey multiple comparison test using the SigmaStat statistical software program (version 3.5, 2006). Before the statistical analysis was performed, the sediment data were square root transformed to meet the assumptions of a parametric statistical test. The ANOVA was used to determine percent sediment differences among sampling stations and to find out if Beef and Jacobs branches were significantly different ($P < 0.05$) from the Mikes Creek small candidate reference stream.

2.6 Biological Assessment

Biological assessments consist of macroinvertebrate collection and physicochemical sampling for two sample periods.

2.6.1 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**) (2010b) for riffle/pool (**RP**) streams. Three standard habitats, flowing water over coarse substrate (**CS**), depositional substrate in non-flowing water (**NF**), and rootmat (**RM**) were collected at the sampling stations.

Macroinvertebrate data were analyzed using three methods. The first analysis was to calculate the Macroinvertebrate Stream Condition Index (**MSCI**) using the biological criteria for perennial/wadeable streams from the Ozark/Neosho EDU using the four general biological metrics found in the SMSBPP (MDNR 2010b; MDNR 2002). The four general biological metrics used and found in the SMSBPP are: 1) Taxa Richness (**TR**); 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**); 3) Biotic Index (**BI**); and 4) Shannon Diversity Index (**SDI**).

The second analysis was calculating MSCI scores using macroinvertebrate data collected at the small candidate reference streams from the Ozark/Neosho EDU using the four general biological metrics found in the SMSBPP. The metric criteria used in the MSCI were calculated using samples collected during the fall 2009 and spring 2010 sampling seasons. This analysis was done to determine whether stream size was important in assessing the impairment of Beef and Jacobs branches using the macroinvertebrate community since the sampling stations were much smaller than the perennial/wadeable biological criteria reference streams used to calculate biological criteria for the Ozark/Neosho EDU.

The third analysis was an evaluation of macroinvertebrate community composition by percent composition of EPT, sensitive taxa, functional feeding groups (FFG), functional habitat groups (FHG), and dominant macroinvertebrate families and taxa. Comparisons of the macroinvertebrate community of Beef and Jacobs branches and the small candidate reference streams were made.

2.7 Physicochemical Data Collection and Analysis

2.7.1 *In situ* Water Quality Measurements

During each sampling period, *in situ* water quality measurements were collected at all of the bioassessment sampling stations. Field measurements included water temperature (°C), dissolved oxygen (mg/L), conductivity (µS/cm), and pH.

2.7.2 Water Chemistry

Grab samples of stream water were collected and returned to ESP's Chemical Analysis Section (**CAS**). Samples from the bioassessment sampling stations were analyzed for non-filterable residue (NFR = TSS), ammonia-nitrogen (mg/L), nitrate+nitrite-nitrogen (mg/L), total nitrogen (mg/L), chloride (mg/L), total phosphorus (mg/L), and dissolved metals for samples collected at the bioassessment sampling stations. Metal constituents analyzed included arsenic, barium, cadmium, chromium, calcium, cobalt, copper, lead, manganese, mercury, nickel, selenium, thallium, and zinc. Samples for metals were filtered in the field. Procedures outlined in MDNR-ESP-002, Field Sheet and Chain of Custody Record, Standard Operating Procedure (**SOP**) (MDNR 2010c) and MDNR-ESP-001, Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations SOP (MDNR 2011), were followed when collecting water quality samples. Stream velocity was measured at each station during the survey period using a Marsh-McBirney Flo-Mate™ Model 2000. Discharge was calculated per the methods in the SOP MDNR-ESP-113, Flow Measurement in Open Channels (MDNR 2010d).

2.7.3 Sediment Pore Water Sampling and Characterization

Sediment pore water was sampled by deploying instream diffusion samplers called peepers using methods described in Brumbaugh et al. (2007). Two peepers in one riffle of each test stream were buried in 4 to 6 cm of sediment for about two weeks. The peepers were set out on September 17, 2010, at about 1315h at Jacobs Branch and 1345h at Beef Branch. The two peepers were retrieved from Beef Branch on October 6, 2010, at 1305h and 1310h. The two peepers were retrieved from Jacobs Branch on October 7, 2010, at 0820h and 0825h. The samples were then submitted to the ESP laboratory to be analyzed for dissolved metals (mg/L). Metal constituents analyzed included arsenic, barium, cadmium, chromium, calcium, cobalt, copper, lead, manganese, mercury, nickel, selenium, thallium, and zinc.

2.7.4 Fine Sediment Metals Characterization

Fine sediment was characterized for metals by determining its content of total recoverable arsenic, barium, cadmium, chromium, calcium, cobalt, copper, lead, manganese, mercury, nickel, selenium, thallium, and zinc (µg/kg). One composite sample of the fine sediment was collected at each test station. Each composite consisted of three two-ounce samples of fine sediment sized particles that were dredged from the substrate and placed into a clear glass jar. Dredging did not exceed a depth of two inches. The lid of the two-ounce jar was used to retain the fine sediment while retrieving

the sample through the water column. Sediment samples were kept on ice and delivered to the ESP CAS in Jefferson City, Missouri for analysis.

2.7.5 Data Analysis and Quality Control

The surface water and pore water data were examined by variable to identify stations that had violations of the Missouri Water Quality Standards (MDNR 2012). The sediment samples were compared to PEC values for total recoverable metals. Probable Effects Quotients, ∑PEQ, and average PEQ were determined to show the possible cumulative toxicity effect of various metals concentrations in the sediment. Probable Effects Quotient was determined by dividing the individual metal concentration found in the sediment by the PEC value. MacDonald et al. (2009) determined that ∑PEQ values greater than 7.92 and average PEQ value greater than 1.11 is toxic to the aquatic biological community. Sampling stations with values higher than the water quality standards, PEC values, and PEQ values will be discussed and possible influences will be identified.

3.0 Results

3.1 Stream Habitat Assessment

Table 5 provides habitat assessment scores for the Beef Branch and Jacobs Branch test stations and the Mikes Creek biological criteria reference station. Stream habitat assessments were conducted in October 2009 at Mikes Creek and October 2010 at Beef and Jacobs branches by Carl Wakefield and Mike Irwin. SHAPP guidance states that test stations scoring at least 75 percent of the total score of reference/control stations should support a similar biological community. The stream habitat total scores indicated that Beef and Jacobs branches should support a similar macroinvertebrate community since the scores were greater than 75 percent of the Mikes Creek habitat score. Beef Branch scored fairly well on most of the metrics except channel flow status, vegetative protection, and riparian zone width. Jacobs Branch had a much lower score caused primarily by lower scores for epifaunal substrate, sediment deposition, and riffle quality. Like Beef Branch, vegetative protection and riparian zone width were in poor condition.

3.2 Visual Estimate of Benthic Sediment

Benthic sediment measurements using the visual estimation method are presented in Table 6. The results of the One-Way ANOVA and Tukey multiple comparison test on square root transformed data are shown in Appendix A.

Jacobs Branch had significantly more fine sediment covering the stream bottom compared to Beef Branch ($P < 0.001$) and Mikes Creek ($P < 0.001$). There was not a significant difference in benthic sediment levels between Beef Branch and Mikes Creek ($P = 1.00$).

Table 5
Predominant Category Habitat Values, Category Habitat Scores, and Total Habitat Scores from Stream Habitat Assessments for the Beef Branch and Jacobs Branch Test Stations and the Mikes Creek Biological Criteria Reference Station

	Beef Branch #1	**Jacobs Branch #1**	**Mikes Creek #1**
Sample Date	10/06/10	10/07/10	10/21/09
Stream Habitat Parameters			
Epifaunal Substrate/Available Cover	I (16)	III (8)	III(9)
Embeddedness	I (18)	I (17)	I (19)
Velocity/Depth Regime	II (14)	II (15)	I (20)
Sediment Deposition	II (15)	III (6)	II (13)
Channel Flow Status	III (7)	II (12)	III (8)
Channel Alteration	I (20)	I (20)	I (20)
Riffle Quality	II (12)	III (10)	III (10)
Bank Stability – Left Bank	I (9)	I (9)	I (9)
Bank Stability – Right Bank	I (10)	I (9)	I (10)
Vegetative Protection – Left Bank	IV (1)	IV (2)	IV (1)
Vegetative Protection – Right Bank	IV (1)	IV (1)	IV (2)
Riparian Zone Width – Left Bank	III (3)	IV (1)	I (10)
Riparian Zone Width – Right Bank	IV (1)	IV (1)	I (9)
Total Habitat Score	127	111	140

Habitat parameter categories range from I to IV with category I = optimal, category II = suboptimal, category III = marginal, and category IV = poor. Habitat parameter scores are listed in parentheses and range from 0 to 20 except for vegetative protection and riparian zone categories which range from 0 to 10.

Table 6
Percentage of Benthic Sediment Observed per Grid and Quadrat Using Visual Estimation Method at the Beef Branch and Jacobs Branch Test Stations and Mikes Creek Small Candidate Reference Station, Fall 2010

	Beef Branch #1	**Jacobs Branch #1**	**Mikes Creek #1**
Grid Number-Quadrat Number			
1-1	27.5	45.0	3.5
1-2	27.5	60.0	5.0
1-3	1.0	92.5	2.0
1-4	1.5	95.0	2.5
1-5	5.5	95.0	6.0
1-6	1	90.0	1.5
2-1	2	72.5	4.0
2-2	5	35.0	4.0
2-3	2	75.0	1.5
2-4	7	37.5	4.0
2-5	3.5	45.0	2.0
2-6	2.0	65.0	9.0
3-1	1.5	95.0	5.0
3-2	2.0	100	3.5
3-3	1.0	100	3.0
3-4	0	85.0	0
3-5	2.0	90.0	4.0
3-6	0	100	2.5
Mean	5.1	76.5	3.6
Standard Deviation	8.4	23.0	2.0

3.3 Macroinvertebrate Biological Assessment

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

Macroinvertebrate Stream Condition Index **(MSCI)** scores were calculated at the test stations using both the biological criteria from the perennial/wadeable reference streams and criteria calculated from the macroinvertebrate data collected at the small candidate reference streams. The two assessments were conducted to determine if stream size affected the macroinvertebrate community since Beef and Jacobs branches were much smaller than the biological criteria reference streams.

The MSCI scores using the perennial/wadeable biological criteria for the fall 2010 sampling season are shown in Table 7 and Table 8 for the spring 2011 sampling season. During the fall 2010 sampling season, Beef Branch had an MSCI score in the partially supporting category with a score of 12 and Jacobs Branch was in the fully supporting

category with an MSCI score of 18. Lower values compared to biological criteria for TR and SDI and a higher value for BI led to the lower MSCI score at Beef Branch during the fall 2010 sampling season. The only metric that was lower than biological criteria at Jacobs Branch during the fall 2010 sampling season was EPTT. Both streams had MSCI scores in the fully supporting range with scores of 16 during the spring 2011 sampling season. Lower EPTT and higher BI compared to biological criteria during the spring 2011 sampling season led to the MSCI score of 16 at both streams.

The MSCI scores using small candidate reference biological criteria are shown in Table 9 for the fall 2010 sampling season and Table 10 for the spring 2011 sampling season. Both streams scored in the fully supporting range during the fall 2010 sampling season using small stream biological criteria. Beef Branch had an MSCI score of 16 and Jacobs Branch had a score of 18. A higher value for BI and lower value for SDI compared to small stream criteria led to the MSCI score of 16 at Beef Branch. At Jacobs Branch, a lower value for EPTT compared to criteria led to the MSCI score of 18. During the spring 2011 sampling season, MSCI scores were in the fully supporting range with a score of 16 at both streams. A lower value for EPTT and a higher value for BI compared to small stream criteria led to the MSCI score of 16 at both streams.

Table 7
Fall 2010 Riffle/Pool Neosho/Ozark EDU Perennial/Wadeable Biological Criteria, Biological Support Categories, and Macroinvertebrate Stream Condition Index (MSCI) Scores at Beef Branch and Jacobs Branch Test Stations

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	**Support**
Beef Branch #1	1004126	77	23	5.8	2.84	12	P
Jacobs Branch #1	1004127	85	18	5.1	3.41	18	F
Metric Score=5	If	>77	>24	<5.50	>2.97	20-16	**F**ull
Metric Score=3	If	77-39	24-12	5.50-7.70	2.97-1.49	14-10	**P**artial
Metric Score=1	If	<39	<12	>7.70	<1.49	8-4	**N**on

MSCI Scoring Table (in light gray) developed from BIOREF stream samples (n=10) TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index

Table 8
Spring 2011 Riffle/Pool Neosho/Ozark EDU Perennial/Wadeable Biological Criteria, Biological Support Categories, and Macroinvertebrate Stream Condition Index (MSCI) Scores at the Beef Branch and Jacobs Branch Test Stations

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	**Support**
Beef Branch #1	110341	81	23	5.6	3.07	16	P
Jacobs Branch #1	110342	82	24	5.4	3.18	16	P
Metric Score=5	If	>72	>27	<5.30	>3.01	20-16	**F**ull
Metric Score=3	If	72-36	27-13	5.30-7.70	3.01-1.51	14-10	**P**artial
Metric Score=1	If	<36	<13	>7.70	<1.51	8-4	**N**on

MSCI Scoring Table (in light gray) developed from BIOREF stream samples (n=12) TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index

Table 9
Fall 2010 Riffle/Pool Neosho/Ozark EDU Small Candidate Reference Biological Criteria, Biological Support Categories, and Macroinvertebrate Stream Condition Index (MSCI) Scores at the Beef Branch and Jacobs Branch Test Stations

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	**Support**
Beef Branch #1	1004126	77	23	5.8	2.84	16	F
Jacobs Branch #1	1004127	85	18	5.1	3.41	18	F
Metric Score=5	If	>59	>20	<5.30	>3.07	20-16	**F**ull
Metric Score=3	If	59-29	20-10	5.30-7.70	3.07-1.54	14-10	**P**artial
Metric Score=1	If	<29	<10	>7.70	<1.54	8-4	**N**on

MSCI Scoring Table (in light gray) developed from small candidate reference stream samples (n=5). TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index

Table 10
Spring 2011 Riffle/Pool Neosho/Ozark EDU Small Candidate Reference Biological Criteria, Biological Support Categories, and Macroinvertebrate Stream Condition Index (MSCI) Scores at the Beef Branch and Jacobs Branch Test Stations

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	**Support**
Beef Branch #1	110341	81	23	5.6	3.07	16	F
Jacobs Branch #1	110342	82	24	5.4	3.18	16	F
Metric Score=5	If	>71	>26	<4.60	>2.92	20-16	**F**ull
Metric Score=3	If	71-35	26-13	4.60-7.30	2.92-1.49	14-10	**P**artial
Metric Score=1	If	<35	<13	>7.30	<1.49	8-4	**N**on

MSCI Scoring Table (in light gray) developed from small candidate reference stream samples (n=6). TR=taxa richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index

3.3.2 Macroinvertebrate Percent and Community Composition

The percent composition of sensitive taxa, EPT, functional feeding groups (FFG), functional habitat groups (FHG), and the five dominant macroinvertebrate families and taxa at each station are presented in Tables 11-14. Values in the tables in bold type represent the five dominant macroinvertebrate families and taxa for each station.

The biotic index value for the Beef Branch macroinvertebrate sample was higher than Jacobs Branch during the fall 2010 sampling season with almost 50 percent of the Beef Branch macroinvertebrate sample made up taxa with biotic index values in the tolerant range (>7.5). At Jacobs Branch, about half of the sample was made up of taxa with biotic index values in the moderately tolerant (5.0 - 7.5) range. The percentage of taxa in the tolerant range at biological criteria and small candidate reference streams were much lower than at Beef Branch but much higher than Jacobs Branch. Biological criteria and small candidate reference streams had a higher abundance of moderately tolerant taxa than Beef Branch but lower than Jacobs Branch. Both streams had about a quarter of the samples made up of taxa with biotic index values in the intolerant range (2.5 - 5.0), which was similar to biological criteria reference conditions and slightly higher than the small candidate reference streams. The percentage of samples in the very intolerant range (<2.5) was much lower at Beef Branch and slightly lower at Jacobs Branch compared to biological criteria and the small candidate reference streams.

Results from the EPT metrics showed that many of the Ephemeroptera metrics were lower during the fall 2010 sampling season at the test streams compared to the biological criteria reference streams and the small candidate reference streams (Table 11). The number of mayfly taxa was slightly lower at Beef Branch and much lower at Jacobs

Branch than both biological criteria and small candidate reference streams. The number of heptageniid mayfly taxa was much lower at Jacobs Branch than the biological criteria and small candidate reference streams. At Beef Branch, the number of heptageniid mayfly taxa was slightly lower than biological criteria reference conditions and similar to the small candidate reference streams. Percent Ephemeroptera was lower at both test stations compared to biological criteria and small candidate reference streams. The number of Plecoptera taxa and percent Plecoptera metrics did not show a strong trend of lower values for these metrics compared to the biological criteria and small candidate reference streams. The number of Trichoptera taxa was slightly higher at both test stations compared to the biological criteria and small candidate reference streams. Percent Trichoptera was lower at Beef Branch than both biological criteria and small candidate reference streams. At Jacobs Branch, percent Trichoptera was slightly higher than the biological criteria streams and slightly lower than the small candidate reference streams. The number of EPTT was lower at Jacobs Branch than both the biological criteria and small candidate reference streams. At Beef Branch the number of EPTT was slightly lower than the biological criteria reference streams and slightly higher than the small candidate reference streams. Percent EPT was lower at Beef Branch than both the biological criteria and small candidate reference streams. Percent EPT at Jacobs Branch was slightly lower than the biological criteria reference streams and lower than the small candidate reference streams.

Gatherer-collectors were the most common FFG at both test stations during the fall 2010 sampling season (Table 11). Percent gatherer-collectors at Beef Branch were higher than both biological criteria and small candidate reference streams. At Jacobs Branch, the percentage of gatherer-collectors was higher than biological criteria reference streams but lower than the small candidate reference streams. Percent filterers were much lower at Beef Branch and much higher at Jacobs Branch than biological criteria and small candidate reference streams. Percent predators were slightly higher at both test streams than biological criteria and small candidate reference streams. Scrapers were very common in Beef Branch, making up about 27 percent of the sample. Percent scrapers at Beef Branch were slightly higher than small candidate reference streams and lower than biological criteria streams. Scraper abundance was much lower at Jacobs Branch, making up about 13 percent of the sample. Shredders made up about 3 percent of the sample at Beef Branch and were lower than the biological criteria streams and higher than the small candidate reference streams. Percent shredders were higher in the Jacobs Branch sample, making up about 8 percent of the sample. The Jacobs Branch shredder percentage was higher than the biological criteria and small candidate reference streams.

Clingers were the most common FHG in the two test streams during the fall 2010 sampling season, making up about 40 percent of the Beef Branch sample and about 44 percent of the Jacobs Branch sample (Table 11). The clinger values at the test streams were lower than values found at the biological criteria and small candidate reference streams. Climbers made up about 16 percent of the sample at Jacobs Branch, which was higher than the biological criteria and small candidate reference streams. At Beef

Branch, climbers made up about 8 percent of the sample, which was lower than biological criteria streams but higher than small candidate reference streams. Burrowers made up about 3 percent of the sample at Beef Branch and 6 percent at Jacobs Branch, which was higher than biological criteria and small candidate reference streams. Sprawlers made up about 4 percent of the Beef Branch sample, which was lower than the biological criteria and small candidate reference streams. Sprawlers made up about 21 percent of the sample at Jacobs Branch and were much higher than the biological criteria and small candidate reference streams. Swimmers made up about 6 percent of the sample at Beef Branch and about 9 percent at Jacobs Branch. Percent swimmers were lower at Beef Branch and similar at Jacobs Branch compared to biological criteria and small candidate reference streams.

The asellid isopod *Lirceus* was the most common taxon found in Beef Branch during the fall 2010 sampling season, making up about 22 percent of the sample (Table 12). *Lirceus* was much more abundant in Beef Branch than Jacobs Branch, biological criteria streams, and small candidate reference streams. Other taxa that were common in Beef Branch were the water penny *Psephenus herricki*, the amphipod *Hyalella azteca*, the heptageniid mayfly *Maccaffertium pulchellum*, and unidentified heptageniid mayflies. *P. herricki* abundance in Beef Branch was much greater than in Jacobs Branch and the small candidate reference streams but was similar to the biological criteria reference streams. *H. azteca* abundance in Beef Branch was much more abundant than Jacobs Branch, biological criteria reference streams, and small candidate reference streams. *M. pulchellum* made up 5 percent of the sample in Beef Branch and was similar to Jacobs Branch in abundance but was much higher than biological criteria and small candidate reference streams. Unidentified heptageniid mayfly abundance in Beef Branch was similar to small candidate reference streams but was much higher than biological criteria streams and Jacobs Branch.

Jacobs Branch had a much different macroinvertebrate community structure than Beef Branch during the fall 2010 sampling season. Quantitative Similarity Index (**QSI**), a measure of macroinvertebrate community similarity between two samples, was 26.7 for the Beef and Jacobs Branch samples. The only taxon that was common in both samples was *M. pulchellum*, which made up about 5 percent of the macroinvertebrates in each sample. Chironomids made up about 47 percent of the Jacobs Branch sample and were much more abundant than in Beef Branch and reference conditions. Most of the chironomid abundance was made up of three taxa: *Tanytarsus*, *Rheocrictopus*, and *Parachaetocladius*. All of these chironomid taxa were much more abundant in Jacobs Branch than Beef Branch, biological criteria reference streams, and small candidate reference streams. The philopotamid caddisfly *Chimarra* was also abundant in the Jacobs Branch sample. *Chimarra* made up about 7 percent of the sample in Jacobs Branch and was much more abundant than in Beef Branch, biological criteria reference streams, and small candidate reference streams.

Table 11
Biological Metric Values for Sensitive Taxa, EPT Metrics, Functional Feeding Groups (FFG) and Functional Habitat Groups (FHG) at the Beef Branch and Jacobs Branch Test Stations and the Biological Criteria Reference Samples, Fall 2010

Variable-Station	**Biocriteria Data**	**Small Stream Data**	**Beef Branch #1**	**Jacobs Branch #1**
Sample Number			1004126	1004127
Sensitive Taxa				
% Biotic Index >9.0	3.57	1.24	1.42	1.85
% Biotic Index 7.5-9.0	18.34	22.04	47.42	6.90
% Biotic Index 5.0-7.5	34.20	39.23	18.52	51.85
% Biotic Index 2.5-5.0	28.94	22.62	27.41	27.88
% Biotic Index <2.5	14.95	14.87	5.22	11.52
EPT Metrics				
# Ephemeroptera Taxa	15.4 ± 2.8	12.4 ± 2.2	11	6
# Heptageniidae Taxa	6.6 ± 0.5	4.8 ± 0.4	5	2
# Plecoptera Taxa	3.3 ± 0.7	3.6 ± 1.5	4	3
# Trichoptera	7.2 ± 2.0	5.8 ± 1.3	8	9
# EPT	25.9 ± 3.5	21.8 ± 2.0	23	18
% Ephemeroptera	21.6 ± 1.3	25.8 ± 1.9	16.5	17.9
% Plecoptera	2.0 ± 0.1	3.2 ± 0.5	2.1	2.4
% Trichoptera	11.5 ± 0.4	14.9 ± 0.8	7.0	13.8
% EPT	35.1 ± 1.3	43.9 ± 2.6	28.4	34.1
FFG Metrics				
% Filterers	9.02	11.69	4.24	20.26
% Gatherer Collectors	42.14	49.61	53.28	45.82
% Parasites	1.10	1.14	0.75	0.58
% Piercers	1.51	1.37	0.32	2.27
% Predators	6.77	6.07	7.57	9.16
% Scrapers	31.08	25.50	27.18	12.73
% Shredders	6.97	1.70	3.38	8.26
FHG Metrics				
% Burrowers	2.84	1.93	3.02	5.63
% Clingers	48.77	49.81	39.99	43.92
% Climbers	10.46	7.19	8.29	15.60
% Divers	0	0.01	0	0
% Skaters	0.09	0.38	0	0.04
% Sprawlers	12.04	6.33	4.15	21.27
% Swimmers	9.11	8.88	5.81	8.91

Table 12
Comparison of the Dominant Macroinvertebrate Families and Taxa at the Beef and Jacobs Branch Test Stations during the Fall 2010 Sampling Season to Data from Biological Criteria and the Small Candidate Reference Streams

Variable-Station	**Biocriteria Data**	**Small Stream Data**	**Beef Branch #1**	**Jacobs Branch #1**
Sample Number			1004126	1004127
Percent Dominant Families				
Psephenidae	**16.7 ± 1.6**	2.8 ± 0.3	**14.9**	1.1
Chironomidae	**12.9 ± 0.6**	**11.8 ± 1.0**	**6.9**	**47.1**
Heptageniidae	**8.8 ±0.5**	**13.6 ± 1.4**	**11.0**	**5.5**
Hyalellidae	**8.2 ±0.6**	4.0 ± 0.6	**18.9**	1.5
Elmidae	**7.5 ± 0.4**	**8.9 ± 1.3**	4.1	**4.8**
Hydropsychidae	5.3 ± 0.5	**8.2 ± 0.7**	0.7	3.8
Gammaridae	0.6 ± 0.2	**7.5 ± 3.4**	0	0
Baetidae	4.7 ± 0.4	**7.4 ± 0.5**	3.9	**10.2**
Asellidae	3.8 ± 0.4	10.4 ± 1.8	**22.4**	1.1
Philopotamidae	0.5 ± 0.1	2.9 ± 0.4	0.1	**6.7**
Percent Dominant Taxa				
Psephenus herricki	**15.9 ±1.5**	2.7 ± 0.3	**14.8**	1.1
Hyalella azteca	**8.2 ± 0.6**	**4.0 ± 0.6**	**18.9**	1.5
Cheumatopsyche	**4.8 ± 0.5**	**7.9 ± 0.6**	0.7	3.6
Paraleptophlebia	**4.6 ± 0.4**	3.2 ± 0.5	0	0
Baetis	**3.2 ±0.3**	2.7 ± 0.4	3.4	5.1
Lirceus	3.1 ± 0.4	**10.4 ± 1.8**	**22.3**	0
Gammarus	0.6 ± 0.2	**7.5 ± 3.4**	0	0
Optioservus sandersoni	2.9 ± 0.3	**7.4 ± 1.0**	0	0.1
Maccaffertium pulchellum	0.3 ± 0.0	0.4 ± 0.2	**5.0**	**5.4**
Heptageniidae	1.2 ± 0.1	3.5 ± 1.2	**3.9**	0
Tanytarsus	1.6 ± 0.1	3.2 ± 0.7	0.6	**14.5**
Rheocricotopus	0	0	0.4	**8.3**
Parachaetocladius	0	0	0	**6.7**
Chimarra	0.5 ± 0.1	2.9 ± 0.4	0.1	**6.7**

Biocriteria and small stream data values are average percent ± standard deviation.

The biotic index value for the Beef Branch macroinvertebrate sample was slightly higher than Jacobs Branch during the spring 2011 sampling season. About 36 percent of the Beef Branch macroinvertebrate sample was made up of taxa with biotic index values in the tolerant range (>7.5) compared to about 7 percent at Jacobs Branch (Table 13). Jacobs Branch had about 62 percent of the sample made up of taxa with biotic index values in the moderately tolerant (5.0 - 7.5) range compared to about 31 percent at Beef Branch. The percentage of taxa in the tolerant range at biological criteria and small candidate reference streams was much lower than at Beef Branch but much higher than Jacobs Branch. For moderately tolerant taxa, biological criteria and small candidate reference streams had a higher abundance than at Beef Branch but much lower than Jacobs Branch. Both streams had about a quarter of the samples made up of taxa with biotic index values in the intolerant range (2.5 - 5.0), which was slightly higher than biological criteria reference conditions and small candidate reference streams. The percentage of the samples in the very intolerant range (<2.5) was much lower at both test streams than the biological criteria and the small candidate reference streams.

Results from the EPT metrics showed that many of the Ephemeroptera metrics were lower during the spring 2011 sampling season at the test streams compared to the biological criteria reference and the small candidate reference streams (Table 13). The number of mayfly taxa was lower at Beef Branch and much lower at Jacobs Branch than both biological criteria and small candidate reference streams. The number of heptageniid mayfly taxa was lower at Beef Branch and much lower at Jacobs Branch than the biological criteria and small candidate reference streams. Percent Ephemeroptera was much lower at both test streams than the biological criteria and small candidate reference streams. The number of Plecoptera taxa was similar and percent Plecoptera was lower at the test streams than biological criteria and small candidate reference streams. The number of Trichoptera taxa and percent Trichoptera was similar to reference conditions at Beef Branch but was higher for both metrics at Jacobs Branch. The number and percent of EPTT was lower at both test streams than the biological criteria and small candidate reference streams.

Gatherer-collectors were the most common FFG at both test stations during the spring 2011 sampling season (Table 13). Gatherer-collectors made up a similar percentage of the sample compared to reference conditions at Beef Branch but a lower percentage at Jacobs Branch. Percent filterers were slightly higher at Beef Branch and much higher at Jacobs Branch than biological criteria and small candidate reference streams. Percent predators were slightly higher at Beef Branch and higher at Jacobs Branch than biological criteria and small candidate reference streams. Scrapers made up about 17 percent of the Beef Branch sample, which was slightly lower than biological criteria reference streams and higher than small candidate reference streams. Percent scrapers at Jacobs Branch were lower than biological criteria reference streams and slightly higher than small candidate reference streams. Shredders made up about 12 percent of the sample at Beef Branch, which was slightly lower than the biological criteria and small candidate reference streams. Shredders were lower in the Jacobs Branch sample, making up about

7 percent of the sample, which was lower than biological criteria and small candidate reference streams.

Clingers were the most common FHG in the two test streams during the spring 2011 sampling season, making up about 44 percent of the macroinvertebrates in the samples, which was a little higher than both the biological criteria and small candidate reference streams (Table 13). Climbers made up about 22 percent of the sample at Jacobs Branch and were much higher than Beef Branch, biological criteria streams, and the small candidate reference streams. The Beef Branch climber value of about 5 percent was slightly lower than reference conditions. Burrowers made up about 14 percent of the sample at Beef Branch and 10 percent at Jacobs Branch, which was a little higher than biological criteria streams and much higher than small candidate reference streams. Sprawlers made up about 8 percent of the Beef Branch sample, which was lower than the biological criteria and small candidate reference streams. At Jacobs Branch, sprawlers made up about 16 percent of the sample, which was slightly lower than biological criteria streams and slightly higher than the small candidate reference streams. Swimmers made up about 3 percent of the sample at both test streams and were much lower than the biological criteria and small candidate reference streams.

The asellid isopod *Lirceus* was the most common taxon found in Beef Branch during the spring 2011 sampling season, making up about 27 percent of the sample (Table 14). *Lirceus* was much more abundant in Beef Branch than Jacobs Branch, biological criteria streams, and small candidate reference streams. Other taxa that were common in Beef Branch were the chironomid *Cricotopus/Orthocladius* group, the heptageniid mayfly *M. pulchellum*, the water penny *P. herricki*, and the chironomid *Tanytarsus*. *Cricotopus/Orthocladius* group abundance was slightly more abundant at Beef Branch than the biological criteria streams and much more abundant than Jacobs Branch and the small candidate reference streams. *M. pulchellum* made up about 7 percent of the sample in Beef Branch and was similar to Jacobs Branch in abundance, but was much higher than biological criteria and small candidate reference streams. *P. herricki* abundance in Beef Branch was much more abundant than Jacobs Branch, the biological criteria streams, and the small candidate reference streams. *Tanytarsus* was slightly more abundant than the biological criteria and small candidate streams but had a much lower abundance than Jacobs Branch.

Jacobs Branch had a much different macroinvertebrate community structure than Beef Branch during the spring 2011 sampling season (Table 14). A QSI value of 34.2 was calculated by comparing the macroinvertebrate structure of the two test streams. Chironomids were much more abundant in Jacobs Branch than Beef Branch, the biological criteria streams, and the small candidate reference streams. All of the most common taxa found in the Jacobs Branch sample were chironomids except for *M. pulchellum*. *Tanytarsus* was most abundant chironomid and taxon in Jacobs Branch, making up about 27 percent of the sample. Although three taxa (*Cricotopus/Orthocladius* group, *M. pulchellum*, and *Tanytarsus*) were common in both

streams, *Cricotopus/Orthocladius* group and *Tanytarsus* were present in different abundance in the two streams. Whereas *Cricotopus/Orthocladius* group was much more abundant in Beef Branch, *Tanytarsus* was much more abundant in Jacobs Branch. Other chironomid taxa that were common in Jacobs Branch were *Thienemannimyia* group and *Cladotanytarsus*. Both of these taxa each made up about 5 percent of the Jacobs Branch sample and were more abundant than Beef Branch, the biological criteria streams, and the small candidate streams. The only other taxon that was common in Jacobs Branch was the heptageniid mayfly *M. pulchellum*, which made up about 7 percent of the sample.

Table 13
Biological Metric Values for Sensitive Taxa, EPT Metrics, Functional Feeding Groups (FFG) and Functional Habitat Groups (FHG) at the Beef Branch and Jacobs Branch Test Stations and the Biological Criteria Reference Samples, Spring 2011

Variable-Station	**Biocriteria Data**	**Small Stream Data**	**Beef Branch #1**	**Jacobs Branch #1**
Sample Number			110341	110342
Sensitive Taxa				
% Biotic Index >9.0	1.96	1.28	1.76	1.96
% Biotic Index 7.5-9.0	21.32	13.36	33.87	4.98
% Biotic Index 5.0-7.5	38.16	41.44	31.14	61.75
% Biotic Index 2.5-5.0	19.06	19.26	23.86	23.02
% Biotic Index < 2.5	19.50	24.66	9.37	8.28
EPT Metrics				
# Ephemeroptera Taxa	15.3 ± 2.2	12.3 ± 1.5	9	5
#Heptageniidae Taxa	6.2 ± 1.0	4.7 ±0.8	4	2
# Plecoptera Taxa	7.3 ± 1.2	6.7 ± 2.1	7	8
# Trichoptera	6.6 ± 1.5	8.3 ±1.4	7	11
# EPT	29.3 ± 3.4	27.3 ± 2.9	23	24
% Ephemeroptera	27.5 ± 0.6	26.9 ± 2.1	15.5	12.1
% Plecoptera	7.4 ± 0.2	10.0 ± 0.9	5.8	3.8
% Trichoptera	4.8 ± 0.4	6.4 ± 0.8	5.7	10.0
% EPT	39.7 ± 0.8	43.4 ± 2.9	27.0	26.0
FFG Metrics				
% Filterers	3.81	5.81	7.14	23.64
% Gatherer Collectors	49.92	52.91	51.10	42.53
% Parasites	1.05	0.82	0.34	0.08
% Piercers	2.61	1.45	0.73	3.61
% Predators	8.21	6.21	8.54	11.25
% Scrapers	19.24	9.58	17.03	10.75
% Shredders	12.62	13.80	12.37	6.51
FHG Metrics				
% Burrowers	8.60	4.00	14.54	9.84
% Clingers	40.68	38.23	43.68	43.89
% Climbers	7.36	8.88	5.25	22.07
% Divers	0	0.05	0.06	0
% Skaters	0.07	0	0	0
% Sprawlers	16.29	13.62	7.78	15.71
% Swimmers	9.64	13.99	3.03	2.96

Table 14
Comparison of the Dominant Macroinvertebrate Families and Taxa at the Beef and Jacobs Branch Test Stations during the Spring 2011 Sampling Season to Data from Biological Criteria and the Small Candidate Reference Streams

Variable-Station	**Biocriteria Data**	**Small Stream Data**	**Beef Branch #1**	**Jacobs Branch #1**
Sample Number			110341	110342
Percent Dominant Families				
Chironomidae	**28.6 ± 1.2**	**24.7 ± 2.3**	**25.9**	**54.7**
Asellidae	**14.3 ± 0.9**	**8.8 ± 1.4**	**26.7**	0
Heptageniidae	**9.9 ±0.4**	4.3 ± 0.6	**11.8**	**7.1**
Baetidae	**6.1 ±0.3**	**13.5 ± 2.0**	**3.7**	**3.8**
Leptophlebidae	**5.6 ± 0.4**	**6.6 ± 1.1**	0	0
Gammaridae	0.4 ± 0.1	**13.1 ± 5.3**	0	0
Psephenidae	1.3 ± 0.1	0	**6.8**	0.5
Elmidae	3.7 ± 0.2	3.1 ± 0.2	1.5	**5.7**
Philopotamidae	0.2 ± 0.0	1.2 ± 0.2	0	**3.0**
Percent Dominant Taxa				
Lirceus	**13.1 ±0.9**	**8.5 ± 1.5**	**26.7**	0
Cricotopus/Orthocladius grp.	**10.6 ± 0.9**	4.6 ± 0.6	**13.2**	**4.6**
Leucrocuta	**3.9 ± 0.3**	1.9 ± 0.4	2.3	0
Thienemannimyia grp.	**3.4 ± 0.2**	1.7 ± 0.2	0.5	**5.2**
Paraleptophlebia	**3.6 ±0.3**	**5.2 ± 1.2**	0	0
Gammarus	0.4 ± 0.1	**13.1 ± 5.3**	0	0
Diphetor	2.5 ± 0.3	**9.5 ± 1.3**	2.2	0
Micropsectra	1.6 ± 0.2	**5.8 ± 0.8**	0	0.4
Maccaffertium pulchellum	0.2 ± 0.0	0.1 ± 0.0	**7.4**	**6.9**
Psephenus herricki	1.2 ± 0.1	0	**6.8**	0.5
Tanytarsus	2.1 ± 0.1	1.1 ± 0.1	**2.9**	**26.7**
Cladotanytarsus	0	0	0	**4.8**
Cheumatopsyche	1.0	3.8	1.0	2.0
Chimarra	0.2	1.2	0	3.0

Biocriteria and small stream data values are average percent ± standard deviation.

4.0 Water, Sediment Pore Water, and Fine Sediment Metals Characterization

4.1 Surface Water Chemistry

Water samples and field measurements were collected during the fall 2010 and spring 2011 macroinvertebrate sampling periods. Physicochemical results are arranged to demonstrate trends of certain variables that may identify a source for effects at the Beef and Jacobs Branch test stations. Results can be found in Table 15 for fall 2010 sampling season and Table 16 for the spring 2011 sampling season. Results shown here are for stream discharge, turbidity, nitrate + nitrite-N, total nitrogen, dissolved cadmium, and dissolved zinc by season.

4.1.1 Stream Discharge

Discharge was low at the Beef Branch and Jacobs Branch test stations during the fall 2010 sampling season. Discharge was 1.3 cfs at Beef Branch and 1.1 cfs at Jacobs Branch. During the spring 2011 sampling season, discharge was a little higher with a value of 8.0 cfs at Beef Branch and 6.5 cfs at Jacobs Branch.

4.1.2 Turbidity

Turbidity was low at Jacobs Branch with a value of 0.89 NTU, but Beef Branch was much higher with a value of 10.2 NTU. The turbidity value at Beef Branch was elevated compared to the U.S. EPA recommended reference value of 1.43 NTU for the Level III Ozark Highlands ecoregion (U.S. EPA 2000). Bottom sediments at Beef Branch may have been stirred up accidently during sampling leading to elevated turbidity value since field observations indicated that water clarity at Beef Branch was similar to Jacobs Branch. During the spring 2011 sampling season, turbidity was 0.74 NTU at Beef Branch and 1.68 NTU at Jacobs Branch. The turbidity value at Jacobs Branch was slightly higher than the U.S. EPA recommended reference value for turbidity in the Ozark Highlands ecoregion.

4.1.3 Nitrate + Nitrite-N

Nitrate + nitrite-N was fairly low during the fall 2010 sampling season with values of 0.44 mg/L at Beef Branch and 0.32 mg/L at Jacobs Branch. These values were slightly higher than the Level III Ozark Highlands ecoregion recommended reference value of 0.24 mg/L (U.S. EPA 2000). Nitrate + nitrite-N was 0.56 mg/L at Beef Branch and 0.79 mg/L at Jacobs Branch during the spring 2011 sampling season which was slightly higher than the values from the fall 2010 sampling season.

4.1.4 Total Nitrogen

Total nitrogen was fairly low during the fall 2010 sampling season with a value of 0.50 mg/L at both Beef and Jacobs branches. These values were slightly higher than the Level III Ozark Highlands ecoregion recommended reference value of 0.38 mg/L. Total nitrogen was 0.54 mg/L at Beef Branch and 0.79 mg/L at Jacobs Branch during the spring 2011 sampling season, which was slightly higher than the values from the fall 2010 sampling season.

4.1.5 Dissolved Cadmium

Dissolved cadmium was 0.42 µg/L at Beef Branch and 1.20 µg/L at Jacobs Branch during the fall 2010 sampling season. Both of these values were higher than the chronic hardness dependent water quality standard of 0.35 µg/L (MDNR 2012a). During the spring 2011 sampling season, dissolved cadmium was 0.44 µg/L at Beef Branch and 1.32 µg/L at Jacobs Branch. Both of these values were above the chronic hardness dependent water quality standard of 0.31 µg/L.

4.1.6 Dissolved Zinc

Dissolved zinc was 125 µg/L at Beef Branch and 620 µg/L at Jacobs Branch during the fall 2010 sampling season. The value at Jacobs Branch was higher than the hardness dependent water quality standard of 164 µg/L for chronic toxicity and 179 µg/L for acute toxicity (MDNR 2012a). During the spring 2011 sampling season, dissolved zinc was 190 µg/L at Beef Branch and 556 µg/L at Jacobs Branch. Both of these values were higher than the hardness dependent water quality standard of 142 µg/L for chronic toxicity and 156 µg/L for acute toxicity.

4.2 Sediment Pore Water

Peeper samplers deployed and retrieved during the fall 2010 sampling season were analyzed for dissolved metals. Two peepers were deployed at each sampling station and two trip blanks were used for quality control purposes as outlined in Quality Assurance/Quality Control for Environmental Data Collection, Standard Operating Procedure (**SOP**) MDNR-ESP-210 (MDNR 2011). Table 17 shows the results of the dissolved metals analyses and are arranged to demonstrate trends of certain variables that may identify a source of effects at the Beef and Jacobs branch test stations. Two metals, dissolved cadmium and dissolved zinc, were omitted from Table 17 because of high levels for these metals in the trip blanks. As a result, the results for cadmium and zinc will not be discussed further in this report, which leaves dissolved lead as the only metal that is valid for discussion.

4.2.1 Dissolved Lead

Dissolved lead from sample number 1006991 had a value of 4.58 µg/L from Jacobs Branch, which was higher than the chronic hardness dependent water quality standard of 4.27 µg/L. The other sample from Jacobs Branch was elevated, but below water quality standards.

Table 15
Physicochemical Variables for Surface Water Samples Collected at the Beef Branch and Jacobs Branch Bioassessment Study Stations, Fall 2010

	Beef Branch #1	Jacobs Branch #1
Invertebrate Sample Number	1004126	1004127
Physicochemical Sample Number	1006987	1006989
Sample Date	10/06/10	10/07/10
Sample Time	1520	0800
Ammonia	<0.03*	<0.03*
Chloride	7.55	5.63
Dissolved Oxygen	9.12	8.32
Discharge (cfs)	1.3	1.1
pH (Units)	8.0	7.5
Conductivity (µmhos/cm)	352	338
Temperature (°C)	15.9	14.5
Turbidity (NTU)	**10.2**	0.89
Total Suspended Solids	<5*	<5*
Nitrate + Nitrite	**0.44**	**0.32**
Total Nitrogen	**0.50**	**0.50**
Total Phosphorus	<0.01*	<0.01*
Dissolved Calcium	61.0	62.3
Dissolved Magnesium	3.00	2.63
Hardness as $CaCO_3$	165	166
Dissolved Arsenic (µg/L)	0.44**	0.38**
Dissolved Barium (µg/L)	57.2	59.4
Dissolved Cadmium (µg/L)	**0.42**	**1.20**
Dissolved Chromium (µg/L)	1.42	0.82**
Dissolved Cobalt (µg/L)	<1.00*	<1.00*
Dissolved Copper (µg/L)	0.54**	0.49**
Dissolved Lead (µg/L)	<0.25*	1.82
Dissolved Manganese (µg/L)	2.12	23.0
Dissolved Mercury (µg/L)	<0.04*	<0.04*
Dissolved Nickel (µg/L)	0.54**	1.08
Dissolved Selenium (µg/L)	<1.00*	<1.00*
Dissolved Thallium (µg/L)	0.25*	<0.25*
Dissolved Zinc (µg/L)	125	**620**

*Below detectable limits
**Estimated value, detected below Practical Quantitation Limit
Units mg/L unless otherwise noted. Values in bold are elevated compared to water quality standards or U.S. EPA recommended reference condition values

Table 16
Physicochemical Variables for Surface Water Samples Collected at the Beef Branch and Jacobs Branch Bioassessment Study Stations, Spring 2011

	Beef Branch #1	Jacobs Branch #1
Invertebrate Sample Number	110341	110342
Physicochemical Sample Number	1104188	1104190
Sample Date	03/30/2011	03/30/2011
Sample Time	1235	1355
Ammonia	<0.03*	<0.03*
Chloride	7.71	5.56
Dissolved Oxygen	11.44	10.95
Discharge (cfs)	8.0	6.5
pH (Units)	8.1	8.3
Conductivity (µmhos/cm)	282	284
Temperature (°C)	9.3	10.1
Turbidity (NTU)	0.74	**1.68**
Total Suspended Solids	<5*	<5*
Nitrate + Nitrite	**0.56**	**0.82**
Total Nitrogen	**0.54**	**0.79**
Total Phosphorus	<0.01*	<0.01*
Dissolved Calcium	52.7	53.8
Dissolved Magnesium	2.16	2.22
Hardness as $CaCO_3$	140	143
Dissolved Arsenic (µg/L)	<0.25*	0.26**
Dissolved Barium (µg/L)	47.5	44.8
Dissolved Cadmium (µg/L)	**0.44**	**1.32**
Dissolved Chromium (µg/L)	1.49	1.36
Dissolved Cobalt (µg/L)	<1.00*	<1.00*
Dissolved Copper (µg/L)	<0.50*	<0.50
Dissolved Lead (µg/L)	<0.25*	0.84**
Dissolved Manganese (µg/L)	5.47	26.7
Dissolved Mercury (µg/L)	0.08**	<0.04**
Dissolved Nickel (µg/L)	0.70	1.21
Dissolved Selenium (µg/L)	<1.00*	<1.00*
Dissolved Thallium (µg/L)	0.25*	<0.25*
Dissolved Zinc (µg/L)	**190**	**556**

*Below detectable limits
**Estimated value, detected below Practical Quantitation Limit
Units mg/L unless otherwise noted. Values in bold are elevated compared to water quality standards or U.S. EPA recommended reference condition values

Table 17
Sediment Pore Water Sample Results from Beef Branch and Jacobs Branch Bioassessment Study Stations, Fall 2010

	Beef Branch #1		**Jacobs Branch #1**		**Trip Blanks**	
Invertebrate Sample Number	1004126	1004126	1004127	1004127		
Pore Water Sample Number	1006985	1006986	1006990	1006991	1006993	1006994
Sample Date	10/06/10	10/06/10	10/07/10	10/07/10	10/08/10	10/08/10
Sample Time	1505	1510	0820	0825	1345	1350
Dissolved Calcium (mg/L)	59.3	59.4	60.9	61.1	0.19*	0.28*
Dissolved Magnesium (mg/L)	2.92	2.92	2.62	2.59	<0.10**	<0.10**
Hardness as $CaCO_3$ (mg/L)	160	160	163	163	1.50*	1.73*
Dissolved Arsenic	0.43*	0.39*	0.51*	0.52*	<0.25**	<0.25**
Dissolved Barium	58.1	59.2	46.7	61.3	1.96	2.30
Dissolved Chromium	0.44*	0.40*	<0.25**	<0.25**	0.55*	0.53*
Dissolved Cobalt	<1.00**	<1.00**	<1.00**	<1.00**	<1.00**	<1.00**
Dissolved Copper	1.18	0.65*	0.61*	0.90*	2.15	2.66
Dissolved Lead	1.47	0.77*	2.92	**4.58**	<0.25**	<0.25**
Dissolved Manganese	5.08	3.21	20.6	6.09	0.26*	0.60*
Dissolved Mercury	<0.04**	<0.04**	<0.04***	<0.04***	<0.04***	<0.04***
Dissolved Nickel	0.80*	0.65*	1.04	1.11	0.75*	0.87*
Dissolved Selenium	<1.00**	<1.00**	1.07*	<1.23*	<1.00**	<1.00**
Dissolved Thallium	0.25**	0.25**	0.25**	<0.25**	<0.25**	<0.25**

*Estimated value, detected below Practical Quantitation Limit
**Below detectable limits
*** Estimated value, detected below Practical Quantitation Limit and below detectable limits
Units µg/L unless otherwise noted. Values in bold are elevated compared to water quality standards

4.3 Fine Sediment Metals Characterization

Sediment samples were collected during the fall 2010 and spring 2011 sampling seasons and were analyzed for total recoverable metals. Results from the sediment samples for the fall 2010 sampling season are shown in Table 18 and Table 19 for the spring 2011 sampling season. Results for PEQ, ∑PEQ, and average PEQ are shown in Table 20. The results of the analyses are arranged to demonstrate trends that may identify a source of effects at the Beef and Jacobs branch test stations. Results are shown here for total recoverable cadmium, lead, and zinc, and PEQ.

4.3.1 Cadmium

Cadmium was elevated during both sampling seasons compared to the PEC value of 4.98 mg/kg (MacDonald et al. 2000). During the fall 2010 sampling season, cadmium was 11.4 mg/kg at Beef Branch and 34.3 mg/kg at Jacobs Branch. The concentration of cadmium in the sediment during the spring 2011 sampling season was 13.0 mg/kg at Beef Branch and 134 mg/kg at Jacobs Branch.

4.3.2 Lead

Lead was elevated during both sampling seasons compared to the PEC value of 128 mg/kg. During the fall 2010 sampling season, lead was 3,040 mg/kg at Beef Branch and 751 mg/kg at Jacobs Branch. The concentration of lead in the sediment during the spring 2011 sampling season was 3,420 mg/kg at Beef Branch and 1,560 mg/kg at Jacobs Branch.

4.3.3 Zinc

Zinc was elevated during both sampling seasons compared to the PEC value of 459 mg/kg. During the fall 2010 sampling season, zinc was 9,550 mg/kg at Beef Branch and 5,840 mg/kg at Jacobs Branch. The concentration of zinc in the sediment during the spring 2011 sampling season was 11,600 mg/kg at Beef Branch and 16,500 mg/kg at Jacobs Branch.

4.3.4 Probable Effects Quotients (PEQ)

Probable Effects Quotients, ∑PEQ, and average PEQ were calculated to show the possible cumulative toxicity effect of various metals concentrations in the sediment. Probable Effects Quotient was determined by dividing the individual metal concentration found in the sediment by the PEC value. The results for PEQ, ∑PEQ, and average PEQ were much higher than threshold levels for both test streams during the fall 2010 and spring 2011 sampling seasons (Table 20). During the fall 2010 sampling season, the Beef Branch ∑PEQ was almost 6 times and the average PEQ was 14 times higher than threshold levels. At Jacobs Branch, the ∑PEQ was about 3 times higher and the average PEQ was 8 times higher than threshold levels. During the spring 2011 sampling season, Beef Branch had ∑PEQ about 7 times higher and average PEQ 16 times higher than threshold levels. At Jacobs Branch, ∑PEQ was about 9 times higher and the average PEQ was 22 times higher than threshold levels.

Table 18
Sediment Sample Results and Available PEC Values (mg/kg) from Beef Branch and Jacobs Branch Bioassessment Study Stations, Fall 2010

Variable-Station	**Beef Branch #1**	**Jacobs Branch**	**PEC Value**
Sample Number	1006988	1006992	
Sample Date	10/06/10	10/07/10	
Sample Time	1615	0945	
Arsenic	4.63	6.7	33.0
Barium	73	34.3	
Cadmium	**11.4**	**34.3**	4.98
Chromium	22	15.1	111
Cobalt	12	8.30	
Copper	32.6	5.74***	149
Lead	**3,040**	**751**	128
Manganese	454	719	
Mercury	0.59*	0.085*	1.06
Nickel	14.6	8.83	48.6
Selenium	<1.000**	<1.0**	
Thallium	<1.0**	<1.0**	
Zinc	**9,550*** **	**5,840*** **	459
Percent Moisture	0.046	0.029	

*Exceeded holding time
**Below detectable limits
*** Sample was diluted during analysis
Units mg/kg unless otherwise noted. Values in bold are elevated compared to Probable Effects Concentration (PEC)

Table 19
Sediment Sample Results and Available PEC Values (mg/kg) from Beef Branch and Jacobs Branch Bioassessment Study Stations, Spring 2011

Variable-Station	**Beef Branch #1**	**Jacobs Branch**	**PEC Value**
Sample Number	1104189	1104191	
Sample Date	03/30/11	03/30/11	
Sample Time	1240	1405	
Arsenic	4.75	5.24	33
Barium	76.3	103	
Cadmium	**13**	**134**	4.98
Chromium	20.5	14.8	111
Cobalt	10.8	16.3	
Copper	43.7	21.9	149
Lead	**3,420**	**1,560**	128
Manganese	299	1,410**	
Mercury	0.39	0.18	1.06
Nickel	14.7	19.1	48.6
Selenium	<0.5*	3.03	
Thallium	<0.5*	1.97***	
Zinc	**11,600****	**16,500****	459
Percent Moisture	0.0511	0.0291	

*Below detectable limits
** Sample was diluted during analysis
*** Estimated value, detected below Practical Quantitation Limit and below detectable limits
Units mg/kg unless otherwise noted. Values in bold are elevated compared to Probable Effects Concentration (PEC)

Table 20
Probable Effects Quotients (PEQ); Mixture of Metals, (∑PEQ and mean PEQ) and Threshold Levels (MacDonald et al. 2009) for Total Recoverable Metals for Cadmium, Lead, and Zinc

(a) Fall 2010 Sampling Season

Parameter PEQ Station	Cadmium	Lead	Zinc	∑PEQ	Mean PEQ
Beef Branch #1	**2.29**	**23.75**	**20.81**	46.85	15.62
Jacobs Branch #1	**6.89**	**5.87**	**12.72**	25.48	8.49
Thresholds	**>1.0**	**>1.0**	**>1.0**	**>7.92**	**>1.11**

(b) Spring 2011 Sampling Season

Parameter PEQ Station	Cadmium	Lead	Zinc	∑PEQ	Mean PEQ
Beef Branch #1	**2.61**	**26.72**	**25.27**	54.60	18.20
Jacobs Branch #1	**26.91**	**12.19**	**35.95**	75.05	25.02
Thresholds	**>1.0**	**>1.0**	**>1.0**	**>7.92**	**>1.11**

MacDonald et al. 2009; **Bold** = intermittently or *continuously partially supporting the AQL; and above PEQ, ∑PEQ, or mean PEQ

5.0 Discussion

5.1 Effect of Stream Size on MSCI Scores

A comparison of the MSCI scores showed that most of the macroinvertebrate samples had MSCI scores in the same support category using criteria from biological criteria reference streams as the small candidate reference streams (Tables 7-10). The only exception was the fall 2010 Beef Branch sample, which had a partially supporting biological criteria MSCI score of 12 and a fully supporting small candidate reference MSCI score of 16. The lower criteria value for TR and EPTT for the small candidate reference streams led to the difference in the MSCI score for this sample. The criteria for the other two metrics, BI and SDI, were similar. A comparison of the criteria for the biological metrics during the spring sampling season showed that TR, EPT, and SDI were slightly lower and BI was much lower for the small candidate reference streams than the biological criteria reference streams. The remaining three samples had identical MSCI scores when compared to the biological criteria and the criteria from the small candidate streams. Jacobs Branch had a fully supporting MSCI score of 18 during the fall 2010 sampling season and a fully supporting MSCI score of 16 during the spring 2011 sampling season. Beef Branch was in the fully supporting category of 16 during the spring 2011 sampling season. These results indicate that there was generally not a notable difference in the criteria based on stream size during the spring sampling season,

but there were differences for two of the metrics (TR and EPTT) during the fall sampling season.

5.2 Heavy Metal Concentrations in the Water, Pore Water, and Sediment

Results from the surface water, pore water, and sediment samples showed that cadmium, lead, and zinc were elevated in both test streams. Dissolved cadmium in the surface water samples was slightly elevated compared to the chronic hardness dependent water quality standard at Beef Branch during both sampling seasons (Tables 15 and 16). Dissolved cadmium at Jacobs Branch was about 3.4 times higher during the fall 2010 sampling season and about 4.3 times higher during the spring 2011 sampling season than the chronic water quality standard. Dissolved zinc at Beef Branch was below the chronic hardness dependent water quality standard during the fall 2010 sampling season but was about 1.2 times higher than the acute water quality standard during the spring 2011 sampling season. At Jacobs Branch, dissolved zinc was about 3.5 times higher than the acute water quality standard during both sampling seasons.

The pore water results during the fall 2010 sampling season for dissolved lead were above chronic hardness dependent water quality standard for one of the peeper samples from Jacobs Branch (Table 17). But the other peeper sample from Jacobs Branch and the two samples from Beef Branch were below water quality standards.

Cadmium, lead, and zinc concentrations were elevated in the sediment of both streams compared to PEC values during the fall 2010 and spring 2011 sampling seasons (Tables 18 and 19). The PEQ results showed that cadmium was over 2 times higher, lead about 24 times higher, and zinc about 21 times higher than the PEC values in Beef Branch during the fall 2010 sampling season (Table 20). During the spring 2011 sampling season at Beef Branch, cadmium was over 2 times higher, lead about 27 times higher, and zinc about 25 times higher than PEC values. The fall 2010 results at Jacobs Branch showed that cadmium was about 7 times higher, lead about 6 times higher, and zinc about 13 times higher than PEC values. During the spring 2011 sampling season at Jacobs Branch, cadmium was about 27 times higher, lead about 12 times higher, and zinc about 36 times higher than the PEC values. The PEQ values at Jacobs Branch during the spring 2011 sampling season were much higher and most likely were caused by a lower percentage of the sample being made up of sand compared to the fall 2010 sample. The ∑PEQ and mean PEQ were calculated to show the possible cumulative effect of the metal concentration in the sediment and were much higher than threshold levels. The results of the surface water, pore water, and sediment samples in both streams showed that metal concentrations were elevated, especially in the sediment, and are likely to be toxic to metal sensitive macroinvertebrates.

5.3 Heavy Metal Effects on MSCI and the Macroinvertebrate Community

5.3.1 MSCI

The results of the MSCI scores did not indicate impairment even though metals concentrations were elevated at both sampling stations. All of the samples except for the

fall 2010 Beef Branch sample had fully supporting MSCI scores when compared to biological criteria data. All of the samples including the fall 2010 Beef Branch sample had fully supporting MSCI scores when compared to the small candidate reference stream criteria. The metric values for the fall 2010 Beef Branch sample was slightly lower for TR, EPTT, and SDI while BI was higher than biological criteria (Tables 7-10). But when the metrics for this sample was compared to the small candidate reference stream criteria, TR, EPTT, BI was higher and SDI was lower. The only metric that was lower than biological criteria and the small candidate reference stream criteria at Jacobs Branch during the fall 2010 sampling season was EPTT. During the spring 2011 sampling season, both test streams had a fully supporting MSCI score of 16 using both the biological criteria and the small candidate reference stream criteria. The spring 2011 results showed that EPTT was slightly lower compared to both criteria data sets and BI was slightly higher than biological criteria and much higher than the small candidate reference streams. These results indicate that the elevated metals concentration may have affected EPTT and BI values in the test streams.

5.3.2 Biological Metrics and Taxonomic Composition

Previous studies have shown that some commonly used multi-metric biological indexes like the MSCI are relatively insensitive in detecting impairment from elevated heavy metal concentrations. Clements et al. (1988) found that Tanytarsini chronomids and Ephemeroptera were highly sensitive to metals and hydropsychiid caddisflies and orthoclad chironomids were tolerant to metals in outdoor stream mesocosms and in the Clinch River in Virginia. Studies conducted in Colorado mountain streams found that heptageniid mayflies were the most metals sensitive taxonomic group followed very closely by ephemerellid mayflies (Clements 1994, Clements et al. 2000). The results from Beef and Jacobs branches showed that the number of Ephemeroptera taxa, percent Ephemeroptera, and percent EPTT were lower compared to the biological criteria and small candidate streams during both sampling seasons (Tables 11 and 13). Except for the fall 2010 Beef Branch sample, the number of heptageniid taxa and EPTT were lower than both biological criteria and small candidate reference streams. The number of heptageniid taxa and EPTT for the fall 2010 Beef Branch sample was slightly higher than the small candidate reference criteria but was lower than biological criteria. The results for two of these metrics, number of Ephemeroptera taxa and number of heptageniid mayfly taxa, were much lower at Jacobs Branch compared to both reference criteria data sets. But percent Heptageniidae, a metric that has been used to show impairment from high metal concentrations, was not consistently lower at Beef and Jacobs branches compared to reference conditions (Tables 12 and 14). This was mostly caused by *Maccaffertium pulchellum*, which was one of the most common taxa found in the Beef Branch and Jacobs Branch samples during both sampling seasons. Other MDNR bioassessment studies have shown that *M. pulchellum* were common in stream reaches with elevated metal concentrations, indicating that it might be tolerant to metals (MDNR 2009, MDNR 2012b). Two other heptageniid mayflies, *M. modestum* and *M. vicarium*, were found in low abundance in the biological criteria reference and the small candidate reference streams during both sampling periods, but were not present in the Beef Branch

and Jacobs Branch samples. Clements et al. (1992) found that *M. modestum* was very sensitive to elevated levels of copper. The heptageniid mayflies *Stenacron* and *Stenonema femoratum*, which are much more tolerant to organic pollution than other heptageniid mayflies, were greatly reduced in Jacobs Branch compared to reference conditions. *Stenacron* was greatly reduced compared to reference conditions at Beef Branch during the fall 2010 sampling season but not during the spring 2011 sampling season. Unlike Jacobs Branch, *S. femoratum* was not reduced at Beef Branch during either sampling season compared to reference conditions. Percent Heptageniidae was lower at Jacobs Branch than Beef Branch during both sampling seasons and lower than both reference criteria data sets during the fall 2010 sampling season. During the spring 2011 sampling season, percent Heptageniidae at Jacobs Branch was higher than the small candidate reference streams but lower than biological criteria streams. The Jacobs Branch surface water and sediment sample results showed that metal concentrations were elevated, especially for zinc.

Results from the visual estimate of benthic sediment showed that Jacobs Branch had a significantly higher percent of the stream bottom covered by fine sediment than Beef Branch and the small candidate reference reach on Mikes Creek (Table 6 and Appendix A). Topographic maps and aerial photographs showed that there were more past mining activities in the Jacobs Branch watershed than the Beef Branch watershed. The high metal concentrations and the higher amount sedimentation at Jacobs Branch were likely sources for the lower number of Ephemeroptera taxa and number of heptageniid mayfly taxa.

The Clements et al. (2000) study determined the cumulative effect of various metals by calculating a metric called the Cumulative Criterion Unit (CCU). The CCU was defined as the ratio of the measured metal concentration to the U.S. EPA criterion value, summed for all metals at a sampling station. This study found that Plecoptera abundance, Plecoptera richness, and Trichoptera abundance were not notably affected by elevated metal concentrations and Trichoptera taxa richness was only affected at stream stations with high metal concentrations (CCU >10). Plecoptera and Trichoptera taxa richness were generally not reduced in Beef and Jacobs branches compared to the biological criteria and small candidate reference streams for both sampling seasons (Tables 11 and 13). But there were differences in Trichoptera between the two test streams. Trichoptera taxa richness and percent Trichoptera both were higher at Jacobs Branch during each sampling season. Hydropsychid caddisfly abundance in Beef and Jacobs branches was not more abundant than reference conditions (Tables 12 and 14). This result was different than has been found in previous studies such as Clements et al. (1988 and 2000) that showed increasing abundance of Hydropsychiid caddisflies in streams with elevated metal concentrations. But a philopotamid caddisfly, *Chimarra*, was much more abundant in Jacobs Branch during both sampling seasons than Beef Branch, biological criteria reference streams, and small candidate reference streams.

Chironomids were much more abundant during both sampling seasons at Jacobs Branch than Beef Branch, biological criteria streams, and small candidate reference streams (Tables 12 and 14). A closer look at the chiromomids showed that the results were different than in previous studies such as Clements et al. (1988), but possibly similar to the results found by Clements et al. 2000. Clements et al. (1988) found that Orthocladinae chironomids were tolerant and Tanytarsini chironomids were sensitive to elevated metal concentrations, but the Clements et al. 2000 study found that all chironomids, including taxa with low biotic index values like *Tvetenia bavarica* and the Tanytarsini chironomid *Micropsectra*, were tolerant of heavy metals except at high concentrations (CCU>10). Tanytarsini chironomids were more common in the Jacobs Branch samples than orthoclad chironomids. Tanytarsini chiromomids made up about 15 percent of the fall 2010 sample and 27 percent of the spring 2011 sample. Orthoclad chironomids made up about 19 percent of the fall 2010 sample and 11 percent of the spring 2011 sample. *Tanytarsus* was the most abundant taxon in Jacobs Branch during both sampling seasons and another Tanytarsini chironomid, *Cladotanytarsus*, was common in the spring 2011 sample. But there were two orthoclad chironomids, *Rheocricotopus* and *Parachaetocladius* that were common in the fall 2010 Jacobs Branch sample. At Beef Branch, chironomids were less abundant compared to reference conditions during fall 2010 sampling season and similar during the spring 2011 sampling seasons.

5.3.3 Functional Feeding Groups

There were differences in FFG compositions between the test streams and reference conditions. Percent filterers were generally much higher and percent scrapers much lower during both sampling seasons at Jacobs Branch than Beef Branch and both reference criteria datasets (Tables 11 and 13). The only exception was that percent scrapers at Jacobs Branch during the spring 2011 sampling season was slightly higher than the small candidate stream criteria but lower than Beef Branch and the biological criteria. Gatherer-collectors were the most abundant FFG at both test streams during both sampling seasons. Percent gatherer-collectors at Beef Branch was higher than biological criteria and slightly higher than the small candidate reference streams during the fall 2010 sampling season. During the spring 2011 sampling season, Beef Branch percent gatherer-collectors were similar to both reference criteria datasets. At Jacobs Branch, percent gatherer-collectors was slightly higher than biological criteria and slightly lower than small candidate reference streams during the fall 2010 sampling season. During the spring 201l sampling season, Jacobs Branch percent gatherer-collectors were lower than both reference criteria datasets. Percent predators was slightly higher than reference conditions during both sampling seasons. Percent shredders varied by sampling season. Percent Shredders at Beef Branch during the fall 2010 sampling season was lower than biological criteria and higher than small candidate reference stream criteria, but was similar to both reference criteria data sets during the spring 2011 sampling season. Shredders were slightly more abundant than biological criteria and much higher than small candidate stream criteria at Jacobs Branch during the fall 2010 sampling season, but were much lower than both reference criteria datasets during the spring 2011

sampling season. Clements et al. (2000) found that scrapers and predators were the most sensitive FFGs to heavy metal contamination. The study found that these two FFGs were sensitive starting at medium concentrations of metals (CCU values between 2 and 10), whereas two other FFGs (gatherer-collectors and shredders) were only sensitive at high heavy metal concentrations (CCU>10). This study did not look at the filterer FFG, but the results at Jacobs Branch compared to reference conditions indicates that filterers could be tolerant to high metals concentrations. The results for scrapers at Jacobs Branch compared to reference conditions indicated that scrapers were generally sensitive to metals, but predators did not show the same trend. The results for gatherer collectors at Jacobs Branch showed lower values for this FFG, especially when compared to the small candidate reference criteria, which indicated that they could be somewhat sensitive to metals. Shredders showed different results by sampling season. During the fall 2010 sampling season, there was no evidence of metals sensitivity, but the lower shredder value at Jacobs Branch during the spring 2011 sampling season compared to reference conditions indicated that this FFG might be sensitive to high metals concentrations.

5.3.4 Functional Habitat Groups

Percent climbers and sprawlers were generally higher during both sampling seasons at Jacobs Branch compared to Beef Branch and reference conditions. The only exception was that sprawlers in Jacobs Branch during the spring 2011 sampling season had a slightly lower percentage than biological criteria. Unlike the FFGs, previously mentioned studies such as Clements et al. (2000) did not look at the effects of elevated heavy metal concentrations on FHGs. The higher percentage of climbers and sprawlers could be the result of the elevated levels of benthic sediment instead of the high heavy metal concentrations. Rabeni et al. (2005) classified FHGs for sediment tolerance from intolerant to tolerant in the following order: clingers < swimmers < sprawlers < climbers < burrowers. Clingers made up the highest percentage of the samples in the test streams and both reference criteria datasets, but this FHG varied by sampling season. Percent clingers in both test streams were lower than reference conditions during the fall 2010 sampling season, but were slightly higher than reference conditions during the spring 2011 sampling season.

6.0 Conclusions

Despite elevated metals concentrations in both test streams, all of the macroinvertebrate samples in this study had fully supporting MSCI scores using biological criteria except the fall 2010 Beef Branch sample. The fall 2010 Beef Branch sample was the only sample that had a different support category when the two criteria data sets were used to calculate MSCI scores. The fall 2010 Beef Branch sample had an MSCI score of 12 using biological criteria and an MSCI score of 16 using small candidate reference stream criteria. The difference between the two criteria data sets during the fall sampling season was due to two of the MSCI metrics, TR and EPTT, at the small candidate reference streams. These two metrics along with SDI were slightly lower and BI was much lower at the small candidate reference streams compared to the biological criteria streams

during the spring sampling season, but all of the spring 2011 samples scored in the same MSCI support category using both criteria data sets.

Most of the MSCI scores did not indicate impairment of the macroinvertebrate community in the test streams, but there was evidence that the macroinvertebrate community was altered, especially at Jacobs Branch, based on the results of previous studies. Previous studies have shown that mayflies, especially heptageniid mayflies, are sensitive to elevated metals concentrations, whereas many or most stoneflies, caddisflies, and chironomids are tolerant to elevated metals concentrations. The results at Beef and Jacobs branches showed that Ephemeroptera taxa, percent Ephemeroptera, and percent EPTT were lower than the reference criteria data sets during both sampling seasons. All of the samples, except the fall 2010 Beef Branch sample, showed that the number of EPTT and heptageniid mayfly taxa were lower than both reference criteria datasets. Two of the mayfly metrics, number of Ephemeroptera taxa and number of heptageniid mayfly taxa, were much lower at Jacobs Branch than Beef Branch. Stoneflies and caddisflies at Beef and Jacobs branches were not reduced compared to reference conditions. Chironomids were also much more abundant at Jacobs Branch than Beef Branch and reference conditions. These results indicate that the MSCI may not always detect macroinvertebrate community effects from elevated heavy metal concentrations.

The first null hypothesis stated that the macroinvertebrate assemblages in Beef and Jacobs branches will be similar to the Ozark/Neosho EDU wadeable/perennial stream biological criteria. The second null hypothesis stated that the macroinvertebrate assemblages in Beef and Jacobs branches will be similar to the Ozark/Neosho EDU small candidate reference stream criteria. The first null hypothesis was rejected and the second was accepted based on the results of the MSCI results. The first hypothesis was rejected based on the fall 2010 biological criteria MSCI score at Beef Branch. The second null hypothesis was accepted since both test streams had small candidate reference MSCI scores in the fully supporting range during both sampling seasons. But other biological metrics, such as the mayfly composition metrics, showed differences in the macroinvertebrate community at test streams compared both reference criteria datasets.

The third null hypothesis stated that physicochemical water quality at Beef and Jacobs branches will meet the Water Quality Standards (WQS) of Missouri (MDNR 2012a). This hypothesis was rejected because dissolved cadmium in the surface water was above the hardness dependent chronic water quality standard in both test streams during the fall 2010 and spring 2011 sampling season. Dissolved zinc was above the hardness dependent acute water quality standard at Jacobs Branch during both sampling seasons and at Beef Branch during the spring 2011 sampling season.

The fourth null hypothesis stated that the metals content in the stream sediment in Beef and Jacobs branches will be less than PEC values. This null hypothesis was rejected because the metal concentrations for cadmium, lead, and zinc were much higher than PEC values for both streams during the fall 2010 and spring 2011 sampling season.

The fifth null hypothesis stated that the relative percent coverage of fine sediment observed in Beef and Jacobs branches will be similar to that of Mikes Creek, a small candidate reference stream. This hypothesis was rejected because the estimated percent of the stream bottom covered by fine sediment was higher at Jacobs Branch than Beef Branch and the small candidate reference sampling reach on Mikes Creek.

The sixth null hypothesis stated that the stream habitat assessment scores at Beef and Jacobs branches will not differ from Mikes Creek, a biological criteria reference stream in the Ozark/Neosho EDU. This null hypothesis was accepted since the stream habitat scores at the test streams were greater than 75 percent of the stream habitat score for the biological criteria sampling reach on Mikes Creek. But some of the stream habitat metrics had low scores that could have affected the macroinvertebrate community quality. The stream habitat score at Jacobs Branch was much lower than at Beef Branch and Mikes Creek. The lower score at Jacobs Branch was caused primarily by lower scores for three substrate habitat metrics: epifaunal substrate, sediment deposition, and riffle quality. Both streams had very low scores for vegetative protection and riparian zone.

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Appendix A

Statistical Analysis Comparing Benthic Sediment Between Sampling Stations. One Way ANOVA and Tukeys Multiple Comparison Test was used to Test Differences in the Percent of the Stream Bottom covered by Benthic Sediment between the Sampling Stations

One Way Analysis of Variance Friday, January 21, 2011, 12:55:57 PM

Data source: Visual Estimate of Benthic Sediment

Dependent Variable: Square-root(Percent Sediment)

Normality Test: Passed (P = 0.082)

Equal Variance Test: Passed (P = 0.092)

Group Name	N	Missing	Mean	Std Dev	SEM
Mikes Creek #1	18	0	1.794	0.605	0.143
Beef Branch #1	18	0	1.798	1.414	0.333
Jacobs Branch #1	18	0	8.639	1.421	0.335

Source of Variation	DF	SS	MS	F	P
Between Groups	2	561.902	280.951	192.235	<0.001
Residual	51	74.536	1.461		
Total	53	636.438			

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

Power of performed test with alpha = 0.050: 1.000

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: **Station**

Comparison	Diff of Means	p	q	P	P<0.050
Jacobs Branch #1 vs. Mikes Creek #1	6.844	3	24.020	<0.001	Yes
Jacobs Branch #1 vs. Beef Branch #1	6.841	3	24.009	<0.001	Yes
Beef Branch #1 vs. Mikes Creek #1	0.00319	3	0.0112	1.000	No

Appendix B

Beef and Jacobs Branch Macroinvertebrate Taxa Lists

Aquid Invertebrate Database Bench Sheet Report

Beef Br [1004126], Station #1, Sample Date: 10/6/2010 4:45:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	8	2	4
AMPHIPODA			
Hyalella azteca			279
Stygobromus	1	2	1
COLEOPTERA			
Ancyronyx variegatus		3	2
Dubiraphia		34	11
Ectopria nervosa		2	
Macronychus glabratus	1	1	5
Psephenus herricki	54	158	6
Stenelmis		2	1
DECAPODA			
Orconectes neglectus	-99		-99
DIPTERA			
Ceratopogoninae	1	1	
Cladotanytarsus		1	
Corynoneura	1	2	13
Cricotopus/Orthocladius	4		5

Aquid Invertebrate Database Bench Sheet Report

Beef Br [1004126], Station #1, Sample Date: 10/6/2010 4:45:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Dicrotendipes		2	14
Empididae			1
Hemerodromia	1		1
Labrundinia	1		1
Micropsectra			2
Microtendipes			1
Paratanytarsus		2	7
Phaenopsectra			3
Polypedilum aviceps	2		
Polypedilum convictum	2		1
Polypedilum illinoense grp			1
Pseudosmittia		1	
Rheocricotopus	5		1
Rheotanytarsus	2		3
Simulium	9		
Stempellinella			2
Tanytarsus		2	7
Thienemanniella	6		3
Thienemannimyia grp.		1	2
Tribelos			1

Aquid Invertebrate Database Bench Sheet Report

Beef Br [1004126], Station #1, Sample Date: 10/6/2010 4:45:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Zavrelimyia		1	
EPHEMEROPTERA			
Baetis	50		
Caenis latipennis		10	
Diphetor	6		
Heptageniidae	56	2	
Isonychia bicolor	1		
Leptophlebiidae		11	1
Leucrocuta	1		
Maccaffertium pulchellum	67	3	3
Procloeon			2
Stenacron		2	
Stenonema femoratum	1	26	1
ISOPODA			
Caecidotea (Blind & Unpigmented)		1	
Lirceus	225	88	16
LEPIDOPTERA			
Petrophila	1		
LIMNOPHILA			

Aquid Invertebrate Database Bench Sheet Report

Beef Br [1004126], Station #1, Sample Date: 10/6/2010 4:45:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Ancylidae	2		2
Lymnaeidae	3		
Physella			1
LUMBRICINA			
Lumbricina	-99	-99	
MEGALOPTERA			
Corydalus	1	-99	
ODONATA			
Argia		9	3
Enallagma		1	14
Gomphidae	17	1	
Hagenius brevistylus		1	
Macromia		-99	
Stylogomphus albistylus		2	
PLECOPTERA			
Acroneuria	1	1	
Leuctridae	1		
Neoperla	2		
Perlesta	19	5	2
TRICHOPTERA			

Aquid Invertebrate Database Bench Sheet Report

Beef Br [1004126], Station #1, Sample Date: 10/6/2010 4:45:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Cheumatopsyche	10		
Chimarra	1		
Helicopsyche	21	6	1
Lype diversa		1	1
Nectopsyche		1	4
Oecetis		3	10
Polycentropodidae	18	3	2
Triaenodes			22
TRICLADIDA			
Planariidae	7	1	
TUBIFICIDA			
Branchiura sowerbyi		1	
Quistradrilus multisetosus		1	
Tubificidae		2	
VENEROIDA			
Pisidiidae	1	2	

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [1004127], Station #1, Sample Date: 10/7/2010 10:00:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	14		2
AMPHIPODA			
Hyalella azteca	1		26
Stygobromus		1	
COLEOPTERA			
Ancyronyx variegatus	3	1	1
Dubiraphia		16	1
Optioservus sandersoni	1		
Psephenus herricki	15	5	-99
Scirtidae			1
Stenelmis	49	14	3
DECAPODA			
Orconectes neglectus	-99	-99	-99
DIPTERA			
Ablabesmyia	1	7	1
Ceratopogoninae	6		
Chironomidae		9	2
Chrysops			1

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [1004127], Station #1, Sample Date: 10/7/2010 10:00:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Cladotanytarsus	3	7	6
Clinotanypus		3	1
Corynoneura	1	1	4
Cricotopus bicinctus	4	2	7
Cricotopus/Orthocladius	14		9
Cryptochironomus		1	
Dicrotendipes		5	2
Forcipomyiinae	1		
Hemerodromia		1	4
Hexatoma	17	4	
Labrundinia		2	7
Nanocladius		2	1
Parachaetocladius	103	17	3
Parakiefferiella			1
Parametriocnemus	1		
Paratanytarsus	1	3	4
Pericoma	1		
Phaenopsectra		4	
Pilaria	2		
Polypedilum convictum	4		

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [1004127], Station #1, Sample Date: 10/7/2010 10:00:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Psectrocladius			1
Pseudochironomus		42	
Rheocricotopus	131	4	18
Rheotanytarsus	3	2	2
Simulium	45		1
Stempellinella	26	17	41
Stenochironomus	3	2	
Tabanus	-99		
Tanytarsus	5	147	115
Thienemanniella	15		6
Thienemannimyia grp.	7	5	23
Zavrelia		1	5
Zavrelimyia			2
EPHEMEROPTERA			
Acerpenna	83		10
Baetis	91		3
Caenis latipennis	6	16	1
Leptophlebiidae	1	13	3
Maccaffertium pulchellum	87	2	11
Stenonema femoratum		1	1

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [1004127], Station #1, Sample Date: 10/7/2010 10:00:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
HEMIPTERA			
Gerridae			1
ISOPODA			
Caecidotea (Blind & Unpigmented)		20	
LIMNOPHILA			
Physella			1
LUMBRICINA			
Lumbricina		2	-99
MEGALOPTERA			
Corydalus	2		-99
ODONATA			
Argia	1	3	11
Boyeria	1		-99
Calopteryx		1	1
Enallagma		4	18
Gomphidae	1	4	
Gomphus		2	
Hagenius brevistylus		3	
Ischnura	-99		1

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [1004127], Station #1, Sample Date: 10/7/2010 10:00:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Libellulidae		1	
Macromia			-99
Stylogomphus albistylus	1	1	
PLECOPTERA			
Acroneuria		-99	
Neoperla	43		1
Zealeuctra	1		
TRICHOPTERA			
Cheumatopsyche	64	1	1
Chimarra	122		1
Helicopsyche	6		1
Hydropsyche	3		
Hydroptila			7
Lype diversa		1	
Oecetis		3	11
Polycentropus	12	3	2
Triaenodes			16
TRICLADIDA			
Planariidae	11	4	2
TUBIFICIDA			

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [1004127], Station #1, Sample Date: 10/7/2010 10:00:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Branchiura sowerbyi		1	
Tubificidae			1
VENEROIDA			
Pisidiidae	5	5	

Aquid Invertebrate Database Bench Sheet Report

Beef Br [110341], Station #1, Sample Date: 3/30/2011 12:50:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina		6	
AMPHIPODA			
Hyalella azteca			27
Stygobromus	1	2	
COLEOPTERA			
Ancyronyx variegatus		1	1
Dubiraphia		9	4
Dytiscidae		1	
Helichus basalis			2
Macronychus glabratus			1
Optioservus sandersoni		1	
Psephenus herricki	35	47	3
Stenelmis	1	3	1
DECAPODA			
Orconectes neglectus	-99		-99
Orconectes virilis		-99	
DIPTERA			
Ablabesmyia		3	1

Aquid Invertebrate Database Bench Sheet Report

Beef Br [110341], Station #1, Sample Date: 3/30/2011 12:50:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Brillia			1
Ceratopogoninae		9	1
Chelifera	4		
Chironomidae			1
Clinocera	1	1	
Corynoneura	2	4	4
Cricotopus/Orthocladius	63	30	72
Cryptochironomus			1
Dicrotendipes		9	12
Diptera		2	1
Eukiefferiella	18		13
Hemerodromia	3	2	3
Labrundinia		2	1
Parakiefferiella		1	2
Paraphaenocladius			2
Paratanytarsus		1	2
Phaenopsectra			1
Polypedilum convictum	10		5
Polypedilum fallax grp		3	
Polypedilum illinoense grp		1	

Aquid Invertebrate Database Bench Sheet Report

Beef Br [110341], Station #1, Sample Date: 3/30/2011 12:50:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Rheocricotopus	1		3
Rheotanytarsus			1
Simulium	10		10
Stempellinella	1	3	
Tanytarsus	1	19	16
Thienemanniella	3	1	3
Thienemannimyia grp.	1	3	2
Tipula	2		-99
EPHEMEROPTERA			
Acentrella	8		1
Acerpenna	1	1	7
Caenis latipennis		1	
Diphetor	23	1	4
Leptophlebia		-99	
Leucrocuta	18	11	
Maccaffertium pulchellum	77	10	5
Stenacron		10	
Stenonema femoratum		16	
ISOPODA			
Caecidotea (Blind &		1	

Aquid Invertebrate Database Bench Sheet Report

Beef Br [110341], Station #1, Sample Date: 3/30/2011 12:50:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Unpigmented)			
Lirceus	186	92	55
LIMNOPHILA			
Ancylidae	1		
Physella	1		
LUMBRICINA			
Lumbricina	-99	1	
MEGALOPTERA			
Corydalus	-99		
MESOGASTROPODA			
Elimia			3
ODONATA			
Argia	1	1	1
Boyeria			-99
Enallagma			7
Gomphidae	9	8	
Stylogomphus albistylus		-99	-99
PLECOPTERA			
Acroneuria	12	-99	2
Amphinemura	5		6

Aquid Invertebrate Database Bench Sheet Report

Beef Br [110341], Station #1, Sample Date: 3/30/2011 12:50:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Clioperla clio			-99
Isoperla	4		
Leuctridae	7	5	2
Neoperla	21	3	2
Perlesta		2	1
TRICHOPTERA			
Agapetus	8	1	1
Cheumatopsyche	13		
Helicopsyche	13		-99
Oecetis			1
Polycentropus	28	2	3
Pycnopsyche		-99	-99
Triaenodes			1
TRICLADIDA			
Planariidae	7	5	1
TUBIFICIDA			
Limnodrilus hoffmeisteri		4	1
Tubificidae		4	2
VENEROIDA			
Pisidiidae			3

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [110342], Station #1, Sample Date: 3/30/2011 2:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	2		
AMPHIPODA			
Hyalella azteca		2	
Stygobromus	1		
COLEOPTERA			
Ancyronyx variegatus		1	1
Dubiraphia	1	12	2
Macronychus glabratus			1
Optioservus sandersoni	2		
Psephenus herricki	7		
Scirtidae	1		
Stenelmis	53	5	3
DECAPODA			
Orconectes neglectus		-99	1
DIPTERA			
Ablabesmyia		11	
Ceratopogoninae	4	21	8
Cladotanytarsus	27	33	9

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [110342], Station #1, Sample Date: 3/30/2011 2:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Clinotanypus		7	
Corynoneura	1	2	
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	48	6	12
Cryptochironomus	1	3	1
Dicrotendipes	2	5	5
Diptera		2	
Eukiefferiella	3		3
Hemerodromia	8	1	13
Hexatoma	11	3	1
Labrundinia		1	
Limnophila		1	
Micropsectra	2	2	1
Myxosargus	1	1	
Nilotanypus			1
Paratanytarsus	1		5
Polypedilum convictum	1		
Pseudochironomus	1	4	2
Pseudolimnophila	15		
Rheocricotopus	33	3	26

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [110342], Station #1, Sample Date: 3/30/2011 2:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Simulium	6		4
Stempellinella	30	14	6
Tabanus	4	2	
Tanytarsus	41	245	94
Thienemanniella	5	4	3
Thienemannimyia grp.	46	11	17
Tipula	3	-99	-99
EPHEMEROPTERA			
Acerpenna	39	1	11
Baetis	2		1
Caenis latipennis	2	13	3
Maccaffertium pulchellum	96		3
Stenacron		2	
ISOPODA			
Caecidotea (Blind & Unpigmented)	1	3	
LEPIDOPTERA			
Petrophila	1		
LUMBRICINA			
Lumbricina	3		

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [110342], Station #1, Sample Date: 3/30/2011 2:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
MEGALOPTERA			
Corydalus	1		-99
Sialis			-99
ODONATA			
Argia	1	2	9
Boyeria	1		2
Calopteryx			2
Enallagma	1		5
Gomphidae	5	4	-99
Hagenius brevistylus		1	
Macromia			-99
PLECOPTERA			
Acroneuria	-99		-99
Amphinemura	1		
Chloroperlidae	2		
Clioperla clio	-99		-99
Isoperla	8		-99
Leuctridae	9		
Neoperla	30		-99
Perlesta	3		1

Aquid Invertebrate Database Bench Sheet Report

Jacobs Br [110342], Station #1, Sample Date: 3/30/2011 2:15:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
TRICHOPTERA			
Agapetus	19		
Cheumatopsyche	25	1	3
Chimarra	42		1
Helicopsyche	31		
Ironoquia			-99
Neophylax	1		
Oecetis		1	3
Polycentropus	5		3
Pycnopsyche	-99		-99
Rhyacophila			1
Triaenodes			7
TRICLADIDA			
Planariidae	12		2
TUBIFICIDA			
Branchiura sowerbyi			-99
Limnodrilus hoffmeisteri			2
Tubificidae		1	1
VENEROIDA			
Pisidiidae	5	2	5