Missouri
Department of
Natural Resources

Stream Survey Sampling Report

Hinkson Creek Stream Study
Columbia, Missouri
Boone County

November 22, 2004

Prepared For:

Missouri Department of Natural Resources
Water Protection and Soil Conservation Division
Water Protection Program
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EXECUTIVE SUMMARY

The Missouri Department of Natural Resources, Water Protection Program placed a 14-mile segment of Hinkson Creek on the 1998 list of impaired waters designated under section 303(d) of the federal Clean Water Act, for "unspecified pollutants" due to urban runoff. A history of fish kills, the physical alteration of stream channels and adjacent riparian corridors, and other problems associated with urbanization has resulted in the designated beneficial uses becoming impaired. These urbanization concerns include the potential for water quality degradation, increased flow intensity due to storm water runoff of impervious surfaces, and the likely detrimental effects of development on the stream channel and riparian areas.

Numerous scientific studies have indicated that urban streams are particularly vulnerable to water quality and habitat degradations. Water quality could be reduced by any number of factors: wastewater treatment plant discharges; accidental or deliberate spills; illegal dumping; and non-point runoff from parking lots, roadways, golf courses, lawns, etc. In addition, habitat losses often result from residential or commercial development.

Biological monitoring during the fall of 2001 and the spring of 2002 by the Environmental Services Program determined that the biological integrity of Hinkson Creek was impaired for approximately 14.0 miles below the Interstate 70 bridge crossing. Therefore, it was determined that further water quality work was required to confirm the impairment of the aquatic community and attempt to determine the nature and source(s) of the impairment. The Environmental Services Program's Water Quality Monitoring Section conducted a study consisting of a combination of biological and chemical monitoring combined with toxicity testing in the upper portion of the impaired segment. Water and sediment samples were collected from mainstem Hinkson Creek and storm drainages located within this portion of Hinkson Creek.

Because the source and type of pollutant(s) were unknown, a water quality triad was used to document impairments to the aquatic community and identify pollutants that are likely contributing to those impairments. The water quality triad is an integrated assessment of information obtained from the aquatic community, chemical analyses, and toxicity testing. The first step in the triad was to document that impairment to the aquatic community still existed. This step was done during the fall of 2001 and spring of 2002 and again in the fall of 2003 and spring of 2004. The next step was to collect and test a variety of instream, storm water, and sediment samples for toxicity using a bioluminescent microorganism (*Vibrio fischeri*) and in some cases a freshwater daphnid (*Ceriodaphnia*). The purpose of this was to correlate effects of laboratory test organisms with instream effects on the biological community. Toxic samples were further manipulated using Toxicity Identification Evaluation procedures which are standard procedures that allowed us to determine what broad classes of chemical compounds (e.g. metals, organics) might be causing or contributing to the observed toxicity. The final step in the triad was to analyze the toxic samples for the chemical constituents indicated through the Toxicity Identification Evaluation procedures.

Results of this study documented that the aquatic community was, and continues to be, impaired in Hinkson Creek between I-70 and Broadway and the impairment extends downstream. Toxicity tests documented toxicity in approximately 20% of storm water discharges and in mainstem Hinkson Creek at Broadway. Toxicity Identification Evaluation procedures implicated a variety of urban-associated chemical constituents including organic chemicals (polycyclic aromatic hydrocarbons, pesticides, petroleum compounds, and metals) in some storm water discharges and high levels of sodium and calcium chloride in snowmelt samples. Although the presence of chemicals and toxicity of storm water does not automatically translate to toxicity instream, it does suggest possible contaminants and sources that are likely contributors to instream effects. Instream toxicity was documented in Hinkson Creek at the Broadway bridge during the snowmelt sampling. This observation is significant because it ties instream effects to a particular runoff event.

E. coli counts occasionally exceed recommended levels and may result from a variety of sources. The presence of this fecal bacterium is particularly significant, because as urbanization continues in the Hinkson Creek watershed, human recreational contact with the stream will likely increase.

A visual sediment survey documented increased sediment in the impaired segment of Hinkson Creek compared to upstream estimates. Observations of land disturbance and erosion may explain these observations.

During this first phase of the study, the Department of Natural Resources found it beneficial to release some of the preliminary findings. During spring 2004, preliminary Hinkson Creek data were presented to a variety of entities within the Hinkson Creek watershed. During this time, a number of recommendations were made, such as:

- improve storage and handling of road materials to minimize runoff and prevent movement off site;
- construct more and better designed storm water control structures that would slow and disperse the flow of storm water into the stream to reduce scouring and soil erosion;
- make a concerted effort to utilize best management practices to minimize soil erosion when conducting land disturbance activities;
- implement better parking lot management to minimize pollutant export into Hinkson Creek;
- strive to maintain or increase the existing riparian corridor whenever possible.

Releasing preliminary data allowed the entities to look at how business is currently being conducted and take the necessary steps to reduce impacts to Hinkson Creek. The City of Columbia, Public Works is considering a variety of watershed issues and promoting watershed educational efforts. However, improvements can only be made with cooperation from all entities (local government, business owners, and citizens) located within in the Hinkson Creek watershed.

1.0 Introduction

In 1998 the Missouri Department of Natural Resources, Water Protection Program, Water Pollution Control Branch (**WPCB**) placed approximately 14-miles of Hinkson Creek on the impaired waters list designated under section 303(d) of the federal Clean Water Act. Hinkson Creek was listed as impaired for "unspecified pollutants" due to urban runoff. The impaired beneficial use was listed as "protection of warm water aquatic life." This means that Hinkson Creek does not meet the following criteria: "waters in which naturally occurring water quality and habitat conditions allow the maintenance of a wide variety of warm-water biota, including naturally reproducing populations of recreationally important fish species…." (MO CSR 2004).

During the state fiscal year 2001, the Water Pollution Control Branch requested sampling of the aquatic macroinvertebrate community to determine the biological integrity of Hinkson Creek. During the fall of 2001 and spring of 2002, an aquatic macroinvertebrate community study was conducted (MDNR 2002a). Information obtained from the study showed a decline in the aquatic macroinvertebrate populations. Biological matrix comparisons were made against similar size, high quality streams within the same geographical area. The study results indicated that Hinkson Creek downstream of the Interstate 70 bridge (I-70) crossing was only "partially supporting" for aquatic life and confirmed stream impairment as summarized below.

- During the fall 2001season, the number of invertebrates in the orders Ephemeroptera, Plecoptera, and Tricoptera (**EPT**) taxa were similar among stations. A slight increase in both the total numbers of taxa and EPT taxa occurred in downstream stations, likely due to an increase in water quantity downstream. The percent EPT (# of EPT taxa/total # of taxa present) tended to be slightly greater upstream of the impaired segment.

- During the spring 2002 season, there was a sharp decline of EPT taxa in the urban portion of Hinkson Creek, with a significant decline in the order Plecoptera. The total number of taxa also declined substantially. Percent EPT was greater upstream of the impaired segment.

Because of the aquatic macroinvertebrate findings, further work was required to determine the nature and cause of impairment. The WPCB requested that the Environmental Services Program (**ESP**) conduct a comprehensive study of mainstem Hinkson Creek and major storm drainages located within the impaired segment of Hinkson Creek. This study consisted of additional biological sampling along with water quality and sediment monitoring and toxicity testing.

1.1 Study Area

Hinkson Creek is considered a Missouri Ozark border stream. It is located in a unique area that is characterized as a transitional zone between the Glaciated Plains and Ozark Natural Divisions (Thom and Wilson 1980). Pfleiger (1989) stated that streams within this region generally originate on level uplands underlain by shales and descend into rolling to hilly terrain underlain by limestone. The soil type within the Hinkson Creek watershed drains soils located geographically in the Central Clay Pan and Central Mississippi Valley Wooded Slopes regions (USDA 1978). According to the "Characteristics of Ecoregions of Iowa and Missouri" map (Chapman et al. 2002), the soil type within the upper segments of Hinkson Creek is characterized as being loamy till with well developed clay pan. Pennsylvanian sandstone, limestone, and shale also characterize this region. The soil types within the lower segments of Hinkson Creek are characterized as being thin cherty clay and silty to sandy clay. Mississippian and Pennsylvanian limestones, sandstones, and shales with considerable bedrock exposure characterize this region.

Hinkson Creek originates northeast of Hallsville, in Boone County, and flows approximately 26 miles in a southwesterly direction to its mouth at Perche Creek (Figure 1). The Hinkson Creek watershed is approximately 90 square miles. The land use in the upper portion of the watershed consists of rural pastureland and wooded areas, whereas the lower portion of the watershed is within the urbanized section of Columbia. The upper reaches of Hinkson Creek (from Mount Zion Church Road to approximately Providence Road) are classified as a Class C stream. The stream may cease flowing in dry periods but maintains permanent pools that support life. The beneficial uses in this reach consist of "livestock and wildlife watering" and "protection of warm water aquatic life and human health associated with fish consumption." The lower reaches of Hinkson Creek (from approximately Providence Road to Perche Creek) are classified as a Class P stream, where the stream is capable of maintaining permanent flow even in drought periods. The beneficial uses in this reach consist of "livestock and wildlife watering," "protection of warm water aquatic life and human health associated with fish consumption" and "boating and canoeing." During this study, the Hinkson Creek sampling locations were located within the Class C reach.

Within an aquatic ecological system, Hinkson Creek is located within the Ozark/Moreau/Loutre ecological drainage unit (**EDU**) (Figure 2) (MoRAP, Map Series 2001-001, unpublished data). The streams listed in Figure 2 are reference streams, selected by ESP aquatic biologists to represent the best attainable biological and habitat quality conditions of streams in the Ozark/Moreau/Loutre EDU. Biological and habitat data from these reference streams and Bonne Femme Creek were used for comparisons with Hinkson Creek. According to 1991-1993 land cover data, the Hinkson Creek watershed consisted of 12.7% urban, 6.7% crops, 47.4% grassland, 32.2% forest, and 1.0% other (MDNR 2002a).

Bonne Femme Creek is a nearby drainage within the same EDU that flows through a rural rather than urban watershed. It was used as a control stream during the biological and sediment portions of the study. Bonne Femme Creek originates southeast of Columbia and flows southwest through a watershed dominated by forestland. The stream reach assessed is Class P with beneficial use designations of "livestock and wildlife watering" and "protection of warm water aquatic life and human health associated with fish consumption." According to 1991-1993 land cover data, the Bonne Femme watershed consisted of 0.0% urban, 17.3% crops, 40.3% grassland, 41.9% forest and 0.5% other (MDNR 2002a).

Bonne Femme Creek was chosen as a control in the study due to several factors: its close proximity to the study stream within the same EDU; a watershed of comparable size to the mid to upper reaches of Hinkson Creek; and a relative lack of urbanization in the watershed. The biological comparison was to determine whether a biological impairment exists in a system largely comprised of urban runoff compared to one that lacks urban influence. In addition, sediment comparisons were made to estimate the amount of deposited sediment within each system.

Figure 1. Map of Study Area

The City of Columbia is centrally located in Boone County. During 2003, Columbia city limits contained of 55.87 square miles of land. According to the 2000 U.S. Census Bureau, the population of Columbia was 84,531. The City of Columbia estimated a population of 89,174 during the year 2003.

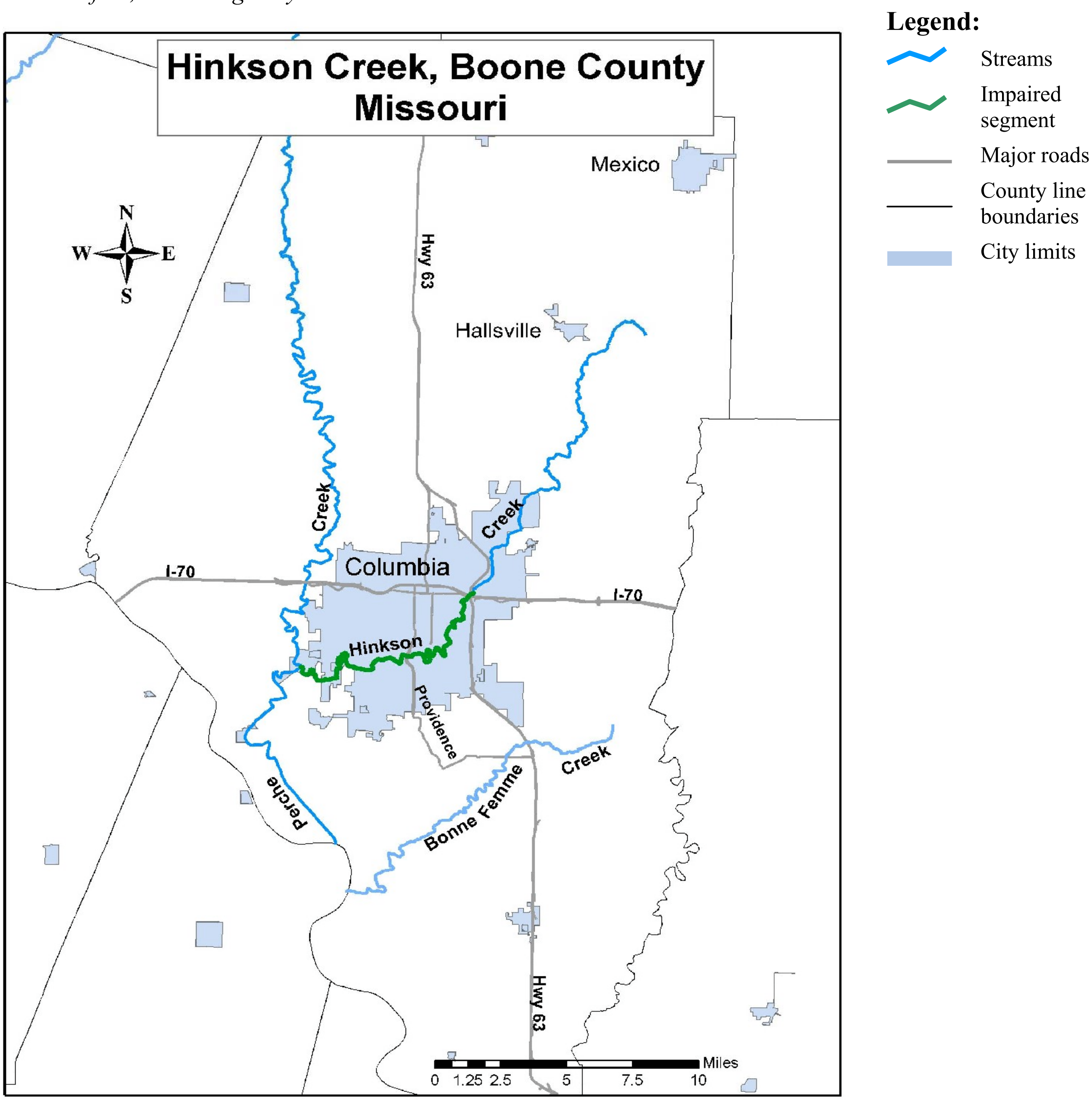
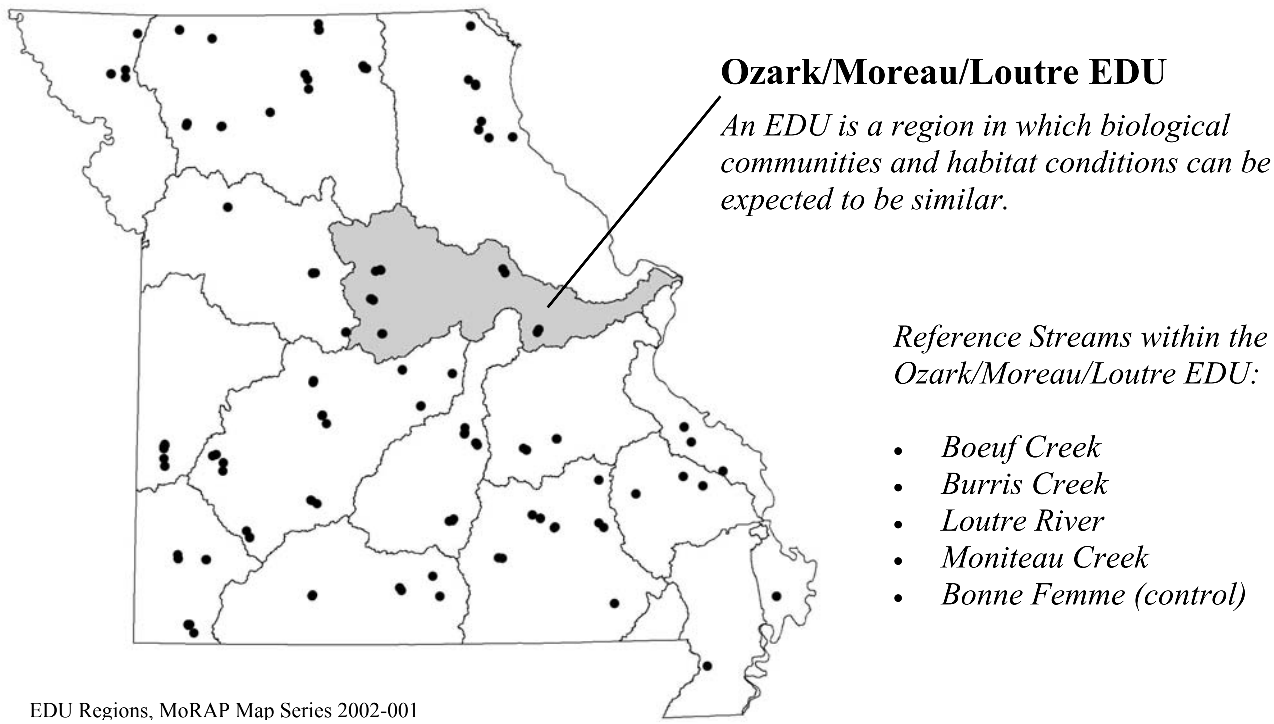


Figure 2. Ecological Drainage Units of Missouri and Location of Biological Reference Sites

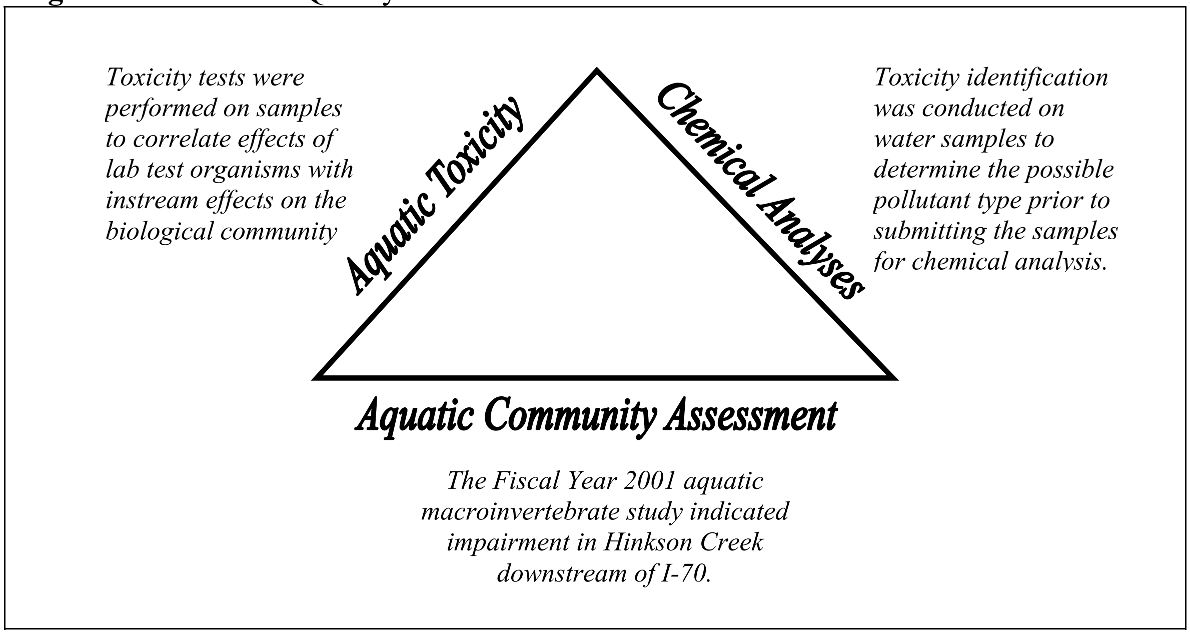


1.2 Study Design

Because the source and the type of pollutant(s) were unknown, a water quality triad was used to document impairments to the aquatic community and identify pollutants that are likely contributing to those impairments. The triad is a non-numeric, weight of evidence approach that is becoming frequently used as a regulatory tool for water quality impact assessment and management (Lee and Lee-Jones 2002, Burton and Pitt 2002). This approach is an integrated assessment of information obtained from the aquatic organism assemblages, chemical analyses, and toxicity testing.

Figure 3 summarizes how the water quality triad was implemented during this study. Because the fall 2001 and spring 2002 macroinvertebrate data indicated impairment to Hinkson Creek downstream of the I-70 bridge crossing, a series of water and sediment samples were collected. Before the samples were submitted for chemical analysis, aquatic toxicity was determined using a Microtox test system. If the water samples were found to be toxic, a Toxicity Identification Evaluation procedure was conducted to determine the possible pollutant type(s) (e.g. organic, metals, etc). The water samples were then submitted for analysis based on the toxicity identification results. Toxicity identification manipulations were not performed on sediment samples; therefore, if a sediment sample was found to be toxic it was submitted for further chemical analysis. The toxicity methods are explained in detail in section 2.0 of this report.

Figure 3. The Water Quality Triad



1.3 Study Objectives

The overall objective is to conduct a water quality assessment of the entire “impaired” 14-mile segment of Hinkson Creek. However, due to manpower and funding limitations, it is necessary to study Hinkson Creek in phases. The first phase of the study, which this report discusses, was started during the summer of 2003 and continued throughout the 2004 state fiscal year that ended June 30, 2004. The first phase concentrated on an approximately 1.5-mile long segment of Hinkson Creek located between the I-70 and Broadway crossings. The second phase of the Hinkson Creek study began in July 2004 and continues through June 2005. This phase will focus on an approximately five-mile long segment of Hinkson Creek located between Broadway and Providence Road. The third phase (planned for fiscal year 2006) will concentrate on an approximately 7.5-mile long segment of Hinkson Creek located between Providence Road and Perche Creek.

The intent of this study is to locate possible pollutant sources and identify contaminants contributing to impairment of the stream. Mainstem Hinkson Creek, major storm water drainages, and major tributaries were, and will be, monitored throughout each phase of the study. Sediment studies will continue throughout each of the remaining two study phases.

During the first phase of the study, a Quality Assurance Project Plan (MDNR QAPP 2004a) was submitted to the WPCB. In summary, the plan consisted of:

- analyzing mainstem Hinkson Creek samples collected by citizen volunteers during baseflow;
- analyzing mainstem Hinkson Creek samples collected by ESP personnel following rainfall events in excess of 0.5 inches of rain;
- storm water sample collections from significant storm water discharges located between I-70 and Broadway;

- conducting microtox testing on sediment and water samples collected from mainstem Hinkson Creek and storm water drainages located throughout the study reach;
- conducting visual sediment observations on mainstem Hinkson Creek at various locations throughout the study reach;
- analyzing sediment samples collected from several locations along Hinkson Creek and within storm water drainages;
- conducting an abbreviated follow-up study of the FY 2003 biological assessment from three locations, focusing on the stream reach located between Hinkson Creek Road and Broadway.

2.0 Study Methods

The methods that were used during this study were consistent with the department's standard operating procedures, Standard Methods (APHA 1998), and widely accepted by the scientific community. The specifics regarding a particular sampling event (e.g. the type of equipment used and when and where samples were collected) will be discussed in the respective sections.

2.1 Aquatic Toxicity Testing Methods

2.1.1 Microtox Bacterial Bioluminescence Overview

The toxicity of surface waters, storm waters, and sediments were determined for samples collected during the study using the Microtox bacterial bioluminescence test (APHA 1998). Establishing a connection between observed toxicity in waters or sediments and documented impairments in the aquatic community is a critical step when the potential for toxic components exists. Microtox has been shown to correlate well with other standard toxicity test organisms, including fathead minnows (*Pimephales promelas*) and daphnids (*Ceriodaphnia dubia*) (Bulich et al. 1981, Kaiser and Palabrica 1991, Munkittrick, K.R. et al. 1991). In Microtox, the commercially available freeze-dried strain of the bacterium *Vibrio fischeri* is exposed to water or sediment samples. Under suitable conditions, the bacteria convert a portion of their metabolic respiratory energy into visible light that can be measured by a photometer. Under adverse (toxic) conditions, this rate of light production is affected and is typically reduced in proportion to the toxicity of the test sample. The greater the toxicity, the greater the percent effect level that is recorded by the photometer.

2.1.2 Microtox Screens for Water Samples

Microtox acute toxicity tests were used to screen water samples for further toxicity and/or chemical analyses. Surface water and storm water samples were screened using the Microtox SOLO acute toxicity test or the Microtox Basic test (Microtox Omni 1999). A finding of toxicity in these screening tests resulted in further Microtox analyses of portions of the toxic sample that were manipulated using standard Toxicity Identification Evaluation procedures (US EPA 1991). The purpose of manipulating toxic samples prior to additional testing was to attempt to determine broad classes of chemicals that might be causing or contributing to the toxicity. For example, if toxicity is reduced or eliminated following filtration, it might indicate that the toxic component was adhering to suspended particles. Toxicity that is reduced or eliminated in the presence of a strong chelating agent, such as EDTA, might indicate that metals are a toxic component. Toxicity that is reduced or eliminated following passage of the sample through a Solid Phase Extraction **(**C_{18}**)** column might indicate that non-polar organic chemicals are contributing to the toxicity. See Appendix C for a more complete description of the manipulations used in this study.

Characterizing observed toxicity into broad chemical classes, in turn, allowed more specific analyses for those constituents that were more likely causing or contributing to the toxic conditions in the sample. The objective was to increase the likelihood of documenting pollutants having a deleterious effect on Hinkson Creek and its aquatic community.

2.1.3 Microtox Analysis of Sediment Samples

The Microtox Basic Solid Phase acute toxicity test was performed on all sediment samples collected during the study. Although Toxicity Identification Evaluation procedures were not performed on sediment samples, all test samples that resulted in observed toxicity were submitted for further chemical analysis. In addition, sufficient sediment samples collected throughout the study area were analyzed for a variety of chemical constituents, regardless of their toxicity, to help characterize the study area.

2.1.4 *Ceriodaphnia dubia* Toxicity Testing

In addition to using the Microtox test system, selected water samples were also analyzed for toxicity using the freshwater daphnid, *Ceriodaphnia dubia*. *C. dubia* is a standard toxicity test organism utilized by the state of Missouri as part of its National Pollutant Discharge Elimination System program. When chemical monitoring of storm water and surface water samples suggested spikes in chloride and conductivity levels at specific monitoring locations within the study area, it was decided to utilize both the Microtox and *C. dubia* tests. Because the Microtox organisms are marine bacteria, they are less sensitive to the presence of chlorides, especially sodium and calcium salts. *C. dubia* are relatively sensitive to the presence of these salts (US EPA 1991, MDNR unpublished reference toxicity data). The use of both organisms provided an opportunity to obtain data from organisms with known differences in sensitivity to these chemicals.

2.2 Water Quality Monitoring Methods

2.2.1 Collection Methods

All field instruments were calibrated according to the manufacturers instructions. The water samples were collected in appropriate sample containers (MDNR 2003a), handled, and transported to the ESP laboratory according to standard procedures (MDNR 2002b). The samples received a numbered label and were placed on ice. The corresponding label number was entered onto a chain-of-custody record form indicating the location, date and time of collection, any field measurements, and parameters to be analyzed (MDNR 2001 and MDNR 2003b). Custody of the water samples was maintained by ESP field personnel until relinquishing them to the state environmental laboratory sample custodian within the ESP in Jefferson City, Missouri.

2.2.2 Analytical Methods

All water analyses were conducted in accordance with methods outlined in the Quality Assurance Project Plan for Hinkson Creek (MDNR QAPP 2004a). Nutrients and chloride were analyzed using a Lachat QuickChem 8000. Total recoverable metals (except mercury) were analyzed using a Varian

Vista MPX Inductively Coupled Plasma - Optical Emission Spectrometer or Varian Inductively Coupled Plasma - Mass Spectrometer. Mercury analysis was performed using a Perkin Elmer Flow Injection Mercury System 100 cold vapor analyzer. Non filterable residue (**NFR**) was analyzed with a Lab-Line oven, Boekel desiccator, and Sartorius analytical balance. Qualitative organic analyses (**QOA**), base neutral/acid extractables (**BNAs**), and petroleum fractions were analyzed using a Varian Saturn 2000R Ion Trap Gas Chromatograph/Mass Spectrometer. Because of the qualitative nature of the QOA, individual peaks produced by the gas chromatograph are identified but not quantified. In order to quantify a given chemical that is identified through QOA, an internal standard of that chemical must be run for comparison. All samples were screened with a Microtox Solo acute toxicity test using a Microbics Model 500 Toxicity Analyzer. Microbiological samples were analyzed with an IDEXX Colilert Quantitray system.

2.3 Benthic Sediment Monitoring

2.3.1 Collection Methods

Sediment samples were collected according the department's standard operating procedure (MDNR 2003c). All sediment samples were collected in appropriate sample containers (MDNR 2003a), handled, and transported to the ESP laboratory according to standard procedures (MDNR 2002b). The labeling and maintenance of chain of custody procedures were identical to those outlined in Section 2.2.2.

2.3.2 Analytical Methods

All sediment analyses were conducted in accordance with methods outlined in the Quality Assurance Project Plan for Hinkson Creek (MDNR QAPP 2004a). Acute toxicity tests were conducted using a Microbics Model 500 Toxicity Analyzer using the Basic Solid-Phase test. Total recoverable metals (except mercury) were analyzed using a Varian Vista MPX Inductively Coupled Plasma - Optical Emission Spectrometer or Varian Inductively Coupled Plasma - Mass Spectrometer. Mercury analysis was performed using a Perkin Elmer Flow Injection Mercury System 100 cold vapor analyzer. Qualitative organic analyses, base neutral/acid extractables, and petroleum fractions were analyzed using a Varian Saturn 2000R Ion Trap Gas Chromatograph/Mass Spectrometer. Organochlorine and organophosphate pesticides were analyzed using a Varian 3800 Gas Chromatograph/Electron Capture Detector. Total organic carbon (**TOC**) analysis was performed using a Tekmar Dohrmann Phoenix 8000 UV-Persulfate TOC analyzer. Sediment results were converted to dry weight basis following analysis. In addition, contaminant concentrations were normalized to a 1% TOC concentration for comparison with published consensus-based sediment quality guidelines (MacDonald et al. 2000).

3.0 Hinkson Creek Water Quality Monitoring

To increase efficiency, various sampling devices and many individuals were utilized during the study. The following sections describe the sampling efforts that were conducted during the Hinkson Creek study to assess water quality. This included baseflow sampling conducted by citizen volunteers and storm water and snowmelt samples collected by ESP field personnel.

3.1 Level 4 Citizen Volunteer Water Quality Monitoring

3.1.1 Background

For this portion of the study, the Missouri Department of Natural Resources utilized citizen volunteers to collect Hinkson Creek baseflow data. The use of citizen volunteers in this capacity was a pilot project for the Missouri Department of Natural Resources and the Volunteer Water Quality Monitoring Program (**VWQMP**). The VWQMP, sponsored by the Missouri Department of Natural Resources, the Missouri Department of Conservation, and the Conservation Federation of Missouri, provides education and training regarding the water quality of Missouri's rivers and streams. As a main component of the VWQMP training, citizen volunteers are taught to monitor the physical, biological, and chemical parameters of a stream system (MDNR QAPP 2004b).

Citizen volunteers who successfully participated in all levels of the VWQMP training workshops (Introduction, Level 1, Level 2, and Level 3), were chosen to participate in the Hinkson Creek Level 4 monitoring. The selected VWQMP volunteers were trained by Missouri Department of Natural Resources personnel on proper sample collection, handling, and documentation. All samples were collected in accordance with the department's standard operating procedures.

3.1.2 Sample Collection Overview

VWQMP Level 4 sampling occurred on the third Sunday of: July, September, November, January, March, April, and May. The VWQMP QA/QC Officer collected surface water samples from the Rogers Road sampling location on each Monday following the volunteers' sample trip.

All samples were collected in Missouri Department of Natural Resources approved sample containers and in accordance with the standard operation procedure (MDNR 2003a). The samples remained in the custody of a VWQMP Level 4 volunteer until they were either relinquished to the VWQMP QA/QC Officer or personally hand delivered and relinquished to the ESP laboratory located in Jefferson City.

The VWQMP Level 4 volunteers were assigned to monitor five sites located on mainstem Hinkson Creek (Rogers Road, Hinkson Creek Road, I-70, East Walnut, and Broadway). Please refer to Appendix A for general depiction of the sampling locations. Surface water grab samples were collected and analyzed for the following parameters: ammonia as nitrogen (**NH_3-N**); nitrite plus nitrate as nitrogen (**NO_2+NO_3-N**); total Kjeldahl nitrogen (**TKN**); total phosphorus (**T (P)**); NFR; chloride; and Microtox toxicity. Bacteriological samples for *Escherichia coli* were collected by the VWQMP quality assurance/quality control (**QA/QC**) officer. Surface water grab samples were also collected for petroleum fractions, qualitative organic analysis (**QOA**), and volatile organic analysis (**VOA**), but only submitted for analysis based upon the Microtox toxicity results. Regardless of the toxicity results and for background purposes, mainstem Hinkson Creek surface water grab samples were submitted for analysis of the aforementioned nutrient and organic chemical parameters during November 2003, April 2004, and May 2004 sampling events. During the January 2004 sampling event, water samples were analyzed for nutrient and total recoverable metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn) analyses.

In situ field measurements were collected for the following parameters using VWQMP equipment and procedures: water temperature using a Hach thermometer; pH using a Hach two-point calibrated pH pen; specific conductivity using a Hach conductivity pen; and dissolved oxygen (**DO**) using a Hach Dissolved Oxygen kit Model OX-2P. Instream discharge measurements were collected by the VWQMP QA/QC Officer at the Hinkson Creek Road and Broadway sampling locations using a Marsh-McBirney Flo-Mate 2000. All other instream discharge measurements were estimated by the citizen volunteers following the VWQMP procedure (MDNR QAPP 2004b). All field instruments were calibrated according to the manufacturers' instructions.

3.2 Level 4 Volunteer WQ Monitoring Results

Table 1 summarizes the Level 4 citizen volunteer sampling events and water quality data. According to the MDNR 10 CSR 20-7.030 (MO CSR 2004) for water quality standards, instream water quality limits were not exceeded at any time during the volunteer monitoring portion of the study.

3.2.1 Microtox Toxicity

Of 34 baseflow water samples collected by Level 4 Volunteers, only two showed Microtox toxicity. During April, baseflow monitoring conducted by Volunteers at I-70 and Broadway showed toxicity at a 100% and 17% effect level, respectively. Upon initiation of toxicity identification manipulations on the following day, however, the toxicity that had been observed the previous day in both samples had disappeared. The Broadway sample had barely exceeded our 15% cutoff criteria that had been established for the project, so the decrease in toxicity of that sample was not unexpected. The total elimination of toxicity in the I-70 sample, however, was surprising. Whether this decrease was a result of a toxicant that had volatilized, an artifact of the test method, or laboratory error could not be determined.

3.2.2 Analytical Results

With a few exceptions, the *in situ* conductivity field measurements were within expected ranges for streams in the Ozark/Moreau/Loutre EDU. However, during the September 2003 and November 2003 sampling events, elevated levels of specific conductivity [>900 microsiemens per centimeter (µS/cm)] were observed at the Hinkson Creek Road and I-70 sampling stations. Longitudinally, the greatest percent increase in conductivity was between the Rogers Road and Hinkson Creek Road locations. An increase in conductivity was observed at the Hinkson Creek Road location during the July 2003 (61.9%) and September 2003 (50%) sampling events. Higher conductivity levels were also observed at the Hinkson Creek Road sampling location during the FY 2002 biological sampling event (MDNR 2002a). This sampling location is located downstream of the City of Columbia Sanitary Landfill and near an area that had been mined for coal during the late 1960's to early 1970's.

Table 1. Level 4 Citizen Volunteer Water Quality Data

Sample Date	Sample Location *(Sample #)*	Microtox Results	pH (S.U.)	Spec. Cond. (µS/cm)	Temp (°C)	DO (mg/L)	*E. coli* (cfu/ 100mL)	Chloride (mg/L)	NFR (mg/L)	NH3-N (mg/L)	NO3+NO2-N (mg/L)	TKN (mg/L)	Total P (mg/L)	Flow (cfs)
07/20/03	Broadway Ave *(0333350)*	Not Toxic	7.95	662	26	9	--	35.8	<5	<0.03	<0.01	0.57	0.02	0.45
	East Walnut *(0333351)*	Not Toxic	7.9	625	27	8	--	31	<5	<0.03	0.02	0.55	0.02	0.55
	I-70 *(0333352)*	Not Toxic	8.2	670	29	8	--	32	6	<0.03	<0.01	0.67	0.02	1.06
	Hinkson Creek Rd *(0333353)*	Not Toxic	7.8	**745**	30	10	--	23.3	7	<0.03	**1.19**	0.77	0.02	0.2
	Rogers Rd *(0333359)*	Not Toxic	8.01	460	26.7	6.6	--	14.8	18	<0.03	<0.01	0.87	0.02	< 0.1
09/21/03	Broadway Ave *(0335650)*	Not Toxic	8.2	680	17	11	--	57.6	<5	<0.03	<0.01	0.63	0.06	2.1
	East Walnut *(0335651)*	Not Toxic	8.1	770	17	11	--	67.1	5	<0.03	<0.01	0.71	0.06	--
	I-70 *(0335652)*	Not Toxic	8.2	**910**	18	11	--	92.9	5	<0.03	<0.01	0.83	0.06	--
	Hinkson Creek Rd *(0335653)*	Not Toxic	8.6	664	19	13	--	43.1	7	<0.03	<0.01	0.78	0.09	1.23
11/16/03	Broadway Ave *(0335671)*	Not Toxic	7.9	868	8	10	15	45.5	<5	<0.03	<0.01	0.23	0.04	1.11
	East Walnut *(0335672)*	Not Toxic	7.7	898	8	10	48	46.4	<5	<0.03	<0.01	0.31	0.05	--
	I-70 *(0335673)*	Not Toxic	7.5	894	9	10	**>200.5**	45.2	<5	<0.03	<0.01	0.32	0.07	--
	Hinkson Creek Rd *(0335674)*	Not Toxic	7.9	**910**	9	10	29	49.6	<5	<0.03	0.03	0.53	0.07	0.44
	Rogers Rd *(0335680)*	Not Toxic	7.02	606	8.9	10.2	50	23.9	<5	<0.03	<0.01	0.56	0.06	<0.5
01/12/04	Broadway Ave *(0410000)*	Not Toxic	8.23	600	1.8	16.6	9	28.5	9	<0.03	0.54	0.41	0.05	10.1
	East Walnut *(0410001)*	Not Toxic	8.18	599	2	15.9	28	26.1	6	<0.03	0.59	0.59	0.05	7.54
	I-70 *(0410002)*	Not Toxic	8.14	588	1.2	16.4	15	22.8	7	<0.03	0.57	0.43	0.05	5.02
	Hinkson Creek Rd *(0410003)*	Not Toxic	8.02	509	1.1	16.4	21	19.5	7	<0.03	0.62	0.47	0.06	5.86

Table 1. Level 4 Citizen Volunteer Water Quality Data

Sample Date	Sample Location *(Sample #)*	Microtox Results	pH (S.U.)	Spec. Cond. (µS/cm)	Temp (°C)	DO (mg/L)	*E. coli* (cfu/ 100mL)	Chloride (mg/L)	NFR (mg/L)	NH3-N (mg/L)	NO3+NO2-N (mg/L)	TKN (mg/L)	Total P (mg/L)	Flow (cfs)
	Rogers Rd *(0410004)*	Not Toxic	6.91	445	0.4	15.9	71	16.7	8	<0.03	0.46	0.53	0.07	5.14
03/21/04	Broadway Ave *(0411551)*	Not Toxic	7.8	620	8	12	28	26.1	5	<0.03	<0.01	0.4	0.03	8.39
	East Walnut *(0411552)*	Not Toxic	7.8	626	9	12	28	25.4	10	<0.03	<0.01	0.34	0.02	--
	I-70 *(0411553)*	Not Toxic	7.9	645	12	13	67	24	8	<0.03	<0.01	0.34	0.03	--
	Hinkson Creek Rd *(0411554)*	Not Toxic	8.3	541	13	12	34	18.6	11	<0.03	0.11	0.36	0.02	5.23
	Rogers Rd *(0411561)*	Not Toxic	7.5	465	6.6	12.4	13	17	11	<0.03	0.05	0.61	0.04	3.31
04/18/04	Broadway Ave *(0410428)*	**Toxic***	8.00	713	19.0	10.0	190	26.3	<5	<0.03	<0.01	0.34	0.03	4.38
	East Walnut *(0410429)*	Not Toxic*	8.20	688	20.0	10.0	**240**	24.7	<5	<0.03	<0.01	0.34	0.03	--
	I-70 *(0410430)*	**Toxic***	7.90	695	20.0	9.00	**250**	23.8	<5	<0.03	<0.01	0.42	0.05	--
	Hinkson Creek Rd *(0410431)*	Not Toxic*	8.00	660	21.0	11	200	18.6	<5	<0.03	0.14	0.48	0.04	2.85
	Rogers Rd *(0410403)*	Not Toxic*	7.85	604	19.6	7.81	**370**	16.5	<5	<0.03	0.02	0.4	0.04	2.17
05/16/04	Broadway Ave *(0410435)*	Not Toxic**	8.20	660	16.0	11.0	48	30.7	7	<0.03	0.03	0.43	0.03	4.90
	East Walnut *(0410436)*	Not Toxic**	8.30	663	17.0	10.0	170	28.8	5	<0.03	0.03	<0.05	0.03	--
	I-70 *(0410437)*	Not Toxic**	8.30	660	17.0	11.0	200	25.1	15	<0.03	0.01	0.41	0.04	--
	Hinkson Creek Rd *(0410438)*	Not Toxic**	8.10	620	17.0	11.0	66	21.3	5	<0.03	0.11	0.46	0.03	1.64
	Rogers Rd *(0411568)*	Not Toxic**	7.91	580	18.2	7.80	110	17.3	6	<0.03	0.07	0.45	0.03	0.57

* 1,1,2,2-tetrachloroethane present in sample
** 1,1,2,2-tetrachloroethane and atrazine present in sample

The Missouri Department of Natural Resources, Land Reclamation Program and Solid Waste Management Program (personal communication) believe that neither strip mining nor the landfill is causing impacts to Hinkson Creek. However, additional studies are necessary to determine the cause and/or source of the elevated conductivity readings.

On September 21, 2003, conductivity readings were approximately 37% higher at the I-70 sample location compared to the Hinkson Creek Road location. The VWQMP I-70 sampling point was located downstream of the I-70 storm drainage system (hereafter referred to as the I-70 drainage). The I-70 drainage generally had very little to no flow throughout the study period, except following a rainfall event. The drainage itself was monitored throughout the study during rainfall events. Specific conductivity readings collected from the drainage were frequently found to be in excess of 1000 µS/cm and were believed to contribute to the higher instream conductivity readings reported by the VWQMP volunteers.

Chloride values ranged from 14.8 milligrams per liter (mg/L) at Rogers Road to 92.9 mg/L at the I-70 sample location. No longitudinal trends were noted. The highest values were reported during the months of September and November 2003. Nutrient (NH_3-N, NO_3+NO_2-N, TKN, and T(P)) values were reported below the laboratory detection limits or within a "typical" range for this stream system, with one exception. During July 2003, an NO_2+NO_3-N concentration was reported at 1.19 mg/L at the Hinkson Creek Road location.

In reviewing the volunteer Level 4 analytical results for petroleum fractions and VOA, all the organic constituents were reported below the analytical detection limits. The QOA indicated the presence of 1,1,2,2-tetrachloroethane and atrazine in several of the samples collected during the spring of 2004.

"Whole body contact" is not a beneficial use listed for Hinkson Creek although draft revisions to the Water Quality Standards have been presented to the Clean Water Commission that would extend the whole body contact designation to all classified streams. Historical studies have indicated high levels of fecal bacteria present at various times. Over the past several years, reports of raw wastewater bypasses from municipal sewer system manholes have caused fish kills and/or entered Hinkson Creek (MDNR, Environmental Emergency Response database [http://www.dnr.mo.gov/meerts/index.do]). This repeated influx of untreated wastewater is of particular concern because, although not designated for whole body contact, as urbanization encompasses more of the Hinkson Creek watershed, the chances of recreational contact with its waters is increased. On at least one occasion, a kayaker became seriously ill after kayaking Hinkson Creek following a rainfall event (Bengston 2002). Although bacteriological sampling was not warranted based on the listed beneficial uses, one of the objectives of the Level 4 monitoring was to gather background bacteriological data in Hinkson Creek during base flow conditions.

E. coli is the abbreviated name of the bacterium in the family *Enterobacteriaceae. E. coli* is a specific type of fecal coliform bacteria that inhabits the digestive tract of all warm-blooded animals (humans, dogs, geese, etc.). By themselves, these bacteria are not harmful; however, they are indicators of the presence of other harmful bacteria. According to the US Environmental Protection Agency (US EPA 1986), E. *coli* levels of recreational waters should not exceed a geometric mean of 126 colony forming units (cfu) per 100 milliliters (mL) of water or a single sample maximum of 235 cfu per 100 mL.

E. coli samples were collected by the VWQMP QA/QC coordinator. Samples were collected from the aforementioned VWQMP stations from November 2003 to May 2004. Elevated levels of *E. coli* were found at I-70 in November 2003, at all locations in April 2004 (where three sites exceeded EPA's single sample maximum), and at East Walnut Street, I-70, and Rogers Road in May of 2004. These elevated levels were not correlated with any rainfall events. The upper portion of the Hinkson Creek watershed drains a rural agricultural area. In addition to the Columbia Sanitary Landfill, several small domestic wastewater treatment facilities are also located within the upper reaches of the watershed (MDNR, NPDES Facilities 2004). The elevated levels of *E. coli* at the Rogers Road and Hinkson Creek Road stream locations most likely can be attributed to agricultural sources and/or discharges from small wastewater treatment facilities. Although, elevated levels of *E. coli* in the lower stream segments of Hinkson Creek cannot be fully explained, they might be correlated with the following factors noted and/or occurring at the time of the study.

- According to the Missouri Department of Natural Resources, Geographic Information System facility permit layer, the lower sections of Hinkson Creek downstream of Hinkson Creek Road do not receive wastewater discharges. The homes located within this area should be connected to the City of Columbia Municipal Wastewater Treatment Facility. However, even in non-storm events, sewer systems sometimes clog and bypass untreated wastewater, where it has the potential of entering stream systems. At the time of the study, the City of Columbia was conducting a sewer line upgrade. During the month of September 2003, there was evidence that a recent sewer line break had occurred and entered Hinkson Creek from a wet weather tributary located near the Columbia Country Club Golf Course. Incidents such as this could have contributed to elevated readings.

- Pet and other animal waste can enter storm water that discharges to the creek. USGS (2002a) reported that genetic source-tracking of *E. coli* in the Blue River and Brush Creek in Kansas City showed nearly equal contributions from dogs, geese, and humans. The Missouri Department of Conservation has documented an increase in the resident Giant Canada goose (*Branta canadenis maxima*) populations in recent years (McMurtry 2002). The geese tend to concentrate around water systems, golf courses, lawns, and ball fields where goose droppings accumulate and where fecal bacteria can remain viable for several weeks, (Brown 2001, unpublished data) with the potential of entering streams during rainfall events.

- Several camps apparently used by homeless individuals were observed during the study that appeared to be actively used between the early spring to late fall months. These camps were located in a wooded area between the I-70 and Highway 63 connector bridge crossings, in a wooded area behind the Broadway Market Place complex, and at the Broadway and East Gate bridge crossings. The lack of sanitary facilities at these camps could contribute to elevated *E. coli* levels.

3.3 Hinkson Creek Storm Water Monitoring

3.3.1 Background

Characteristics of heavily populated urban areas include more impervious surfaces; automobiles and emissions; construction; and chemicals used for pest control, maintenance of roadways, and golf courses. Urban stream studies, such as those conducted by the USGS (2002a & b) have found that a variety of chemical constituents can be deposited on impervious surfaces during dry periods. During rainfall events, these constituents are transported into streams as runoff moves across the impervious surfaces.

3.3.2 Sample Collection Overview

Since the 303(d) list designated pollutants in Hinkson Creek as unknown, a holistic approach was necessary to determine which pollutants might be present. For background purposes, the October 14 and October 27, 2003 storm water samples were collected from all sites and analyzed for the following parameters: Microtox, QOA, petroleum fractions, BNAs, chemical oxygen demand (**COD**), chloride, and NFR. All other storm water samples collected during the study were screened for toxicity prior to submitting them for chemical analysis. Any further analytical work was dependent on the outcome of the toxicity testing.

Storm water monitoring was conducted at six storm water drainages located between I-70 and Broadway after a significant rainfall event that followed a relative dry period (refer to Appendix A inset map). These monitoring locations are described below.

- The I-70 drainage has a watershed of approximately 120 acres. At the time of sampling, the I-70 drainage collected runoff from roadways, a gas station, small businesses, several motels, and a portion of the Missouri Department of Transportation (**MoDOT**) maintenance facility.

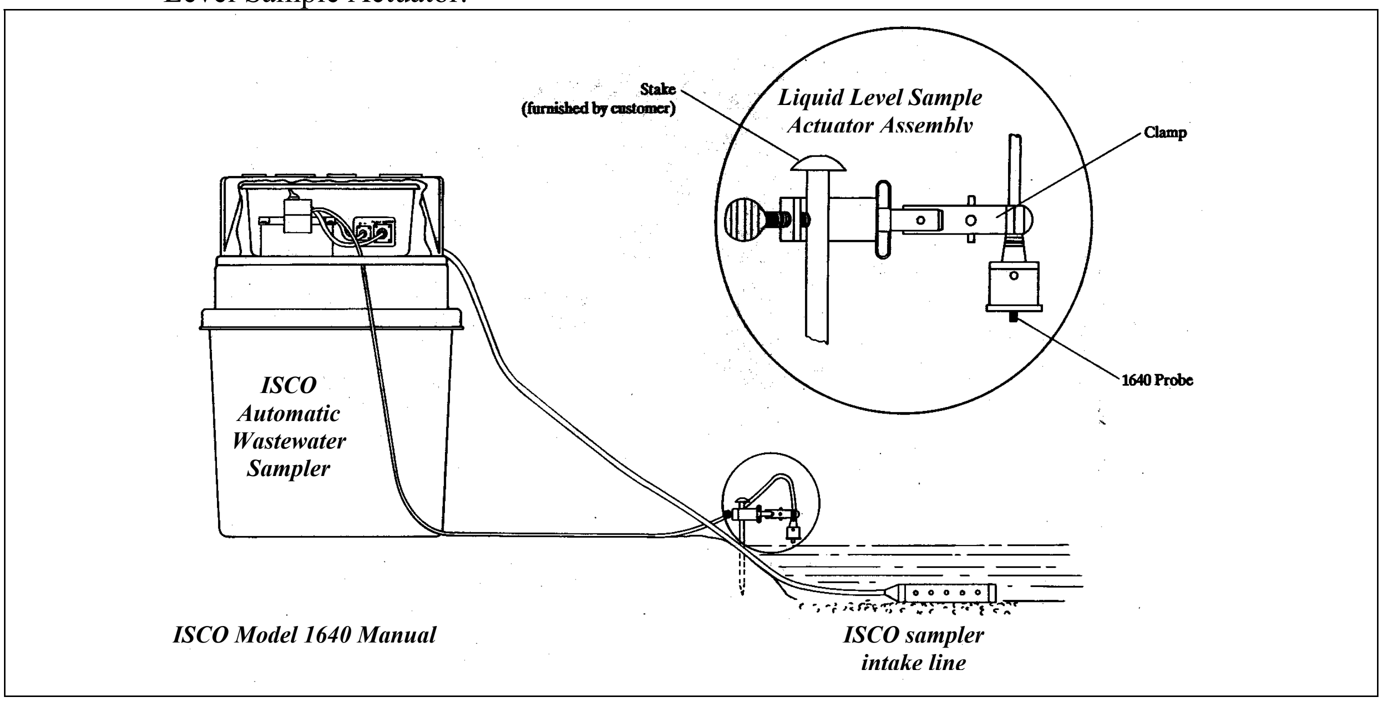
- The MoDOT maintenance facility is located southwest of the I-70/Highway 63 interchange just north of the Broadway Market Place shopping complex. It sits on approximately nine acres of land and is used to store asphalt and road deicing materials. The main storm water drainage for the MoDOT facility is located at the southwest corner of the property, and a smaller portion of the property drains to the northeast and into the I-70 drainage system.

- Three main storm water drainages located behind Wal-Mart, Sam's/Lowe's, and Mega Market drain the Broadway Market Place shopping complex. The shopping complex is located immediately south of the MoDOT maintenance facility and has approximately 57 acres of impervious surface consisting mainly of parking lot and rooftops.

- A wet weather tributary that drains the Columbia Country Club Golf Course was also monitored. The tributary drains approximately 200 acres that consists mainly of golf course property. When possible, samples were collected from mainstem Hinkson Creek at Hinkson Creek Road and Broadway.

Three types of water collection techniques were conducted over the course of the study: ISCO samplers; stage samplers; and surface water grab samples. Where possible, ISCO automatic wastewater samplers were used in conjunction with ISCO Model 1640 Liquid Level Sample Actuators to collect storm water samples from storm drainages during significant runoff events. Depending on the water level and placement of the actuator's sensor, the ISCO Liquid Level Sample Actuator initiated the programmed sampling routine of the automatic sampler. The actuator was placed above the base of the discharge channel, near the intake line of the ISCO sampler. The actuator was set so that when the water level reached a predetermined height the actuator would trigger, sending a signal to the ISCO automatic wastewater sampler and initiate the sampling routine (Figure 3). The ISCO sampler was programmed to collect a discrete sample once every two minutes over a 45-minute duration. The discrete samples were then combined to create a composite sample (MDNR 2002c).

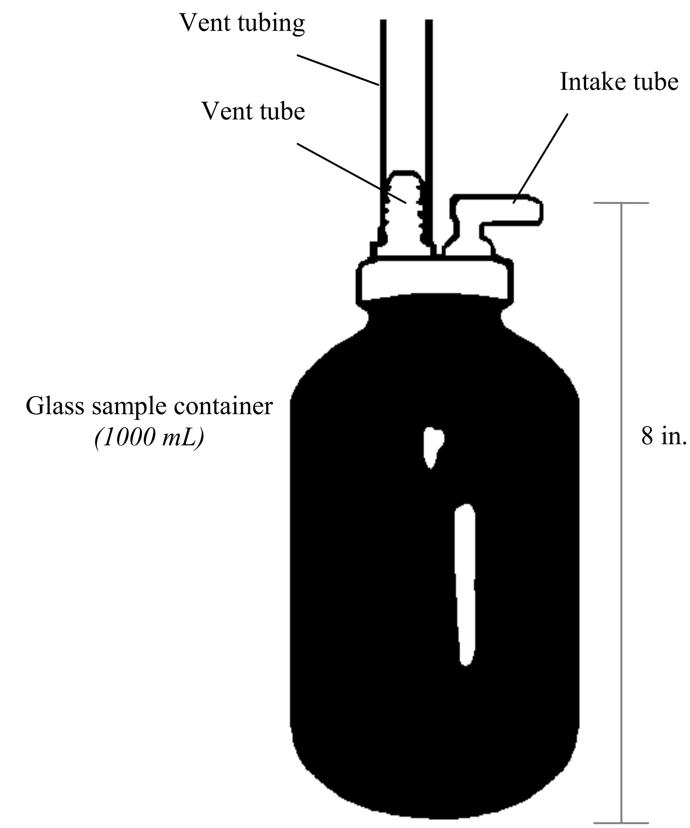
Figure 3. Example of how the ISCO automatic wastewater sampler is used in conjunction with a Liquid Level Sample Actuator.



In areas where it was not practical or feasible to set an ISCO sampler due to the risk of loss or vandalism, a stage sampler was used (refer to Figure 4). Stage samplers used during the study were a modified version of the rising-stage sampler (ICWRSS 1961). They have been shown to be an effective way to collect samples in a cost-effective manner because they are easy to build, operate, and maintain.

A stage sampler consisted of a 100-mL amber glass sample container, a lid fitted with two barbed connector fittings, and flexible tubing. The stage sampler was secured within a protective corrugated pipe and fastened to a fence post. The stage samplers were set at a predetermined height so as the stream stage rose to the elevation of the intake tube, water entered the sample intake tube and filled the sample container. As the sample bottle filled, the air within the bottle was expelled through the vent tube. Sample collection was complete when the bottle was full or when the stream stage fell below the elevation of the intake level.

Figure 4. Design of Stage Sampler



Modified version of the rising-stage sampler (ICWRSS 1961)

3.4 Storm Water Monitoring Results

On July 11, 2003, storm water samples were collected from MoDOT, Wal-Mart, and the Sam's/Lowe's storm water drainages using stage samplers. Thereafter, ISCO automatic samplers were used in conjunction with the ISCO Liquid Level Sample Actuator as described in the previous section. As noted in Table 2, not all the storm water drainages were sampled during a particular rainfall event due to sampler malfunction, sampler loss/vandalism, or when water levels did not reach the height necessary to trigger the actuator. Surface water grab samples were collected from the drainages during or immediately following storm water events on March 4 and May 13, 2004. Due to increased chances of loss or vandalism, stage samplers were deployed at Hinkson Creek Road and at the I-70 drainage. Table 2 summarizes the storm water sampling events and the results of the toxicity tests. Please refer to Appendix D for a complete list of all the reported analytical results.

3.4.1 Microtox Toxicity

Table 3 gives the results of Microtox toxicity and Toxicity Identification Evaluation manipulations. Of the storm water discharge samples, 32% (12 of 37) were toxic to the Microtox organisms. Toxicity Identification Evaluation manipulations implicated non-polar organics in 10 (27%) of the samples, either by reduction or total elimination of toxicity. Chelating agents (EDTA) reduced or eliminated toxicity in four (11%) of the samples. Filtration reduced toxicity in four (11%) samples and eliminated toxicity in two (5%). In six (16%) of the samples, toxicity was reduced by more than one manipulation.

In July 2003, sample #0300852 was found to be toxic. Toxicity identification evaluation manipulations reduced toxicity from 46% level of effect (toxic) in a raw (unmanipulated) sample to 0% effect (non-toxic) by passing a portion of it through a solid phase extraction column (C_{18} column). Carbaryl, a common lawn and garden insecticide, was present in sufficient quantities (~64 µg/L) to cause or contribute to the observed toxicity in the sample. Carbaryl is listed as a general use carbamate pesticide that is moderately toxic to many aquatic organisms. It can be toxic to many aquatic macroinvertebrate at low (10-20 µg/L) concentrations (ECTOX 2004).

In October 2003, Toxicity Identification Evaluation manipulations of sample #0300689 implicated non-polar organic chemicals as the cause of toxicity. Chemical analysis revealed waste oil in a concentration of 6360 µg/L. Specific organic components in the sample that were identified in the qualitative organic analysis are included in Table 4. The biological effects of petroleum products, including waste oil, can be quite complex because they are mixtures of saturated hydrocarbons (alkanes and cycloalkanes), aromatic hydrocarbons (aromatic and polycyclic aromatics), and high molecular weight resins and asphaltenes. Green and Trett (1989) provide an excellent review of the effects of petroleum on aquatic systems. In general, the acute toxicity of a petroleum mixture is directly related to its content of low molecular weight aromatic hydrocarbons. Concentrations of the water soluble fractions of most refined petroleum products in excess of 1000 ug/L can frequently result in acute toxicity to a wide range of aquatic organisms (API 1983).

On March 4, 2004, sample #0411506 collected at the I-70 drainage was found toxic at a 27% effect level. The addition of EDTA eliminated toxicity, therefore the sample was submitted for total recoverable metals listed in Table 3. Concentrations of Cr (28 µg/L), Cu (22.4 µg/L), Ni (29µg/L), and Zn (113 µg/L) were present. Although these concentrations individually would not be expected to be toxic, their combined presence in the sample may account for, or at least contribute to, the observed toxicity. Spehar and Fiandt (1986) found that adverse effects to fathead minnows and *C. dubia* occurred when they were exposed to a mixture of metals at concentrations that were a fraction of the generally reported maximum acceptable individual toxicant concentrations. They suggest that single chemical water quality criteria might not be sufficiently protective of some species when other toxicants are also present.

Also on March 4, 2004, a storm water sample collected from MoDOT (#0411502) was found to be toxic at a 30% effect level. Although Toxicity Identification Evaluation manipulations revealed that ionic metals might be the source of toxicity, no follow-up chemical analyses were conducted.

On March 16, 2004, sample #0411518 collected from the Sam's/Lowe's drainage was toxic at a 20% effect level. Passage through a C_{18} column eliminated toxicity but chemical analysis was inconclusive.

On March 19, 2004, sample #0410370 collected from the Mega Market drainage was toxic with a 77% level of effect. Reductions in toxicity were seen in both the filtered sample and in the sample in which EDTA was added. Passage through a C_{18} column, however, eliminated toxicity. Chemical analyses revealed relatively high concentrations of sodium (380 mg/L), calcium (224 mg/L), and nickel (75.8 µg/L). This may explain the high conductivity (2830 us/cm) measured and could contribute to the observed toxicity. Qualitative organic analyses found several organic constituents in the sample, but none can be specifically linked to the observed toxicity.

Toxicity at the Wal-Mart drainage was documented to have an 82% effect level in March 2004 and a 31% effect level in May 2004. Toxicity Identification Evaluation manipulations of the March 24 sample (#0410015) implicated organic chemicals and chemical analyses indicated the presence of several polycyclic aromatic hydrocarbons (**PAHs**) (pyrene, phenanthrene, fluoranthene, and benzo(a)anthracene) as well as other organic chemicals that were identified through the qualitative organic analyses (Table 4). The concentrations of PAHs approached or exceeded levels reported by other researchers to be toxic to daphnids (Green and Trett 1989). Toxicity Identification Evaluation manipulations also implicated non-polar organic chemicals in the May 2004 sample (#0411483), but further analyses failed to conclusively identify any chemical constituents that could be contributing to the observed toxicity. Several organic chemicals, however, were identified through qualitative organic analyses (Table 4).

On March 24, 2004, toxicity of sample #0410017 collected from the Sam's/Lowe's drainage was eliminated by filtration and passage through a C_{18} column. Follow-up chemical analyses were inconclusive in determining the cause of the observed toxicity, although several organic chemicals including tetrachloroethane (a solvent and fumigant) were identified in the sample through qualitative organic analyses (Table 4). Although tetrachloroethane cannot be linked conclusively to the observed toxicity, its presence was detected in storm water at each of the Broadway Market Place discharges (Wal-Mart, Sam's/Lowe's, and Mega Market) in March and May of 2004. During this time all of these discharges were found to be toxic to Microtox organisms at effect levels ranging from 20% to 82%. Tetrachloroethane is a halogentated organic solvent that is slightly to moderately toxic to fish and aquatic invertebrates (ECOTOX 2004). Toxicity associated with filterable materials is also suspect due to the reduction of toxicity through filtration.

Again, on March 24, 2004, sample #0410016 collected from the Mega Market drainage was toxic with a 48% level of effect. Filtration and passage through a C_{18} column reduced toxicity to some extent, but EDTA addition had little effect. Chemical analyses found some organic chemicals (Table 4) including tetrachloroethane.

On May 13, 2004, toxicity of sample #0411485 collected from the Sam's/Lowe's drainage was reduced by filtration and eliminated by passage through a C_{18} column. Qualitative organic analyses found several organic constituents, including tetrachloroethane and alachlor, in the sample. Alachlor is a widely used general use herbicide and is the active ingredient in herbicides such as Lasso and Lariat.

It is moderately toxic to aquatic life (daphnids) in the 2-35 parts per million range (PAN Pesticide database 2004 [http://www.pesticideinfo.org/Index.html]).

On May 13, 2004, toxicity in sample #0411484 collected from the Mega Market drainage was eliminated by passage through a C_{18} column. Qualitative organic analyses found tetracholorethane, as well as some other organic constituents, but none that could be definitely tied to the observed toxicity.

Table 2. Summary of the Storm Water Sampling Event

Sample Date	Sample Number	Sample Location	Microtox Result		Sample Type	Precipitation (date range, inches)
			Non-Toxic	Toxic		
11-Jul-03	0300678	Sam's/Lowe's	x		Stage	7/9-7/11/04
	0300852	Wal-Mart		x	Stage	0.52"
	0300851	MoDOT	x		Stage	
					No samples were collected from Hinkson Creek Rd, Golf Course	
14-Oct-03	0300680	Golf Course	x		Composite	10/13-10/14/03
	0300681	Sam's/Lowe's	x		Composite	0.51"
	0300682	Wal-Mart	x		Composite	
	0300683	I-70	x		Stage	
	0300684	Hinkson Cr Rd	x		Stage	
					No samples were collected from MoDOT	
27-Oct-03	0300685	I-70	x		Stage	10/24-10/27/04
	0300686	Sam's/Lowe's	x		Composite	0.33"
	0300687	Wal-Mart	x		Composite	
	0300689	MoDOT		x	Composite	
					No samples were collected from Hinkson Creek Rd, Golf Course	
4-Mar-04	0411501	Golf Course	x		Grab	3/3-3/4/04
	0411502	MoDOT		x	Grab	2.26"
	0411503	Wal-Mart	x		Grab	
	0411504	Sam's/Lowe's	x		Grab	
	0411505	Mega Market	x		Grab	
	0411506	I-70		x	Grab	
	0411507	Rogers Rd	x		Grab	
	0411508	Broadway	x		Grab	
	0411509	Hinkson Cr Rd	x		Grab	
16-Mar-04	0411518	Sam's/Lowe's		x	Composite	3/11-3/16/04
						0.88"
					No samples were collected from Rogers Rd, Hinkson Creek Rd, I-70, MoDOT, Wal-Mart, Mega Market	
24-Mar-04	0410009	I-70	x			3/23-3/24/04
	0410010	MoDOT	x			0.41"
	0410015	Wal-Mart		x	Composite	
	0410017	Sam's/Lowe's		x	Composite	
	0410016	Mega Market		x	Stage	
	0410014	Golf Course	x			
					No samples were collected from Rogers Rd, Hinkson Creek Rd	
13-May-04	0411483	Wal-Mart		x	Grab	5/11-5/13/2004
	0411484	Mega Market		x	Grab	0.45"

Table 2. Summary of the Storm Water Sampling Event

Sample Date	Sample Number	Sample Location	Microtox Result		Sample Type	Precipitation (date range, inches)
			Non-Toxic	Toxic		
	0411485	Sam's/Lowe's		x	Grab	
	0411486	MoDOT	x		Grab	
		Broadway	x		Grab	
		Golf Course	x		Grab	
		I-70	x		Grab	
		Hinkson Cr Rd	x		Grab	

Table 3. Storm Water Sampling Toxicity Results and Parameters Table

Sample Date	Sample Number	Sample Location	Level of Effect (%)*				Parameters Analyzed
			Raw	Filtered	EDTA	C_{18}	
11-Jul-03	0300852	Wal-Mart	46	--	56	- 24	QOA, Petroleum Fractions
27-Oct-03	0300689	MoDOT	54	--	60	4	QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR
4-Mar-04	0411506	I-70	27	--	-13	31	Chloride, TR (As,Ca,Cd,Cr,Cu,Na,Pb,Hg,Ni,Zn)
	0411502	MoDOT	30	--	15	24	Chloride *No Metals follow-up*
16-Mar-04	0411518	Sam's/Lowe's	20	40	27	8	QOA, BNAs, Total Petroleum Fractions
19-Mar-04	0410370	Mega Market	77	45	57	14	QOA, Total Petroleum Fractions, BNAs, TR (As,Cd,Cr,Cu,Pb,Hg,Ni,Zn)
24-Mar-04	0410015	Wal-Mart	82	47	18	15	QOA, Total Petroleum Fractions, BNAs, TR (As,Cd,Cr,Cu,Pb,Hg,Ni,Zn)
	0410017	Sam's/Lowe's	20	14	25	11	QOA, Total Petroleum Fractions, BNAs
	0410016	Mega Market	48	21	47	32	QOA, Total Petroleum Fractions, BNAs
13-May-04	0411483	Wal-Mart	31	22	40	13	QOA, Petroleum Fractions, BNAs, TR (As,Cd,Cr,Cu,Pb,Hg,Ni,Zn)
	0411485	Sam's/Lowe's	25	15	28	-1	QOA, Petroleum Fractions, BNAs, TR (As,Cd,Cr,Cu,Pb,Hg,Ni,Zn),
	0411484	Mega Market	34	32	33	8	QOA, Petroleum Fractions, BNAs, TR (As,Cd,Cr,Cu,Pb,Hg,Ni,Zn)

* *The higher the percent level of effect, the greater the toxicity*

3.4.2 Analytical Results

Several of the common organic constituents listed in Table 4 were referenced using the Merck Index (1989) and/or by using resources found on the World Wide Web (e.g. http://www.chemicalland21.com/, http://chemfinder.cambridgesoft.com, and http://www.pesticideinfo.org/List_ChemicalsAlpha.jsp). Table 4 summarizes the constituents that were detected in the storm water samples that were found to be toxic.

Of the BNA constituents reported above the detectable limits, benzo(a)anthracene, fluoranthene, phenanthrene, and pyrene are classified as PAHs and are associated with products from incomplete combustion of fossil fuels and are derivative of coal tar and asphalt. The occurrence of the PAHs in the Wal-Mart drainage may be the result of parking lot resurfacing activities that occurred just prior to the rain event, maintenance activities occurring within Wal-Mart automotive department, and/or general automotive emission-related activities in a busy shopping center.

Many of the same components found during this study were also found in urban stream studies conducted by other researchers (USGS 2002a & b). The occurrence of insecticides (e.g. carbaryl, diethyltolumide [commonly referred to as DEET], and benzoic acid) and herbicides (e.g. alachlor) in the Wal-Mart and Sam's/Lowe's storm water drainages most likely can be attributed to lawn and garden products observed stored on the Broadway Market Place parking lot and/or those that were used locally prior to the rainfall event. Other components, such as caffeine, are common and likely result from caffeinated drink products being disposed/discarded on the parking lot or directly into a storm drain.

The occurrence of plasticizers (phthalates) can be attributed to plastic debris found within several of the storm drains, the leaching of plasticizers from polyvinyl chloride (commonly referred to as PVC) drainpipes and/or sampling equipment. Long chain fatty acids (e.g. hexadecanoic acid and octadecanoic acid) are often used in surfactants and lubricants. The presence of 1,1,2,2,-tetrachloroethane in all the Broadway Market Place drainages during March and May 2004 was somewhat surprising. It is often used in solvents, degreasing agents, and some fumigants.

The occurrence of total petroleum waste oil in the MoDOT drainage was not surprising. A petroleum like odor was frequently observed in or around the drainage area. During the FY 2002 aquatic macroinvertebrate study, a petroleum sheen in Hinkson Creek was traced back to the drainage (MDNR 2002a).

Table 4. Summary of the Constituents Detected in Storm Water Samples

Sample Date	Sample Location *(Sample #)*	Inorganic Constituents:	Organic Constituents:	
			BNA Analysis Results	**Qualitative Organic Analysis**
11-Jul-03	Wal-Mart *(0300852)*			Caffeine Carbaryl
27-Oct-03	MoDOT *(0300689-0300690)*	Chloride (129 mg/L) COD (210 mg/L) NFR (627 mg/L)	Total Petroleum Hydrocarbon as waste oil (6360 µg/L) 3-Nitroaniline (30.8 µg/L)	3-cyclohexene-1-methanol, alpha, alpha, 4-trimethyl- 1,2,4-trioxolane-2-octanoic acid, 5-octyl, methyl ester Dotriacontane Hexacosanoic acid, methyl ester N-Ethyl benzamide Trans-p-mentha-2,8-dienol 1-Methylene-3-(1-methylethenyl) cyclohexane (R)
4-Mar-04	I-70 *(0411506)*	Chloride (185 mg/L) Total Recoverable Metals: As (5.11 µg/L) Ca (52.4 mg/L) Cd (0.55 µg/L) Cr (27.7 µg/L) Cu (22.4 µg/L) Na (94.2 mg/L) Ni (28.9 µg/L) Pb (26.1 µg/L) Hg (0.05 µg/L) Zn (113 µg/L)		
	MoDOT *(0411502)*	Chloride (291 mg/L)		
16-Mar-04	Sam's/Lowe's *(0411518)*		BNA not analyzed (Lab Error)	None Detected
19-Mar-04	Mega Market *(0410370)*			Oleyl alcohol N,N-Diethyl-1-dodecanamine N,N-Dimethyltetradecanamine n-Hexadecanoic acid 9-Octadecenoic acid Bis (2-ethylhexyl) phthalate

Table 4. Summary of the Constituents Detected in Storm Water Samples

Sample Date	Sample Location *(Sample #)*	Inorganic Constituents:	Organic Constituents: BNA Analysis Results	Organic Constituents: Qualitative Organic Analysis
24-Mar-04	Wal-Mart *(0410015)*	Total Recoverable Metals: Cr (2.79 µg/L) Cu (4.56 µg/L) Ni (2.48 µg/L) Pb (1.56 µg/L) Zn (38.0 µg/L)	Benzo(a)anthracene (8.43 µg/L) Benzoic Acid (81.9 µg/L) bis(2-Ethylhexyl) phthalate (15.4 µg/L) Fluoranthene (15 µg/L) Phenanthrene (5.23 µg/L) Pyrene (10.6 µg/L)	1,1,2,2-Tetrachloroethane 2-Ethylhexanoic acid Caffeine n-Hexadecanoic acid 9,10-Anthracenedione 9-Octadecenoic acid (E) Octadecanoic acid
	Mega Market *(0410016)*			1,1,2,2-Tetrachloroethane 2-(2-butoxyethoxy)-Ethanol acetate Caffeine 2-Butoxyethanol, phosphate (3:1)
	Sam's/Lowe's *(0410017)*		Benzoic Acid (29.2 µg/L)	1,1,2,2-Tetrachloroethane Phthalic acid, Monoethyl ester p-Tert-butyl benzoic acid 2-Butoxyethanol, phosphate (3:1)
13-May -04	Wal-Mart *(0411483)*	Total Recoverable Metals: As (3.54 µg/L) Cd (0.25 µg/L) Cr (11.7 µg/L) Cu (11.8 µg/L) Ni (7.91 µg/L) Pb (7.89 µg/L) Zn (110 µg/L)		1,1,2,2-Tetrachloroethane Camphorsulfonic Acid Diethyltoluamide Diethyl phthalate 2-Butoxy ethanol, phosphate (3:1) Squalene
	Mega Market *(0411484)*			1,1,2,2-Tetrachloroethane n-Hexadecanoic acid
	Sam's/Lowe's *(0411485)*			1,1,2,2-Tetrachloroethane Monoethyl ester phthalic acid Alachlor n-Hexadecanoic acid 2-Butoxy ethanol, phosphate (3:1) 1,2-Benzenedicarboxylic acid, diisooctyl ester Squalene

3.5 Snowmelt Monitoring

3.5.1 Background

Prior to February 9, 2004, the area received three inches of snow accumulation that remained on the ground over a nine-day period (Agricultural Electronic Bulletin Board [http://agebb.missouri.edu/]). On February 9, 2004, a warming trend occurred and the snow began to melt. To characterize runoff during this snowmelt event, surface water grab samples were collected.

3.5.2 Sample Collection Overview

Snowmelt grab samples were collected from mainstem Hinkson Creek at Rogers Road, Hinkson Creek Road, and Broadway. Samples were also collected from all the aforementioned storm water drainages. All samples were submitted for acute toxicity (using Microtox and *C. dubia*), QOA, petroleum fractions, BNAs, COD, chloride, NFR, and *E. coli* (Table 5).

3.6 Snowmelt Monitoring Results

3.6.1 Microtox Toxicity

Table 5 summarizes the snowmelt sampling event and results of toxicity testing. *C. dubia* were used in conjunction with Microtox during the February snowmelt sampling event. As shown in Graph 1, Microtox toxicity was observed at three monitoring sites (MoDOT, Wal-Mart, and Sam's/Lowe's). Of the nine samples tested for *C. dubia* toxicity, four showed acute toxicity (I-70 drainage, MoDOT, Wal-Mart, Mega Market) and two others (Sam's/Lowe's and instream at Broadway) exhibited sublethal toxicity. During this sampling event, *C. dubia* toxicity was found every time Microtox toxicity was observed and twice when Microtox toxicity was not observed. Although no Microtox toxicity was found instream at Broadway, sublethal toxicity to *C. dubia* was observed. This is significant because it documents that instream water conditions at this Hinkson Creek site were toxic to aquatic organisms.

Results of the toxicity testing and subsequent Toxicity Identification Evaluation manipulations are given in Table 4. Results of testing clearly showed that the toxic component(s) tended to behave in a similar manner at all locations with the exception of the Sam's/Lowe's drainage. In most instances, toxicity was comparatively greater to the *C. dubia* than to the Microtox organisms. In addition the toxicity seemed to be relatively unaffected by the Toxicity Identification Evaluation manipulations. Indications were that the toxic component(s) were water-soluble and were likely neither non-polar organics nor ionic metals.

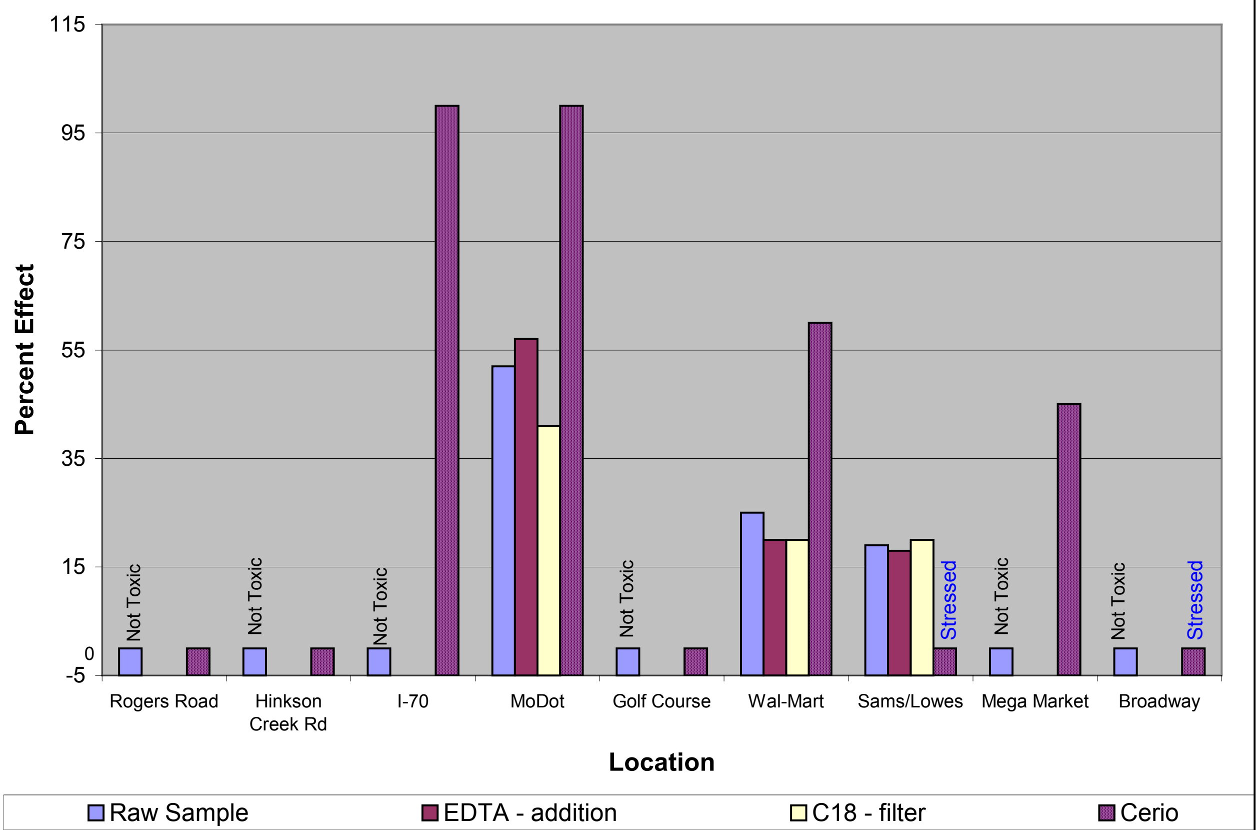
Field analysis of specific conductance correlated well with chemical analyses of the water samples (Table 6) analyzed for sodium and calcium chloride. The concentrations of these salts, in turn, correlated well with the toxicity observed at each site.

At the Sam's/Lowe's drainage Microtox toxicity (19 % effect level), as well as sublethal *C. dubia* toxicity, was observed during the February snowmelt event. Although the chloride concentration was high enough to cause the observed toxicity in the *C. dubia*, it was not at levels that should have been toxic to the marine bacteria used in the Microtox test. These results lead to speculation that some other factor might be contributing to the effects observed at these two sites. It was noted that the metals zinc, copper, chromium, and cadmium were present in higher concentrations than at most of the other sites. Exceptions were concentrations of cadmium and nickel at the I-70 drainage which were greater and concentrations of nickel, copper, and cadmium at the Mega Market drainage which were equal to or greater than the Sam's/Lowe's drainage. It is possible that the high levels of calcium and sodium present in these samples affected the ability of EDTA addition to effectively chelate the other ionic metals present in the sample, allowing their toxicity to be expressed.

Table 5. Snowmelt Sampling Toxicity Results and Parameters Table ***(M=Microtox, C=C. dubia)***

Sample Date	Sample Number	Sample Location	Toxicity Result		TIE Result	Parameters Analyzed
			Non-Toxic	Toxic		
9-Feb-04	0411464	Rogers Rd	M,C			QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR, TR(As,Cd,Cr,Cu,Pb,Hg,Ni,Zn,Na,Ca), *E. coli*
	0411468	Hinkson Cr Rd	M,C			QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR, TR(As,Cd,Cr,Cu,Pb,Hg,Ni,Zn,Na,Ca), *E. coli*
	0411470	I-70	M	C		QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR, TR(As,Cd,Cr,Cu,Pb,Hg,Ni,Zn,Na,Ca), *E. coli*
	0411462	MoDOT		M,C	**C_{18}** - Toxic, **EDTA** - Toxic	QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR, TR(As,Cd,Cr,Cu,Pb,Hg,Ni,Zn,Na,Ca), *E. coli*
	0411463	Wal-Mart		M,C	**C_{18}** - Toxic, **EDTA** - Toxic	QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR, TR(As,Cd,Cr,Cu,Pb,Hg,Ni,Zn,Na,Ca), *E. coli*
	0411466	Golf Course	M,C			QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR, TR(As,Cd,Cr,Cu,Pb,Hg,Ni,Zn,Na,Ca), *E. coli*
	0411467	Sam's/ Lowe's		M,C	**C_{18}** - Toxic, **EDTA** - Toxic	QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR, TR(As,Cd,Cr,Cu,Pb,Hg,Ni,Zn,Na,Ca), *E. coli*
	0411465	Mega Market	M	C		QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR, TR(As,Cd,Cr,Cu,Pb,Hg,Ni,Zn,Na,Ca), *E. coli*
	0411469	Broadway	M	C		QOA, Petroleum Fractions, BNAs, COD, Chloride, NFR, TR(As,Cd,Cr,Cu,Pb,Hg,Ni,Zn,Na,Ca), *E. coli*

Graph 1. Hinkson Creek Toxicity Identification - Feburary 9, 2004



3.6.2 Analytical Results

Elevated *E. coli* levels were found at Rogers Road and Broadway during the snowmelt event. They were above the US EPA (1986) recommended limit of 235 cfu/100 mL (660 cfu/100 mL and >2419 cfu/100 mL, respectively). The elevated *E. coli* at the Rogers Road bridge crossing can likely be attributed to the rural activities such as cattle and small wastewater treatment facilities located in the upper Hinkson Creek watershed. The elevated levels found at Broadway are not as easily explained and may correlate with several factors noted in section 3.2.2 of this report. In addition, when soils become saturated due to excessive precipitation, sewer systems can become infiltrated by ground water or storm water through service connections, defective cracks, joints, manhole walls, or corrosion-damaged pipes (Kerri et al. 1998). In extreme situations, sewer systems can become overwhelmed causing them to bypass from manholes located in low lying areas, increasing the likelihood of sewage entering a stream system.

As indicated in Table 6, specific conductivity readings ranged from 2900 µS/cm to 83300 µS/cm in the I-70, MoDOT, and Broadway Market Place shopping complex drainage systems. With the exception of the Broadway location, the mainstem Hinkson Creek conductivity readings were within the expected ranges. The Broadway conductivity was in excess of 1000 µS/cm whereas the chloride concentration was 125 mg/L. The chloride levels were approximately 22% greater compared to the upstream locations. The organic analyses (QOAs, petroleum fractions, BNAs) were reported below the analytical detection limits with the exception of the Wal-Mart drainage. A level of 1020 µg/L for total petroleum hydrocarbons as waste oil was reported in the Wal-Mart storm drainage and pyrene (5.40 µg/L) and fluoranthene (5.80 µg/L) were reported in the Mega Market storm drainage.

Table 6. Snowmelt Analytical Results

	Rogers Rd	Hinkson Cr Rd	I-70	MoDOT	Wal-Mart	Golf Course	Sam's/ Lowe's	Mega Market	Broadway
Sample #	0411464	0411468	0411470	0411462	0411463	0411466	0411467	0411465	0411469
***E. coli* (colony units/100 mLs)**	660	120	17	<1	19	7	56	61	>2419
Conductivity (µS/cm)	635	693	11600	83300	4520	747	2900	4130	1120
COD (mg/L)	11	11	21	280	58	10	34	51	14
NFR (mg/L)	<5	<5	<5	2220	144	<5	200	137	<5
Arsenic (µg/L)	<1	<1	<1	63.6	3.79	<1	5.95	2.19	<1
Cadmium (µg/L)	<0.25	0.32	9.12	5.9	0.51	<0.25	0.76	0.65	<0.25
Calcium (mg/L)	79	91	352	543	60.6	139	79	97.5	114
Chloride (mg/L)	27.2	26.7	3170	22800	1280	47.6	817	1130	125
Chromium (µg/L)	<1	<1	<1	113	13.3	<1	19.1	12	<1
Copper (µg/L)	<5	<5	<5	172	16.5	<5	28.9	21.7	<5
Lead (µg/L)	<0.25	<0.25	<0.25	281	24.8	<0.25	41.3	22.6	0.31
Mercury (µg/L)	<0.05	<0.05	<0.05	0.17	<0.05	<0.05	<0.05	0.06	<0.05
Nickel (µg/L)	6.44	4.35	27.6	112	8.01	2.59	8.82	17.2	5.24
Sodium (mg/L)	23	23.8	1520	12500	832	34.7	418	701	75.7
Zinc (µg/L)	4.24	4.54	34.1	869	250	3.58	285	244	7.70

3.7 Aquatic Toxicity Overview for All Sampling Locations

Overall, of 79 water samples screened for toxicity using Microtox, 16 (20%) were found to be toxic. Observed toxicity tended to be sporadic. No sites were toxic every time they were sampled. Microtox toxicity was observed four times each at the Wal-Mart and Sam's/Lowe's drainages and three times each at the MoDOT discharge and at the Mega Market discharge. Microtox toxicity was observed once at the I-70 drainage.

Although many chemical constituents were detected in storm water and snowmelt samples, they were not always present in sufficient concentrations to be linked to observed toxicity with certainty. In addition, the presence of contaminants in toxic amounts in storm water discharges does not necessarily mean that instream toxicity will result. In fact, as was found in the current study, instream toxicity would not be expected frequently due to dilution of contaminants and the fact that many organisms are able to survive the relatively short duration with which contaminant exposures tend to occur. Lee et al. 2002 caution against assuming toxicity observed in standard toxicity tests of storm water runoff will result in significant instream effects due to the typical short-term pulses of toxicity associated with these types of events. Because the objectives of this study were to locate possible sources and contaminants contributing to the impairment of Hinkson Creek, the findings of toxicity in storm water runoff was significant and assisted us in being successful in meeting those objectives. In addition, the finding of toxicity to *C. dubia* instream at the Broadway site during the February snowmelt sampling is even more significant because it documents instream effects that can be directly attributed to inputs from the storm water drainages.

3.7.1 Summary of Toxicity Results

Following is a summary of all the toxicity results for surface, storm water, and snowmelt samples that were documented at each sampling site:

<u>Upstream sites</u>

Of six water samples collected at the upstream Hinkson Creek sites (Hinkson Creek Road and Rogers Road) during storm events and 13 water samples collected during baseflow periods, none exhibited toxicity.

<u>I-70 Level 4 instream site</u>

Of seven instream baseflow water samples collected by Level 4 volunteers, one (#0410430) showed toxicity. During April, baseflow monitoring conducted by volunteers at I-70 showed toxicity at a 100% effect level. Upon initiation of Toxicity Identification Evaluation manipulations the next day, however, the toxicity that had been observed the previous day had disappeared.

<u>I-70 drainage</u>

The I-70 drainage was sampled six times during storm events. On March 4, 2004 sample #0411506 collected at the I-70 drainage was found toxic at a 27% effect level. Toxicity Identification Evaluation manipulations implicated metals as possibly being responsible for the observed toxicity. Although no toxicity was found using Microtox during the February snowmelt sampling (#0411470), mortality to *C. dubia* (100% mortality in 24-hours) was observed. Chemical analyses showed very high levels of calcium and sodium chloride, which could account for the toxicity observed.

<u>MoDOT drainage</u>

The drainage at the southwest corner of the MoDOT facility was sampled six times during storm water runoff events. Toxicity to the Microtox organisms was documented on three occasions. In October 2003 (#0300689), Toxicity Identification Evaluation manipulations implicated non-polar organic chemicals as the cause of toxicity. Chemical analysis revealed waste oil in a concentration of 6360 µg/L. During the February 2004 snowmelt sampling, toxicity was found to both Microtox organisms and *C. dubia* in sample #0411462. Toxicity Identification Evaluation manipulations implicated a water-soluble toxic component that chemical analyses revealed to be high levels of calcium and sodium chloride. On March 4, 2004, a storm water sample (#0411502) was found to be toxic at a 30% effect level. Although Toxicity Identification Evaluation manipulations revealed that ionic metals might be the source of toxicity, no follow-up chemical analyses were conducted.

Wal-Mart drainage

The Wal-Mart drainage was sampled six times and toxicity to Microtox was documented on four of those occasions. Organic chemicals appeared to be involved on three occasions, although filtration and EDTA addition also reduced toxicity in March of 2004 and filtration reduced toxicity in May of 2004. The July 2003 sample, which implicated organic chemicals, was found to contain the insecticide carbaryl at concentrations that are toxic to a variety of aquatic organisms. Several PAHs were found in the March 2004 sample and several organic chemicals were found through qualitative organic analyses in the May 2004 sample. Toxicity to both Microtox and *C. dubia* was observed during the February snowmelt sampling event. Toxicity Identification Evaluation manipulations suggested a water-soluble toxicant. As with many samples collected at this time, high levels of chloride were present in concentrations that were not only toxic to *C. dubia*, but also were toxic to the Microtox marine bacterium.

Sam's/Lowe's drainage

The Sam's/Lowe's drainage was sampled seven times and Microtox toxicity was observed on four occasions. The level of effect of observed toxicity was consistently around 20% whenever toxicity was found. Toxicity Identification Evaluation manipulations reduced or eliminated toxicity on three occasions by passing the toxic sample through a C_{18} column. In each case, follow-up chemical analyses were inconclusive in determining the cause of the observed toxicity, although several organic chemicals including tetrachloroethane (solvent) and the herbicide alachlor were identified in some of the samples through qualitative organic analyses.

Mega Market drainage

The Mega Market drainage was sampled five times. Microtox toxicity was documented on two occasions. On March 19, 2004, a sample was toxic with a 79% level of effect. Passage through a C_{18} Solid Phase Extraction column, however, eliminated the toxicity. On March 24, 2004, a sample was toxic with a 48% level of effect. Filtration and passage through a C_{18} Solid Phase Extraction column reduced toxicity to some extent. Chemical analyses found some organic chemicals and levels of nickel high enough to be of concern. Although Microtox toxicity was not documented during the February snowmelt sampling , toxicity (~50% mortality) did occur to *C. dubia*. As in many samples collected during this snowmelt event, high concentrations of calcium and sodium chloride resulted in conditions that were toxic to the daphnids.

Golf Course Tributary

Samples collected from the Columbia Country Club Golf Course tributary were collected five times during the study. No Microtox toxicity was documented in any of the samples collected. The sample collected during the February snowmelt sampling was also non-toxic to *C. dubia*.

Hinkson Creek at Broadway

Water samples from Hinkson Creek were collected six times during baseflow periods and three times during storm water/snowmelt events. Toxicity to Microtox was observed at the Broadway site on one baseflow sampling in April 2004, but the toxicity disappeared by the next day when manipulations were scheduled. Although no toxicity to Microtox was observed during the February snowmelt sampling, toxicity to *C. dubia* was documented.

4.0 Hinkson Creek Sediment Monitoring

4.1 Visual Fine Sediment Estimates

4.1.1 Background

Waters (1995) stated that the greatest sediment problems are either fine organic particles that flow with the current causing turbidity or those that are deposited on the streambed causing loss of benthic productivity and fish habitat. Likewise, Doisy and Rabeni (2004) reviewed literature that discusses the effects of sediment on native Missouri fishes. Literature has documented that increased sediment loads into a stream system has an adverse effect on the aquatic communities. For instance, too much sediment covers and fills the interstitial spaces found between rocks where invertebrates seek refuge, covers fish nesting sites, and smothers fish eggs.

Due to construction and/or land disturbance activities occurring in the Hinkson Creek watershed, it was speculated there might be a correlation between land disturbance activities and the amount of fine sediment deposits observed throughout the study reach. Therefore, to determine if there was a correlation between land activities and instream sediment deposits, a visual fine sediment estimate procedure was used to estimate the relative percent coverage per area. A modified version of Zweig's (2001) sediment estimate procedure was used. For this study, the term "sediment" includes instream deposits of both fine sediment and fine sand particles that were less than two (<2) millimeters in size.

4.1.2 Visual Estimate Overview

Visual fine sediment estimates were conducted on Hinkson Creek at the three locations indicated in Table 7 on September 9, 2003, March 3, 2004, and June 3, 2004. For comparison and background purposes, two visual estimates were also conducted on Bonne Femme Creek near the Nashville Church Road bridge on October 16, 2003 and June 4, 2004.

Table 7. Visual Fine Sediment Estimate Locations

Grid Reach Name	Grid #	General Locations
Broadway	1	Upstream of Broadway Bridge
	2	Upstream of E. Walnut Bridge
	3	Upstream of Columbia Golf Course Drainage
Hwy. 63 Connector	1	Downstream of E. Bound I-70 Bridge
	2	Upstream of Hwy. 63 Connector Bridge
	3	Upstream of Home Depot Drainage
Hinkson Creek Road	1	Downstream of Hinkson Creek Road Bridge
	2	Upstream of Hinkson Creek Road Bridge
	3	Upstream of Hinkson Creek Road Bridge

Each sampling station contained three sediment estimation areas (i.e. grids). To ensure sampling method uniformity, grids were located at the top margins of pools and base margins of riffle/run habitats. Depths of the sample areas did not exceed two (2.0) feet and water velocity was less than 0.5 feet per second. A Marsh McBirney flow meter was used to ensure that water velocity of the sample area was within this range.

The percentage of fine sediment was estimated at each station by constructing a virtual grid of potential quadrats (Figure 5). A tape measure anchored on each bank served as the downstream edge of each grid. Each grid consisted of six contiguous transects that traversed the stream. One sample quadrat, a 10" x 10" metal square frame, was randomly placed directly on the substrate within each of the six transects. Placement of the quadrat within each transect was determined by using a random number that equated to one foot increments from one bank. The trailing edge of the quadrat was placed on the downstream transect edge. Two investigators estimated the percentage of the stream bottom that consisted of fine sediment sized particles within each quadrat. The estimates were accepted if the two observations were within a 10% of one another. If estimates diverged more than ten percent, the investigators repeated the process until the estimates were within the acceptable margin of error. An average of these two estimates was recorded and used for analyses. Figure 5 is an example of a grid transect located where the stream width was 20 feet and random placement of the quadrats were located at the 18, 9, 4, 17, 8, 2 foot markings.

Figure 5. Grid of transects (T) and quadrats (Q#) for estimating percent fine sediment.

BASE OF RIFFLE
(Upstream, direction of flow ↓)

T6		Q6																		
T5								Q5												
T4																	Q4			
T3				Q3																
T2									Q2											
T1																		Q1		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**

Tape Measure Reading (feet)

TOP OF POOL
(Downstream, direction of flow ↓)

4.2 Visual Fine Sediment Estimate Results

During the sediment surveys, it was noted that the fine deposits in the upper reaches of Hinkson Creek mainly consisted of silt with some sand, whereas the downstream reaches (below the I-70 bridge crossing) were noted as mainly sand with some silt. When making longitudinal comparisons among stations, it was noted that the substrate in the upper reaches consisted mainly of small boulders, cobble, and gravel, with areas of exposed bedrock. However, the reverse was noted in the downstream reaches, where exposed bedrock predominated with areas of small boulders, cobble, and gravel. The Bonne Femme Creek location consisted mainly of small boulders and gravel with silty-sand deposits.

In general, the percent sediment coverage tended to increase while progressing downstream (Table 8). Sediment coverage at the Hinkson Creek stations was considerably higher when compared to the control station, Bonne Femme Creek, indicating that even in the upstream, non-urbanized portion of Hinkson Creek, excessive sedimentation exists at least occasionally.

Table 8. Percent Fine Sediment Estimates

Station Name	9/9/03	3/4/04	6/3/04
Broadway	95%	97%	97%
Hwy. 63 Connector	79%	91%	67%
Hinkson Creek Road	71%	87%	33%
Bonne Femme Creek	30%	No Data	25%

We initially thought that rough substrate (e.g. boulder/gravel) would capture more fine sediment than that of a relatively smooth substrate surface (e.g. bedrock). Therefore, this might lead to lower visual estimates in areas where bedrock substrates predominate. However, this was not the case. During the Hinkson Creek study, an epilithic algal growth covered rock surfaces at many locations in both Hinkson and Bonne Femme creeks. Wherever algae were present, fine sediment tended to be trapped in the algae and/or the algae appeared to be growing on a thin layer of fine sediment.

It was also noted that following rainfall events, Hinkson Creek tended to become turbid and brown in color and remained so for several days following the rainfall event (Parris 2000). Bonne Femme Creek became turbid but returned to "normal" conditions within a shorter period following a rainfall event. Although it was beyond the scope of this study, the duration of instream turbidity should be investigated to determine if this is a natural phenomenon of Hinkson Creek or caused by anthropogenic activities. Literature states that prolonged turbid conditions may adversely impact the aquatic systems and communities. For instance, increased turbidity beyond background levels can clog the gills of fish and invertebrates and it can make it difficult for sight feeding fish such as bass to find food. It can also affect other water quality conditions such as temperature and dissolved oxygen (Doisy and Rabeni 2004).

Throughout the study, severe soil erosion and gully erosion were observed occurring below many of the storm water discharge points. Gully erosion was estimated to be up to 8 feet in depth below the MoDOT maintenance facility and the Wal-Mart storm water discharges (Appendix B, photos 1 & 2). During the spring of 2004, a significant rainfall event in excess of three inches in approximately a 24-hour period occurred. The amount of runoff from the storm drainages was impressive (Appendix B, photo 3) and showed the potential for severe soil erosion and gully erosion. This may contribute to the observed sediment deposition and prolonged turbid conditions.

During the summer of 2003, the City of Columbia was upgrading and replacing a section of an existing municipal sewer line along Hinkson Creek (Appendix B, photos 4, 5, & 6). During the upgrade, two instream crossings were built: 1) upstream of the Broadway bridge and 2) downstream of the East

Walnut bridge. In addition, the City of Columbia bored under Hinkson Creek upstream of the East Walnut bridge. At these locations, excess sediment was noted. During a summer of 2003 site visit, Department of Natural Resources ESP staff noted that best management practices (e.g. erosion controls, silt fences, etc.) were not in place. Contact was made with the Northeast Regional Office where a Department of Natural Resources inspector worked closely with the City of Columbia and contractors to install and utilize best management practices.

The depth of fine deposits was not part of the scope of this study; however, it was noted that the depth of fines varied from grid to grid and across the width of stream. Generally, the depth of fines varied from a light dusting to a layer less than 1/4-inch covering the rock surfaces. On September 9, 2003, the highest amount of fine sediment deposits was noted just upstream of East Walnut and downstream of the sewer line expansion. The depth of fines was estimated to be at least one foot and consisted mainly of fine silt. Approximately 200 yards downstream of the bridge, the substrate was evenly covered with approximately one inch of fine silt. As discussed by Waters (1995) and Hall et al. (1994), most stream systems are capable of moving away fine deposits depending upon stream gradient and flow conditions. However, when fine deposit inputs exceed the stream's capacity to remove them, sediments will accumulate with potential to drastically alter the invertebrate community. Additional studies are necessary to determine if sediment deposition may be affecting the aquatic community.

4.3 Sediment Chemistry Monitoring

4.3.1 Background

Contaminants are introduced to aquatic ecosystems via man-induced routes such as point source and non-point source discharges, spills, and air-borne deposition. Sediment contamination is often the result of anthropogenic activities where chemical constituents can become sorbed into sediments. In fact, most organic and inorganic contaminants eventually accumulate in sediment, occasionally at toxic levels. Sediments are generally considered the end path for both natural and anthropengenic materials/contaminants (Power and Chapman 1992).

The bioavailability and toxicity of sediment-sorbed contaminants are of concern because sediments can serve as both sinks and sources of contamination (Baudo and Muntau 1990 and Power and Chapman 1992). Many aquatic organisms live in close association with the sediment where it serves as both habitat and a food source. Sediment contamination can have implications to the aquatic community because of toxicity to aquatic life and/or transport of contaminants throughout the food chain.

4.3.2 Sediment Collection Overview

Hinkson Creek sediment samples were collected twice during the study for chemical analysis (Table 8). The first sampling event occurred on September 9, 2003, where sediment samples were collected from Hinkson Creek Road, I-70, MoDOT, and golf course drainages. The second sampling event occurred on June 3, 2004, where sediment samples were collected from Hinkson Creek Road, East Walnut, and Broadway and from the I-70, MoDOT, Wal-Mart, golf course, Sam's/Lowe's, and Mega Market drainages. On October 16, 2003, control sediment samples were collected from Bonne Femme Creek. In addition, the Hinkson Creek sediment samples were also compared to data collected from the ESP's fine silt reference sediment site located at the Reform Conservation Area.

Table 9. Sediment Sampling Toxicity Results and Parameters Table

Sampling Date	Sample Number	Station Name	Microtox Result		Parameters Analyzed
			Non-Toxic	Toxic	
16-Feb-99	0991200	Reform CA	x		Total Metals, BNA, Organochlorine Pesticides, organophosphorus, TOC
04-Sep-03	0300853	Golf Course	x		Total Metals, BNA, Organochlorine Pesticides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0300854	MoDOT		x (6.2)*	Total Metals, BNA, Organochlorine Pesticides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0300855	I-70		x (14.8)*	Total Metals, BNA, Organochlorine Pesticides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0300856	Hinkson Cr Rd	x		Total Metals, BNA, Organochlorine Pesticides, Organophosphorus, Petroleum Fractions, QOA, TOC
16-Oct-03	0321091	Bonne Femme	x		Total Metals, BNA, Organochlorine Pesticides, Organophosphorus, Petroleum Fractions, QOA, TOC
03-Jun-04	0411452	Broadway	x		Total Metals, BNA, Organochlorine Pesticides, Chlorinated Herbicides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0411455	Mega Market	x		Total Metals, BNA, Organochlorine Pesticides, Chlorinated Herbicides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0411454	Sam's/Lowe's	x		Total Metals, BNA, Organochlorine Pesticides, Chlorinated Herbicides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0411453	E. Walnut	x		Total Metals, BNA, Organochlorine Pesticides, Chlorinated Herbicides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0411459	Golf Course	x		Total Metals, BNA, Organochlorine Pesticides, Chlorinated Herbicides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0411456	Wal-Mart	x		Total Metals, BNA, Organochlorine Pesticides, Chlorinated Herbicides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0411458	MoDOT	x		Total Metals, BNA, Organochlorine Pesticides, Chlorinated Herbicides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0411461	I-70		x (9.1)*	Total Metals, BNA, Organochlorine Pesticides, Chlorinated Herbicides, Organophosphorus, Petroleum Fractions, QOA, TOC
	0411460	Hinkson Cr Rd	x		Total Metals, BNA, Organochlorine Pesticides, Chlorinated Herbicides, Organophosphorus, Petroleum Fractions, QOA, TOC

* Toxicity Units

4.4 Sediment Chemistry Monitoring Results

All sediment contaminant concentrations in the body of this report have been converted to a dry weight basis for comparison to sediment quality guidelines for freshwater sediments established by MacDonald, et al. 2000. In addition, the organic chemical constituents found in the sediments have been normalized to 1% TOC.

With the exception of the September 9, 2003 sample, sediment samples collected from the I-70 and MoDOT drainages, and the June 3, 2003 sample collected from the I-70 drainage, all the sediment samples were non-toxic. Table 9 summarizes the results of the sediment samples found to be toxic due to organic constituents. The sample results are those reported above the detectable limits and/or were present in the QOA. Refer to Appendix D for a complete list of the analytical results.

4.4.1 Microtox Toxicity

Because many types of sediment contain some natural background toxicity, sediment toxicity test results were compared with background or reference sediments to account for any naturally occurring toxicity. This was done by comparing test sediments to either the department's long-standing fine silt reference sediment or sediment collected from Bonne Femme Creek, the control site for this study. The physical characteristics of the sampled sediments determined whether reference or control sediment was used for comparison. In addition, all sediment toxicity data were normalized by converting LC50 data to Toxicity Units (TU). TU were calculated by dividing the LC50 value expressed in parts per million (ppm) into the maximum concentration value (99,000 ppm) used in the analysis. For example, if an LC50 value of 10,000 ppm is obtained:

$$\mathbf{TU = 99{,}000 / 10{,}000 = 9.9}$$

The closer the TU value is to 1 the less toxic the sample.

A total of 15 Hinkson Creek sediment samples were tested for Microtox toxicity using the solid-phase test. Of those, three exhibited toxicity. Table 9 gives the toxicity results of the sediments for these and for reference sediments. Although Toxicity Identification Evaluation manipulations were not performed on sediment analyses, they were submitted for additional chemical analyses.

In September of 2003, sediment samples collected at the I-70 drainage (#0300855) and at the MoDOT drainage (#0300854) were found to exhibit toxicity. TU values were 14.8 and 6.2, respectively. Reference and control sediments also collected during this time had TU values of 3.3 (Reform) and 1.0 (Bonne Femme).

Chemical analyses of the I-70 sediments found a variety of polycyclic aromatic hydrocarbons (PAHs) that may have contributed to the toxicity observed. Benzo (a) anthracene, benzo (a) pyrene, chrysene, fluoranthene, and pyrene were found in concentrations higher than the Threshold Effects Concentration (TEC) given in MacDonald, et al. 2000 (Table 11). The TEC is a concentration of a particular contaminant, below which toxicity generally does not occur. All, however, were present at levels well below the Probable Effects Concentration (PEC) reported by MacDonald, et al. 2000. The PEC is a concentration of a particular contaminant, above which toxicity is expected. Concentrations of Pb, Ni, and Zn were also present at levels greater than the TEC but below the PEC, although Ni (32 mg/kg) approached the PEC. Without further investigation, it is difficult to link the observed sediment toxicity with any specific chemical constituents.

Analysis of sediment sample #0300854 collected at the MoDOT drainage (Table 11) showed the presence of Cu, Ni, and Co at levels higher than found in most of the other sediments, except for the I-70 sample, but no clear correlation between observed toxicity and contaminants found could be made. Nickel was the only constituent present in a concentration (31.8 mg/kg) that approached the PEC reported by MacDonald, et al. 2000.

Sediment sample #0411461 collected at the I-70 drainage in June of 2004 was found to be toxic (TU= 9.1). The presence of pentachlorophenol (427 µg/kg) and No. 2 diesel fuel (40,672 µg/kg) may account for its toxicity. Total metals concentrations tended to be similar to the concentrations found the previous year.

Table 10. Organic Constituents Detected in Toxic Sediment Samples

Sample Date	Station Name	Organic Constituent(s):	
		BNA Analysis Results	**Qualitative Organic Analysis**
9/4/03	I-70	Benzo(a)anthrancene (132 µg/kg) Benzo(a)pyrene (356 µg/kg) Chrysene (196 µg/kg) Fluoranthene (479 µg/kg) Ideno(1,2,3-cd)pyrene (164 µg/kg) Phenanthrene (166 µg/kg) Pyrene (442 µg/kg)	9,10-Anthracenedione Cyclic octaatomic sulfur n-Hexadecanoic acid Squalene
9/4/03	MoDOT		9-Octadecanoic acid n-Hexadecanoic acid unknown peak
6/3/04	I-70	Total Petroleum Hydrocarbons as No. 2 Diesel (20,200 µg/kg)	1,8-Demethylnaphthalene 1-Dotriacontanol 1-Nonadecene 2,7-Dimethylnaphthalene 3,7,11-Trimethyl-1-dodecanol Cholestrol

Table 11. Threshold Effects Concentrations and Probable Effects Concentration *

Analyte				TEC	PEC
	I-70	**MoDOT**	**I-70**		
Sample Number	0300855	0300854	0411461		
PAHs (ug/kg)**					
benzo (a) anthracene	210 **(155)**	<20	<20	108	1050
benzo (a) pyrene	568 **(418)**	<20	<20	150	1450
chrysene	313 **(230)**	<20	<20	166	1290
fluoranthene	764 **(561)**	<20	<20	423	2230
ideno (1,2,3-cd)pyrene	262 (193)	<20	<20	200	3200
phenanthrene	265 (195)	<20	<20	204	1170
pyrene	705 **(518)**	<20	<20	195	1520
pentacholophenol	<20	<20	427	----	----
No.2 Diesel fuel	<10,000	<10,000	42,706 (40,672)	----	----
Total Metals (mg/kg)					
As	5.8	7.3	1.9	9.8	33
Cd	0.51	0.15	0.54	0.99	5.0
Cr	18.2	14.4	26.9	43	110
Cu	20.1	24.2	20.7	32	150
Pb	**42.7**	13.0	18.8	36	130

Hg	0.05	0.018	0.033	0.18	1.1
Ni	**32.0**	**31.8**	**43.4**	23	49
Zn	**126**	45.8	96.4	120	460
TOC (mg/kg)	13,600	5260	10,500		

* dry weight basis
** numbers in parentheses have been normalized to 1% TOC as recommended in MacDonald et al. 2000

4.4.2 Sediment Analytical Results

After reviewing the analytical results for sediment, the presence of all the constituents cannot be explained. As stated in section 3.4 of this report, several of the common organic constituents were referenced using the Merck Index (1989) and/or by using resources found on the World Wide Web (e.g. http://www.chemicalland21.com/, http://chemfinder.cambridgesoft.com, and http://www.pesticideinfo.org/List_ChemicalsAlpha.jsp).

The BNA constituents reported above the detectable limits are classified as PAHs and are associated with incomplete combustion of fossil fuels and/or derivative of coal tar. Several of these PAHs were also found in the I-70 storm water sample. During the summer of 2003, while installing a stage sampler in the I-70 drainage, a petroleum sheen was noted on the water surface upon disturbing the sediments. Therefore, it was not surprising to find PAHs and total petroleum hydrocarbons (#2 diesel) in the sediment samples. The presence of these constituents in the sediment samples may be attributed to the drainage's proximity to the I-70/Highway 63 interchange, the result of a gas station located higher in the drainage, and/or other anthropogenic activities.

5.0 Hinkson Creek Biological Assessment

Additional biological assessment monitoring was conducted in the fall of 2003 and spring of 2004 in order to confirm that impairment to the macroinvertebrate community still existed. In addition, this allowed us to focus more closely on the segment of stream being evaluated relative to storm water and sediment monitoring. The study area consisted of approximately 5.5 miles of Hinkson Creek, of which approximately 2.0 miles is included in the upper portion of the impaired segment. A total of four Hinkson Creek and two Bonne Femme Creek biological monitoring stations were surveyed:

Station Reference Number	Stream Name	Station Location
7	Hinkson Creek	Hinkson Creek Road
6.5	Hinkson Creek	Hwy. 63 Connector
6	Hinkson Creek	East Walnut
5.5	Hinkson Creek	Broadway
2	Bonne Femme Creek	Upstream Nashville Church Road
1	Bonne Femme Creek	Downstream Nashville Church Road

5.1 Biological Assessment Methods

5.1.1 Macroinvertebrate Collection and Analysis

Please refer to Appendix A for a map of general locations of the biological monitoring stations. Each station consisted of a length of approximately 20 times the average stream width, and contained at least two riffle areas, as outlined in the Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (MDNR 2003d). Sampling was conducted during fall 2003 and spring 2004. Comparisons of the macroinvertebrate communities of the above stations were made to reference streams within the same EDU. Additionally, two Bonne Femme Creek stations were surveyed between Three Creeks Conservation Area and the entrance of Fox Hollow Branch for comparison with the Hinkson Creek sites.

Hinkson Creek is considered a “riffle/pool” predominant stream; therefore, samples were collected from flow over coarse substrate and from non-flowing water with depositional (nonflow) and rootmat habitats. Each macroinvertebrate sample was a composite of six subsamples within each habitat.

The macroinvertebrate samples were returned to the ESP Laboratory where the aquatic macroinvertebrates were sorted from debris, enumerated, and identified to the lowest taxonomic level (generally genus or species). A standardized sample analysis procedure was followed as described in the Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (MDNR 2003d). Below is a summary of the matrices used:

- Taxa Richness (**TR**)
  Reflects the health of the community through a measurement of the number of taxa present. In general, the total number of taxa increases with improving water quality, habitat diversity, and/or habitat suitability. Taxa richness is calculated by counting all taxa from the subsampling effort.

- Total Number of Taxa in the Orders Ephemeroptera, Plecoptera, and Trichoptera (**EPT Taxa**)
  This value summarized taxa richness within the insect orders that are generally considered to be pollution sensitive. The EPT Taxa index generally increases with increasing water quality.

- Biotic Index (**BI**)
  This value is a means of detecting organic pollution tolerance of individual taxa within the macroinvertebrate communities expressed as a single value between 1 and 10, with 1 being the most sensitive and 10 the most tolerant.

- Shannon Diversity Index (**SDI**)
  This index is a measure of community composition which takes into account both richness and evenness. It is assumed that a more diverse community is a more healthy community. Diversity increases as the number of taxa increase and as the distribution of individuals among those taxa is more evenly distributed.

Using the values calculated from the TR, EPT Taxa, BI, and SDI data, a Stream Condition Index (**SCI**) score was assigned to the data for each sample station. The SCI scores were divided into three categories. Study reaches that scored from 16-20 were considered fully biologically supporting, scores from 10-14 were considered partially biologically supporting, and scores of 4-8 were considered non-biologically supporting.

The macroinvertebrate data were analyzed in three specific ways. First, upstream to downstream longitudinal comparisons of Hinkson Creek were made. Secondly, Hinkson Creek stations were compared to Bonne Femme Creek stations. Finally, the data from both Hinkson Creek and Bonne Femme Creek were compared to biological criteria from regional reference streams within the same EDU and the same watershed size classification. Biocriteria data collected from these streams in previous survey years constituted the basis of the comparison.

5.1.2 Physicochemical Data Collection and Analysis

During each survey period (fall 2003 and spring 2004), *in situ* water quality measurements were collected at all stations. These included temperature, DO concentration, conductivity, and pH. Additionally, surface water grab samples were collected and analyzed by the ESP's Chemical Analysis Section for turbidity, chloride, T (P), NH_3-N, NO_2+NO_3-N, and TKN. Grab samples were collected from each station and preserved in accordance with the Department of Natural Resources standard operating procedures.

In recognition of the fact that habitat availability and quality can directly affect the biological community, physical assessments of stream and riparian habitat were conducted at all stations. Stream habitat characteristics for each sampling station were measured during the study periods using a standardized assessment analysis procedure as described for riffle/pool habitat in the Stream Habitat Assessment Project Procedure (MDNR 2003e). The assessments were used to score habitat at Hinkson Creek stations and compare it to scores collected at stations on Bonne Femme Creek, the control stream. A measure for this study was for the total score from the physical habitat assessment conducted at Hinkson Creek sample stations to be at least 75% similar to scores of the assessments conducted at Bonne Femme Creek stations. If the habitat scores were 75% or greater in similarity, Hinkson Creek would be expected to support biological communities comparable to those at the control stations.

5.2 Biological Assessment Results

5.2.1 Physicochemical Data

Physical characteristics of each Hinkson Creek and Bonne Femme Creek station are presented in Table 12. Stream widths at Hinkson Creek ranged from 45 to 62 feet, with no discernible pattern relative to the position in the watershed. Flow rates tended to be higher in downstream Hinkson Creek stations when compared to the upper stations. Hinkson Creek stream flow during the spring sample season was slightly higher than during the fall season. Flow rates observed during the spring season at Bonne Femme Creek were more than twice as much as those observed during the fall. This observation is at least partially due to a record rainfall event that occurred over much of Boone County one week prior to spring sampling at Bonne Femme Creek. Streams throughout the region had peaked and were continuing to fall throughout the week during which the Bonne Femme Creek sampling was conducted.

Table 12. Physical Characteristics of the Stations

Stream	Station	Avg. Width (ft.)	Fall 2003	Spring 2004
			Flow (cfs)	Flow (cfs)
Hinkson Creek	5.5	59	23.6	27.2
Hinkson Creek	6	48	18.9	20.6
Hinkson Creek	6.5	62	No Data	20.2
Hinkson Creek	7	49	8.9	13.2
Bonne Femme Creek	1	45	6.7	14.5
Bonne Femme Creek	2	49	6.7	14.5

In situ water quality measurements are summarized in Table 13 (Fall 2003) and Table 14 (Spring 2004).

Table 13. *In situ* Water Quality Measurements at all Stations (Fall 2003)

Stream/ Station	Parameter				
	Temperature (°C)	Diss. O_2 (mg/L)	Conductivity (µS/cm)	pH	Turbidity (NTU)
Hinkson #5.5	16.5	8.6	291	7.8	95.3
Hinkson #6	17.0	8.3	291	7.9	91.7
Hinkson #7	19.0	8.9	406	7.9	84.0
B. Femme #1	18.0	7.0	306	7.7	15.1
B. Femme #2	18.0	7.0	306	7.7	15.0

Table 14. *In situ* Water Quality Measurements at all Stations (Spring 2004)

Stream/ Station	Parameter				
	Temperature (°C)	Diss. O_2 (mg/L)	Conductivity (µS/cm)	pH	Turbidity (NTU)
Hinkson #5.5	11.0	11.2	506	8.2	29.3
Hinkson #6	11.5	10.0	597	8.2	9.0
Hinkson #6.5	12.5	10.7	517	8.4	12.2
Hinkson #7	13.0	11.2	438	8.4	12.8
B. Femme #1	9.0	9.4	382	7.7	5.25
B. Femme #2	9.0	9.4	382	7.7	8.29

Turbidity levels were higher at both Hinkson and Bonne Femme creeks during the fall 2003 season. Approximately one inch of rain fell in the area two days prior to the fall sampling event and over 5.5 inches of rain had fallen in the area in the previous 12 days. In the spring of 2004, the area experienced approximately 0.5 inches of rain in the two days prior to the sampling event (Agricultural Electronic Bulletin Board 2004). The highest turbidity readings observed occurred at Hinkson Creek Station 5.5 during both seasons. This difference was more pronounced during the spring season, when turbidity was more than twice as high at Station 5.5 compared to the other sites. Hinkson Creek had considerably higher turbidity readings than Bonne Femme Creek, particularly during fall 2003. The lowest Hinkson Creek turbidity level was more than five times higher than the Bonne Femme Creek levels, despite relatively high flows at Bonne Femme Creek at the time of sampling. Parris (2000) measured suspended sediment concentrations and durations during high flows in Hinkson Creek and found suspended sediment concentrations did not return to near mean base flow concentrations for a median period that exceeded 96 hours.

Nutrient concentrations as well as chloride concentrations are presented in Table 15 (fall 2003) and Table 16 (spring 2004). All nutrient parameters present in detectable concentrations were higher among sites during the fall sample season. Chloride concentrations, however, tended to be lower in the fall with the one exception observed at Hinkson Creek Station 7. This increased chloride level may partially account for the relatively high conductivity readings also observed at this site. Fall 2003 total phosphorus concentrations were approximately twice as high among Hinkson Creek samples than those collected from Bonne Femme Creek. Fall TKN concentrations were approximately twice as high as spring levels for both Hinkson and Bonne Femme creek samples. When comparing between the two streams, Hinkson Creek TKN concentrations were approximately three times higher than levels observed at Bonne Femme Creek for both sample seasons.

Table 15. Nutrient Concentrations at all Stations (Fall 2003)

Stream/ Station	Parameter (mg/L)				
	NH_3-N	NO_2+NO_3-N	TKN	Total Phos.	Chloride
Hinkson #5.5	<0.03	0.39	1.50	0.26	10.8
Hinkson #6	<0.03	0.40	1.13	0.24	11.7
Hinkson #7	<0.03	0.48	1.35	0.25	36.7
B. Femme #1	<0.03	0.32	0.45	0.13	5.97
B. Femme #2	<0.03	0.32	0.48	0.13	<0.50

Table 16. Nutrient Concentrations at all Stations (Spring 2004)

Stream/ Station	Parameter (mg/L)				
	NH_3-N	NO_2+NO_3-N	TKN	Total Phos.	Chloride
Hinkson #5.5	<0.03	0.14	0.66	0.10	29.6
Hinkson #6	<0.03	0.04	0.47	0.03	34.0
Hinkson #6.5	<0.03	0.01	0.52	0.04	23.5
Hinkson #7	<0.03	0.04	0.46	0.04	17.2
B. Femme #1	<0.03	0.39	0.18	0.09	10.4
B. Femme #2	<0.03	0.39	0.19	0.10	10.4

5.2.2 Habitat Assessment

Habitat assessment scores were recorded for each sampling station. Results are presented in Table 17. According to the project procedure (MDNR 2003e), for a study site to fully support a biological community, the total score from the physical habitat assessment should be greater than 75% similar to the total score of the control or reference site. The mean habitat score for the two Bonne Femme Creek sites was 133.5. Because all Hinkson Creek stations had habitat scores that exceeded or were within the required range of similarity, it was inferred that the sites should support comparable biological communities.

Table 17. Reference Streams and Hinkson Creek Habitat Assessment Scores

Reference Streams	Habitat Score	Hinkson Creek	Habitat Score	% of Mean Reference
Bonne Femme #1	124	Station 5.5	133	100
Bonne Femme #2	143	Station 6	126	94
		Station 6.5	145	109
		Station 7	124	93
Mean Ref. Stream Score	**133.5**			

5.2.3 Assessment of the Macroinvertebrate Communities

Hinkson Creek Longitudinal Comparison

The largely rural upstream Hinkson Creek macroinvertebrate community (Stations 6.5 and 7) was compared with the urbanized downstream community (Stations 5.5 and 6) to observe whether the differences observed in a previous biological assessment (MDNR 2002a) were still present. Biological indices that exhibited notable changes among stations in fall 2003 samples (i.e., Taxa Richness and EPT Taxa) tended to increase while progressing upstream (Table 18), a trend opposite that observed in the previous assessment's fall data. A similar trend also was observed among sites in spring 2004, with the exception that Station 5.5, the most downstream study site, had Taxa Richness equal to the most upstream site (Table 19). In fall 2003 samples, Taxa Richness dropped by 13 and EPT Taxa declined by 9 (Graph 2) in the overall survey reach. In spring 2004, Taxa Richness decreased by 14 and EPT Taxa fell by 5 between the uppermost site and Station 6, the first urbanized study site. Interestingly, the site immediately downstream, Station 5.5, had an equal number of taxa as the uppermost site and an equal number of EPT Taxa as Station 6.5, the lower non-urbanized site. Despite the changes in Taxa Richness and EPT Taxa, there was little difference in the SCI or supportability rankings among Hinkson Creek sites. All sites achieved a fully supporting ranking in fall 2003 and all but Station 6 achieved a fully supporting ranking in spring 2004.

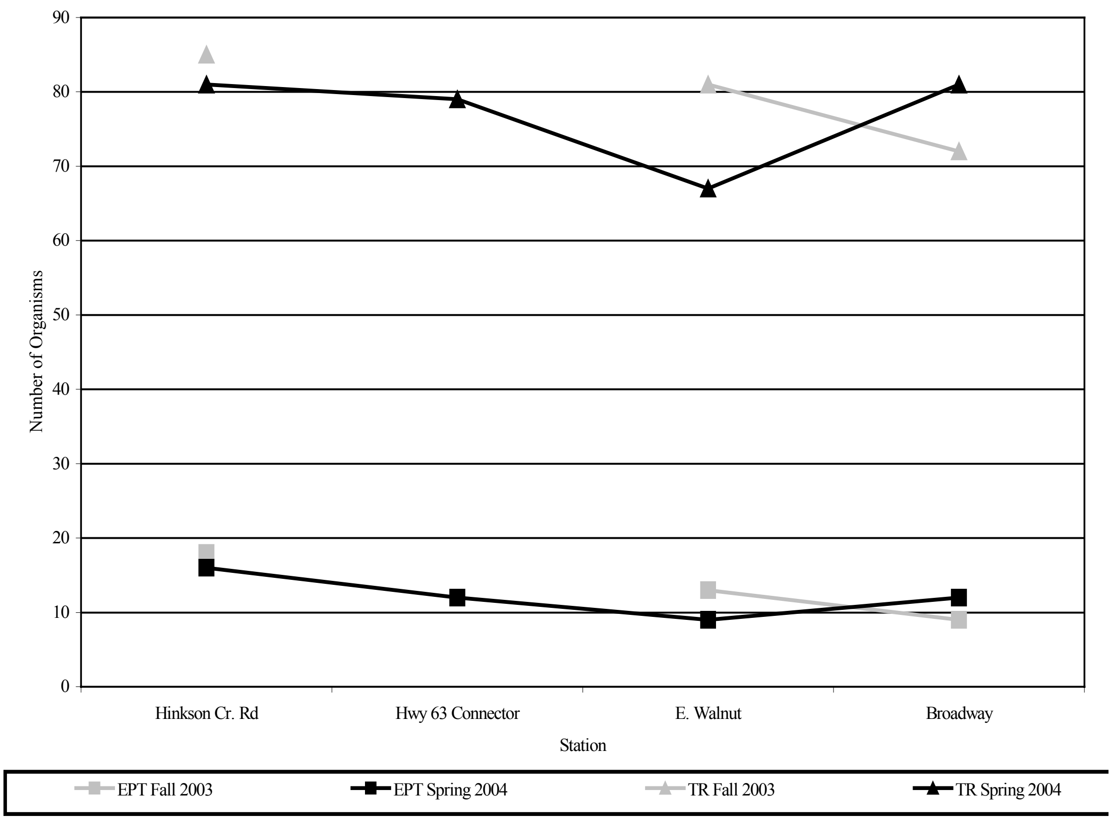
Table 18. Hinkson Creek Metric Values and Scores, Fall 2003 Season, Using Ozark/Moreau/Loutre Biocriteria Reference Database

Station #	TR	EPT Taxa	BI	SDI	SCI	Support
#7 Value	85	18	7.20	3.26		
#7 Score	5	5	3	5	18	Full
#6 Value	81	13	7.37	3.26		
#6 Score	5	3	3	5	16	Full
#5.5 Value	72	9	7.15	3.31		
#5.5 Score	5	3	3	5	16	Full

Table 19. Hinkson Creek Metric Values and Scores, Spring 2004 Season, Using Ozark/Moreau/Loutre Biocriteria Reference Database

Station #	TR	EPT Taxa	BI	SDI	SCI	Support
#7 Value	81	16	7.32	3.06		
#7 Score	5	5	3	5	18	Full
#6.5 Value	79	12	6.85	3.26		
#6.5 Score	5	3	3	5	16	Full
#6 Value	67	9	7.23	3.10		
#6 Score	3	3	3	5	14	Partial
#5.5 Value	81	12	6.90	3.40		
#5.5 Score	5	3	3	5	16	Full

Graph 2. The Number of EPT Taxa and Taxa Richness for Each Sample Season



Comparison of Hinkson Creek versus Bonne Femme Creek

The fall 2003 values of Taxa Richness, EPT Taxa, and Stream Condition Index were comparable to or slightly higher at Hinkson Creek Stations 6 and 7 compared to the Bonne Femme Creek control sites (Table 20). Hinkson Creek Station 5.5 exhibited slightly lower Taxa Richness, EPT Taxa, but similar Stream Condition Index values as Bonne Femme Creek. The Biotic Index score, however, was higher among all Hinkson Creek sites than the control, indicating that the overall aquatic community may be generally more tolerant of organic pollution.

With the exception of Station 6, each of the spring 2004 samples from the Hinkson Creek stations had slightly higher Taxa Richness scores and slightly lower EPT Taxa scores than Bonne Femme Creek (Table 21). Hinkson Creek Station 6 had noticeably lower Taxa Richness and EPT Taxa values in addition to being the only site to score a partially supporting Stream Condition Index ranking. As with the fall samples, Biotic Index scores were higher at each of the Hinkson Creek sites than Bonne Femme Creek in spring 2004.

Table 20. Bonne Femme Creek Metric Values and Scores, Fall 2003 Season, Using Ozark/Moreau/Loutre Biocriteria Reference Database

Station #	TR	EPT Taxa	BI	SDI	SCI	Support
#2 Value	75	11	6.59	3.14		
#2 Score	5	3	5	3	17	Full
#1 Value	79	11	6.79	3.05		
#1 Score	5	3	5	3	16	Full

Table 21. Bonne Femme Creek Metric Values and Scores, Spring 2004 Season, Using Ozark/Moreau/Loutre Biocriteria Reference Database

Station #	TR	EPT Taxa	BI	SDI	SCI	Support
#2 Value	74	14	6.40	3.06		
#2 Score	5	3	5	5	18	Full
#1 Value	78	14	6.50	3.17		
#1 Score	5	3	3	5	18	Full

<u>Comparisons of Hinkson and Bonne Femme Creeks versus Ozark/Moreau/Loutre EDU Biocriteria Reference Sites</u>

The metrics calculated for Hinkson and Bonne Femme creeks were compared to biological criteria derived for the Ozark/Moreau/Loutre EDU Biocriteria Reference Sites. These criteria are listed for the fall and spring sampling seasons in Tables 22 and 23, respectively. This comparison was made to assess the degree to which using biological criteria was applicable for Hinkson and Bonne Femme creeks. Most of the biocriteria reference streams are fourth and fifth order streams, whereas Hinkson and Bonne Femme creek survey sites are second and third order. Larger streams may have more available habitat and higher numbers of macroinvertebrate taxa and diversity than smaller streams. The four metrics calculated for the fall and spring sample seasons at Hinkson (Tables 18 and 19) and Bonne Femme creeks (Tables 20 and 21) were comparable and, in some cases, better than the biological criteria reference metrics. Each Hinkson Creek station was categorized as fully supporting during the fall season and all but one station achieved this ranking in the spring. Bonne Femme Creek stations were fully supporting during both seasons.

Table 22. Biological Criteria for Warm Water Reference Streams Database in the Ozark/Moreau/Loutre EDU Fall Season

	Score = 5	Score = 3	Score = 1
TT	>71	71-35.5	35.5-0
EPT Taxa	>14	13.5-6.8	6.8-0
BI	<6.9	6.9-8.45	8.45-10
SDI	>3.17	3.17-1.6	1.6-0

Table 23. Biological Criteria for Warm Water Reference Streams Database in the Ozark/Moreau/Loutre EDU Spring Season

	Score = 5	Score = 3	Score = 1
TT	>74	74-37	37-0
EPT Taxa	>16	16.5-8.25	8.25-0
BI	<6.51	6.51-8.26	8.26-10
SDI	>2.89	2.89-1.44	1.44-0

Macroinvertebrate Percent and Community Composition

Macroinvertebrate Taxa Richness, EPT Taxa, and percent EPT are presented in Tables 24 and 25. These tables also provide percent composition data for the five dominant macroinvertebrate families at each Hinkson and Bonne Femme creek station. The percent relative abundance data were averaged from the sum of three macroinvertebrate habitats-coarse substrate, nonflow, and rootmat-sampled at each station.

Fall 2003 macroinvertebrate samples from Hinkson Creek upstream control Station 7 contained 85 total taxa and 18 EPT Taxa (Table 22). Test Station 5.5, downstream of all storm water and other urban influences relative to this study, had 72 total taxa and 9 EPT Taxa. The two dominant Ephemeroptera taxa-squaregill mayfly (Caenidae) and flatheaded mayfly (Heptageniidae)-made up 29.8 percent of samples at Station 7, 22.9 percent at Station 6, and 16.3 percent at Station 5.5. Chironomidae (midge) larvae were the dominant taxa at each Hinkson Creek station and their relative percentages were similar among sites. Caenid mayflies, chironomids, riffle beetles (Elmidae), and scuds (Hyalellidae) were consistently among the dominant taxa present in all Hinkson Creek fall samples. The relative abundance of Caenidae dropped by approximately half in urbanized stations, but this trend was not as consistent for heptageniid mayflies. Aquatic worms were present among dominant taxa at only Station 6, where they were nearly as numerous as chironomids, the most abundant taxa at this site. No stoneflies (Plecoptera) were collected in any Hinkson Creek fall samples.

Spring 2004 macroinvertebrate data exhibited more variability among sites than was observed in the fall data. The upper- and lowermost stations each had the highest Taxa Richness value of 81 (Table 24). EPT Taxa ranged from 16 at Hinkson Creek Station 7 to 9 at Station 6. As with the fall scores, a decrease in the total number of taxa and EPT Taxa was observed while progressing downstream into the urban reaches from Station 7 to Station 6. At Station 5.5, however, EPT Taxa values were comparable to those of upstream stations and Taxa Richness was equal to that of Station 7. The proportion of mayflies in samples was similar among stations, although Station 5.5 had slightly fewer individual mayflies in the sample, there were an equal number of mayfly taxa as were present in the control stations. The highest abundance of stoneflies among Hinkson Creek samples was observed at Station 7, with a total of four stonefly taxa comprising 4.2 percent of the sample. Station 6 had two stonefly taxa whereas Stations 6.5 and 5.5 each had a single taxon. A single genus, *Perlesta*, accounted for over half the stonefly abundance at Station 7 and made up between 82 and 100 percent of stoneflies collected at the remaining Hinkson Creek sites. Chironomids, caenid mayflies, scuds, and riffle beetles were among the dominant taxa in nearly all Hinkson Creek spring samples. As was observed in fall samples, the relative abundance of caenid mayflies declined by at least half in the urbanized reach surveyed; heptageniid mayflies, however, tended to increase in downstream urbanized stations. At Station 6, heptageniid mayflies were nearly twice as abundant as in Station 6.5 and were nearly three times more numerous as in Station 7 samples. Although chironomid larvae were the dominant group at each of the Hinkson Creek sites in spring samples, more variability among stations was present than in fall samples. Chironomids accounted for over 60 percent of the total sample at Stations 7 and 6, but only 36 percent at Station 6.5 and 48 percent at Station 5.5.

With respect to Taxa Richness and number of EPT Taxa, fall 2003 Bonne Femme Creek macroinvertebrate samples were comparable to samples collected from Hinkson Creek stations within the urbanized reach of the study (Table 24). Biotic Index values, however, were lower at the Bonne Femme Creek sites (Table 20), suggesting that the overall biotic community may be less tolerant of pollution compared to the community of Hinkson Creek. Mayflies comprised a smaller percentage of individuals collected in Bonne Femme Creek samples, but caddisfly larvae (Trichoptera) were much more numerous than at Hinkson Creek. Although more caddisfly individuals were collected in Bonne Femme Creek samples, there was no distinct difference in the number of caddisfly taxa between the two streams. For both streams, more caddisfly taxa were collected in upstream samples; downstream samples had no more than half the number of taxa than their upstream counterparts. *Chimarra*, the most abundant caddisfly at Bonne Femme Creek, was absent from Hinkson Creek samples. Although chironomids were among the five dominant taxa at the Bonne Femme Creek stations, they ranked second and third at Stations 2 and 1, respectively. Riffle beetles, particularly *Stenelmis*, were the most numerous taxa at each Bonne Femme Creek station. Tubificid worms were the second most dominant group at Station 1, with a slightly higher proportion than chironomids. Caenidae and Heptageniidae were the dominant mayfly families at Bonne Femme Creek. Both families were present at Bonne Femme Creek in densities comparable to the two downstream Hinkson Creek stations. As with Hinkson Creek, no stoneflies were present in Bonne Femme Creek fall samples.

Table 24. Fall 2003 Hinkson and Bonne Femme Creek Macroinvertebrate Composition

	Hinkson Creek Stations			Bonne Femme Creek Control Stations	
Variable-Station	7	6	5.5	2	1
Taxa Richness	85	81	72	75	79
Number EPT Taxa	18	13	9	11	11
% EPT Taxa	21	16	12.5	14.6	13.9
% Ephemeroptera	33.0	25.5	18.0	16.6	14.3
% Plecoptera	-	-	-	-	-
% Trichoptera	1.5	2.2	1.6	8.3	6.4
% Dominant Families					
Chironomidae	22.1	18.0	19.8	17.8	14.1
Elmidae	12.3	13.2	15.3	25.5	25.4
Hyalellidae	6.9	-	11.6		
Caenidae	19.6	9.3	9.0	8.4	-
Heptageniidae	10.7	13.6	7.6	6.9	7.1
Tubificidae	-	17.6	-	12.2	16.7
Coenagrionidae	-	-	-	-	5.6

Taxa richness was nearly identical in Spring 2004 Bonne Femme Creek samples compared to the fall samples, and the number of EPT Taxa increased slightly (Table 25). Biotic Index values were lower among Bonne Femme Creek sites compared to Hinkson Creek, but the difference between the two creeks was not as great in the spring samples compared to fall samples (Table 21). The proportion of mayflies and stoneflies in samples at the upstream Bonne Femme Creek station was higher than the downstream station. However, the taxa representing these insect orders were identical among sites. Stoneflies were present in much higher numbers at the Bonne Femme Creek sites than Hinkson Creek. Whereas *Perlesta* was the dominant stonefly genus among Hinkson Creek sites, *Isoperla* was dominant at Bonne Femme Creek. This single genus accounted for 10 percent of individuals at Station 2 and composed 7 percent at Station 1. *Isoperla* also was present in samples from two of the four Hinkson Creek stations, but in much lower numbers. Chironomids were the dominant taxa in Bonne Femme Creek spring samples; however, they were present in much lower proportions compared to Hinkson Creek. Heptageniid mayflies and scuds (Crangonyctidae), along with chironomids, were among the top five dominant taxa at both Bonne Femme Creek stations.

Table 25. Spring 2004 Hinkson and Bonne Femme Creek Macroinvertebrate Composition

	Hinkson Creek Stations				Bonne Femme Creek Control Stations	
Variable-Station	7	6.5	6	5.5	2	1
Taxa Richness	81	79	67	81	74	78
Number EPT Taxa	16	12	9	12	14	14
% EPT Taxa	20	15	13	15	18.9	17.9
% Ephemeroptera	12.0	15.3	15.9	10.2	19.4	15.9
% Plecoptera	4.2	0.6	2.3	0.7	16.7	11.0
% Trichoptera	0.7	0.6	0.9	1.0	0.5	1.1
% Dominant Families						
Chironomidae	63.6	35.9	61.3	48.0	18.8	22.9
Caenidae	7.8	8.4	4.3	-	-	-
Hyalellidae	4.5	7.2	4.0	7.1	-	-
Tubificidae	4.3	-	-	3.9	-	9.6
Elmidae	3.1	17.5	6.5	14.4	-	12.1
Tipulidae	-	8.0	-	-	-	-
Heptageniidae	-	-	9.8	5.4	11.1	9.5
Crangonyctidae	-	-	-	-	14.9	12.2
Perlodidae	-	-	-	-	10.5	-
Asellidae	-	-	-	-	9.7	-

<u>Percent EPT Taxa Comparison</u>

The percent EPT Taxa was determined in order to provide another way to compare macroinvertebrate data between sites. This calculation tends to normalize sites relative to differences in stream size, discharge, and other factors. The total number of taxa within the orders Ephemeroptera, Plecoptera, and Trichoptera was divided by the total number of taxa collected at each site to obtain this percentage. Graph 3 provides a comparison of the percent EPT Taxa found in reference streams and control streams in the Ozark/Moreau/Loutre EDU with that determined for Hinkson Creek.

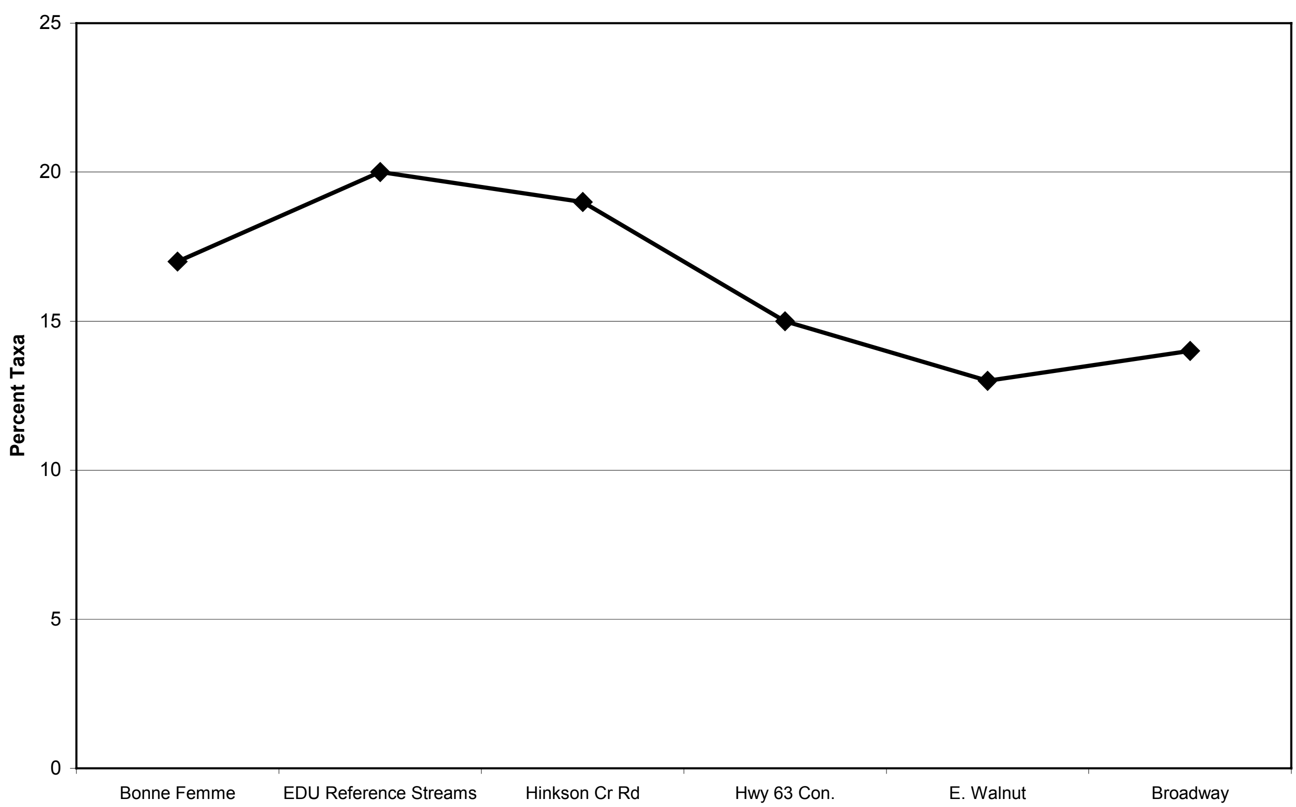
Generally, in the reference streams of the Ozark/Moreau/Loutre EDU, the percentage of EPT Taxa makes up over 15% and frequently over 20% of the total number of taxa collected. The percent EPT Taxa of these reference sites, collected in the fall of 2001 and the spring of 2002, averaged 20% and

22%, respectively. Only one site had a percentage below 15% (Loutre River with 14.5% in the fall of 2001).

A total of nine fall and spring samples collected from Bonne Femme Creek during the study period averaged 17% EPT Taxa. Only the fall 2001 (14%) and fall 2003 (14%) samples were below 15% EPT Taxa.

Throughout the current study, the Hinkson Creek Road location (Station #7) consistently had a percent EPT Taxa of 20%, with the exception of the fall of 2001 where the percentage dropped to 14%, likely due to a near complete cessation of stream flow. Even so, the fall of 2001 percent EPT Taxa at the upstream stations were still as high or higher than that of most of the downstream stations. Stations within the current study area (Station 6 @ East Walnut and Station 5.5 @ Broadway) averaged 13% EPT Taxa and 15% EPT Taxa, respectively, during the study. Broadway had the greatest variability, ranging from a low of 12% in the spring of 2002 to a high of 21% in the fall of 2001. The lowest percentages at Broadway (12% in the spring of 2002 and 12.5% in the fall of 2003) coincided with construction activities related to the City of Columbia's sewer extension. East Walnut was consistently low, ranging between 11% and 16%. The highest percentage (16%) occurred during the fall of 2003, the only time during the study the East Walnut site could be scored as fully supporting.

Graph 3. Mean Percent EPT Taxa of Hinkson Creek and Reference/Control Streams Stations



5.3 Biological Assessment Discussion

Habitat scores for Hinkson Creek Stations 6 and 5.5 were at least 94 percent of the average of control sites despite flowing through a watershed with greater urban influence than upstream control sites or Bonne Femme Creek. The Stream Habitat Assessment Project Procedure is designed to measure habitat available to aquatic macroinvertebrates, factors associated with bank stability, and channel alteration (e.g. channelization). As a result, land disturbance factors mentioned throughout the report, such as equipment crossings, construction disturbance in the floodplain, and storm water discharge points, did not significantly affect the overall score of these sites although they may have had some impacts on the aquatic community.

Water quality samples that were collected concurrent with macroinvertebrate samples most commonly exhibited trends associated with seasonal differences. Generally temperature, turbidity, TKN, NO_2+NO_3-N, and total (P) were higher in the fall, whereas dissolved oxygen concentrations, conductivity, and chloride were higher in the spring. Two exceptions to these trends were observed. First, chloride levels were higher at Hinkson Creek Station 7 in fall 2003 than any of the spring samples. Second, NO_2+NO_3-N concentrations at the Bonne Femme Creek stations were slightly higher in spring samples compared to the fall; in comparison, Hinkson Creek NO_2+NO_3-N levels were substantially lower in spring.

A general decline was observed among Taxa Richness and EPT Taxa in downstream stations at Hinkson Creek in fall 2003. Taxa Richness fell by 13 and EPT Taxa declined by half, from 18 to 9, from the uppermost to the lowermost site. The percent EPT Taxa was 21% at the upstream station (#7) and declined to 16% at Station 6 and 12.5% at Station 5.5. The relative abundance of Caenidae (scraper functional feeding group) declined by half in the urbanized portion of the study area. MDNR (1992) found that scrapers and filter-feeders were the taxa most adversely impacted by a spill of rhyolite fines into Big Creek, Iron County, due to catastrophic sedimentation. By contributing to increased turbidity, the construction activity in this area may have similarly affected the macroinvertebrate community in downstream stations. Despite reduction of Taxa Richness and EPT Taxa in downstream stations, conditions were not degraded sufficiently to cause the overall Stream Condition Index to deviate from a fully supporting status.

With the exception of EPT Taxa and percent EPT Taxa, spring 2004 Hinkson Creek metric scores were similar at Stations 7 and 5.5. Station 7 totaled 16 EPT Taxa for a percent EPT Taxa of 20%, whereas Station 5.5 totaled 12 EPT Taxa and a percent EPT Taxa of 15%. Notably, Taxa Richness was equal among the upper- and lowermost sample sites. Although Taxa Richness was the same for these two sites, there was low similarity among taxa for the macroinvertebrate community at these two stations. The Quantitative Similarity Index, a measure of taxa similarity between two sample stations, was 56.4 percent when comparing Stations 7 and 5.5 (the lowest similarity of any two Hinkson Creek stations). Several taxa differences between these two sites account for this low similarity index. Compared to Station 7, the largest differences in taxa observed at Station 5.5 were a loss of three stonefly taxa and a net loss of two non-chironomid Diptera taxa; at the same time, however, Station 5.5 had a net gain of two snail, dragonfly, and chironomid taxa. Despite equality in the Taxa Richness metric at Stations 7 and 5.5, the difference in taxa and the percent EPT Taxa shows that this metric alone does not indicate that the macroinvertebrate community is equitable at the two sites.

Hinkson Creek Station 6 stood apart from the remaining sites by having the lowest Taxa Richness, EPT Taxa, percent EPT Taxa, and Stream Condition Index scores among the four stations sampled in spring 2004. The percent EPT Taxa dropped from 20% at Station 7 and Station 6.5 (63 connector) to 13% at Station 6 and then rose to 15% at Station 5.5. Two other metrics, Biotic Index and Shannon Diversity Index, were not appreciably different from the other Hinkson Creek sites. Station 6 also had the fewest mayfly taxa with four (each of the remaining Hinkson Creek sites had seven mayfly taxa). Only Station 7 had a substantial number of stonefly taxa and individuals. Stations 6.5 and 5.5 each had a single stonefly taxon and Station 6 had two stonefly taxa. The most abundant stonefly genus among Hinkson Creek sites was *Perlesta* which, unlike most stoneflies, includes species considered moderately tolerant of organic pollution (Poulton and Stewart 1991).

Storm water runoff near Hinkson Creek Station 6 may have contributed to the lower biotic metrics observed at this site. Among the contaminants documented as having entered into Hinkson Creek near the Broadway Marketplace shopping complex were road salt, waste oil and the common lawn and garden insecticide carbaryl (please see section 3.4.1 Microtox Toxicity). Although the above constituents were detected in storm water flowing into Hinkson Creek, these are not the only contributors to water quality degradation that may have resulted in a reduction of Taxa Richness and EPT Taxa observed in spring samples at Station 6. A variety of chemical compounds were detected in storm water runoff in the vicinity of Station 6, which represents an overall decline in water quality as Hinkson Creek changes from a rural to an urbanized stream. The macroinvertebrate community appears to reflect these impacts to water quality by the fact that taxa reductions occur in the spring, following winter and early spring precipitation events that carry urban runoff and other storm water contaminants. Even if the concentrations of contaminants entering Hinkson Creek are not high enough to be lethal, repeated influxes of these pollutants may result in a chronic exposure situation for aquatic macroinvertebrates in which the condition of individuals within sensitive taxa is repeatedly reduced. This reduced condition could eventually result in their demise through such factors as lower predator avoidance abilities, greater susceptibility to disease and parasites, and decreased reproductive potential.

6.0 Summary

According to the US EPA (1994), non-point source pollution is the number one cause of water quality impairment in the United States, accounting for the pollution of approximately 40% of all waters surveyed across the nation. As found in this study and others, there is typically not one pollutant or entity that is the sole cause of impairment to streams that flow through urbanized areas. Impairments to urbanized streams are often a reflection of what is occurring in the watershed. The Hinkson Creek phase one findings are summarized in the paragraphs below.

When compared to Parris (2000) findings, nutrient samples collected during base flow were considered within typical ranges for this stream system. Conductivity levels ranged from 445 µS/cm to 910 µS/cm throughout the study. On occasion, conductivity readings were >900 µS/cm at the Hinkson Creek Road and I-70 locations. During the spring of 2004, *E. coli* counts occasionally exceeded the US EPA's recommended levels for the single sample maximum of 235 cfu. The conductivity and *E. coli* levels should be further investigated to determine the cause and/or source of the elevated levels.

The percent fine sediment estimate survey indicated a trend of increasing coverage from upstream to downstream locations. The mean percent coverage for each grid (Hinkson Creek Road, 63 Connector, and Broadway) was 63.6%, 79%, and 96%, respectively. This was not surprising, with the noted observations of land disturbance and erosion occurring within the study area and below many of the storm drainages.

As was found during this study and discussed by Waters (1995), storm waters can carry a variety of toxic materials such as road salt, chemical herbicides/pesticides, PAHs, and other organic materials. Toxicity tended to be sporadic, with none of the sampled drainages being found consistently toxic. The Toxicity Identification Evaluation manipulations have implicated organic chemicals in some storm water samples. The finding of toxicity in mainstem Hinkson Creek at Broadway was significant. The Toxicity Identification Evaluation manipulations implicated high levels of sodium and calcium in snowmelt samples. This documents that impacts to the aquatic communities do occur, at least seasonally. Additional studies are necessary to determine any long-term effects to the aquatic communities.

During the bioassessment portion of this study, we learned that the aquatic community is impaired between I-70 and Broadway, and potentially downstream through the urbanized section of Hinkson Creek. These findings correlate with other urban studies conducted by other researchers (e.g. Yoder et al. 1999). They found that the given EPT Taxa abundance was significantly reduced at relatively low levels of urbanization and that the EPT Taxa acted as sentinels of urbanization.

Growth and development within the City of Columbia in the last few years have dramatically increased. With increasing urbanization, more impacts to Hinkson Creek are likely. We suspect that hydrologic changes have and will continue to occur in Hinkson Creek. Other urban stream studies have documented links between development and alterations to the natural landscape. There appears to be a strong correlation between the imperviousness of a drainage basin and the health of its receiving streams (Arnold and Gibbons 1996, US EPA 1993, Stankowski 1972, Schueler 1994). As the percentage of the land covered by impervious surfaces increases, there is a consistent degradation of water quality. Degradation occurs at relatively low levels of imperviousness (10-20%) and worsens as more areas are paved. The US EPA (1993) also reported that urbanization negatively affects streams and results in water quality problems such as loss of habitat, increased temperatures, sedimentation, and loss of fish populations.

During this first phase of the study, the Department of Natural Resources found it beneficial to release some of the preliminary findings. During spring 2004, preliminary Hinkson Creek data was presented to a variety of entities within the Hinkson Creek watershed. During this time, a number of recommendations were made such as:

- improve storage and handling of road materials to minimize runoff and prevent movement off site;
- construct more and better designed storm water control structures that would slow and disperse the flow of storm water into the stream to reduce scouring and soil erosion;
- make a concerted effort to utilize best management practices to minimize soil erosion when conducting land disturbance activities;
- implement better parking lot management to minimize pollutant export into Hinkson Creek;
- strive to maintain or increase the existing riparian corridor whenever possible.

Releasing preliminary data allowed the community to take the necessary steps to reduce the impact to Hinkson Creek as soon as problems were discovered. The City of Columbia is looking at a variety of watershed issues and promoting watershed educational efforts. However, improvements can only be made with cooperation from all involved (local government, business owners, and citizens) in the Hinkson Creek watershed.

7.0 Acknowledgements

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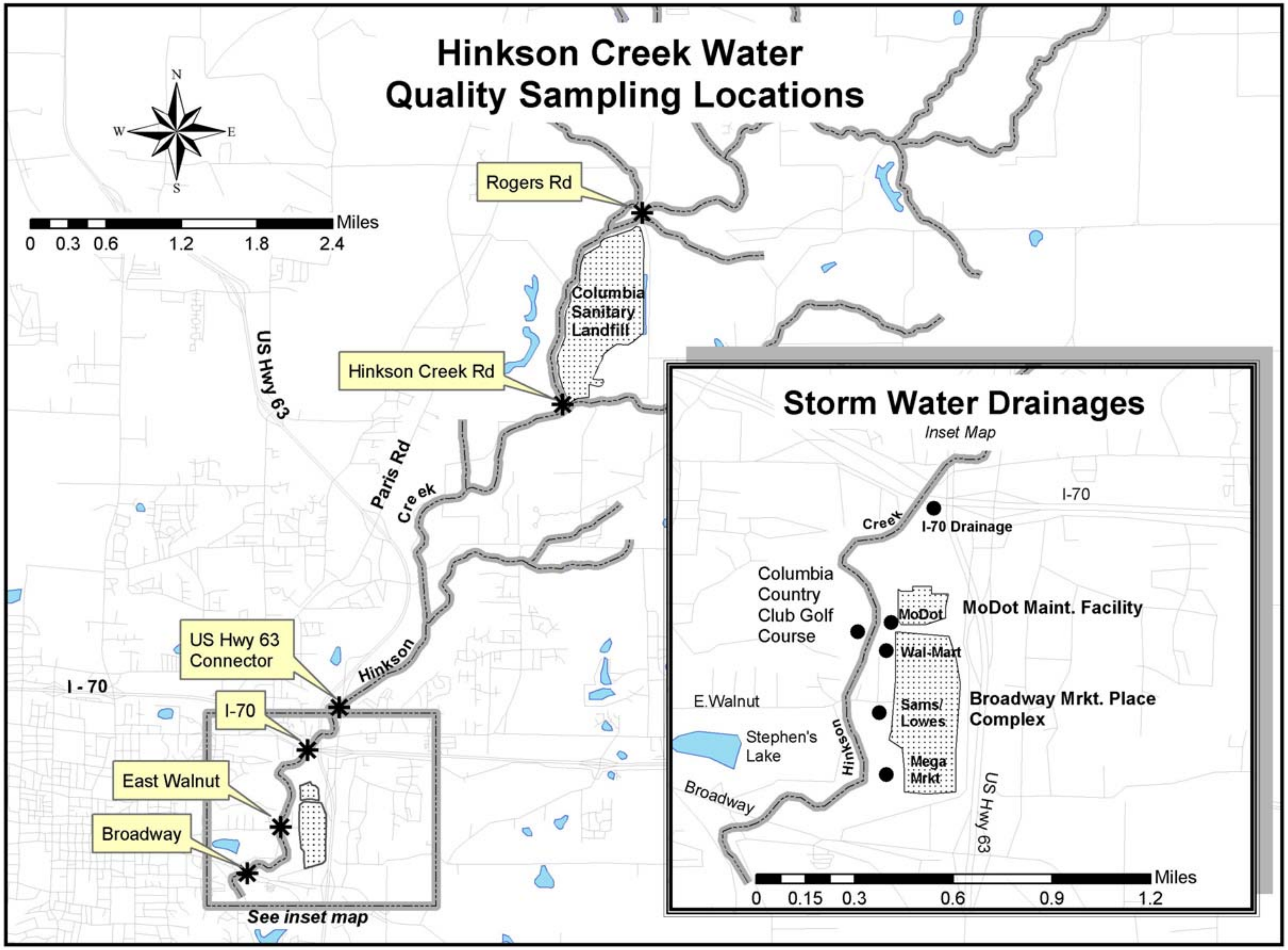
APPENDIX A
Map of Sampling Locations



Hinkson Creek Water Quality Sampling Locations
N
S
E
W
Miles
0 0.3 0.6 1.2 1.8 2.4
Rogers Rd
Columbia Sanitary Landfill
Hinkson Creek Rd
US Hwy 63
Paris Rd
Creek
Hinkson
US Hwy 63 Connector
I - 70
I-70
East Walnut
Broadway
See inset map
Storm Water Drainages
Inset Map
I-70
Creek
I-70 Drainage
Columbia Country Club Golf Course
MoDot
MoDot Maint. Facility
Wal-Mart
E.Walnut
Sams/ Lowes
Broadway Mrkt. Place Complex
Stephen's Lake
Hinkson
Mega Mrkt
US Hwy 63
Broadway
Miles
0 0.15 0.3 0.6 0.9 1.2

APPENDIX B
Instream Activities/Storm Water Soil Erosion
Photographs

Appendix B

Photo 1. MoDOT Drainage

Approximate 8-foot gully erosion

Photo 2. Wal-Mart Drainage

Approximate 8-foot gully erosion

Photo 3. Wal-Mart Drainage

During significant storm water runoff event

Photo 4. City of Columbia sewer line upgrade

Equipment crossing located upstream of the East Walnut bridge crossing.

Photo 5. City of Columbia sewer line upgrade

Construction and equipment crossing located downstream of the East Walnut bridge crossing.

Photo 6. City of Columbia sewer line upgrade

Construction and equipment crossing located upstream of the Broadway bridge crossing.

APPENDIX C
Modified Phase I Toxicity Characterization Tests

Appendix C

Modified phase I toxicity characterization tests (USEPA 1991) were performed on samples that showed observable acute toxicity. Observable toxicity for this study was defined as any percent (%) effect level greater than 15%. The higher the % level of effect, the more toxic the sample. These tests were designed to characterize and assist identify broad classes of compounds that might be contributing to the toxicity. The information obtained from these tests was then used to prioritize samples for further chemical analysis.

Sample Handling and Manipulations

Samples showing toxicity were immediately subjected to three modified phase I toxicity characterization tests described below:

Filtration test-Toxic pollutants may be associated with particles and the route of exposure may be significant, especially for organisms that ingest these particles. Removal of these particles by filtration may result in a complete or partial removal of toxicity.

Approximately 25 mLs of sample were filtered through a Nalgene 0.45 um cellulose fiber filter membrane. The resulting filtrate was then analyzed using the Microtox SOLO or Microtox Basic test. A decrease in the % effect in the Microtox SOLO test was indicative of toxicity reduction in the sample.

EDTA chelation test-Toxicity that is caused by certain cationic metals can be reduced by exposing the sample to a chelating agent such as ethylenediaminetetraacetate ligand (EDTA). EDTA is a strong chelating agent that produces relatively non-toxic complexes with many metals.

Ten drops (0.5 ml) of a 0.01M EDTA solution was added to a 20-mL volume of sample and mixed. After 30-60 minutes at room temperature, the manipulated sample was analyzed using the Microtox SOLO test. A decrease in the % effect in the Microtox SOLO test was indicative of toxicity reduction in the sample.

C_{18} Solid Phase Extraction (SPE) test-Toxicity that is caused by relatively non-polar organic compounds can be reduced by passing the sample through a small column packed with octadecyl (C_{18}) sorbent. Compounds in the sample interact with, and can be extracted onto, the sorbent.

Approximately 20 mLs of sample were passed slowly through the SPE column. The first 5 mLs of sample were discarded and the next 10 mLs collected for analysis. The manipulated sample was analyzed using the Microtox SOLO test. A decrease in the % effect in the Microtox SOLO test was indicative of toxicity reduction in the sample.

Based on the results of the toxicity characterization tests, samples were submitted for additional analyses.

For example, Table 3 shows the results of sample #0411484. The initial toxicity of the raw (unmanipulated) sample showed a 34% level of effect (toxic). Following filtration, a 32% level of effect remained, indicating that filtration did not reduce or eliminate toxicity. Following the addition of EDTA, the level of effect was measured to be 33%, indicating that toxicity was not reduced or eliminated. Passage through a Solid Phase Extraction (C_{18}) column, however, reduced the level of effect to 8%, which indicated that chemical constituents that were removed by the column were likely responsible for the observed toxicity. The sample, therefore, was submitted for organic chemical analysis.

APPENDIX D

Collection of all the Analytical Results

Hinkson Creek
Volunteer Water Quality Monitoring
Analytical Results

Hinkson Creek
Storm Water Monitoring
Analytical Results

Hinkson Creek
Sediment Monitoring
Analytical Results