Missouri Department of Natural Resources

Stream Survey Sampling Report

Phase II
Hinkson Creek Stream Study
Columbia, Missouri
Boone County

July 2004-June 2005

Prepared For:

Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Branch
Water Pollution Control Program

Prepared By:

Missouri Department of Natural Resources
Field Services Division
Environmental Services Program
Water Quality Monitoring Section

Table of Contents Page

List of Figures:

List of Tables:

Attachments:

EXECUTIVE SUMMARY

The Missouri Department of Natural Resources, Water Protection Branch, Water Pollution Control 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 have resulted in the designated beneficial uses becoming impaired. These urbanization concerns include the potential for water quality degradation, increased flow intensity due to stormwater runoff of impervious surfaces, and the likely detrimental effects of development on the stream channel and riparian areas.

Biological monitoring during the fall of 2001 and the spring of 2002 by the Missouri Department of Natural Resources, Field Services Division, 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 phase I of 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 main-stem Hinkson Creek and storm drainages located within this portion of Hinkson Creek.

Results of the phase I study documented that the aquatic community was impaired in Hinkson Creek between I-70 and Broadway and that the impairment extended downstream. Toxicity tests documented toxicity in approximately 20% of stormwater discharges and in main-stem 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 stormwater discharges and high levels of sodium and calcium chloride in snowmelt samples. Although the presence of chemicals and toxicity of stormwater does not automatically translate to toxicity in-stream, it did suggest possible contaminants and sources that are likely contributors to in-stream effects. In-stream toxicity was documented in Hinkson Creek at the Broadway bridge during the snowmelt sampling. This observation is significant because it ties in-stream effects to a particular runoff event.

Escherichia coli *(E. coli)* counts occasionally exceeded recommended levels during phase I and may have resulted 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 suggested an explanation for this increase in sedimentation.

Phase II of the Hinkson Stream Study was performed in a similar manner as was phase I. Because the source and type of pollutant(s) were listed as 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 steps in the triad include documenting that impairment to the aquatic community still exists, testing a variety of in-stream, stormwater, and sediment samples for toxicity using a bioluminescent microorganism (*Vibrio fischeri*) and in some cases a freshwater daphnid (*Ceriodaphnia dubia*). The purpose of this was to correlate effects of laboratory test organisms with in-stream 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.

The Hinkson Creek phase II findings are summarized below:

- *In-situ* conductivity values were higher in Hinkson Creek during base flow when compared to reference/control streams within the same EDU.

- Turbidity levels were highest at the Highway 63 connector and old Highway 63 sites during base flow events. High turbidity during periods of low or base flow conditions is indicative of in-stream activity such as that which occurs during land disturbance activities.

- Chloride values in Hinkson Creek were approximately 40% higher when compared to reference/control streams within the same EDU during base flow events.

- Toxicity tended to be sporadic. None of the sampled drainages were found consistently toxic. Of the stormwater samples collected, eight (8) samples were toxic to the Microtox organisms. Metals (arsenic, chromium, copper, lead, nickel, zinc), organic constituents (e.g., PAHs), and plasticizers were the main constituents found.

- SPMD analyses indicated the presence of several low-level semi-volatile organic chemicals (e.g., pesticides and/or breakdown products, phthalates, and pharmaceutical drugs) that have the potential to bioaccumulate in aquatic organisms.

- Biological metrics describing the macroinvertebrate community at Station 6 during this study exhibited improvement compared to spring samples collected in 2002 and 2004 and, for the first time among three sample seasons, were sufficient to merit a fully supporting SCI score. Compared to 2002, Taxa Richness increased by 14 taxa and EPT Taxa nearly doubled, increasing by 7.

- The improvement in metric scores and the increasing similarity index between Station 6 and Station 7 could be interpreted as a demonstration that Station 6 is developing better potential to support a diverse macroinvertebrate community. This increased potential at Station 6 may result from a decrease of the quantity and frequency of perturbations that were observed and/or suspected in previous years (e.g., sewer bypasses, petroleum products, insecticides, road salt, and sediment).

- Although Station 6 appears to have improved compared to previous years, the macroinvertebrate community within the urbanized reach nevertheless showed some important differences compared to the upstream reference reach. Most notably, Station 3.5 had a fraction of the number of mayflies and stoneflies compared to each of the other stations. In addition, each of the urbanized reaches had much higher numbers of tubificid worms than Station 7. Tubificids were nearly twice as abundant at Station 3.5 than at the next nearest site. Tubificid worms tend to be tolerant of sediment and also organic pollutants. This might reflect previously documented inputs of sediment and organic loading (e.g., bypasses, etc.).

With the growing amount of impervious surfaces located in the Hinkson Creek watershed, we can 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 surface 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.

Progressive and innovative land management and land use practices are needed to prevent further degradation of Hinkson Creek and other urban streams located throughout the state of Missouri. Low impact development such as decreasing and slowing stormwater discharges and creating grassy and/or vegetative swales to capture small precipitation events that allow water to percolate through the soil to recharge groundwater systems are methods that can help mitigate detrimental effects of urbanization on streams. Educational efforts focusing on the importance of stormwater management practices are currently being used in the Great Lakes region and in the eastern and western coastal regions and should be increasingly considered in Midwestern communities.

1.0 Introduction

In 1998 the Missouri Department of Natural Resources, Division of Environmental Quality, Water Protection Program, Water Pollution Control Branch 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 that the Field Services Division, Environmental Services Program **(ESP)**, Water Quality Monitoring Section **(WQMS)** conduct an assessment of the aquatic macroinvertebrate community to determine the biological integrity of Hinkson Creek. As a result, an aquatic macroinvertebrate community study was conducted (MDNR 2002a) during the fall of 2001 and spring of 2002. Information obtained from the study showed impairment to the aquatic macroinvertebrate populations within the urbanized reach surveyed. Biological metrics 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 (**I-70**) bridge crossing was only "partially supporting" for aquatic life and confirmed stream impairment as summarized below.

- During the fall 2001 season, 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 Water Pollution Control Branch requested that the WQMS conduct a comprehensive study of main-stem Hinkson Creek and major storm drainages located within the impaired segment of Hinkson Creek. The phase I study was conducted from July 2003 to June 2004. The phase II, which is the focus of this report, was conducted from July 2004 to June 2005. The studies consist of water quality and sediment monitoring, toxicity testing, and additional biological sampling through the duration of the study.

1.1 Study Area

Hinkson Creek is 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 shale 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 limestone, sandstone, and shale 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 88.5 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, where 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," "protection of warm water aquatic life and human health associated with fish consumption," and "whole body contact recreation – level B". 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 - fish consumption," "whole body contact recreation – category B," and "secondary contact recreation." During this study, the main Hinkson Creek sampling locations were located within the Class C reach.

The state of Missouri is divided into 17 aquatic ecological drainage unit (**EDU**) systems. Hinkson Creek is located within the Ozark/Moreau/Loutre EDU (Sowa et al. 2004). The streams listed in Figure 2 are reference stream locations selected by WQMS 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 (control) were used for comparisons with Hinkson Creek.

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 water quality 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," "protection of warm water aquatic life and human health associated with fish consumption," and "whole body contact recreation – category A."

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 middle to upper reaches of Hinkson Creek; and a relative lack of urbanization in the watershed. The biological and water quality comparisons were conducted to determine whether biological and/or water quality impairment exists in a system largely comprised of urban runoff compared to one that lacks urban influence.

Auxvasse River and Loutre River are both located in Callaway County. The Auxvasse River originates in northwestern Callaway County and flows in a southeastern direction across the county and enters the Missouri River near the town of Steedman. The Loutre River originates in southeastern Audrain County and flows in a southeastern direction through Callaway County into Montgomery County. The Loutre River then flows across the county in a southeast direction and enters the Missouri River near the town of McKittrick. The stream reaches that were assessed are both classified as Class C streams with beneficial use designations of "livestock and wildlife watering," "protection of warm water aquatic life and human health – fish consumption," and "whole body contact recreation – category B."

The Auxvasse River and Loutre River were chosen as controls for water quality monitoring due to these stream systems being located within the same EDU, a relative lack of urbanization in the watershed, and they have similar geological and stream gradient conditions to Hinkson Creek. Water quality comparisons were made to determine if there are significant water quality differences between stream systems located in an urban setting and those that lack urban influences.

Hominy Creek, a tributary of Hinkson Creek, originates in east central Boone County just north of I-70 and flows in a southwesterly direction. The confluence of Hominy Creek and Hinkson Creek is located just south of the Broadway bridge crossing. From Highway 63 to its mouth at Hinkson Creek, Hominy Creek is classified as a class C stream with beneficial use designations of "livestock and wildlife watering," and "protection of warm water aquatic life and human health – fish consumption." Approximately 0.45 miles of Hominy Creek is impounded to form a small lake located just before its confluence with Hinkson Creek.

Grindstone Creek is a tributary of Hinkson Creek. The North Fork Grindstone Creek and South Fork Grindstone Creek flow together to form Grindstone Creek just east of Highway 63. Grindstone flows in a westerly direction approximately 1.5 miles before entering Hinkson Creek along the city of Columbia's Capen Park. Grindstone is a class C stream with beneficial use designations of "livestock and wildlife watering," "protection of warm water aquatic life and human health – fish consumption", and "whole body contact recreation – category A."

According to the 2001-2004 land cover data (MoRAP 2005) the following watersheds consisted of the approximated categories:

Watershed	**Watershed size (sq. miles)**	**% Urban**	**% Crop-land**	**% Grass-land**	**% Forest/ woodland**	**% Other**	**% Total**
Hinkson Creek	88.5	21	10	38	26	3	98
Hominy Creek	6.8	23	13	35	22	3	96
Grindstone Creek	14.8	16	11	42	27	2	98
Bonne Femme	50.5	3	22	34	36	2	97
Auxvasse River *	125.3	2	44	29	20	2	97
Loutre River *	65.7	1	38	31	26	2	98

* Watershed estimates from areas located upstream of the furthest downstream monitoring site. All other estimates were of the whole watershed.

Figure 1. Map of the Hinkson Creek Phase II 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 projected a population of 90,967 for 2005 (http://www.gocolumbiamo.com/Documents/demographics.pdf*).*

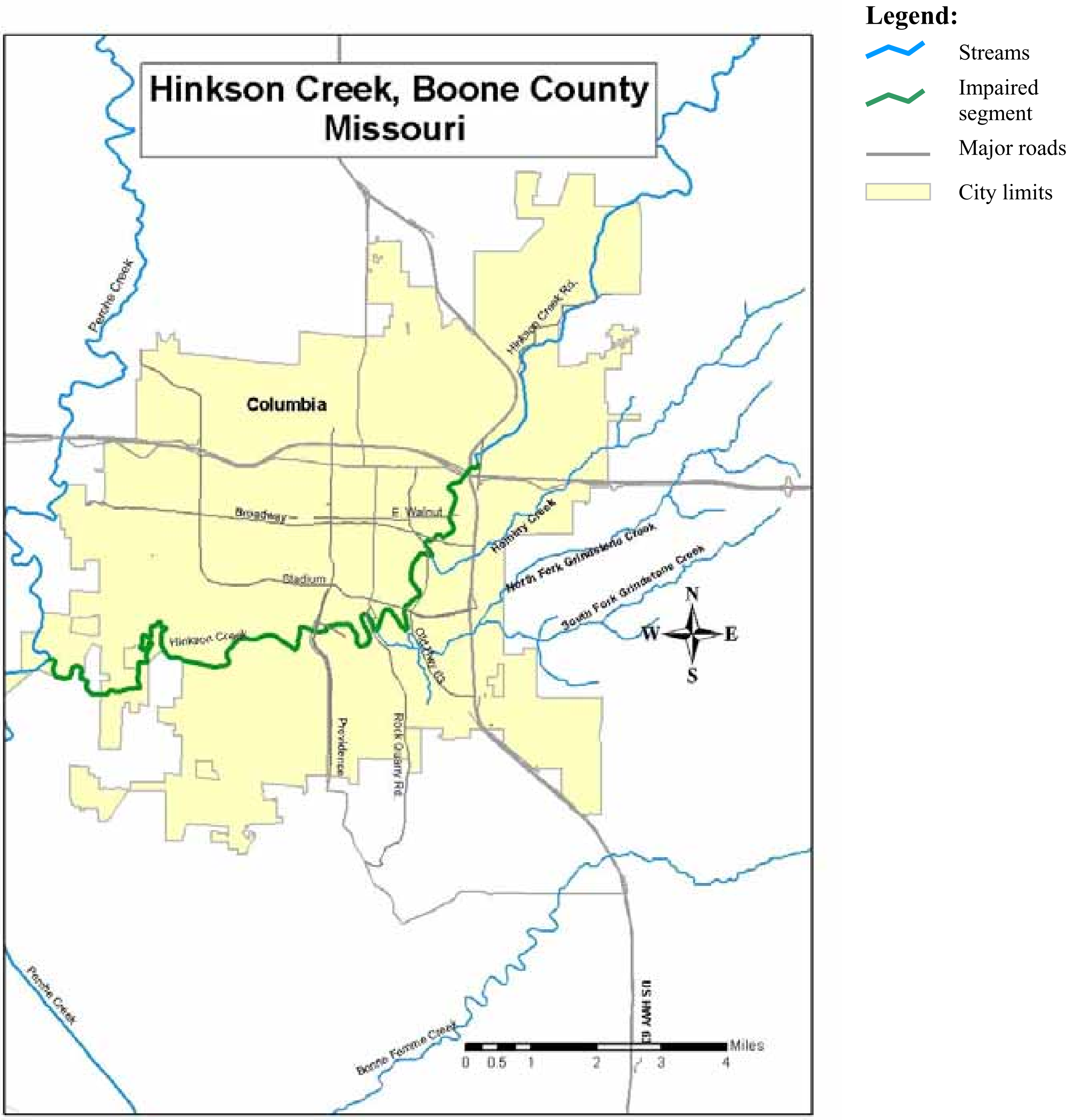
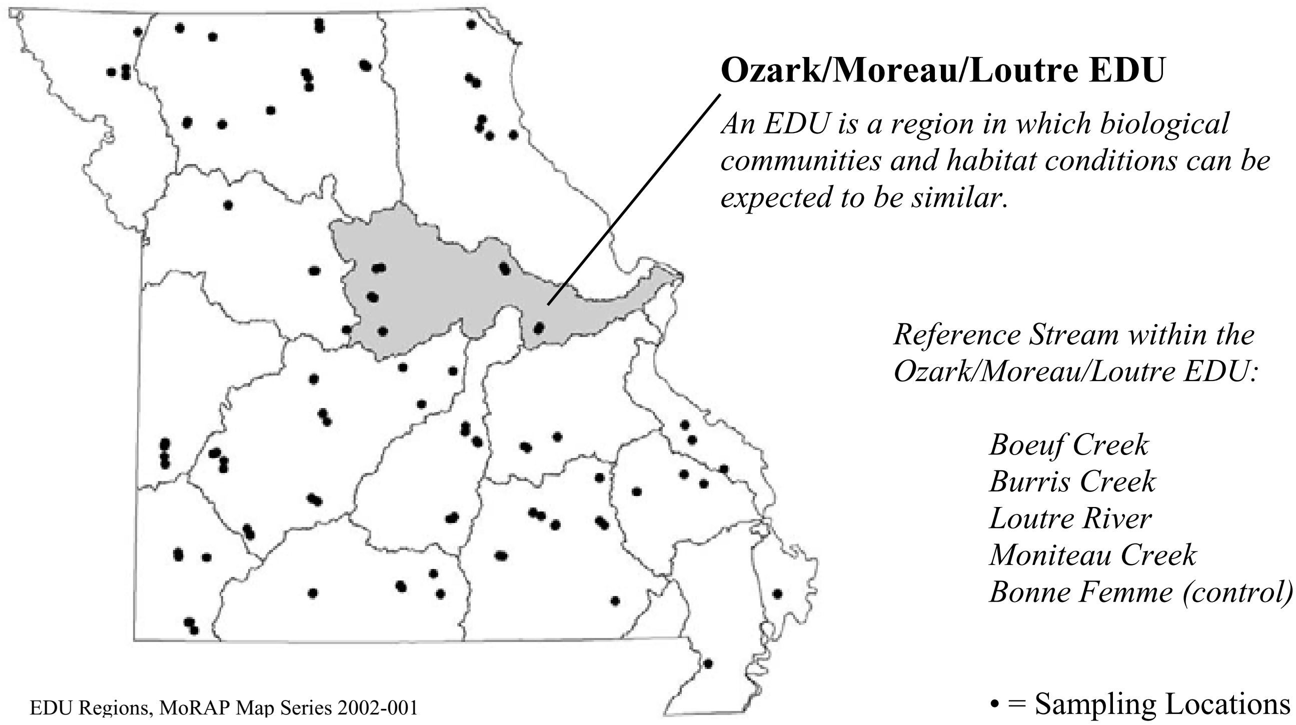


Figure 2. Ecological Drainage Units of Missouri and Location of Biological Reference Sites

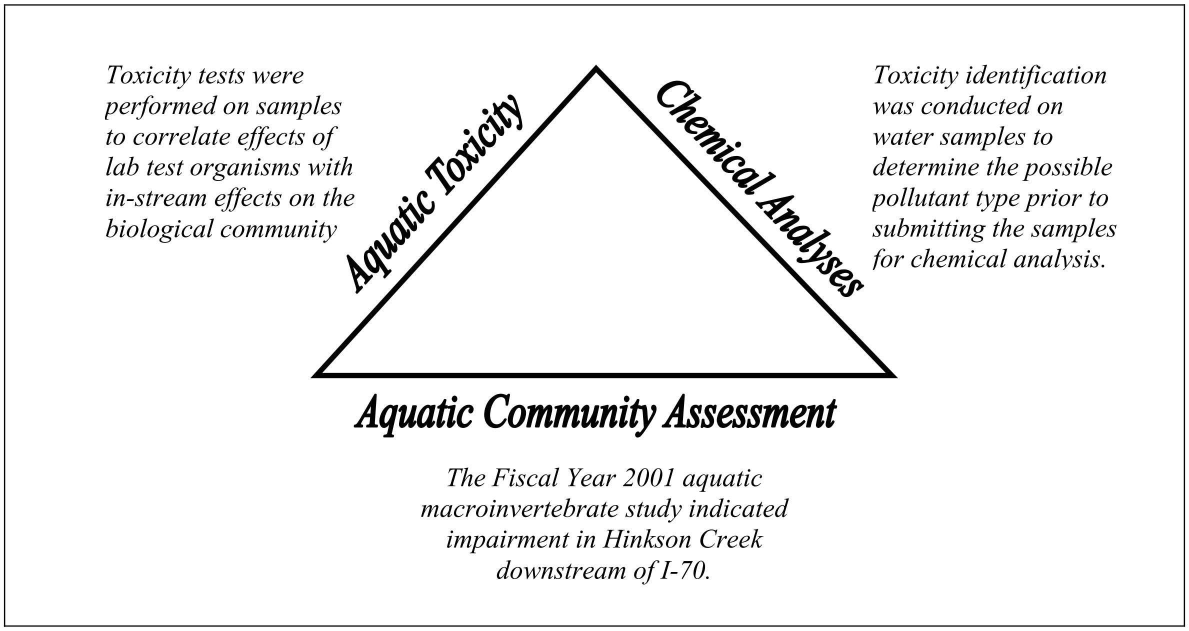


1.2 Study Design

As discussed in the phase I report (MDNR 2004), the source and the type of pollutant(s) were unknown. Therefore, 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 macroinvertebrate data indicated impairment to Hinkson, it was necessary to collect a series of water samples for testing. 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. The toxicity methods are explained in detail in section 2.1 of this report.

Figure 3. The Water Quality Triad



1.3 Study Objectives

The overall objective for the three-phase study is to conduct a water quality assessment of the entire "impaired" 14-mile segment of Hinkson Creek in phases as summarized below.

- The first phase of the study was conducted during the 2004 state fiscal year and concentrated on an approximately 2.0 mile segment of Hinkson Creek between the I-70 and Broadway bridge crossings.

- The second phase of the study, which is discussed in this report, began during July 2004 and continued throughout the 2005 state fiscal year that ended June 30, 2005. The phase II portion of the study concentrated on an approximately 5-mile long segment of Hinkson Creek located between the Broadway bridge and Recreational Drive low-water bridge crossing (located just upstream of Providence Road).

- The third phase of the Hinkson Creek study began in July 2005 and will continue through June 2006. The third phase will focus on an approximately 7.5-mile long segment of Hinkson Creek from Recreational Drive low-water bridge crossing to Perche Creek.

The intent of the three-part study is to locate possible pollutant sources and identify contaminants contributing to impairment of the stream. Main-stem Hinkson Creek, major stormwater drainages, and major tributaries were, and will be, monitored throughout each phase of the study.

During the second phase of the study, a Quality Assurance Project Plan (MDNR QAPP 2005) was submitted to the Water Pollution Control Branch. In summary, the plan consisted of:

- analyzing main-stem Hinkson Creek turbidity samples collected during base flows;
- analyzing main-stem Hinkson Creek water quality samples collected during base flows;
- analyzing main-stem Hinkson Creek water quality samples collected following rainfall events in excess of 0.5 inches of rain;
- analyzing stormwater sample collections from significant stormwater discharges located between Broadway and Recreational Drive low-water bridge crossing;
- analyzing semi-permeable membrane devices deployed at various locations on main-stem Hinkson Creek to determine what types of non-polar organics are present and accumulative;
- conducting Microtox testing on water samples collected from main-stem Hinkson Creek during base flows and storm events;
- conducting Microtox testing on water samples collected from stormwater drainages located throughout the study reach;
- conducting a follow-up study of the FY 2003 biological assessment at four locations, focusing on the stream reach located between Hinkson Creek Road and Broadway.

2.0 Hinkson Creek Phase II 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 and stormwaters were determined for samples collected during the study using the Microtox bacterial bioluminescence test (APHA 1998). Establishing a connection between observed toxicity in waters 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 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 stormwater 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 the observed toxicity into broad chemical classes allowed for more specific analyses of 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 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. During the phase I study, spikes in chloride and conductivity levels at specific locations occurred during the chemical monitoring of stormwater and surface water samples. Since the Microtox organisms are marine bacteria, they are less sensitive to the presence of chlorides, especially sodium and calcium salts, whereas *C. dubia* are relatively sensitive to the presence of these salts (US EPA 1991, MDNR unpublished reference toxicity data). Therefore, it was decided to utilize both the Microtox and *C. dubia* tests. This procedure was then carried over into the phase II portion of the study. 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 manufacturer's instructions. The water samples were collected in appropriate sample containers (MDNR 2003a), handled, and transported to the ESP state environmental laboratory according to standard procedures (MDNR 2002b). The samples received a numbered label and were placed on ice in a cooler. 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 2005a 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 2005). 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**), Volatile Organic Analyses (**VOA**), 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. Bacteriological (*Escherichia coli*) samples were analyzed with an IDEXX Colilert Quantitray system.

2.3 Semi-permeable Membrane Device (SPMD)

Semi-permeable membrane devices (SPMD) were used to monitor for semi-volatile organic chemicals that are susceptible to bioconcentration in aquatic organisms. SPMDs are passive sampling devices that were developed by researchers at the United States Geological Survey (USGS) Columbia Environmental Research Center located in Columbia, Missouri. Sometimes referred to as "fake fish" or "fat bags", the SPMDs consist of a thin film of a neutral lipid that is enclosed in a lay flat, low density, polyethylene membrane tube. As described by USGS, the SPMD is an integrative sampler that provides a time weighted average concentration of sampled chemicals over a deployment period ranging from days to months. When exposed to air or water, any bioavailable organic compounds diffuse through the polyethylene membrane and accumulate in the lipid in a manner that mimics contaminant uptake into the fatty tissues of living organisms. Refer to http://wwwaux.cerc.cr.usgs.gov/SPMD/SPMD-Tech_Tutorial.htm for additional information.

2.3.1 SPMD Collection Methods

The SPMDs were received from Environmental Sampling Technologies (EST) located in St. Joseph, Missouri. The SPMDs were pre-secured in a spider-type rack system from the manufacturer and transported in an airtight canister. Just prior to in-stream deployment, three spiders were removed from an airtight storage container and placed in a stainless steel deployment canister. The deployment canister was then submerged and secured to the streambed. Following the deployment period, the deployment canisters were retrieved from the stream. The spiders were then removed from the deployment canisters and returned to their airtight storage containers. Upon return to the ESP state laboratory, the storage containers were placed in a freezer until shipment to Environmental Sampling Technologies for cleaning, dialytic extraction, and recovery (refer to the Environmental Sampling Technologies web page for additional information http://www.est-lab.com/spmd.php).

2.3.2 SPMD Analytical Methods

The three spiders were placed into a deployment canister. Each canister of spiders was combined into one sample during the extraction process. The extracts were then ampulized by Environmental Sampling Technologies and shipped back to the ESP laboratory in Jefferson City where they were analyzed for qualitative organic chemicals. The qualitative organic analyses 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.

2.4 Biological Assessment Monitoring

2.4.1 Biological Collection Methods

The biological assessment monitoring was conducted according to the MDNR Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**: MDNR 2003c). In summary, macroinvertebrates were collected using a multi-habitat sampling method. The sampling was conducted in a stream reach approximately twenty times the average width of the stream and encompassed two riffle sequences or two meander sequences. Hinkson Creek is considered a "riffle/pool" predominant stream and, therefore, macroinvertebrate samples were collected from three predominant habitats: flowing water over coarse substrate (e.g., riffle); non-flowing water over depositional substrate (e.g., pool); and rootmat substrate. Each macroinvertebrate sample was a composite of six subsamples within each habitat. The sampling periods occurred during periods of stable base flow before peak aquatic insect emergence times. In general, macroinvertebrate sampling occurs in the spring from mid-March through mid-April and in the fall from mid-September through mid-October.

Samples from each major habitat were collected and preserved with 10% formalin. Habitat samples were kept separate to provide the ability to factor out habitat differences among sites.

2.4.2 Biological Assessment Methods

Macroinvertebrate identifications were made to the lowest possible taxonomic level (usually genus or species) and according to MDNR-FSS-209 *Taxonomic Levels for Macroinvertebrate Identifications* (MDNR 2005b). The macroinvertebrates from each habitat were evaluated using the following metrics:

- <u>Taxa Richness (**TR**)</u>
  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 habitat suitability. Taxa Richness is calculated by counting all taxa from the subsampling effort.

- <u>Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPT Taxa**)</u>
  Is the total number of distinct taxa within the orders Ephemeroptera, Plecoptera, and Trichoptera. This value summarizes taxa richness within the insect taxonomic orders that are generally considered to be pollution sensitive. The EPT Taxa index generally increases with higher water quality.

- <u>Biotic Index (**BI**)</u>
  Developed as a means to detect organic pollution. Tolerance values for each taxon range from 1 to 10, with higher values indicating increased tolerance.

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

The above four metrics were aggregated into a single value presented as the Stream Condition Index (**SCI**). The SCI is calculated according to Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure for each season and year and is based upon data collected from reference streams within the same EDU as the study stream. 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 of aquatic life.

The study stream was then evaluated by calculating the metrics, scoring them using the scale determined in the SCI, and totaling the scores into a single value. The study stream is then ranked for aquatic life sustainability using the following criteria for Warm Water Reference Streams in the Ozark/Moreau/Loutre Ecological Drainage Unit:

	Score = 5	**Score = 3**	**Score = 1**
TR	>71	71-36	<36
EPT Taxa	>13	13-6	<6
BI	<6.45	6.45-8.22	>8.22
SDI	>2.80	2.80-1.40	<1.40

3.0 Hinkson Creek Phase II Water Quality Monitoring

To increase efficiency, various sampling devices were utilized during the study. The following sections describe the sampling efforts that were conducted during the Hinkson Creek study to assess water quality. For reporting the information in table and graphical purposes, the following sampling locations were coded in the manner listed below.

Main-stem Hinkson Creek	**Tributaries/Reference/Control Streams**
Hinkson Creek Road (**HCR**)	Hominy Creek (**HOM**)
Hwy 63 connector (**63C**)	Grindstone Creek (**GRI**)
East Walnut (**EWL**)	Auxvasse River @ CR 156 (**AXU**)
Broadway (**BWY**)	Auxvasse River @ CR139 (**AXD**)
Old Hwy 63 (**O63**)	Loutre River @ CR 1053 (**LRU**)
Stadium Boulevard (**STD**)	Loutre River @ CR 1036 (**LRD**)
Hinkson Creek upstream of Grindstone (**HUG**)	Bonne Femme Creek (**BNF**)
Hinkson Creek downstream of Grindstone (**HDG**)	
Recreational Drive (**RCD**)	

3.1 Base Flow Water Quality Monitoring

3.1.1 Base Flow Background

Base flow monitoring provides information regarding the quality of the water in stream systems during normal flow conditions and allows comparisons to be made longitudinally, to reference/control streams, and during high flow events.

3.1.2 Base Flow Sample Collection Overview

All samples were collected in sample containers approved by the Missouri Department of Natural Resources and in accordance with the standard operating procedure (MDNR 2003a). The samples remained in the custody of WQMS field personnel until they were relinquished to the ESP laboratory located in Jefferson City.

Three (3) base flow water quality samples were collected from nine sites located on main-stem Hinkson Creek, tributaries, and Bonne Femme. Two (2) base flow water quality samples were also collected from the Auxvasse and Loutre rivers. Please refer to Appendix A for a 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 nitrogen (**T (N)**), total phosphorus (**T (P)**), NFR, chloride (**Cl**), volatile suspended solids (**VSS**), turbidity, and Microtox toxicity. Bacteriological samples for *E. coli* were collected throughout the study. Surface water grab samples were also collected for petroleum fractions, QOA, and VOA, but only submitted for analysis based upon the Microtox toxicity results.

In situ field measurements were collected for the following: water temperature, pH, specific conductivity, and dissolved oxygen (**DO**). In-stream discharge measurements were collected using a Marsh-McBirney Flo-Mate 2000.

3.1.3 Base Flow Microtox Toxicity Results

None of the base flow water quality samples collected from Hinkson Creek or its tributaries were found to be toxic to the Microtox organisms.

3.1.4 Base Flow Water Quality Monitoring Results and Discussion

Table 1 summarizes the base flow sampling events and water quality data. According to the MDNR 10 CSR 20-7.030 (MO CSR 2004) for water quality standards, in-stream water quality limits were not exceeded at any time during the base flow monitoring portion of the study. Brief discussions of the findings are discussed below.

Specific Conductivity
The *in situ* conductivity field measurements were within expected ranges for streams in the Ozark/Moreau/Loutre EDU. When compared to the phase I base flow results, the phase II conductivity results tended to be slightly lower during the second phase of the study at Hinkson Creek Road, East Walnut, and Broadway bridge crossings. When compared to the reference and control

streams, the conductivity readings were significantly higher (approximately 55 percent higher) in Hinkson Creek at all stations. The higher conductivity readings in Hinkson Creek could possibly be due to influences from the of the city of Columbia Sanitary Landfill and/or past coal mining activities that occurred during the late 1960's to early 1970's. 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.

Of the phase II conductivity readings, Grindstone Creek was consistently higher throughout the study when compared to Hinkson Creek, Hominy Creek, and reference/control streams. The higher readings may be due to the contribution of point source discharges (e.g., small domestic wastewater treatment facilities) located within the Grindstone watershed. According to the MDNR, NPDES facilities GIS layer (2004), several of these facilities either discharge directly to North Fork Grindstone Creek, South Fork Grindstone, or other tributaries of Grindstone Creek (refer to Appendix A, Map B). Of the discharges listed, eight (8) NPDES permits were for wastewater discharges from subdivisions, one (1) for a mobile home park, one (1) for a concentrated animal feeding operation, and three (3) for domestic waste discharges from commercial businesses.

Bacteriological Samples - Escherichia coli

E. coli is a member of the total coliform group and is associated with fecal contamination. "Whole body contact – level B" is a recently added beneficial use listed for Hinkson Creek. Historical studies have indicated high levels of fecal bacteria present at various times. Over the past several years, raw wastewater bypasses from municipal sewer system manholes have reportedly entered Hinkson Creek, with some resulting in fishkills (MDNR, Environmental Emergency Response database [http://www.dnr.mo.gov/meerts/index.do]). This repeated influx of untreated wastewater is of particular concern because as urbanization encompasses more of the Hinkson Creek watershed, the chances of recreational contact with its waters is increased. The objective of bacteriological monitoring was to gather background data in Hinkson Creek during various flow conditions.

Episodic elevated *E. coli* were noted throughout the study during base flow conditions. According to Table A of 10 CSR-20.7.031 of the Water Quality Standards, *E. coli* levels should not exceed a geometric mean of 548 colony forming units (cfu) per 100 milliliters (mL) of water during the recreational season (from April 1 to October 31). Elevated *E. coli* levels were noted in Hinkson Creek at the following sampling locations, however, further investigation is needed to determine if in-stream exceedances occur during the recreational season.

Site Name	*E. coli* Result
63C	365.4 mpn/100 mL
HOM	980.4 & 547.5 mpn/100 mL
STD	1046.2 mpn/100 mL
HUG	410.6 mpn/100 mL
HDG	387.3 mpn/100 mL
RCD	261.3 mpn/100 mL

Although elevated levels of *E. coli* in the lower stream segments of Hinkson Creek cannot be directly attributed to any specific source, they might be correlated with the following factors noted and/or occurring at the time of the study.

- The lower stream reaches of Hominy Creek are impounded to form a small lake. On occasion geese were observed near and/or on the lake. As discussed in the previous report, 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 2002, unpublished data) with the potential of entering streams. In addition, according to the MDNR, NPDES facilities GIS layer (2004), the upper reaches of Hominy Creek receive domestic wastewater from three domestic wastewater systems (two (2) mobile home parks and one (1) subdivision) (refer to Appendix A, Map B).

- Hinkson Creek near Grindstone Creek flows through the city of Columbia Capen Park. The 32.4-acre park is open to the public and provides hiking and dog walking trails.

- Periodic sewer line breaks and/or bypasses can contribute to elevated in-stream *E. coli* readings. The following are examples of some occurrences.

  - On at least one occasion a sewer line bypass occurred during the study. The bypass occurred at a manhole located behind the Wal-Mart store located in the Broadway Market Place shopping complex on August 10, 2004. The sewer lines had become plugged with tree roots and grease, which caused raw wastewater to overflow from the manhole and enter Hinkson Creek (refer to Appendix B, Photos 1-3).

  - During the sampling event field personnel noted two sewer line junction boxes located along the banks of Hinkson Creek. One junction box is located near Stadium Boulevard, while the other is located near Recreational Drive. There were citizen complaints that the junction box located near Stadium Boulevard periodically overflowed and discharged raw wastewater to Hinkson Creek.

  - A sewer line and series of manholes run through the city of Columbia Rock Hill Park. Citizen complaints and visual evidence suggest that a manhole routinely overflows and discharges raw wastewater into a wet weather tributary that drains into Hinkson Creek downstream of old Highway 63.

Turbidity
Turbidity will be discussed in greater detail in the low flow turbidity monitoring section (Section 3.2).

Chloride
Chloride values tended to be slightly less on average when compared to the previous study. No longitudinal trends were noted. Chloride values for Hinkson Creek ranged from 19.6 milligrams per liter (mg/L) to 64.7 mg/L. The highest values were reported in Grindstone Creek, which may be

influenced by the number of point source discharges located throughout the watershed. When compared to the reference/control streams, the Hinkson Creek chloride values on average were approximately 40% higher. The chloride values for the reference/control streams ranged from 8.67 mg/L to 17.1 mg/L.

According to the US EPA (1988), the major anthropogenic sources of chloride in surface water come from deicing salt, urban and agricultural runoff, and discharges from municipal wastewater and industrial plants. All of these occur in the Hinkson Creek watershed. Elevated chloride and conductivity values during base flow periods may also be a result of long term use of de-icing agents used on roadways and parking lots in the form of sodium chloride (salt). The salt accumulates in the soils along roadways and migrates through the soil where, over time, it has the potential to leach into groundwater and surface waters (D'Itri 1992, Hanes et al. 1970, and Kaushal et al. 2005).

Nutrients
The nutrient data collected during the base flow portion of the study was found to be within the expected ranges for a stream within the Ozark/Moreau/Loutre EDU. Slightly elevated $NO_2 + NO_3$ as N and total nitrogen readings occurred during the December 2004 sampling event and corresponded with the higher flow regimes.

In-stream Discharge
In-stream discharge measurements varied from < 0.01 cubic feet per second (cfs) in the upper sections of Hinkson Creek to 19.18 cfs in the lower reaches. The average base flow discharge for each site is calculated below.

Site Name	Average Discharge (cfs)	Site Name	Average Discharge (cfs)
HCR	2.65	GRI	0.89
63C	3.95	HDG	6.77
EWL	4.30	RCD	6.29
BWY	4.02	AXU	5.37
HOM	0.67	AXD	8.09
O63	4.48	LTU	2.29
STD	4.55	LTD	5.31
HUG	4.85	BNF	2.19

Table 1. Hinkson Creek Phase II Base Flow Water Quality Sample Results

Site Name	Sample #	Toxicity Result	pH (pH Units)	Spec. Cond. (µS/cm)	Temp. (C)	D.O. (mg/L)	E. coli (mpn/100 ml)	Turbidity (NTU)	NFR (mg/L)	VSS (mg/L)	Chloride (mg/L)	Total P (mg/L)	NH3 as N (mg/L)	NO2 + NO3 as N (mg/L)	Total N (mg/L)	Discharge (cfs)
7/27/2004																
HCR	0430955	Not Toxic	8.18	472	24.7	10.5	88	6.31	6.00		22.7	<0.02	<0.03	0.20	0.67	0.23
63C	0430956	Not Toxic	8.46	452	26.8	11.6	56	18.5	13.0	<5.00	22.6	<0.03	<0.03	<0.04	0.49	0.58
EWL	0430957	Not Toxic	8.55	433	28.6	12.3	>200.5	21.7	13.0	<5.00	25.7	<0.04	<0.03	0.14	0.68	0.69
BWY	0430960	Not Toxic	5.97	446	24.1	10.2	78	19.0	14.0	<5.00	26.7	<0.03	<0.03	0.07	0.43	0.76
O63	0430958	Not Toxic	7.94	458	25.0	7.75	9	27.5	18.0	<5.00	30.8	<0.04	<0.03	0.10	0.46	0.2
HOM	0430959	Not Toxic	7.81	419	20.9	6.57	>200.5	3.51	5.00	---	24.0	<0.04	<0.03	0.21	0.53	0.03
STD	0430961	Not Toxic	7.89	458	21.7	8.11	>200.5	8.30	7.00	---	31.5	<0.03	<0.03	0.10	0.45	1.32
HUG	0430963	Not Toxic	8.01	460	20.6	7.60	25	16.9	20.0	<5.00	32.3	0.05	<0.03	0.17	0.61	0.57
GRI	0430962	Not Toxic	7.83	595	20.5	8.86	78	4.16	11.0	---	56.3	<0.03	<0.03	<0.02	0.20	0.12
HDG	0430964	Not Toxic	7.45	547	19.4	6.54	94	6.10	7.00	---	36.0	<0.03	<0.03	0.07	0.34	1.66
RCD	0430965	Not Toxic	7.47	491	20.2	6.44	78	7.16	9.00	---	31.0	<0.02	<0.03	<0.05	0.33	1.64
AXU (Cr. 156)	0430953	Not Toxic	8.18	349	24.5	9.20	1	3.86	5.00	---	17.1	<0.03	<0.03	<0.01	0.45	--
AXD (Cr. 139)	0430952	Not Toxic	7.85	281	24.7	7.26	4	6.35	12.0	---	12.2	0.06	<0.03	<0.02	0.68	0.2
LRU (Cr. 1053)	0430950	Not Toxic	7.15	332	20.9	1.54	74	1.97	<5.00	---	10.8	0.06	<0.03	0.06	0.38	--
LRU (Cr. 1053) (Dup.)	0430966	Not Toxic	7.30	325	20.8	1.67	120	2.14	<5.00	---	10.9	0.07	<0.03	0.06	0.40	--
LRD (Cr. 1036)	0430951	Not Toxic	7.26	302	22.7	7.25	21	3.09	6.00	---	8.67	<0.02	<0.03	<0.01	0.27	0.34
BNF	0430954	Not Toxic	7.56	397	23.1	8.75	>200.5	2.25	7.00	---	10.0	<0.04	<0.03	<0.05	0.26	0.26
12/15/2004																
HCR	0434776	Not Toxic	6.90	509	0.50	14.2	56	14.9	7.00	---	20.6	<0.02	<0.03	0.50	0.87	6.38
63C	0434775	Not Toxic	7.57	549	0.20	14.2	56	12.6	7.00	---	19.6	<0.01	<0.03	0.41	0.68	12.79
EWL	0434774	Not Toxic	6.51	578	1.80	14.4	33	12.6	9.00	---	21.1	<0.02	<0.03	0.37	0.66	12.25
BWY	0434773	Not Toxic	5.24	577	1.10	14.8	40	12.0	9.00	---	21.0	<0.01	<0.03	0.36	0.68	12.9
HOM	0434772	Not Toxic	6.71	552	3.60	13.3	52	18.1	9.00	---	23.5	0.06	<0.03	0.31	0.80	1.48
O63	0434771	Not Toxic	6.34	583	1.30	14.3	34	13.0	9.00	---	21.7	<0.02	<0.03	0.35	0.65	11.97
STD	0434770	Not Toxic	6.61	581	1.20	14.4	98	13.4	5.00	---	21.6	<0.02	<0.03	0.35	0.66	11.06
HUG	0434769	Not Toxic	6.43	575	0.70	14.8	91	13.1	5.00	---	21.7	<0.02	<0.03	0.33	0.59	11.99
GRI	0434768	Not Toxic	6.51	737	1.00	14.3	26	3.42	6.00	---	42.8	0.07	0.08	0.71	1.09	2.26
HDG	0434767	Not Toxic	7.05	598	0.30	14.4	110	16.1	11.0	---	24.1	<0.03	<0.03	0.37	0.70	23.23
RCD	0434766	Not Toxic	5.61	612	0.50	14.2	230	10.7	8.00	---	25.8	<0.03	<0.03	0.40	0.72	15.89
RCD (Duplicate)	0434782	Not Toxic	---	---	---	---	290	10.3	6.00	---	25.0	<0.02	<0.03	0.40	0.70	--

Site Name	Sample #	Toxicity Result	pH (pH Units)	Spec. Cond. (µS/cm)	Temp. (C)	D.O. (mg/L)	E. coli (mpn/100 ml)	Turbidity (NTU)	NFR (mg/L)	VSS (mg/L)	Chloride (mg/L)	Total P (mg/L)	NH3 as N (mg/L)	NO2 + NO3 as N (mg/L)	Total N (mg/L)	Discharge (cfs)
12/15/2004 *Cont.*																
AXU	0434781	Not Toxic	---	305	1.30	13.4	17	21.8	10.0	---	10.5	0.09	<0.03	0.46	0.83	16.29
AXD	0434780	Not Toxic	---	325	0.90	13.7	34	18.9	12.0	---	10.9	0.10	<0.03	0.45	0.81	22.22
LRU	0434778	Not Toxic	---	320	0.60	13.8	36	17.8	11.0	---	10.9	<0.03	<0.03	0.59	0.89	7.52
LRD	0434779	Not Toxic	7.17	306	1.20	13.4	21	15.1	12.0	---	9.06	<0.03	<0.03	0.41	0.64	15.96
BNF	0434777	Not Toxic	7.76	409	1.60	12.3	99	4.47	7.00	---	10.6	0.05	<0.03	0.40	0.57	5.04
5/11/2005																
HCR	0503741	Not Toxic	8.04	637	24.0	10.1	>200.5	2.20	7.00	---	22.1	<0.03	<0.03	0.13	0.55	3.09
63C	0503740	Not Toxic	8.07	657	24.1	8.71	74	2.46	5.00	---	20.3	<0.03	<0.03	<0.01	0.36	4.87
EWL	0503739	Not Toxic	8.12	681	24.6	8.89	88	3.61	8.00	---	23.7	<0.03	0.07	<0.01	0.40	4.91
BWY	0503738	Not Toxic	8.17	679	25.0	9.61	74	2.74	5.00	---	24.4	<0.03	<0.03	<0.01	0.37	4.03
HOM	0503737	Not Toxic	7.62	550	25.5	5.71	>200.5	5.95	5.00	---	30.4	0.06	0.05	0.10	0.61	0.69
O63	0503736	Not Toxic	7.91	679	24.4	8.41	130	5.37	8.00	---	25.8	<0.03	<0.03	<0.01	0.38	5.6
STD	0503735	Not Toxic	8.03	668	24.7	8.68	62	3.55	7.00	---	27.6	<0.03	<0.03	<0.01	0.36	4.98
HUG	0503734	Not Toxic	7.79	658	24.4	8.64	200	4.56	8.00	---	29.1	<0.03	<0.03	<0.01	0.33	6.92
GRI	0503733	Not Toxic	8.02	747	22.4	11.0	140	2.55	5.00	---	64.7	0.06	<0.03	<0.03	0.38	0.72
HDG	0503732	Not Toxic	7.77	673	22.9	8.38	100	4.44	6.00	---	32.4	<0.04	<0.03	<0.01	0.37	9.68
RCD	0503731	Not Toxic	7.70	674	22.8	6.85	130	3.18	5.00	---	33.7	<0.03	<0.03	<0.01	0.34	8.1
BNF	0503730	Not Toxic	7.64	442	21.2	7.32	110	3.61	7.00	---	11.9	<0.04	<0.03	0.07	0.29	3.23

3.2 Low Flow Turbidity Monitoring

3.2.1 Low Flow Turbidity Background

Turbidity measures the clarity of the water caused by the presence of suspended material such as clay, silt, algae, and other microscopic organisms. Turbid conditions reduce light penetration and potentially have a negative impact on the aquatic biota by clogging the gills of fish and aquatic insects (Doisey et al. 2004, Relyea et al. 2000). Visual observations of Hinkson Creek during and for several days following a rainfall event showed that water flowing in Hinkson Creek tended to turn brown during rainfall events and remained discolored for several days afterward, suggesting increased turbidity. When compared to other stream systems within the same EDU, Hinkson Creek remained turbid for several days while other tributaries returned to normal conditions within 24-48 hours following rainfall events. A study conducted by Parris (2000) indicated that it took approximately three (3) days for Hinkson Creek to return to base flow turbidity conditions.

During the phase I portion of the study, visual observations indicated that some sites remained turbid even during base flow conditions, which was thought to be related to land disturbance activities. Therefore, in order to assess if recent or on-going land disturbance activities were affecting and/or contributing to Hinkson Creek's turbid conditions, turbidity monitoring was conducted to determine if longitudinal trends existed and/or to isolate the general area.

3.2.2 Low Flow Turbidity Sample Collection Overview

Fifteen base flow turbidity samples were collected from main-stem Hinkson Creek and nine from reference streams (Loutre and Auxvasse rivers). Analysis for turbidity was determined in the field using a Hach (Model 2100P) portable turbidimeter and reported in Nephelometric Turbidity Units (NTU). If turbidity readings were greater than 15 NTUs, surface water grab samples were also collected and submitted for NFR and VSS analyses. In addition, stream discharge measurements were collected at each location.

3.2.3 Low Flow Turbidity Results and Discussion

A summary of the turbidity data is located in Appendix D. The data were evaluated to determine if there were major longitudinal differences between the upstream sites (unurbanized section of Hinkson Creek), downstream sites (urbanized section of Hinkson Creek), and reference/control streams. During non-storm events the Hinkson Creek turbidity values ranged from 1.65 NTU to 49 NTU.

The overall mean and median turbidity values tended to increase from upstream to downstream starting at the Highway 63 connector (Figure 4). Both NFR (also referred to as suspended solids) and VSS were collected when field turbidities were 15 NTU or greater. The collection of VSS and NFR determined if the cause of turbidity was due to organic matter (e.g., suspended algae) or non-organic matter (e.g., colloidal sediments), respectively. Throughout the study, the VSS were at or below the detectable limits, indicating that turbid conditions in Hinkson Creek were the result of suspended or colloidal sediments.

Parris (2000), among other water studies, showed that there is a direct relationship between turbidity and in-stream discharge. Where in-stream discharge increases, turbidity values also increase. The Loutre River, Auxvasse River, and Bonne Femme Creek turbidities followed this relationship. However, the turbidity in Hinkson Creek was often greatest during low flow regimes. The Hinkson Creek turbidity data indicated an increase in the mean turbidity values at the Highway 63 connector. A second, but lower, increase in the mean turbidity occurred at Old Highway 63 then decreased at downstream sites. The following observations made during this study and the previous study (MDNR 2004) may contribute to the elevated turbidity values at the Highway 63 connector and downstream.

- The sharp increase at the Highway 63 connector may relate to construction activity occurring at Liberty Square, the Vandiver and Highway 63 interchange, and Ballenger Road. Visual evidence at the Liberty Square area revealed sediment leaving construction sites and accumulating on street surfaces (refer to Appendix B, Photos 4-5). In addition, other major construction activities were occurring throughout this area including the I-70 and Highway 63 interchange.

- Visual observations at a few of the drainages entering Hinkson Creek between the Mexico Gravel Road and Highway 63 connector bridge crossings indicate that sediments are being transported and deposited into Hinkson Creek. These sediment deposits may also relate to elevated turbidity values at the Highway 63 connector site.

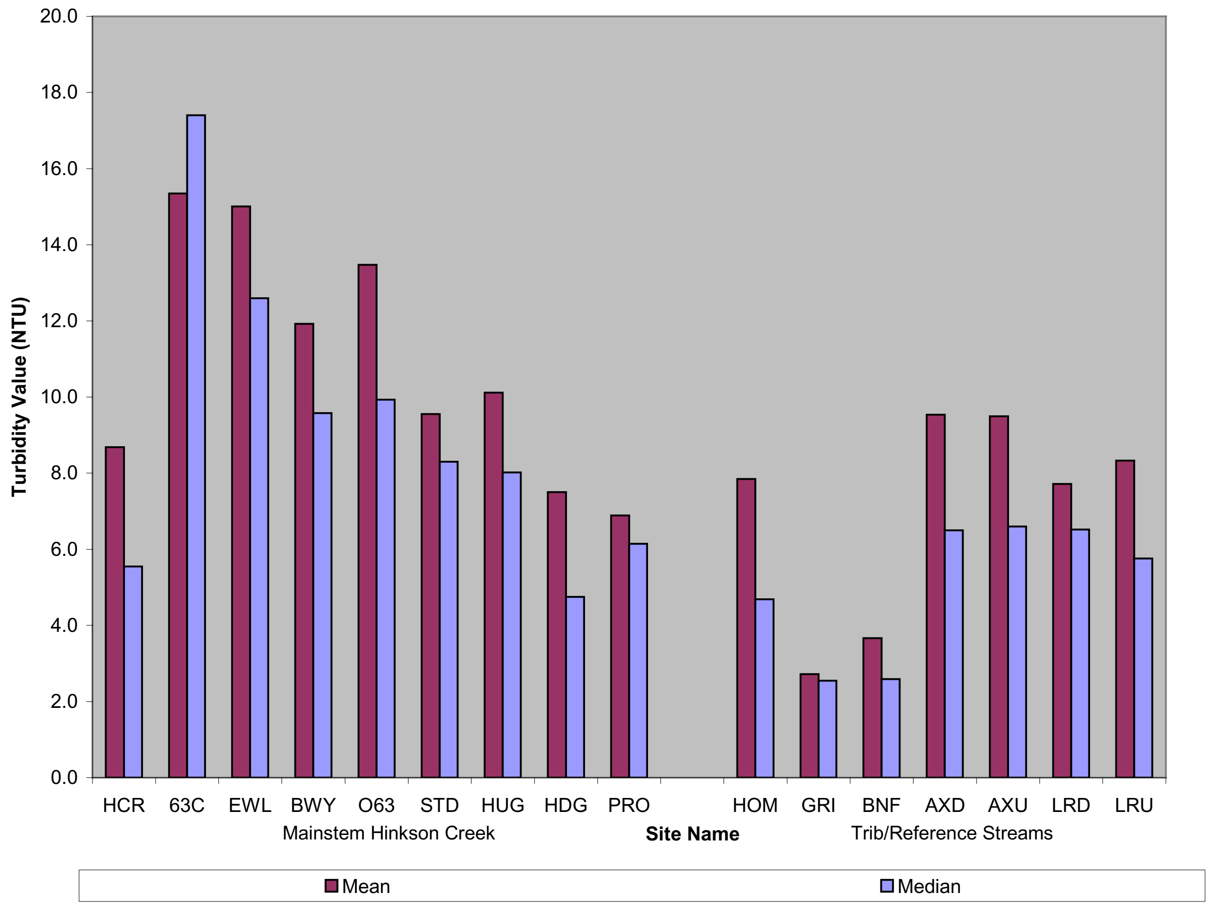
- Upstream of the Broadway bridge crossing, there is on-going construction activity along the upper east bank of Hinkson Creek across from Stephen's Lake and downstream of the old Mega Market drainage. Observations made in March 2004 and April 2005 found the bank to be slumping, creating a potential for soil to enter into Hinkson Creek (refer to Appendix B, Photos 6-7).

- Throughout the study area, there is evidence that during high flow events the stream is cutting away at the stream banks creating erosion along Hinkson Creek. Higher than normal in-stream flows occur as more impervious surfaces (e.g., roadways, parking lots, and rooftops) are constructed throughout the watershed. In addition, to prevent flooding of roadways, buildings, homes, etc., stormwater runoff is conveyed via stormwater systems where it discharges directly into stream systems. As stream flows increase, the stream banks become undercut and eventually fail, causing soil, trees, and other debris to fall into the stream (refer to Appendix B, Photos 8-9).

- During this study, bridge construction activity was occurring on the Broadway bridge crossing. The construction company worked closely with the city of Columbia and the Department of Natural Resources Northeast Regional Office during the planning stages. Best management practices (e.g., silt fences) were in place along the stream banks. A temporary rock bridge was constructed across Hinkson Creek to allow heavy equipment to pass from one side of the stream to the other. During at least one high flow event, the temporary bridge was removed by high water. The elevated turbidity levels at Old Highway 63 could possibly be due to this construction activity (refer to Appendix B, Photos 10-12).

The highest turbidities collected from Hinkson Creek were during the summer and late fall months and correlated with the Parris (2000) findings.

Figure 4. Hinkson Creek Study – Phase II Turbidity Mean/Median Base Flow Values



3.3 Stormwater Monitoring

3.3.1 Stormwater Monitoring 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 (e.g., roadways, parking lots, rooftops, compacted soils) during dry periods. During rainfall events, these constituents are transported into streams as the runoff moves across the impervious surfaces.

3.3.2 Stormwater Sample Collection Overview

During July 2004, an in-stream reconnaissance of Hinkson Creek was conducted to identify major discharge pipes and drainage systems entering Hinkson Creek. Several pipes and drainage system locations were identified (Figure 5).

Many of the drainage pipes were not accessible for monitoring. Stormwater monitoring was conducted at four (4) stormwater drainages located between the Broadway and Stadium Boulevard bridge crossings (refer to Appendix A, Map A inset map). Stormwater monitoring was conducted after a significant rainfall event that followed a relatively dry period. The monitoring locations are described below:

- **D1**: A storm drain located approximately 100 yards downstream of the East Gate bridge crossing along the west bank of Hinkson Creek was monitored. The pipe drains approximately 103.07 acres of impervious surface that drains the East Gate Plaza and two major roadway systems (Broadway and Old Highway 63). The East Gate Plaza includes the Stephens Building office complex, a laundry mat, a grocery store, and a gas station (since removed). The size of the drainage pipe is approximately four (4) feet in diameter.

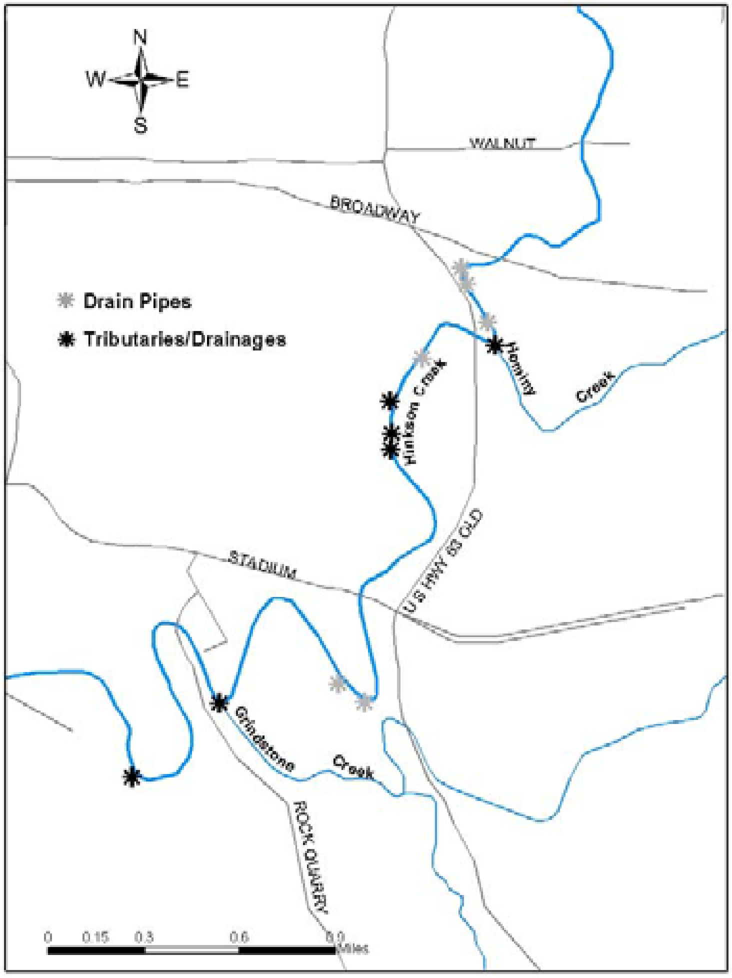
- **D2**: Two small stormwater pipes located approximately 100 yards upstream of the confluence of Hinkson Creek and Hominy Creek. The drainpipes are located along the east bank of Hinkson Creek and drain approximately 33.74 acres of land that consists of a small golf course and the Broadway Apartment complex. The sizes of the two drainage pipes are approximately four to six (4-6) inches in diameter.

- **D3**: A large drainpipe located behind a small apartment complex located off Anthony Street and adjacent to and along the south side of Boone Hospital. The storm drain drains approximately 57.18 acres of impervious surface (roadways and rooftops) located in a residential area of Columbia. The drainpipe is approximately four (4) feet in diameter.

- **D4**: A natural drainage system located in Rock Hill Park consists of two wet weather tributaries that drain a large section of Columbia located between Broadway and Stadium Boulevard. Major stormwater drainpipes (e.g., the drainpipe located near Boone Hospital as described above) convey much of the runoff from street systems and parking lots into this drainage system. In addition, a series of sewer lines and manholes are also located throughout the park system.

Since the 303(d) list designated pollutants in Hinkson Creek as unknown, a holistic approach was necessary to determine which pollutants might be present. On October 9, 2004 and October 14, 2004 stormwater samples were collected from four (4) stormwater drainages for the following parameters: Microtox, total recoverable metal (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn), QOA, VOA, BNA, petroleum fraction, chloride, NFR, and *E. coli*. All other stormwater samples collected during the study were screened for toxicity prior to submitting them for chemical analyses. Any further analytical work was dependent on the outcome of the toxicity testing.

Figure 5. Location of Drain Pipes and Tributaries/Drainages



Two types of water collection techniques were conducted over the course of the study: ISCO samplers and surface water grab samples. ISCO automatic wastewater samplers were used in conjunction with ISCO Model 1640 Liquid Level Sample Actuators to collect samples from stormwater pipes and 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 to initiate the sampling routine (Figure 6). The samplers were set to collect a composite sample of the leading edge of the runoff event (MDNR 2002c). The ISCO samplers were set at sites D1, D3, and D4. An automatic sampler could not be set at the D2 location due to the physical location of the drainpipes and potential risk of vandalism.

Surface water grab samples were collected directly from main-stem Hinkson Creek or storm drainages by collecting water samples directly from the stream or discharge pipe.

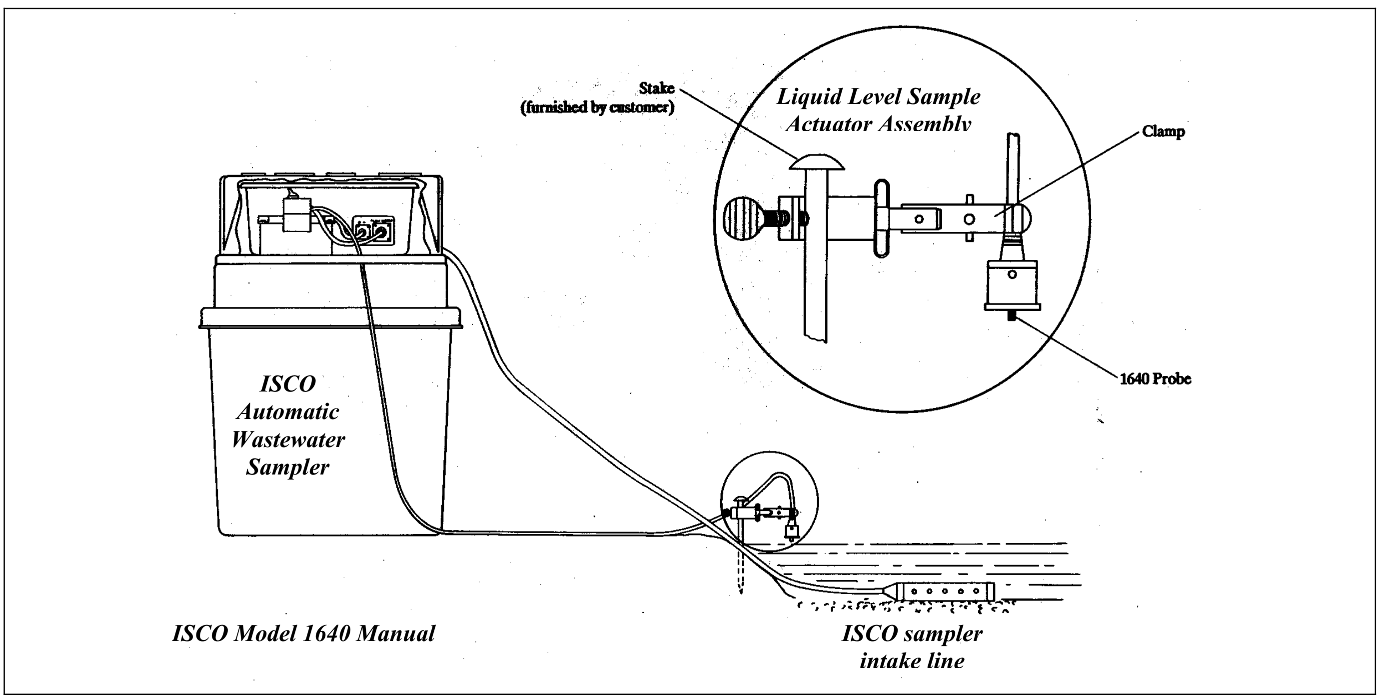
Precipitation data were collected from a weather station located at Sandborn Field at the University of Missouri-Columbia campus (Agricultural Electronic Bulletin Board http://agebb.missouri.edu/).

Stormwater samples were collected from the drainages on seven (7) occasions during the months of August 2004, September 2004, October 2004, March 2005, April 2005, and May 2005. Surface water grab samples were collected from main-stem Hinkson Creek on four (4) occasions during the months of July 2004, August 2004, September 2004, and March 2005. Please refer to Appendix D for a complete list of all the reported analytical results.

Citizen complaints were received regarding the D3 drainpipe (located behind the apartment complex near Boone Hospital). One stated that an enormous amount of water is often observed discharging from the drainpipe during non-rainfall events. The complainant further stated that the discharge is often milky white to tan.

A sewer line and series of manholes run through Rock Hill Park. On at least one occasion, a private citizen complained that a manhole routinely overflows and discharges raw wastewater into a wet weather tributary that drains into Hinkson Creek downstream of old Highway 63. The D4 stormwater sampling location was located in the lower reaches of the natural drainage.

Figure 6. Example of How the ISCO Automatic Wastewater Sampler Is Used in Conjunction With a Liquid Sample Actuator.



3.3.3 Stormwater Microtox Toxicity

None of the stormwater samples collected from main-stem Hinkson Creek or its tributaries were found to be toxic to the Microtox organisms. At various times throughout the study, with the exception of D2, water collected from each of the storm drains was found to be toxic. D1 was found to be toxic two (2) times, D2 zero (0) times, D3 four (4) times, and D4 two (2) times. Table 2 summarizes the Microtox results for the storm drainages, the Toxicity Identification Evaluation manipulations, and the constituents found during chemical analyses. If the Microtox screening test indicated a toxic effect greater than 15%, a Toxicity Identification Evaluation procedure was conducted.

Table 2. Summary of the Stormwater Monitoring Toxicity Results

Sample Date	Sample Location	Level of Effect (%)*				Analytical Results Reported Above the Detectable Limits	
		Raw	Filtered	EDTA	C_{18}	Quantitative Analyses	Qualitative Organic Analyses
8/20/04	D3	16.45	--	--	--	No further analyses requested	
10/8/04	D1	31.2	24.6	18.5	8.9	TR Arsenic 10 ug/L TR Cadmium 0.45 ug/L TR Chromium 10.4 ug/L TR Copper 13.6 ug/L TR Lead 18.7 ug/L TR Nickel 14.1 ug/L TR Zinc 134 ug/L *E. coli* >4840 mpn/100 mL Chloride 32.3 mg/L 4-methyl-2-pentanone (MIBK) 2 ug/L	1,3-Dichloro-1-propene 1-Chloro-2-ntiropropane 2,3-Dichloro-2-methylbutane Bis (2-ethylhexyl) phthalate
	D3	44.96	26.7	33.8	11.3	TR Arsenic 10 ug/L TR Cadmium 0.34 ug/L TR Chromium 12.7 ug/L TR Copper 42.2 ug/L TR Lead 19.5 ug/L TR Nickel 11.1 ug/L TR Zinc 294 ug/L TR Mercury 0.29 ug/L *E. coli* >4840 mpn/100 mL Chloride 27.3 mg/L 4-methyl-2-pentanone (MIBK) 30.2 ug/L	1,2-Dichloro-1-propene 2,3-Dichloro-2-methylbutane 9,10-Anthracenedione Chloroacetic acid anhydride Dibenzthiopene

Sample Date	Sample Location	Level of Effect (%)*				Analytical Results Reported Above the Detectable Limits	
		Raw	Filtered	EDTA	C_{18}	Quantitative Analyses	Qualitative Organic Analyses
	D4	23.21	27.7	12.9	9.8	TR Arsenic 10 ug/L TR Cadmium 0.26 ug/L TR Chromium 6.85 ug/L TR Copper 25.7 ug/L TR Lead 22.8 ug/L TR Nickel 5.84 ug/L TR Zinc 117 ug/L *E. coli* >4840 mpn/100 mL Chloride 16.7 mg/L	2,3-Dichloro-2-methylbutane 2-chloro-2-nitropropane
10/27/04	D3	26.36	14.92	19.64	3.663	Fluoranthene 5.89 ug/L	1,2,3,4,5-Pentamethylcyclopentane m-Menthane (1S,3R)-(+)
3/22/05	D4	58.64	9.72	15.58	1.396	*E. coli* >2419.6 mpn/100mL Chloride 45.4 mg/L	Not analyzed for qualitative organics
4/20/05	D1	36.98	22.52	23.85	21.51	TR Arsenic 11.9 ug/L TR Lead 5.49 ug/L TR Nickel 9.79 ug/L TR Zinc 48.7 ug/L *E. coli* >2419.6 mpn/100mL Chloride 116 mg/L	2,3-Dichloro-2-methylbutane
	D3	22.94	10.22	10.89	-0.103	TR Arsenic 7.10 ug/L TR Chromium 6.91ug/L TR lead 15.1 ug/L TR Nickel 6.01 ug/L TR Zinc 73.1 ug/L *E. coli* >2419.6 mpn/100mL Chloride 7.85 mg/L	1-Ethyl-1-methylcyclohexane 2,3-Dichloro-2-methylbutane

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

3.3.4 Stormwater *C. dubia* Toxicity Testing

On March 22, 2005 and April 21, 2005, acute toxicity tests were performed on stormwater samples using *C. dubia.* Tests were performed following standard whole effluent toxicity (WET) procedures (1998 APHA). The organisms were exposed to 100% concentrations of stormwater samples collected from the aforementioned storm drains and main-stem Hinkson Creek. The organisms were observed over a 48-hour period and mortality recorded.

3.3.5 Stormwater *C. dubia* Toxicity Testing Results

None of the samples were found to be acutely toxic to the *C. dubia* even though they were toxic to Microtox. Differences in sensitivity between the test organisms or the presence of volatile substances may account for the test results. If volatiles were the cause of toxicity to the Microtox organisms, it is possible that any volatile substances may have volatilized from the sample by the time the Ceriodaphnia test procedure was initiated. Because the collected samples are stored on ice during transport, the samples must warm to 25° C before exposing the *C. dubia* to the samples. During this time, any volatiles present may be driven off, reducing or eliminating toxicity to the *C. dubia*. For these reasons, Crunkilton et al. (1997) and Herricks et al. (1997) believe standard WET test protocols may underestimate the toxic effects of urban runoff.

3.3.6 Stormwater Monitoring Analytical Results and Discussion

Although stormwater runoff is not normally a regulated discharge, it can pose a threat to the aquatic systems in the receiving stream. The US EPA (1995) describes nonpoint source runoff pollution as that associated with rainwater or melting snow that washes off impervious surfaces (roads, bridges, parking lots, rooftops, etc.). Runoff picks up dirt and dust, rubber and metal deposits from tire wear, antifreeze and engine oil, pesticides and fertilizers, discarded debris such as cups, plastic bags, cigarette butts, pet waste, and other litter where it is ultimately carried into our lakes, rivers, streams, and oceans. A few of the constituents found in the stormwater discharges are discussed below. Many of the same components found during this study were also found in urban stream studies conducted by other researchers (USGS 2002a & b).

<u>Metals</u>
Metals in some of the stormwater drainages were at elevated levels. The presence of certain metals often is a reflection of the impervious surface types found within the localized area. Metals found in stormwater runoff may be associated with vehicle exhaust, worn tires, brake linings, and weathered paint and rust (US EPA 1995). For example, Duncan (draft document) states that higher total zinc concentrations are often associated with galvanized iron roofs.

Lee et al. (2000) states that urban stormwater runoff associated with heavy metals can contribute to causing a waterbody to be listed as a Clean Water Act 303(d) "impaired" waterbody. The synergistic effect of the metals is likely to contribute to water quality impairments as opposed to a single metal.

<u>Organics</u>
The occurrence of plasticizers (phthalates) can be attributed to plastic debris (e.g., bottles, bags) found within or around storm drains and the leaching of plasticizers from polyvinyl chloride (commonly referred to as PVC) drainpipes and/or sampling equipment. The presence of polycyclic aromatic hydrocarbons (PAH), such as fluoranthene, is often associated with incomplete combustion of fossil fuels and is a derivative of coal tar/asphalt products. The USGS (2005) stated that PAHs were 65% higher in runoff from parking lots sealed with coal-tar based sealcoat than from other types of parking lot surfaces.

<u>Bacteriological – *E. coli*</u>
E. coli values from the stormwater monitoring locations D1, D2, D3, and D4 were in excess of 2400 mpn/100 mL. Pet and other animal waste can enter stormwater that discharges to the creeks. USGS (2002a) reported that genetic source tracking of *E. coli* in the Blue River and Brush Creek in Kansas City, Missouri showed nearly equal contributions from dogs, geese, and humans.

Specific Conductivity

Specific conductivity of stormwater collected from the storm drains ranged from 106 µS/cm (D2) to 1220 µS/cm (D1). The highest conductivity values were collected from drainages D1 (average 675 µS/cm and ranged from 326 µS/cm to 1220 µS/cm) and D3 (average 361.6 µS/cm and ranged from 112 µS/cm to 665 µS/cm). The lowest conductivity values were collected from drainage D2 (average 142 µS/cm and ranged from 106 µS/cm to 198 µS/cm). Pure rainwater contains very little ions and, therefore, has very low conductivity. When elevated conductivity values are found in stormwater runoff, it is an indication that the rainwater runoff is picking up and transporting materials deposited on the ground and/or impervious surfaces.

Chloride

Chloride levels of stormwater ranged from 5.00 mg/L (D2) to 148 mg/L (D1). The highest chloride values were collected from drainages D1 (average 64.5 mg/L and ranged from 23.6 mg/L to 148 mg/L) and D3 (average 34.5 mg/L and ranged from 7.85 mg/L to 74.8 mg/L). The lowest chloride values were collected from drainage D2 (average 5.7 mg/L and ranged from 5.00 mg/L to 7.46 mg/L). Chloride is a component used in road salt that is widely used throughout the United States. For background purposes, chloride samples were collected throughout the study from main-stem Hinkson Creek and from the stormwater drainages. The purpose of the sampling was to compare the non-snow event data to the winter snowmelt event data. However, during the winter of 2005-2006, central Missouri experienced a mild winter in which a significant snowfall accumulation event did not occur.

Turbidity

Turbidity values collected from the storm drains ranged from 2.85 NTU (D2) to 374 NTU (D3). The highest turbidity values were collected from D3 (average 218.3 NTU and ranged from 49.2 NTU to 374 NTU) and D4 (average 90.2 NTU and ranged from 5.0 NTU to 227 NTU). The lowest turbidity values were collected from D2 (average 16.8 NTU and ranged from 2.85 NTU to 35.1 NTU).

Discharge

In-stream discharge and storm drain measurements were not determined during storm events. However, observed discharges from the stormwater drainage pipes after small rainfall events were impressive. Storm drain systems are generally designed to quickly convey runoff (e.g., rain, snowmelt) from impervious surfaces such as parking lots and roadways. In an urban setting, where population densities and areas of impervious surface are greatest, excessive runoff events negatively impact the hydrology of the receiving stream (Stankowski 1972). Increased peak flow rates in the receiving stream increase channelization which, in turn, results in loss and degradation of in-stream and riparian habitats, and in-stream sedimentation due to stream channel scour and stream bank erosion (Arnold and Gibbons 1996, Booth and Jackson 1997, Wang 2001). Increased peak flow events inevitably cause changes in water quality (e.g., suspended sediments) (Byron and Goldman 1989, Trimble 1997), and biotic composition (e.g., invertebrates and fish) (Richards et al. 1996, Yoder et al. 1999).

3.4 SPMD Monitoring

3.4.1 SPMD Background

During the first phase of the Hinkson Creek study, it was noted that periodically stormwater discharges contained pesticides, PAHs, and/or BNAs. The contaminant discharges were considered episodic throughout the study period. During the second phase of the study, Semi-Permeable Membrane Devices (SPMDs) were deployed to determine if bioaccumulative organic compounds were present in Hinkson Creek and were bioavailable to aquatic organisms.

3.4.2 SPMD Sample Collection Overview

Prior to in-stream deployment, three SPMD spindles (spiders) were removed from an airtight storage container and placed in a stainless steel deployment canister. The deployment canister was then submerged and secured to the stream bottom at four locations along Hinkson Creek (Hinkson Creek Road (**HCR**), Broadway (**BWY**), Recreational Drive (**RCD**), and Scott Boulevard (**STB**) bridge crossings). One canister was also deployed in Bonne Femme (**BNF**) near the Nashville Church Road bridge crossing. The SPMDs were deployed during March 2005 for a 14-day deployment period.

3.4.3 SPMD Analytical Results and Discussion

Table 3 provides a list of the organic constituents that were found during the 14-day deployment period. All the constituents were found in low concentrations. A few of the constituents are discussed below:

> Chloropyrifos and Oleic acid, 3-hydroxypropyl ester are associated with pesticide products and/or pesticide breakdown products. Pesticides are often associated with watershed use and the types are often associated with seasonal use. The upper reaches of the Hinkson Creek watershed consist of rural and agricultural land, while the lower reaches are urbanized, containing a variety of urban type land uses (e.g., residential, commercial, industrial).
>
> Phthalates and hexanedioic acid are often associated with plasticizing agents (a type of polymer or resin additive) that are used to give plastics (vinyl) flexibility and durability (http://www.vinylbydesign.com/site/tertiary.asp?TRACKID=&VID=2&CID=5&DID=227). As plastics are exposed to ambient environmental conditions and UV light, they begin to degrade, allowing plasticizing agents to leach into the environment (Carstensen 1998). Throughout this study and on numerous occasions, plastic bottles and plastic grocery type bags were located in and around the drainage pipes and were also found deposited in main-stem Hinkson Creek at various locations.
>
> The presence of low level pharmaceuticals and/or breakdown products (such as Fenretinide and Verapamil) was unexpected yet similar to other urban stream studies.

Long chain fatty acids (such as oleic acid, squalene, stigmastan, octadecanoic acid, and hexadecanoic acid) are found in body oils and are also associated with oil and grease products used in cooking and miscellaneous manufacturing products.

Table 3. Hinkson Creek SPMD Qualitative Organic Analysis Results

SMPD Results	Dialysis Blank	Trip Blank	HCR	BWY	RCD	STB	BNF
.beta-Sitosterol acetate				X	X	X	X
1,1-Dichloro-1-propene			X		X	X	
1,2,3-Trichloro-2-methyl propane				X	X	X	X
1,2-Dichloro-1-propene	X	X					X
1,3-Dichloro-3-methyl butane							X
1,9-Dichlorononane				X			
1-Decyne				X			
1-Heptatriacotanol						X	
2,3-dichloro-2-methyl butane	X	X	X	X	X	X	
2,4,6-Tris (1,1-dimethylethyl) phenol			X				
2,5-Bis (1,1-dimethylethyl) phenol					X		
2-Butyl-1-octanol			X		X		
2-Chloroethyl oleate		X		X	X		
2-Hexyl-1-octanol			X				X
9,17-Octadecadienal (z)							X
9-Octadecenoic Acid		X		X	X	X	
Bis (2-ethylhexyl) phthalate			X		X		
Cholesta-3,5-diene		X		X	X	X	X
Chloropyrifos					X		
Dibutyl phthalate			X		X		
Fenretinide				X		X	
Hexanedioic acid, mono (2-ethylhexyl) ester					X		
Longifolenaldehyde							X
O-Decyl-hydroxylamine			X				
Oleic acid, 3-hydroxypropyl ester					X		
Pregnane-18,20-diol (5.alpha)						X	
Squalene				X	X	X	
Stigmast-5-en-3-ol, oleate			X				
Stigmasta-5,22-dien-3-ol, acetate (3.beta.22E)							X
Stigmastan-3,5,22-trien				X	X		
Triolein					X		
Verapamil			X		X		

4.0 Phase II Hinkson Creek Biological Assessment

Biological assessment monitoring was conducted in the spring and fall of 2005. Spring 2005 data are presented in this portion of the report. Because fall 2005 samples are currently being analyzed, a separate report will be prepared in the future to present both sets of data. This portion of the study adds a biological component to the water quality survey and is focused on the segment of stream being evaluated relative to stormwater and sediment monitoring. The study area consisted of approximately 5.5 miles of Hinkson Creek, with all but the upper site (Station 7) being included in the impaired segment. A total of four Hinkson Creek biological monitoring stations were surveyed:

Station Reference Number	Station Location
7	Hinkson Creek Road
6	East Walnut Street
5.5	Broadway
3.5	Recreation Drive (east of Providence Rd.)

4.1 Macroinvertebrate Collection and Analysis

Please refer to Appendix A, Map C for the general locations of the biological monitoring stations. Sampling was conducted during the spring and fall of 2005. Comparisons of the Hinkson Creek macroinvertebrate community were made longitudinally among stations, with the downstream three stations compared to Station 7. Station 7, located approximately 4.5 miles upstream of I-70, is in a rural portion of the watershed and serves as a comparison to downstream reaches with more urban influence. Hinkson Creek macroinvertebrate data also were compared to reference streams within the same EDU.

The macroinvertebrate data were analyzed in two specific ways. First, upstream to downstream longitudinal comparisons of Hinkson Creek were made. Secondly, data from Hinkson Creek were compared to macroinvertebrate community data collected from biological criteria 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.

4.2 Biological Assessment Results

4.2.1 Assessment of the Macroinvertebrate Communities

Hinkson Creek Longitudinal Comparison
The macroinvertebrate community from Station 7, representative of the largely rural upstream Hinkson Creek watershed, was compared with the community within this study's urbanized reach (Stations 3.5, 5.5, and 6) to observe whether the differences observed in previous biological assessments (MDNR 2002, 2004) were still present. Biological indices that exhibited notable changes among stations were EPT Taxa and Biotic Index scores (Table 4). Numbers of EPT Taxa showed a general downward trend while progressing downstream. Despite this trend, however, Taxa Richness was highest in the middle reaches. Biotic Index was highest at Station 3.5 and lowest at the two upstream stations. Despite the trends demonstrated by the EPT Taxa and Biotic Index values, only Station 3.5 failed to achieve a

sufficient SCI score to merit fully supporting status. Stream Condition Index scores were comparable among the remaining sites, with each of the three upstream sites having SCI scores sufficient to achieve fully supporting status.

Table 4. Hinkson Creek Metric Values and Scores, Spring 2005, Using Ozark/Moreau/Loutre Biocriteria Reference Database

Station #	TR	EPT Taxa	BI	SDI	SCI	Support
#7 Value	70	14	5.93	2.99		
#7 Score	3	5	5	5	18	Full
#6 Value	76	13	5.94	2.84		
#6 Score	5	3	5	5	18	Full
#5.5 Value	76	10	6.62	2.82		
#5.5 Score	5	3	3	5	16	Full
#3.5 Value	69	8	7.04	2.98		
#3.5 Score	3	3	3	5	14	Partial

Comparison of Hinkson Creek versus Ozark/Moreau/Loutre EDU Biocriteria Reference Sites
The metrics calculated for Hinkson Creek were compared to biological criteria derived for the Ozark/Moreau/Loutre EDU Biocriteria Reference Sites. These criteria are listed for the spring sampling season in Table 1. This comparison was made to assess the degree to which using biological criteria was applicable for Hinkson Creek. Most of the biocriteria reference streams are fourth and fifth order streams, whereas Hinkson 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 spring sample season at Hinkson Creek (Table 4) were comparable to the biological reference metrics and, with the exception of Station 3.5, each Hinkson Creek station was categorized as fully supporting.

Macroinvertebrate Percent and Community Composition
Macroinvertebrate Taxa Richness, EPT Taxa, and percent EPT Taxa are presented in Table 5. This table also provides percent composition data for the five dominant macroinvertebrate families at each Hinkson Creek station. The percent relative abundance data were averaged from the sum of three macroinvertebrate habitats—coarse substrate, non-flow, and rootmat—sampled at each station.

The spring 2005 macroinvertebrate sample from Hinkson Creek upstream control Station 7 contained 70 total taxa and 14 EPT Taxa (Table 5). Test stations 5.5 and 6 each had 76 total taxa and slightly lower numbers of EPT Taxa. Station 3.5, the most downstream site, had 69 total taxa and 8 EPT Taxa. One mayfly species, *Caenis latipennis*, was among the dominant five taxa at each of the stations. This species was most abundant at Station 7 and experienced a notable decline among the downstream urban stations. Chironomidae (midge) larvae were the dominant taxa at each Hinkson Creek station and their relative percentages were similar among sites. Caenid mayflies, chironomids, and riffle beetles (Elmidae) were consistently among the dominant taxa present in all Hinkson Creek samples. Perlid stoneflies were among the dominant taxa at all but Station 3.5, where they were present at only a fraction of the abundance of other stations. Only two genera, *Perlesta* and *Amphinemura*, accounted for all of the stoneflies in spring samples. *Perlesta* was the only taxon present at Stations 3.5 and 5.5 and accounted for 98 percent of the stonefly total at Station 6 and 96 percent at Station 7. *Amphinemura*, when present, were very rare, with a total of three individuals occurring among all samples. Aquatic worms (Tubificidae) were among the dominant taxa at all urban stations and were nearly twice as abundant at Station 3.5 compared to the remaining sites. Tubificids were relatively rare at Station 7, where only a few individuals were present in samples.

In addition to a trend of declining EPT Taxa in downstream stations, mayflies and stoneflies tended to account for lower percentages of the total samples in the downstream stations (Table 5). Percentages of caddisflies were low at all stations and no longitudinal trends were observed. Aquatic worms, all of which have high individual Biotic Index values, were over twice as abundant at Station 3.5 as the remaining sites. In addition, stoneflies were much less numerous at Station 3.5; this combination is the likely reason that the overall Biotic Index score was much higher at this site.

Table 5. Spring 2005 Hinkson Creek Macroinvertebrate Composition

Variable-Station	**7**	**6**	**5.5**	**3.5**
Taxa Richness	70	76	76	69
Number EPT Taxa	14	13	10	8
% EPT Taxa	20	17	13	12
% Ephemeroptera	9.0	6.0	4.2	2.6
% Plecoptera	3.7	5.3	2.8	0.5
% Trichoptera	0.9	0.3	1.0	0.2
% Dominant Families				
Chironomidae	64.4	68.4	69.7	67.5
Elmidae	12.4	8.6	8.3	9.9
Caenidae	6.9	4.3	3.0	2.0
Perlidae	3.6	5.2	2.8	--
Hyalellidae	1.7	--	--	--
Tubificidae	--	4.5	5.3	11.8
Coenagrionidae	--	--	--	2.1

Percent EPT Taxa Comparison

The percent EPT Taxa was calculated to provide another way to compare macroinvertebrate data among 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. Table 5 provides a comparison of the percent EPT Taxa found in each of the Hinkson Creek sample sites.

The percentage of EPT Taxa in spring samples collected from Ozark/Moreau/Loutre EDU reference streams between 1998 and 2001 made up an average of 22 percent (range 19-27) of the total number of taxa. By comparison, the 20 percent EPT Taxa at Hinkson Creek Station 7 was similar to many of the reference sites and to the station's percentages from two previous Hinkson Creek studies. Although the percent EPT Taxa at Station 6 has undergone consistent increases since the first spring Hinkson Creek samples were collected in 2002 (11 in 2002, 13 in 2004, 17 in 2005), the percentage remains lower than that of the upstream reference reach.

4.2.2 Biological Assessment Discussion

EPT Taxa tended to decline in downstream stations, although there was not a corresponding trend with Taxa Richness. Taxa Richness values were highest at the two middle stations, with the up- and downstream stations equal to each other at slightly lower levels. There were no consistent differences among sites to explain the relatively low Taxa Richness levels at Station 3.5 and Station 7. Some taxa that were present in lower numbers at Station 7 compared to the middle stations included mollusks and chironomids. Taxa underrepresented at Station 3.5, compared to the middle stations, included mollusks, caddisflies, and chironomids. The fact that there were only minor differences in Taxa Richness among sites is reflected in the Quantitative Similarity Index (QSI) (MDNR 2003), a measure of taxa similarity between two sample stations. The lowest scores occurred when comparing Station 7 with Station 3.5 (QSI = 63.7) and Station 5.5 (QSI = 64). Comparing Station 6 with Station 5.5 yielded the highest QSI score of 75.9. As expected, based on a review of the biological metrics, the two middle sites are most similar to one another and, despite equality in the Taxa Richness metric at Stations 7 and 3.5, the macroinvertebrate community is not equitable at the two sites.

Biological metrics describing the macroinvertebrate community at Station 6 during this study exhibited a considerable increase compared to spring samples collected in 2002 and 2004 and, for the first time among three sample seasons, were sufficient to merit a fully supporting SCI score. Compared to 2002, Taxa Richness increased by 14 taxa and EPT Taxa nearly doubled, increasing by 7. In contrast, these two metrics declined at Station 7 during the same time period. Despite Taxa Richness dropping by 11 taxa and EPT Taxa falling by 4 at Station 7, however, the SCI score has remained constant. The QSI value comparing Station 6 with Station 7 also has increased from spring 2002 (QSI = 63.2) to spring 2005 (QSI = 71.8). The improvement in metric scores and the increasing similarity index between Station 6 and Station 7 could be interpreted as a demonstration that Station 6 is developing better potential to support a diverse macroinvertebrate community. This increased potential at Station 6 may result from a decrease of the quantity and frequency of perturbations that were observed and/or suspected in previous years (e.g., sewer bypasses, petroleum products, insecticides, road salt, and sediment).

Although Station 6 appears to have improved compared to previous years, the macroinvertebrate community within the urbanized reach nevertheless showed some important differences compared to the upstream reference reach. Most notably, Station 3.5 had a fraction of the number of mayflies and stoneflies compared to each of the other stations. In addition, each of the urbanized reaches had much higher numbers of tubificid worms than Station 7. Tubificids were nearly twice as abundant at Station 3.5 than at the next nearest site. Tubificid worms tend to be tolerant of sediment and also organic pollutants. This higher abundance of tubificids within the urbanized sample reach might reflect previously documented inputs of sediment and organic loading (e.g., bypasses, etc.). Regardless of the source, some factor(s) at Station 3.5 appear to favor tubificids and hinder the augmentation of mayflies and stoneflies.

5.0 Phase II Hinkson Creek Study Summary

According to the US EPA (1994), nonpoint 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. As was found during this study and discussed by Waters (1995), stormwaters can carry a variety of materials such as road salt, herbicides/pesticides, and PAHs, along with other organic materials. The Hinkson Creek phase II findings are summarized below:

- *In-situ* conductivity values were higher in Hinkson Creek during base flow when compared to reference/control streams within the same EDU. During runoff events, the highest conductivity levels were from the D1 storm drain located at the East Gate Plaza.

- Turbidity levels were highest at the Highway 63 connector and old Highway 63 sites during base flow events. The trend was higher turbidity in urbanized portions of Hinkson Creek as compared to unurbanized portions of Hinkson Creek and nearby reference streams. During runoff events, the highest turbidity values were collected from the D3 storm drain.

- Chloride values in Hinkson Creek were approximately 40% higher when compared to reference/control streams within the same EDU during base flow events. The highest chloride values were collected from the D1 storm drain located at the East Gate Plaza.

- Toxicity tended to be sporadic. None of the sampled drainages were found consistently toxic. Of the stormwater samples collected, eight (8) samples were toxic to the Microtox organisms. Metals (arsenic, chromium, copper, lead, nickel, zinc), organic constituents (e.g., PAHs), and plasticizers were the main constituents found.

- SPMD analyses indicated the presence of several low-level semi-volatile organic chemicals (e.g., pesticides and/or breakdown products, phthalates, and pharmaceutical drugs) that have the potential to bioaccumulate in aquatic organisms.

- The improvement in macroinvertebrate metric scores and the increasing similarity index between Station 6 and Station 7 could be interpreted as a demonstration that Station 6 is developing better potential to support a diverse macroinvertebrate community. This increased potential at Station 6 may result from a decrease of the quantity and frequency of perturbations that were observed and/or suspected in previous years (e.g., sewer bypasses, petroleum products, insecticides, road salt, and sediment).

- The macroinvertebrate community within the urbanized reach showed some important differences compared to the upstream reference reach. Most notably, Station 3.5 had a fraction of the number of mayflies and stoneflies compared to each of the other stations. In addition, each of the urbanized reaches had much higher numbers of tubificid worms than Station 7. Tubificids were nearly twice as abundant at Station 3.5 than at the next nearest site. Tubificid worms tend to be tolerant of sediment and also organic pollutants. The higher abundance of tubificids within the urbanized reach might reflect previously documented inputs of sediment and organic loading (e.g., bypasses, etc.).

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. As best described by Booth and Jackson (1997): "urbanization of a watershed degrades both the form and the function of the downstream aquatic system, causing changes that can occur rapidly and are very difficult to avoid or correct."

With the growing amount of impervious surfaces located in the Hinkson Creek watershed, we can suspect that hydrologic changes have and will continue to occur in Hinkson Creek. Other urban stream studies cited within this report 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. These negative impacts can be mitigated to varying degrees, however, by proper planning and use of low impact development techniques.

Progressive and innovative land management and land use practices are needed to prevent further degradation of Hinkson Creek and other urban streams located throughout the state of Missouri. Low impact development, such as decreasing and slowing stormwater discharges and creating grassy and/or vegetative swales to capture small precipitation events that allow water to percolate through the soil to recharge groundwater systems, is a method that can help mitigate detrimental effects of urbanization on streams. Educational efforts focusing on the importance of stormwater management practices are currently being used in the Great Lakes region and in the eastern and western coastal regions and are becoming increasingly considered in Midwestern communities.

6.0 References and Citations

Agricultural Electronic Bulletin Board (http://agebb.missouri.edu/). Precipitation data was collected for a weather station located at Sandborn Field on University of Missouri-Columbia campus.

APHA. 1998. American Public Health Association. Standard Methods for the Examination of Water and Wastewater. (20th ed.), Washington D.C., (Part 8050 B).

Arnold, C.L., and C.J. Gibbons. 1996. Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. Journal of the American Planning Association. 62:243-258.

Booth, D. B., C. R. Jackson. 1997. Urbanization of Aquatic Systems – Degradation Thresholds, Stormwater Detention, and Limits of Mitigation. Journal of the American Water Resources Association. Vol. 22. No. 5.

Brown, K. 2002. The Effect of Temperature on the Survival of Fecal Coliform Bacteria Present in Goose Droppings. An Environmental Science Paper Presented to Junior Science, Engineering Symposium, University of Missouri-St. Louis. Unpublished data.

Bulich, A.A., M.W. Green, and D.L. Isenberg. 1981. Reliability of the Bacterial Luminescence Assay for Determination of the Toxicity of Pure Compounds and Complex Effluents. In J.G. Pearson, R.B. Foster, and W.E. Bishops (Eds.), Aquatic Toxicology and Hazard Assessment. ASTM STP 737. American Society for Testing and Materials, Philadelphia, PA: 338-347.

Burton, G. A., and R.E. Pitt. 2002. Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists, and Engineers, Lewis Publishers.

Byron, E. R., C. R. Goldman. 1989. Land-Use and Water Quality in Tributary Streams of Lake Tahoe, California-Nevada. Journal of Environmental Quality. Vol. 18:84-88.

Carstensen, M. 1998. Biochemical Plasticizers. The Carbohydrate Economy Clearinghouse Document Library. Pollution Solutions Fact Sheets. http://www.carbohydrateeconomy.org/library/admin/uploadedfiles/Biochemical_Plasticizers.html

Chapman, S.S., J.M. Omernik, G.E. Griffith, W.A. Schroeder, T.A. Nigh, and T.F. Wilton. 2002. Ecoregions of Iowa and Missouri (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,800,000).

City of Columbia, Missouri. About Columbia. City Facts and Demographics (Budget Document). http://www.gocolumbiamo.com/Documents/demographics.pdf

Crunkilton, R., J. Kleist, J. Ramcheck, W. DeVita, and D. Villeneueve. 1997. Assessment of the Response of Aquatic Organisms to Long-term *Insitu* Exposures of Urban Runoff. Pages 95-111 in L. Roesner, editor. Effects of Watershed Development and Management on Aquatic Ecosystems. Published by the American Society of Civil Engineers. 345 East 47th Street. New York, New York 10017-2398.

D'Itri, F.M. 1992. Editor. Chemical Deicers and the Environment. Lewis Publishers. 121 South Main Street, P.O. Drawer 519, Chelsea, Michigan 48118.

Doisy, K.E., and C.F. Rabeni. 2004. Effects of Suspended Sediment on Native Missouri Fishes: A Literature Review and Synthesis. University of Missouri. Anheuser-Busch Natural Resources Building. Columbia, Missouri. pp. 161.

Duncan, Hugh. Draft Document. Australian Runoff Quality. Chapter 3. Urban Stormwater Pollutant Concentrations and Loads. URL Address: http://www.eng.newcastle.edu.au/~ncwe/ncweARQ/arqDownload.htm

EST - Environmental Sampling Technologies. Product: Semipermeable Membrane Device (SPMD) and its Deployment. http://www.est-lab.com/spmd.php

Hall, T.J., R.K. Haley, J.C. Gislason, and G.G. Ice. 1994. The Relationship Between Fine Sediment and Macroinvertebrate Community Characteristics: A Literature Review and Results from NCASI Fine Sediment Studies. National Council of the Paper Industry for Air and Stream Improvement. Technical Bulletin 418, New York.

Hanes, R.E., L.W. Zelazny, and R.E. Blaser. 1970. Effects of Deicing Salts on Water Quality and Biota. Literature Review and Recommended Research. National Cooperative Highway Research Program. Report 91.

Herricks, E.E., R. Brent, I. Milne, and I. Johnson. 1997. Assessing the Response of Aquatic Organisms to Short-Term Exposures to Urban Runoff. Pages 112-128 in L. Roesner, editor. Effects of Watershed Development and Management on Aquatic Ecosystems. Published by the American Society of Civil Engineers. 345 East 47th Street. New York, New York 10017-2398.

Kaiser L. E. and V. S. Palabrica. 1991. *Photobacterium phosphoreum* Toxicity Data Index, Water Poll. Res. J. Canada, Vol. 26, No. 3, 361-431.

Kaushal S.S, P.M. Groffman, G.E. Likens, K.T Belt, W.P. Stack, V.R. Kelly, L.E. Band, and G.T. Fisher. 2005. Increased Salinization of Fresh Water in the Northern United States. Proceedings of the National Academy of Sciences of the United States of America. Vol. 102. No. 38, 13517-13520.

Lee, G.F., A. Lee-Jones. 2000. "Development of TMDL Goals and Wet Weather Standards for the Control of Heavy Metals in Urban Stormwater Runoff. Proceedings Water Environment Federation National 73rd Annual Conference, Anaheim, California.

Lee, G.F., and A. Lee-Jones. 2002. "Appropriate Use of Chemical Information in a Best Professional Judgement Triad Weight of Evidence Evaluation of Sediment Quality," Report of G. Fred Lee & Associates, El Macero, California.

MacDonald D.D., C.G. Ingersoll, T. Berger. 2000. Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31.

McMurtry, D. 2002. Missouri Department of Conservation. Giant Canada Goose Facts (http://mdc.mo.gov/landown/wild/nuisance/w_geese/canadageese/). Document ID: PLS 051.

MDNR. 2002a. Biological Assessment Report, Hinkson Creek, Boone County. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 29.

MDNR. 2002b. MDNR-FSS-018. Sample Handling: Field Handling, Transportation, and Delivery to the ESP Lab. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 3.

MDNR. 2002c. MDNR-WQMS-215. Set-up and use of the ISCO Model 1640 Liquid Level Sample Actuator. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 7.

MDNR. 2003a. MDNR-FSS-001. Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 21.

MDNR. 2003b. MDNR-FSS-003. Sample Numbering and Labeling. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 6.

MDNR. 2003c. MDNR Project Procedure. Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 24.

MDNR. 2003d. MDNR Project Procedure. Stream Habitat Assessment. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 40.

MDNR. 2004. Hinkson Creek Stream Study. Columbia, Missouri. Boone County. Missouri Department of Natural Resources. pp. 61.

MDNR. 2005a. MDNR-FSS-002. Field Sheet and Chain of Custody Record. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 8.

MDNR. 2005b. MDNR-WQMS-209. Taxonomic Levels for Macroinvertebrate Identifications. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 30

MDNR QAPP. 2005. Quality Assurance Project Plan for Wasteload Allocation. Missouri Department of Natural Resources. Jefferson City, Missouri. pp. 20.

MDNR NPDES Facilities. 2004. Missouri National Pollutant Discharge Elimination System (NPDES) Facilities Shapefile. Missouri Department of Natural Resources. Jefferson City, Missouri.

Mo CSR. 2004. Missouri Code of State Regulations (Mo CSR). Rules of Department of Natural Resources, Division 20 – Clean Water Commission, Chapter 7-Water Quality. pp. 136.

Microtox Omni Software. 1999. Version 1.18. AZUR Environmental.

MoRAP. 2001. Missouri Resources Assessment Partnership (MoRAP). Ecological Drainage Units of Missouri. Map Series 2001-001, Unpublished data. Columbia, Missouri.

MoRAP. 2005. Missouri Resources Assessment Partnership (MoRAP). Missouri Land Cover. Raster Digital Data.

Munkittrick, K.R., E.A. Power, and G.A. Sergy. 1991. The Relative Sensitivity of Microtox, Daphnid, Rainbow Trout, and Fathead Minnow Acute Lethality Tests. Environmental Toxicology and Water Quality, 6: 35-62. Ref #231.

Parris, J. T. 2000. Temporal Variability in the Physical, Chemical, and Biological Parameters of Hinkson Creek in Response to Changes in Discharge. M.S. University of Missouri-Columbia. pp. 173.

Pflieger, W.L. 1989. Aquatic Community Classification System for Missouri. Missouri Department of Conservation. Jefferson City, Missouri. Aquatic Series No. 19. pp. 70.

Relyea, C.D., G.W. Minshall, R.J. Danehy. 2000. Stream Insects as Bioindicators of Fine Sediment. Stream Ecology Center, Department of Biological Sciences, Idaho State University, Pocatello, ID. Watershed Management 2000 Conference. Water Environment Federation.

Richards, C., L. B. Johnson, G. E. Host. 1996. Landscape-Scale Influences on Stream Habitats and Biota. Canadian Journal of Fisheries and Aquatic Science. 53 (Suppl. 1): 295-311.

Schueler, T.R. 1994. The Importance of Imperviousness. Watershed Protection Techniques. 1:100-111.

Sowa, S.P., D.D. Diamond, R. Abbitt, G.M. Annis, T. Gordon, M.E. Morey, G.R. Sorensen, and D. True. 2004. The Aquatic Component of GAP Analysis: Missouri Prototype. Final Report to The United States Department of Defense Legacy Program. Project No. 981713 and 991813.

Stankowski, S.J. 1972. Population Density as an Indicator of Urban and Suburban Land-Surface Modifications. U.S. Geological Survey Professional Paper. 800-B:B219-B224.

Thom, R.H. and J.H. Wilson. 1980. The Natural Division of Missouri. Transactions, Missouri Academy of Sciences. Vol. 14. pp.23.

Trimble, S.W. 1997. Contribution of Stream Channel Erosion to Sediment Yield from an Urbanizing Watershed. Science, 00368075. Vol. 278. Issue 5342.

USDA. 1978. United States Department of Agriculture (USDA). Soil Conservation Service in Cooperation with Missouri Agriculture Experiment Station. General Soil Map: Missouri. CSC 5, S-36-595.

US EPA. 1988. United States Environmental Protection Agency (US EPA). Ambient Water Quality Criteria for Chloride. Unites States Environmental Protection Agency. Office of Research and Development. Environmental Research Laboratory. Duluth, Minnesota. EPA 440/5-88-001.

US EPA. 1991. United States Environmental Protection Agency (US EPA). Methods For Aquatic Toxicity Identification Evaluations: Phase I Toxicity Characterization Procedures. United States Environmental Protection Agency. Washington D.C. 2nd Ed., EPA-600/6-91/003.

US EPA. 1993. United States Environmental Protection Agency (US EPA). Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Water. United States Environmental Protection Agency. Washington D.C. EPA 840-92-002.

US EPA. 1994. United States Environmental Protection Agency (US EPA). The Quality of Our Nations Water. United States Environmental Protection Agency. Washington D.C. EPA 841-S-094-002.

US EPA. 1995. United States Environmental Protection Agency (US EPA). Controlling Nonpoint Source Runoff Pollution from Roads, Highways, and Bridges. Washington D.C. EPA 841-F-095-008a.

USGS. United States Geological Survey (USGS). SPMD Technology Tutorial. 3rd Edition. Updated January 03, 2002. http://wwwaux.cerc.cr.usgs.gov/SPMD/SPMD-Tech_Tutorial.htm

USGS. 2002a. United States Geological Survey (USGS). Effects of Wastewater and Combined Sewer Overflows on Water Quality in the Blue River Basin, Kansas City, Missouri and Kansas, July 1998-October 2000. Water-Resources Investigations Report 02-4107. pp. 162.

USGS. 2002b. United States Geological Survey (USGS). Water Quality, Selected Chemical Characteristics, and Toxicity of Base Flow and Urban Stormwater in the Pearson Creek and Wilson's Creek Basins, Greene County, Missouri, August 1999 to August 2000. Water-Resources Investigations Report 02-4124. pp. 80.

USGS. 2005. Unites States Geological Survey News Release. Parking Lot Sealant Identified as Major Contaminant. Release Date: June 22, 2005.

Waters, T. 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society, Monograph 7.

Wang, L., J. Lyons, P. Kanehl. 2001. Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales. Environmental Management. Vol. 28, No.2. pp. 255-266.

Vinyl by Design: An Information Resource for Building Design Professionals. http://www.vinylbydesign.com/site/tertiary.asp?TRACKID=&VID=2&CID=5&DID=227

Yoder, C.O., R.J. Miltner, and D. White. 1999. Assessing the Status of Aquatic Life Designated Uses in Urban and Suburban Watersheds. Pages 16-28 in R. Kirschner, editor. National Conference of Retrofit Opportunities for Water Resources Protection in Urban Environments EPA/625//R-99/002, Columbus, Ohio.

Submitted by: ______________________________ ______________________________

Patricia A. Rielly	Randy Crawford
Hinkson Creek Project Officer	Water Quality Monitoring Supervisor
Environmental Specialist	Environmental Services Program
Water Quality Monitoring Section	
Environmental Services Program	

Date: ______________________________

Approved by: ______________________________

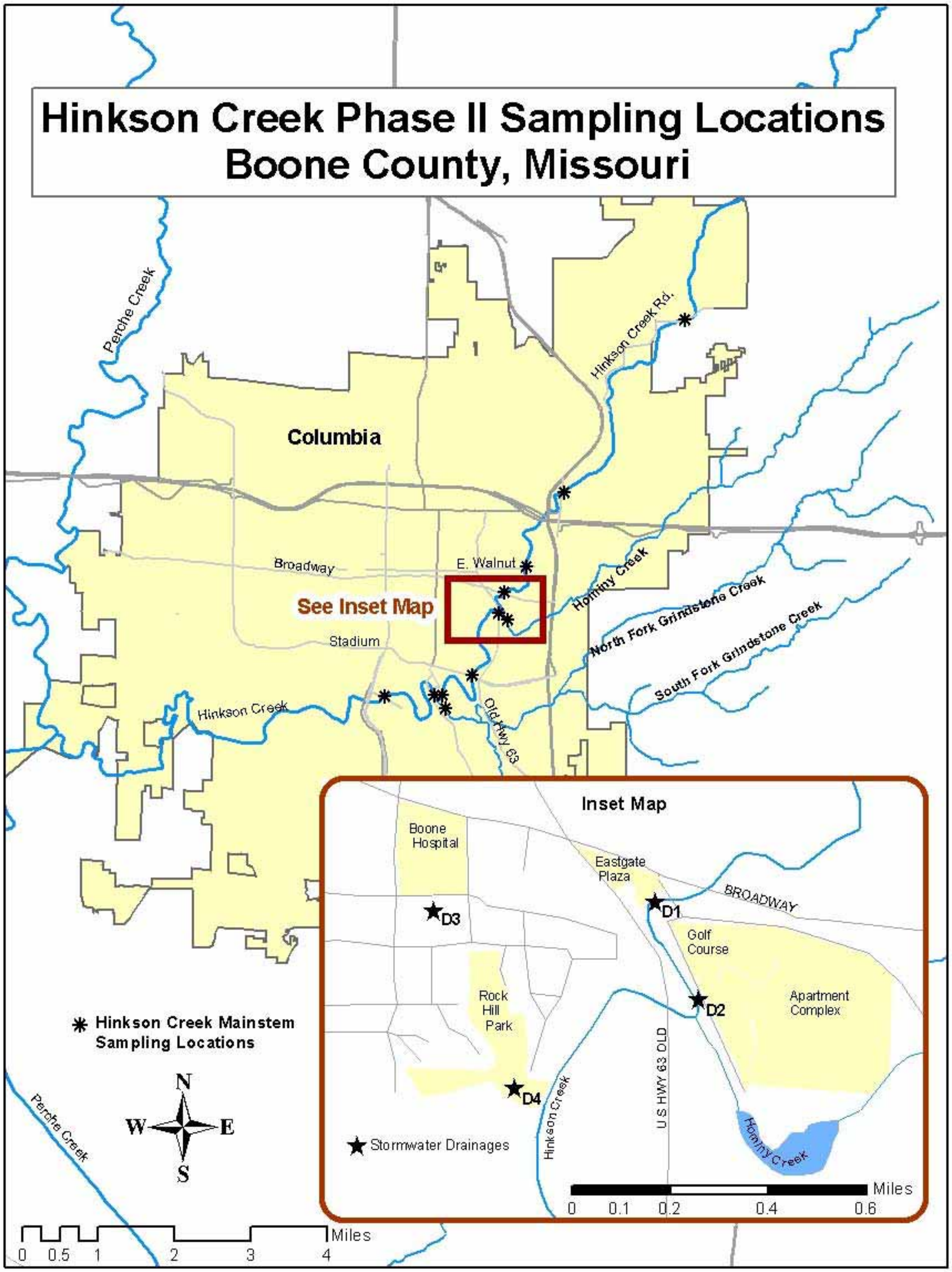
Alan Reinkemeyer
Director
Environmental Services Program

AR:pr:rct

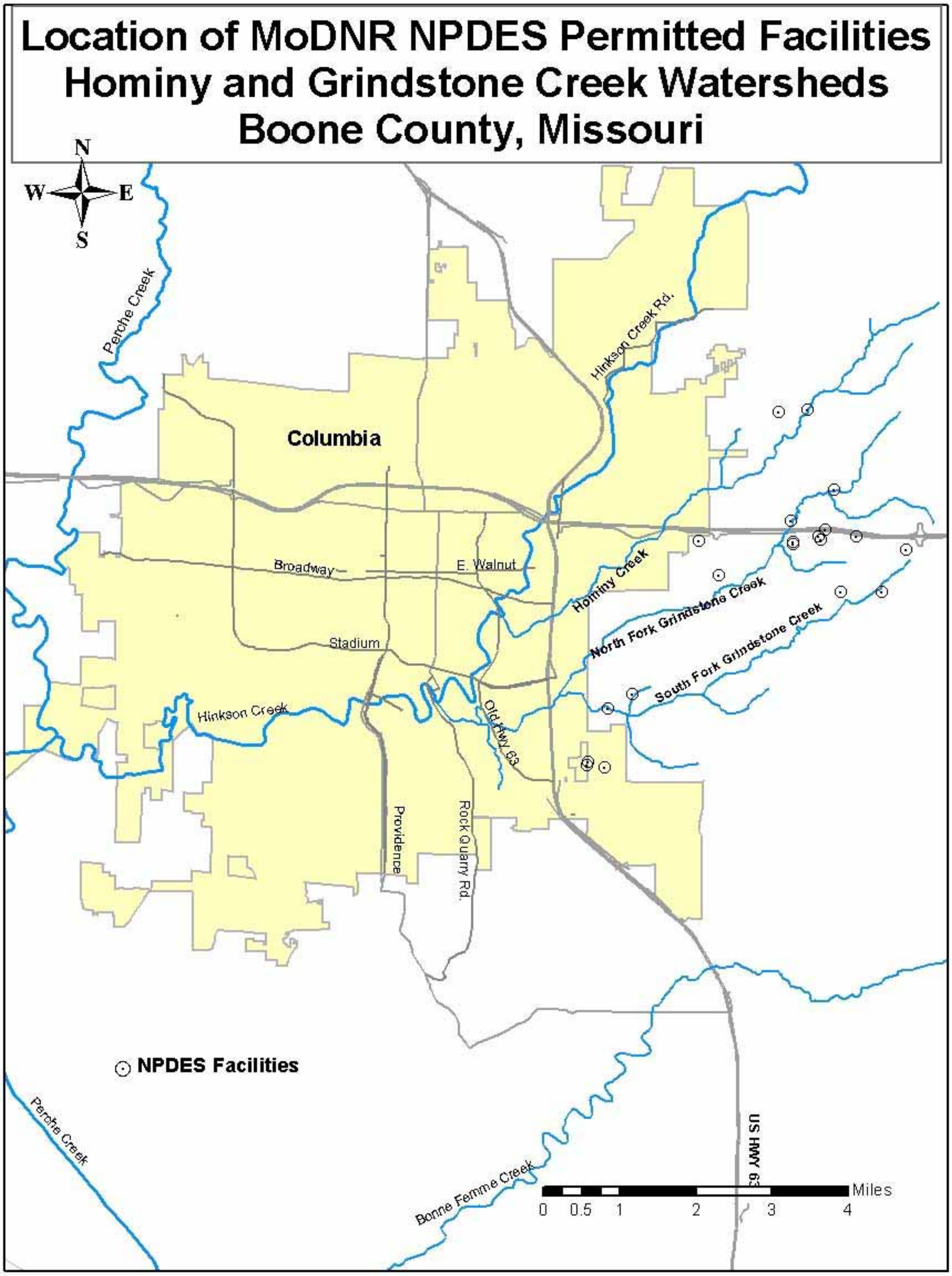
c: Jim Macy, Field Services Division
Irene Crawford, Northeast Regional Office
Phil Schroeder, Water Protection Program

APPENDIX A
Hinkson Creek Maps

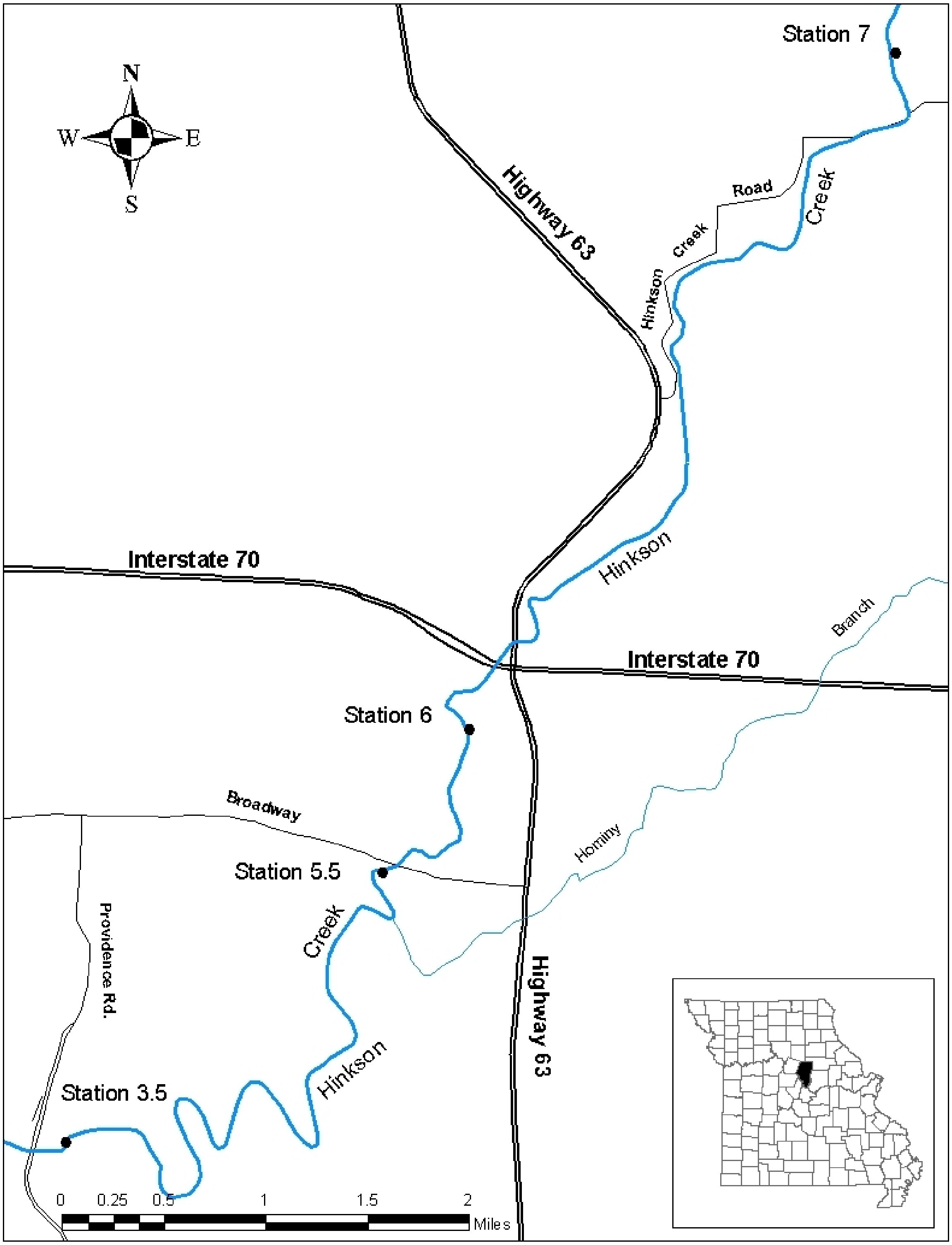
Map A. Hinkson Creek Water Quality Monitoring Locations



Map B. Location of MDNR NPDES Facilities in the Hominy and Grindstone Creek Watersheds



Map C. Hinkson Creek Macroinvertebrate Monitoring Locations



APPENDIX B

Photographs

Appendix B.

Photo 1.

Raw wastewater discharging from manhole located behind Wal-Mart in the Broadway Market Place Shopping Complex.

Sewer line had become clogged by tree roots and grease causing wastewater to back up into the manhole.

Photos 1, 2, & 3 were taken on August 10, 2004

Photo 2.

Raw wastewater overflowed from the manhole and downhill through a wooded area before collecting in a backwater area of Hinkson Creek.

Photo 3.

The raw wastewater that pooled in the backwater area of Hinkson Creek then seeped through the gravel bar and entered main-stem Hinkson Creek.

Appendix B.

Photo 4.

On-going construction activity was occurring near the Home Depot building supply store. Construction of Liberty Square, among other activities in the area, was occurring at the time of this study. An accumulation of sediment on the roadway during the construction of Liberty Square can be seen.

Photos 4 & 5 were taken on December 2, 2004.

Photo 5.

Accumulation of sediment on the roadway during the construction of Liberty Square.

Photo 6.

Photos 6 and 7 were taken upstream of the Broadway bridge crossing, where there is on-going construction activity along the upper east bank/hillside of Hinkson Creek across from Stephen’s Lake Park and downstream of the old Mega Market drainage.

Photo was taken March 2004.

Appendix B.

Photo 7.

It appears that the east bank/hillside is slumping into Hinkson Creek.

Photo was taken April 2005.

Photo 8.

Photos 8 and 9 were taken upstream of the Broadway bridge crossing and across from Stephen's Lake Park. Bank erosion is occurring along Hinkson Creek. During high flow events the water is cutting away at the stream banks, exposing tree roots and bare soil.

Photos 8 & 9 were taken on September 2, 2005

Photo 9.

If undercutting continues the stream bank will eventually fail and collapse into Hinkson Creek.

Appendix B.

Photo 10.

Bridge construction at Broadway was occurring at the time of this study. A temporary rock bridge was constructed along the south side of Broadway to allow heavy equipment to pass from one side of the bridge to the other.

Photos 10, 11, & 12 were taken on January 31, 2005.

Photo 11.

During at least one high rainfall event the temporary bridge was removed by high water.

Photo 12.

Sediment accumulation along the south side of the temporary rock bridge. Sediment deposition could be a result of the bridge construction and/or other activities occurring further upstream.

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 identifying 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 was filtered through a Nalgene 0.45 um cellulose fiber filter membrane. The resulting filtrate was then analyzed using the Microtox SOLO 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.

APPENDIX D

Collection of All the Analytical Results

Hinkson Creek
Base Flow Monitoring
Analytical Results

Hinkson Creek
Low Flow Turbidity Monitoring
Analytical Results

Summary of the Hinkson Creek Low Flow Turbidity Monitoring

Site Name	Sample #	Time	Turbidity (NTU)	NFR (mg/L)	VSS (mg/L)	Discharge (cfs)
8/10/2004						
HCR	0411523	4:10:00 PM	17.4	14.0	<5.00	1.44
63C	0411522	3:30:00 PM	25.1	20.0	<5.00	2.03
EWL	0411521	2:10:00 PM	30.7	23.0	<5.00	2.21
BWY	0411520	1:40:00 PM	21.0	10.0	<5.00	2.37
HOM	0411529	12:45:00 PM	6.11	--	--	0.02
O63	0411519	12:05:00 PM	24.2	20.0	5.00	2.64
STD	0411528	11:10:00 AM	12.3	--	--	--
HUG	0411527	10:30:00 AM	12.6	--	--	0.82
GRI	0411526	10:10:00 AM	2.05	--	--	0.20
HDG	0411525	9:40:00 AM	11.4	--	--	--
RCD	0411524	8:40:00 AM	5.18	--	--	1.81
8/18/2004						
HCR	0452412	1:15:00 PM	5.16	--	--	--
63C	0452411	12:50:00 PM	20.0	20.0	8.00	0.1
EWL	0452410	12:15:00 PM	15.7	13.0	8.00	--
BWY	0452415	11:50:00 AM	9.58	--	--	0.08
HOM	0452414	11:30:00 AM	1.80	--	--	--
O63	0452413	11:10:00 AM	9.78	--	--	--
STD	0411533	2:10:00 PM	5.92	--	--	0.2
HUG	0411530	1:55:00 PM	10.0	--	--	0.2
GRI	0411531	2:00:00 PM	2.58	--	--	0.06
HDG	0411532	1:50:00 PM	1.72	--	--	0.23
RCD	0411534	1:35:00 PM	3.45	--	--	0.72
AXU (CR 156)	0411539	10:25:00 AM	1.80	--	--	--
AXD (CR 139)	0411538	10:50:00 AM	3.54	--	--	--
LTU (CR 1053)	0411536	9:05:00 AM	1.52	--	--	--
LTD (CR 1036)	0411537	9:35:00 AM	4.15	--	--	0.04
BNF	0411535	2:35:00 PM	2.59	--	--	0.31
9/2/2004						
HCR	0434941	1:30:00 PM	26.4	7.00	<5.00	1.4
63C	0434940	12:50:00 PM	46.4	15.0	<5.00	1.18
EWL	0434939	12:05:00 PM	49.7	30.0	<5.00	2.27
BWY	0434938	11:30:00 AM	39.0	15.0	<5.00	2.19
HOM	0434937	11:10:00 AM	5.29	--	--	0.25
O63	0434936	10:50:00 AM	42.6	16.0	6.00	1.25
STD	0434935	10:30:00 AM	31.5	10.0	<5.00	3.17
HUG	0434934	10:00:00 AM	27.6	11.0	<5.00	3.21
GRI	0434933	9:45:00 AM	5.02	--	--	0.66
HDG	0434932	9:30:00 AM	24.0	10.0	<5.00	3.57
RCD	0434931	8:50:00 AM	21.5	7.00	<5.00	3.63

Summary of the Hinkson Creek Low Flow Turbidity Monitoring

Site Name	Sample #	Time	Turbidity (NTU)	NFR (mg/L)	VSS (mg/L)	Discharge (cfs)
9/9/2004						
HCR	0430984	12:05:00 PM	5.48	--	--	0.18
63C	0430983	11:35:00 AM	18.6	13.0	<5.00	0.24
EWL	0430982	11:15:00 AM	15.6	18.0	5.00	0.15
BWY	0430981	10:55:00 AM	10.7	--	--	0.35
HOM	0430980	10:40:00 AM	3.57	--	--	0.02
O63	0430979	10:25:00 AM	16.3	28.0	7.00	0.05
STD	0430978	10:00:00 AM	8.57	--	--	0.44
HUG	0430977	9:35:00 AM	7.22	--	--	0.46
GRI	0430976	9:20:00 AM	1.83	--	--	0.13
HDG	0430975	9:10:00 AM	4.69	--	--	0.63
RCD	0430974	8:45:00 AM	6.15	--	--	0.92
AXU (CR 156)	0430988	4:05:00 PM	3.61	--	--	--
AXD (CR139)	0430987	3:40:00 PM	7.41	--	--	0.72
LRU (CR 1053)	0430985	2:30:00 PM	5.76	--	--	0.06
LRD (CR 1036)	0430986	2:50:00 PM	6.52	--	--	0.04
BNF	0430989	12:55:00 PM	6.50	--	--	0.90
9/23/2004						
HCR	0434953	12:05:00 PM	3.56	--	--	0.08
63C	0434952	11:40:00 AM	20.6	15.0	<5.00	0.23
EWY	0434951	11:10:00 AM	14.8	--	--	0.38
BWY	0434950	10:50:00 AM	14.6	--	--	0.29
HOM	0434949	10:40:00 AM	3.77	--	--	0.00
O63	0434948	10:25:00 AM	11.0	--	--	0.31
STD	0434947	10:00:00 AM	8.72	--	--	0.91
HUG	0434946	9:45:00 AM	9.22	--	--	0.67
GRI	0434945	9:25:00 AM	3.68	--	--	0.06
HDG	0434944	9:15:00 AM	5.36	--	--	0.95
RCD	0434943	8:50:00 AM	6.66	--	--	1.28
9/29/2004						
HCR	0449362	1:00:00 PM	1.94	--	--	0.01
63C	0449361	12:30:00 PM	12.7	--	--	0.06
EWL	0449360	12:00:00 PM	6.44	--	--	0.19
BWY	0449359	11:35:00 AM	7.54	--	--	0.09
HOM	0449358	11:15:00 AM	1.34	--	--	--
O63	0449357	11:00:00 AM	6.45	--	--	0.15
STD	0449356	10:30:00 AM	4.82	--	--	0.19
HUG	0449355	10:00:00 AM	7.85	--	--	0.19
GRI	0449354	9:50:00 AM	1.84	--	--	--
HDG	0449353	9:40:00 AM	1.65	--	--	0.54
RCD	0449352	9:10:00 AM	6.40	--	--	0.49
RCD –DUP	0449368	9:20:00 AM	6.23	--	--	--

Summary of the Hinkson Creek Low Flow Turbidity Monitoring

Site Name	Sample #	Time	Turbidity (NTU)	NFR (mg/L)	VSS (mg/L)	Discharge (cfs)
AXU (CR 156)	0449366	11:40:00 AM	6.60	--	--	0.27
AXD (CR 139)	0449365	11:05:00 AM	2.84	--	--	0.26
LRU (CR 1053)	0449363	9:45:00 AM	1.07	--	--	--
LRD (CR 1036)	0449364	10:10:00 AM	4.81	--	--	--
BNF	0449367	1:45:00 PM	2.40	--	--	0.26

10/6/2004						
HCR	0434964	12:20:00 PM	1.89	--	--	0.00
63C	0434963	11:50:00 AM	17.4	16.0	<5.00	0.05
EWL	0434962	11:25:00 AM	11.2	--	--	0.20
BWY	0434961	11:00:00 AM	4.94	--	--	0.21
HOM	0434960	10:35:00 AM	2.16	--	--	0.02
O63	0434959	10:45:00 AM	4.54	--	--	0.10
STD	0434958	10:10:00 AM	4.91	--	--	0.12
HUG	0434957	9:45:00 AM	5.10	--	--	0.16
GRI	0434956	9:30:00 AM	1.12	--	--	0.08
HDG	0434955	9:20:00 AM	1.75	--	--	0.06
RCD	0434954	9:00:00 AM	2.75	--	--	0.35
11/9/2004						
HCR	0434888	1:15:00 PM	20.2	16.0	<5.00	6.04
63C	0434887	12:50:00 PM	18.3	15.0	<5.00	7.8
EWL	0434886	12:15:00 PM	22.5	9.00	<5.00	10.08
BWY	0434885	11:55:00 AM	20.2	8.00	<5.00	9.77
HOM	0434884	11:35:00 AM	7.41	--	--	1.58
O63	0434883	11:05:00 AM	17.0	8.00	5.00	10.95
STD	0434882	10:45:00 AM	19.4	8.00	<5.00	12.12
HUG	0434881	10:20:00 AM	18.2	11.0	<5.00	11.7
GRI	0434880	10:10:00 AM	3.96	--	--	1.44
HDG	0434849	10:00:00 AM	17.6	7.00	<5.00	14.91
RCD	0434848	9:30:00 AM	14.8	--	--	13.91
AXU (CR 156)	0449394	10:50:00 AM	20.0	10.0	<5.00	10.01
AXD (CR 139)	0449395	11:20:00 AM	21.2	10.0	<5.00	16.16
LRU (CR 1053)	0449396	9:25:00 AM	15.4	9.00	<5.00	3.55
LRD (CR 1036)	0449397	9:55:00 AM	13.4	--	--	7.54
BNF	0434889	1:55:00 PM	6.49	--	--	3.68
11/17/2004						
HCR	0434900	12:25:00 PM	5.91	--	--	2.58
63C	0434899	12:00:00 PM	5.19	--	--	4.08
EWL	0434898	11:45:00 AM	6.84	--	--	4.05
BWY	0434897	11:25:00 AM	4.76	--	--	3.11
HOM	0434896	10:55:00 AM	4.12	--	---	0.7
O63	0434895	10:50:00 AM	4.27	--	--	4.79

Summary of the Hinkson Creek Low Flow Turbidity Monitoring

Site Name	Sample #	Time	Turbidity (NTU)	NFR (mg/L)	VSS (mg/L)	Discharge (cfs)
STD	0434894	10:30:00 AM	4.21	--	--	4.71
HUG	0434893	10:05:00 AM	3.16	--	--	5.21
GRI	0434892	10:00:00 AM	2.09	--	--	0.84
HDG	0434891	9:45:00 AM	2.89	--	--	7.18
RCD	0434890	9:25:00 AM	2.75	--	--	8.31

1/25/2005						
HCR	0500945	1:25:00 PM	10.6	--	--	7.73
63C	0500944	12:55:00 PM	6.21	--	--	11
EWL	0500943	12:25:00 PM	6.30	--	--	12.7
BWY	0500942	11:55:00 AM	6.02	--	--	11.18
HOM	0500941	11:00:00 AM	29.0	10.0	<5.00	1.47
O63	0500940	11:20:00 AM	6.95	--	--	14.21
STD	0500939	10:30:00 AM	8.66	--	--	14.06
HUG	0500938	9:55:00 AM	8.02	--	--	14.13
GRI	0500937	9:35:00 AM	1.92	--	--	3.04
HDG	0500936	9:15:00 AM	7.24	--	--	15.2
RCD	0500935	9:00:00 AM	6.28	--	--	19.18
2/1/2005						
HCR	0500974	12:40:00 PM	5.55	--	--	6.8
63C	0500973	12:10:00 PM	3.73	--	--	8.44
EWL	0500972	11:40:00 AM	3.69	--	--	8.57
BWY	0500971	11:20:00 AM	3.71	--	--	7.5
HOM	0500970	10:45:00 AM	20.9	19.0	5.00	1.17
O63	0500969	10:30:00 AM	9.93	--	--	9.65
STD	0500968	10:05:00 AM	5.80	--	--	9.86
HUG	0500967	9:25:00 AM	5.50	--	--	10.52
GRI	0500966	9:15:00 AM	1.72	--	--	2.75
HDG	0500965	9:05:00 AM	4.75	--	--	12.82
RCD	0500950	8:40:00 AM	3.48	--	--	13.64
AXU (CR 156)	0500949	11:00:00 AM	8.77	--	--	11.07
AUD (CR 139)	0500948	9:55:00 AM	6.50	--	--	17.06
LRU (CR 1053)	0500946	11:50:00 AM	14.8	--	--	4.91
LRD (CR 1036)	0500947	12:20:00 PM	6.96	--	--	13.28
BNF	0500975	1:30:00 PM	2.43	--	--	4.79
5/4/2005						
HCR	0502587	12:37:00 PM	2.75	--	--	3.86
63C	0502586	12:00:00 PM	2.42	--	--	5.85
EWL	0502585	11:33:00 AM	3.74	--	--	5.8
BWY	0502584	11:10:00 AM	3.08	--	--	5.54
HOM	0502583	10:45:00 AM	4.69	--	--	2.66
O63	0502582	10:20:00 AM	3.23	--	--	5.41

Summary of the Hinkson Creek Low Flow Turbidity Monitoring

Site Name	Sample #	Time	Turbidity (NTU)	NFR (mg/L)	VSS (mg/L)	Discharge (cfs)
STD	0502581	9:45:00 AM	3.24	--	--	5.17
HUG	0502580	9:20:00 AM	2.75	--	--	5.99
GRI	0502579	9:03:00 AM	2.91	--	--	0.95
HDG	0502578	8:50:00 AM	2.80	--	--	9.4
RCD	0502577	8:30:00 AM	2.89	--	--	10.56
BNF	0502589	1:20:00 PM	2.26	--	--	2.63

Hinkson Creek
Stormwater Monitoring
Analytical Results

APPENDIX E

Hinkson Creek Spring 2005
Macroinvertebrate Taxa Lists

Aquid Invertebrate Database Bench Sheet Report
Hinkson Ck [0503026], Station #3.5, Sample Date: 4/18/2005 9:15:00 AM
CS = Coarse Substrate; NF = Non-Flow; RM = Rootmat; -99 = present in samples

ORDER: TAXA	CS	NF	RM
AMPHIPODA			
Crangonyx	**8**		**6**
Hyalella azteca			**9**
COLEOPTERA			
Berosus	**1**		
Dubiraphia	**1**	**4**	**10**
Helichus basalis	**1**		
Hydroporus			**5**
Macronychus glabratus			**2**
Peltodytes		**1**	
Stenelmis	**112**	**4**	
DECAPODA			
Orconectes virilis	**-99**		
DIPTERA			
Ablabesmyia			**1**
Ceratopogoninae	**3**	**3**	**2**
Chaoborus		**1**	
Chironomus	**1**	**48**	**5**
Cladotanytarsus	**31**	**34**	
Corynoneura			**2**
Cricotopus bicinctus	**3**		**4**
Cricotopus/Orthocladius	**294**	**4**	**4**
Cryptochironomus	**5**	**7**	
Cryptotendipes		**4**	
Demicryptochironomus	**8**		
Dicrotendipes	**1**		**2**
Eukiefferiella	**1**		
Hexatoma	**1**		
Hydrobaenus	**12**	**2**	**24**
Microtendipes	**2**		**2**
Nanocladius			**9**
Paracladopelma		**1**	
Parakiefferiella		**2**	**12**
Parametriocnemus	**8**		
Paratanytarsus	**3**	**2**	**186**
Paratendipes	**7**	**13**	**1**
Polypedilum convictum grp	**53**		
Polypedilum halterale grp		**21**	
Polypedilum illinoense grp		**1**	
Polypedilum scalaenum grp	**6**	**1**	**1**
Procladius		**3**	**5**
Simulium	**4**		
Stenochironomus	**1**		
Stictochironomus	**7**	**26**	
Tabanidae		**1**	
Tanytarsus	**2**	**2**	**11**
Thienemanniella	**1**		**3**
Thienemannimyia grp.	**8**		**8**
Tipula	**-99**		

ORDER: TAXA	CS	NF	RM
EPHEMEROPTERA			
Acerpenna	**2**		
Baetis	**2**		
Caenis latipennis	**7**	**1**	**19**
Stenonema femoratum	**4**		
Tricorythodes	**1**		
ISOPODA			
Caecidotea	**4**	**1**	**4**
LIMNOPHILA			
Menetus			**1**
LUMBRICINA			
Lumbricidae	**1**		
ODONATA			
Argia			**2**
Enallagma			**27**
Gomphus			**-99**
Somatochlora			**-99**
PLECOPTERA			
Perlesta	**7**		
TRICHOPTERA			
Cheumatopsyche	**2**		
Hydroptila	**2**		
TRICLADIDA			
Planariidae	**4**		
TUBIFICIDA			
Branchiura sowerbyi		**2**	
Enchytraeidae	**2**	**1**	
Limnodrilus cervix		**3**	
Limnodrilus claparedianus		**11**	
Limnodrilus hoffmeisteri	**23**	**8**	**1**
Tubificidae	**37**	**63**	**10**
VENEROIDEA			
Corbicula	**-99**		
Sphaeriidae	**3**	**1**	

Aquid Invertebrate Database Bench Sheet Report
Hinkson Ck [0503026], Station #3.5, Sample Date: 4/18/2005 9:15:00 AM
CS = Coarse Substrate; NF = Non-Flow; RM = Rootmat; -99 = present in samples

Aquid Invertebrate Database Bench Sheet Report
Hinkson Ck [0503027], Station #5.5, Sample Date: 4/18/2005 10:20:00 AM
CS = Coarse Substrate; NF = Non-Flow; RM = Rootmat; -99 = present in samples

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina		**1**	**1**
AMPHIPODA			
Hyalella azteca			**8**
ARHYNCHOBDELLIDA			
Erpobdellidae	**2**	**-99**	
COLEOPTERA			
Dubiraphia	**2**	**4**	
Dytiscidae		**1**	
Hydroporus	**1**	**6**	**3**
Stenelmis	**89**	**11**	**18**
DECAPODA			
Orconectes virilis			**-99**
DIPTERA			
Ablabesmyia		**2**	**1**
Ceratopogoninae	**2**		**3**
Chaoborus		**1**	
Chironomus	**1**	**37**	
Cladotanytarsus	**4**	**10**	
Corynoneura	**1**		**3**
Cricotopus bicinctus	**2**		**2**
Cricotopus/Orthocladius	**460**	**9**	**24**
Cryptochironomus	**6**	**8**	
Dicrotendipes	**4**		
Diptera		**11**	
Eukiefferiella brevicalcar grp	**5**		
Hemerodromia	**1**		
Hexatoma	**-99**		
Hydrobaenus		**2**	**7**
Labrundinia		**1**	
Larsia		**1**	
Limnophyes			**1**
Micropsectra		**1**	**1**
Microtendipes			**1**
Nanocladius	**1**		**4**
Ormosia		**1**	
Parachironomus		**2**	
Paracladopelma		**3**	
Parakiefferiella	**1**	**9**	**25**
Parametriocnemus	**5**		
Paratanytarsus	**4**	**10**	**142**
Paratendipes		**8**	
Polypedilum convictum grp	**128**	**1**	
Polypedilum halterale grp		**4**	
Polypedilum illinoense grp			**8**
Polypedilum scalaenum grp	**3**	**6**	
Procladius		**15**	
Psectrocladius			**2**
Pseudosmittia			**1**

ORDER: TAXA	CS	NF	RM
Simulium	**15**		
Stictochironomus	**3**	**37**	
Tanytarsus	**2**	**6**	**3**
Thienemanniella	**1**		
Thienemannimyia grp.	**7**		**5**
Tipula	**-99**		
EPHEMEROPTERA			
Acerpenna	**4**		
Caenis latipennis	**11**	**14**	**21**
Hexagenia limbata		**2**	
Stenacron	**1**	**1**	
Stenonema femoratum	**8**	**1**	
HEMIPTERA			
Pelocoris			**1**
ISOPODA			
Caecidotea	**3**	**11**	**1**
LIMNOPHILA			
Ancylidae	**3**	**1**	**1**
Lymnaeidae			**1**
Menetus			**2**
Physella			**5**
LUMBRICINA			
Lumbricidae		**1**	
ODONATA			
Argia	**1**		**3**
Enallagma			**17**
Gomphus			**-99**
PLECOPTERA			
Perlesta	**40**	**2**	
TRICHOPTERA			
Cheumatopsyche	**2**		
Chimarra	**1**		
Hydroptila	**11**		
Polycentropus		**1**	
TUBIFICIDA			
Branchiura sowerbyi	**3**	**2**	
Enchytraeidae	**1**		
Limnodrilus cervix		**2**	
Limnodrilus claparedianus		**4**	
Limnodrilus hoffmeisteri	**12**	**12**	**1**
Tubificidae	**17**	**26**	**1**
VENEROIDEA			
Sphaeriidae	**8**		**11**

Aquid Invertebrate Database Bench Sheet Report
Hinkson Ck [0503027], Station #5.5, Sample Date: 4/18/2005 10:20:00 AM
CS = Coarse Substrate; NF = Non-Flow; RM = Rootmat; -99 = present in samples

Aquid Invertebrate Database Bench Sheet Report
Hinkson Ck [0503028], Station #6, Sample Date: 4/18/2005 11:50:00 AM
CS = Coarse Substrate; NF = Non-Flow; RM = Rootmat; -99 = present in samples

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina		**5**	
AMPHIPODA			
Crangonyx	**1**		**6**
BRANCHIOBDELLIDA			
Branchiobdellida			**3**
COLEOPTERA			
Dubiraphia		**3**	**5**
Hydroporus		**1**	
Stenelmis	**63**	**12**	**21**
DECAPODA			
Orconectes virilis		**-99**	**-99**
DIPTERA			
Ablabesmyia		**2**	
Ceratopogoninae		**8**	
Chironomus		**12**	
Cladotanytarsus	**10**	**51**	**7**
Corynoneura		**4**	**2**
Cricotopus bicinctus	**1**		**2**
Cricotopus trifascia	**1**		
Cricotopus/Orthocladius	**229**	**7**	**132**
Cryptochironomus	**3**	**3**	**2**
Demicryptochironomus			**1**
Dicrotendipes	**1**		
Diptera		**3**	
Eukiefferiella	**45**		**2**
Hemerodromia	**5**		
Hydrobaenus	**3**	**7**	**5**
Limnophyes			**1**
Microtendipes			**1**
Nanocladius	**1**	**1**	**4**
Natarsia	**1**		
Nilotanypus			**1**
Paracladopelma		**1**	
Parakiefferiella		**9**	**3**
Parametriocnemus	**6**		
Paratanytarsus		**25**	**35**
Paratendipes	**8**	**3**	**1**
Polypedilum convictum grp	**112**	**1**	**4**
Polypedilum fallax grp		**2**	
Polypedilum halterale grp		**5**	
Polypedilum illinoense grp	**1**	**1**	
Polypedilum scalaenum grp		**2**	
Rheotanytarsus	**1**		**3**
Simulium	**30**		
Smittia		**1**	
Stempellinella		**1**	
Stictochironomus		**28**	**1**
Tabanidae	**1**		

ORDER: TAXA	CS	NF	RM
Tabanus	**2**		
Tanytarsus		**3**	
Thienemanniella	**2**	**1**	**2**
Thienemannimyia grp.	**6**	**2**	**11**
Tipula	**2**		**-99**
Tribelos			**1**
Zavrelimyia	**2**		
EPHEMEROPTERA			
Acentrella	**2**		**2**
Acerpenna			**2**
Baetis	**3**		
Caenis latipennis	**5**	**7**	**40**
Heptageniidae	**1**		**2**
Leptophlebiidae			**1**
Stenacron	**1**		
Stenonema femoratum	**7**	**-99**	
ISOPODA			
Caecidotea			**5**
LIMNOPHILA			
Physella			**-99**
ODONATA			
Anax			**1**
Argia	**1**		
Arigomphus		**-99**	
Calopteryx			**1**
Hagenius brevistylus		**1**	
Progomphus obscurus		**1**	
PLECOPTERA			
Amphinemura	**1**		
Perlesta	**51**	**1**	**11**
TRICHOPTERA			
Cheumatopsyche	**1**		
Hydroptila	**2**		**1**
Ironoquia		**-99**	
TUBIFICIDA			
Branchiura sowerbyi	**1**		
Enchytraeidae	**2**	**1**	
Limnodrilus hoffmeisteri	**2**	**2**	
Tubificidae	**18**	**31**	**1**
VENEROIDEA			
Sphaeriidae		**1**	

CS = Coarse Substrate; NF = Non-Flow; RM = Rootmat; -99 = present in samples

Aquid Invertebrate Database Bench Sheet Report
Hinkson Ck [0503029], Station #7, Sample Date: 4/18/2005 1:00:00 PM
CS = Coarse Substrate; NF = Non-Flow; RM = Rootmat; -99 = present in samples

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina		**8**	
AMPHIPODA			
Crangonyx		**2**	**4**
Hyalella azteca			**21**
COLEOPTERA			
Dubiraphia		**5**	**14**
Hydroporus		**10**	**3**
Peltodytes		**1**	
Stenelmis	**105**	**11**	**16**
DECAPODA			
Orconectes virilis			**-99**
DIPTERA			
Ablabesmyia		**2**	
Ceratopogoninae	**5**	**6**	
Chironomus	**1**	**12**	
Chrysops	**1**		
Cladotanytarsus	**72**	**32**	
Corynoneura		**9**	**2**
Cricotopus/Orthocladius	**196**	**16**	**110**
Cryptochironomus	**3**	**7**	
Cryptotendipes		**1**	
Demicryptochironomus	**12**		
Dicrotendipes	**1**	**1**	**1**
Eukiefferiella brevicalcar grp	**51**		**4**
Hemerodromia	**1**		**1**
Hexatoma	**2**	**-99**	
Hydrobaenus	**1**	**12**	**3**
Larsia	**1**		
Micropsectra			**2**
Nanocladius		**1**	**12**
Nilothauma			**1**
Ormosia	**1**		
Paracladopelma		**2**	
Parakiefferiella	**1**	**11**	**3**
Parametriocnemus	**5**		
Paratanytarsus	**3**	**24**	**26**
Paratendipes	**11**	**2**	
Polypedilum		**5**	**1**
Polypedilum convictum grp	**29**		
Polypedilum halterale grp		**6**	
Polypedilum illinoense grp		**1**	**2**
Polypedilum scalaenum grp	**27**	**6**	
Procladius		**1**	
Rheotanytarsus	**1**		
Simulium	**18**		**1**
Stictochironomus	**12**	**7**	
Tanytarsus			**6**
Thienemanniella	**3**		

ORDER: TAXA	CS	NF	RM
Thienemannimyia grp.	**1**	**8**	**11**
Tipula	**-99**		**-99**
EPHEMEROPTERA			
Acentrella	**6**		**2**
Acerpenna			**1**
Caenis latipennis	**2**	**18**	**64**
Leptophlebiidae		**3**	**8**
Nixe		**4**	
Stenacron	**1**	**1**	
Stenonema femoratum	**-99**		
HEMIPTERA			
Microvelia			**1**
ODONATA			
Calopteryx			**1**
Enallagma		**1**	**6**
Gomphus		**-99**	
PLECOPTERA			
Amphinemura	**2**		
Perlesta	**38**		**6**
TRICHOPTERA			
Helicopsyche	**3**		
Hydroptila	**1**		
Ironoquia			**1**
Oecetis			**1**
Triaenodes			**5**
TRICLADIDA			
Planariidae			**1**
TUBIFICIDA			
Enchytraeidae	**1**		
Limnodrilus claparedianus	**1**	**1**	
Limnodrilus hoffmeisteri	**7**	**1**	
Tubificidae	**3**	**2**	
VENEROIDEA			
Sphaeriidae	**1**		**-99**

Aquid Invertebrate Database Bench Sheet Report
Hinkson Ck [0503029], Station #7, Sample Date: 4/18/2005 1:00:00 PM
CS = Coarse Substrate; NF = Non-Flow; RM = Rootmat; -99 = present in samples