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Prepared in cooperation with the Johnson County Stormwater Management Program

Quality of Streams in Johnson County, Kansas, 2002–10

Scientific Investigations Report 2012–5279

U.S. Department of the Interior
U.S. Geological Survey

Cover photograph: Indian Creek near College Boulevard in Johnson County, Kansas, April, 2010.

Back cover photographs: Upper left, Kill Creek downstream from 95th Street in Johnson County, Kansas, April, 2006. Lower right, Kill Creek upstream from 95th Street in Johnson County, Kansas, October, 2006.

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2012

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Suggested citation:
Rasmussen, T.J., Stone, M.S., Poulton, B.C., and Graham, J.L., 2012, Quality of streams in Johnson County, Kansas, 2002–10: U.S. Geological Survey Scientific Investigations Report 2012–5279, 103 p.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
ounce, fluid (fl. oz)	0.02957	liter (L)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
inch per hour (in/h)	0 .0254	meter per hour (m/h)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Acknowledgments

The authors thank Kent Lage, Lee Kellenberger, and Heather Schmidt of the Johnson County Stormwater Management Program for support and planning related to sampling activities and gathering background information. The authors also thank Tony Holt and other staff members of the Johnson County Environmental Laboratory for cooperation related to sample analyses. The authors are grateful to Shannon Porter with Johnson County Automated Information Mapping System (AIMS) for providing land-use data, and to Layne Knight (Kansas Department of Health and Environment) for providing disturbance maps.

Quality of Streams in Johnson County, Kansas, 2002–10

By Teresa J. Rasmussen, Mandy S. Stone, Barry C. Poulton, and Jennifer L. Graham

Abstract

Stream quality in Johnson County, northeastern Kansas, was assessed on the basis of land use, hydrology, stream-water and streambed-sediment chemistry, riparian and in-stream habitat, and periphyton and macroinvertebrate community data collected from 22 sites during 2002 through 2010. Stream conditions at the end of the study period are evaluated and compared to previous years, stream biological communities and physical and chemical conditions are characterized, streams are described relative to Kansas Department of Health and Environment impairment categories and water-quality standards, and environmental factors that most strongly correlate with biological stream quality are evaluated. The information is useful for improving water-quality management programs, documenting changing conditions with time, and evaluating compliance with water-quality standards, total maximum daily loads (TMDLs), National Pollutant Discharge Elimination System (NPDES) permit conditions, and other established guidelines and goals.

Constituent concentrations in water during base flow varied across the study area and 2010 conditions were not markedly different from those measured in 2003, 2004, and 2007. Generally the highest specific conductance and concentrations of dissolved solids and major ions in water occurred at urban sites except the upstream Cedar Creek site, which is rural and has a large area of commercial and industrial land less than 1 mile upstream on both sides of the creek. The highest base-flow nutrient concentrations in water occurred downstream from wastewater treatment facilities. Water chemistry data represent base-flow conditions only, and do not show the variability in concentrations that occurs during stormwater runoff.

Constituent concentrations in streambed sediment also varied across the study area and some notable changes occurred from previously collected data. High organic carbon and nutrient concentrations at the rural Big Bull Creek site in 2003 decreased to at least one-fourth of those concentrations in 2007 and 2010 likely because of the reduction in upstream wastewater discharge contributions. The highest concentrations of trace metals in 2010 occurred at urban sites on Mill and Indian Creeks. Zinc was the only metal to exceed the probable effects concentration in 2010, which occurred at a site on Indian Creek. In 2007, chromium and nickel at the upstream urban Cedar Creek site exceeded the probable effects concentrations, and in 2003, no metals exceeded the probable effects concentrations. Of 72 organic compounds analyzed in streambed sediment, 26 were detected including pesticides, polycyclic aromatic hydrocarbons (PAHs), fuel products, fragrances, preservatives, plasticizers, manufacturing byproducts, flame retardants, and disinfectants. All 6 PAH compounds analyzed were detected, and the probable effects concentrations for 4 of the 6 PAH compounds analyzed were exceeded in 2010. Only five pesticide compounds were detected in streambed sediment, including carbazole and four pyrethroid compounds. Chronic toxicity guidelines for pyrethroid compounds were exceeded at five sites.

Biological conditions reflected a gradient in urban land use, with the less disturbed streams located in rural areas of Johnson County. About 19 percent of sites in 2010 (four sites) were fully supporting of aquatic life on the basis of the four metrics used by Kansas Department of Health and Environment to categorize sites. This is a notable difference compared to previous years when no sites (in 2003 and 2004) or just one site (in 2007) was fully supporting of aquatic life. Multimetric macroinvertebrate scores improved at the Big Bull Creek site where wastewater discharges were reduced in 2007. Environmental variables that consistently were highly negatively correlated with biological conditions were percent impervious surface and percent urban land use. In addition, density of stormwater outfall points adjacent to streams was significantly negatively correlated with biological conditions. Specific conductance of water and sum of PAH concentrations in streambed sediment also were significantly negatively correlated with biological conditions. Total nitrogen in water and total phosphorus in streambed sediment were correlated with most of the invertebrate variables, which is a notable difference from previous analyses using smaller datasets, in which nutrient relations were weak or not detected. The most important habitat variables were sinuosity, length and continuity of natural buffers, riffle substrate embeddedness, and substrate cover diversity, each of which was correlated with all invertebrate metrics including a 10-metric combined score. Correlation analysis indicated that if riparian and in-stream habitat conditions improve then so might invertebrate communities and stream biological quality. Sixty-two percent of the variance in macroinvertebrate community metrics was explained by the single environmental factor, percent impervious surface. Invertebrate responses to urbanization in Johnson County indicated linearity rather than identifiable thresholds. Multiple linear regression models developed for each of the

four macroinvertebrate metrics used to determine aquatic-life-support status indicated that percent impervious surface, as a measure of urban land use, explained 34 to 67 percent of the variability in biological communities.

Results indicate that although multiple factors are correlated with stream quality degradation, general urbanization, as indicated by impervious surface area or urban land use, consistently is determined to be the fundamental factor causing change in stream quality. Effects of urbanization on Johnson County streams are similar to effects described in national studies that assess effects of urbanization on stream health. Individually important environmental factors such as specific conductance of water, PAHs in streambed sediment, and stream buffer conditions, are affected by urbanization and, collectively, all contribute to stream impairments. Policies and management practices that may be most important in protecting the health of streams in Johnson County are those minimizing the effects of impervious surface, protecting stream corridors, and decreasing the loads of sediment, nutrients, and toxic chemicals that directly enter streams through stormwater runoff and discharges.

Introduction

Johnson County is one of the most rapidly developing counties in Kansas, with a population that has doubled during the past 30 years from about 270,000 in 1980 to about 543,000 in 2010 (U.S. Census Bureau, 2011). Countywide, about one-half of the land is urban, and the potential for negative effects on streams is expected to intensify as many areas continue to populate. Johnson County streams are important for human and environmental health, water supply, recreation, and aesthetic value (ETC Institute, 2009).

Urban development generally affects streams by altering hydrology, geomorphology, water chemistry, ecosystem processes, and aquatic communities (Paul and Meyer, 2001). Hydrology is altered by increases in impervious surfaces, which increases stormwater runoff and the frequency and magnitude of large streamflow events (Leopold, 1968), and usually decrease base flows. Urban stream channels usually have increased streambed scour and bank erosion compared to channels in undeveloped areas (Hession and others, 2003) and also may have higher suspended-sediment concentrations (Walters and others, 2003), which can have negative effects on aquatic ecosystems (Waters, 1995). Urban streams can have increased concentrations and numbers of contaminants including metals, nutrients, dissolved solids, toxic organic compounds, and pathogens (Brown and others, 2009).

Useful benchmarks for evaluating stream health include state water-quality standards, total maximum daily loads (TMDLs), National Pollutant Discharge Elimination System (NPDES) permit requirements, and established national, state, and local guidelines including ecological targets. Water-quality criteria, which originate from national recommended criteria (U.S. Environmental Protection Agency, 2012) and state water-quality standards (Kansas Department of Health and Environment, 2005), include numeric goals for specified water properties and constituents including ammonia and other forms of nutrients, chloride, dissolved oxygen, fecal indicator bacteria, metals, organic compounds, and turbidity. The Kansas Department of Health and Environment (KDHE) also has established aquatic-life-support criteria (Kansas Department of Health and Environment, 2010a). In addition, the State has identified several streams in Johnson County as impaired (Kansas Department of Health and Environment, 2010b), and has established improvement goals as part of the TMDL program. Most stream impairments are related to excessive nutrients, sediment, or fecal bacteria. Provisions of the Clean Water Act require that urban stormwater runoff be controlled through the NPDES permit program, which is administered by the U.S. Environmental Protection Agency (USEPA) and implemented by individual States. As part of that program, Johnson County has established best management practices (BMPs) to reduce nonpoint-source pollution. An annual assessment is required to evaluate appropriateness of BMPs and to monitor progress toward the goal of reducing nonpoint-source pollution.

A comprehensive assessment of stream quality integrates multiple aspects of stream condition including climate, hydrology, land use, riparian and in-stream habitat, physical and chemical properties of water and streambed sediment, and aquatic biological communities. Climate affects hydrology, geomorphology, and biology and can help explain short-term and long-term variability in stream conditions. Streamflow regime describes magnitude, timing, duration, and frequency of high and low flows, which affect the structure and function of biological communities (Poff and Ward, 1989; Konrad and others, 2008). Habitat assessments evaluate the physical habitat characteristics that contribute to the quality of streams and the condition of the aquatic community (Barbour and others, 1996; Fitzpatrick and others, 1998). A decline in the quality and diversity of in-stream habitat generally is considered one of the primary stressors in aquatic systems (Karr and others, 1986). Water and streambed-sediment data allow evaluation of basic requirements for survival of aquatic biota and indicate whether applicable criteria or goals are being met. Sediment data provide information regarding fate, transport, and potential toxicity of chemicals that are associated with sediment, such as metals and wastewater compounds, and can be compared to sediment-quality guidelines. High concentrations of many contaminants in sediment can contribute significantly to toxic effects in the water column because sediment particles are re-suspended during large rain events (Christensen and others, 2006). Macroinvertebrate communities are important because their composition and community structure provide evidence of past physical and chemical conditions in a stream for a period of time. Periphyton consists of algae, bacteria, fungus, and other microorganisms that are attached to submerged substrates such as rocks and vegetation. Algal periphyton are primary producers and serve as an important food source for macroinvertebrates and some fish species.

In part because of the sedentary nature of algal periphyton, these communities can be sensitive to changes in water quality and often are used as indicators of physical and chemical conditions.

Effective management of streams requires a thorough understanding of stream ecosystems and the factors affecting them. In 2002, the U.S. Geological Survey (USGS), in cooperation with the Johnson County Stormwater Management Program, began an investigation to characterize the quality of Johnson County streams and to provide information for use by municipalities in the development of water-quality management plans. In addition, results from this study may be used to evaluate compliance with water-quality standards, TMDLs, NPDES permits, and other established guidelines.

Purpose and Scope

The purpose of this report is to assess the quality of streams throughout Johnson County from 2002 to 2010. Aquatic biological communities and the environmental variables that may affect them are evaluated. Stream quality is characterized on the basis of watershed land use, streamflow, water and streambed-sediment chemistry, riparian habitat conditions, algal periphyton communities, and macroinvertebrate communities. Data collected during 2010 are used to describe conditions at the end of the study period and to evaluate changing conditions by making comparisons to data collected during 2002–06 (Wilkison and others, 2006; Poulton and others, 2007) and 2007 (Rasmussen and others, 2009). This report characterizes stream biological communities and physical and chemical conditions among stream sites and watersheds throughout the county, describes changes from 2002 to 2010, evaluates conditions relative to KDHE impairment categories and water-quality standards, and describes environmental factors that are most strongly correlated with biological stream quality.

Description of Study Area

The study area is Johnson County, which covers 477 square miles (mi^2) of land in northeastern Kansas. The county contains all or parts of 22 watersheds (HUC-14, Seaber and others, 1987), most of which are included within the monitoring network. Contaminants entering streams in both urban and rural areas of the county originate from point sources, such as municipal and industrial wastewater discharges, and from nonpoint sources including stormwater runoff, failing infrastructure, and atmospheric deposition. Because all sites are located within a small spatial area, natural variability caused by factors such as geology and climate is minimized. Average annual precipitation in the study area ranges from 38 to 40 inches (U.S. Department of Agriculture, 2007).

A total of 22 stream sites (table 1, fig. 1) representing a range in watershed size, urbanization and other land uses, and point and nonpoint contaminant sources were sampled during 2003, 2004, 2007, and 2010. Sixteen of the 22 sites were sampled in each of the 4 years. The remaining 6 sites were not sampled in 2003 and 2004, but were sampled in 2007, 2010, or both 2007 and 2010. Drainage areas upstream from monitoring sites range in size from 1.6 mi^2 to 65.7 mi^2. Countywide, about 50 percent of the county is urban, 10 percent is cropland, 30 percent is grassland, and 10 percent is woodland (calculated from 2005 Kansas Land Cover Patterns level 1 data, Peterson and others, 2010). The northeastern part of the county includes part of the Kansas City metropolitan area and is the most urbanized, whereas the western and southern parts of the county remain mostly undeveloped.

In 2010, 11 municipal wastewater treatment facilities (WWTFs) were located in watersheds upstream from monitoring sites, and 6 of the WWTFs had a discharge capacity of more than one million gallons per day (gpd). Eight of the monitoring sites are located downstream from wastewater discharge(s), with distances ranging from 0.6 river miles (IN3a) to about 13 miles (KI6b, MI7) from the upstream WWTF. One site (BR2) is affected by a wastewater bypass discharge directly upstream, which occurs periodically when sewage line capacities are exceeded during stormwater runoff.

Previous Investigations

The quality of streams in Johnson County has been the subject of earlier assessments. A study of the effects of wastewater discharge on biological conditions in the upper Blue River in Johnson County (Graham and others, 2010) indicated that the largest differences between sites upstream and downstream from wastewater discharge were in nutrient concentrations, which were significantly higher downstream, particularly during normal and below-normal streamflows. Aquatic-life-support scores were significantly lower downstream, and ecosystem functional health (assessed on the basis of biological productivity) was mildly impaired downstream from the wastewater discharge.

Macroinvertebrate communities in Johnson County streams were described by Poulton and others (2007) using data collected in 2003 and 2004. A subsequent assessment of macroinvertebrate and periphyton communities was completed using data collected in 2007 (Rasmussen and others, 2009). Results indicated that biological condition generally reflected a gradient in the degree of human disturbance upstream from sites. Environmental factors that most strongly correlated with stream biological conditions included amount of upstream urbanization, specific conductance of stream water, concentration of polycyclic aromatic hydrocarbons (PAHs) in streambed sediment, and habitat variables related to riparian buffer condition and sediment deposition.

Chemical concentrations, loads, and yields in five principal Johnson County streams were described using data and statistical models based on continuous water-quality monitoring during 2002–06 (Rasmussen and others, 2008). Concentrations of suspended sediment, chloride, and fecal-indicator bacteria generally were higher in more urban watersheds than

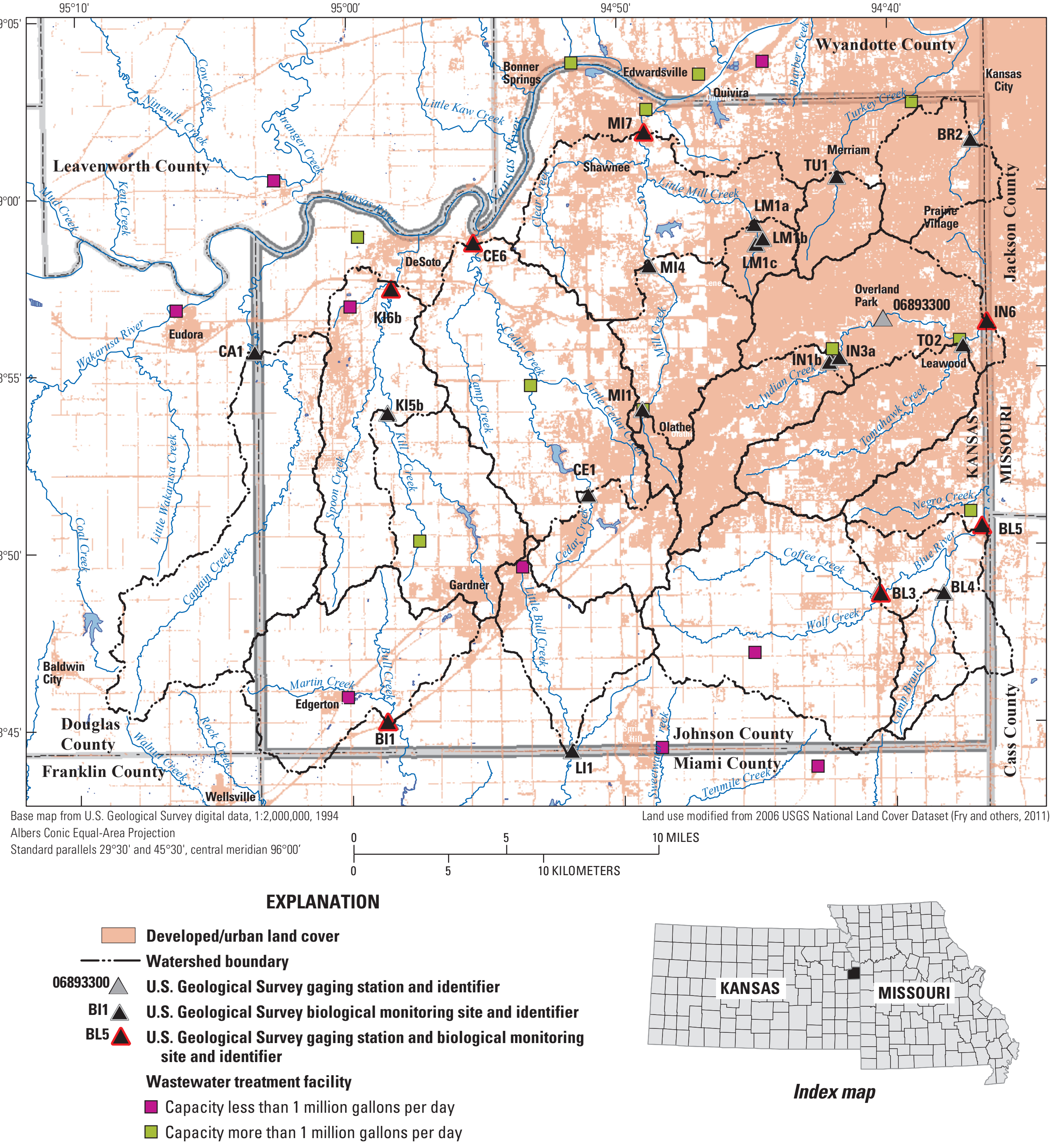

Figure 1. Location of biological monitoring sites in Johnson County, Kansas, 2002–10.

in nonurban watersheds and were substantially higher during periods of increased streamflow. At least 90 percent of the total suspended-sediment load during 2005–06 in all five watersheds was transported in less than 2 percent of the time during periods of increased streamflow.

Lee and others (2005) described the effects of contaminant sources on stream-water quality using samples collected during 2002–04. Results indicated that during base flow, discharge from WWTFs comprised more than one-half of streamflow at sampling sites located downstream from wastewater discharges, and concentrations of nutrients and household organic compounds generally were higher downstream from WWTFs. In addition, stormflow samples contained the highest suspended-sediment concentrations and fecal-indicator bacteria densities.

Assessments of water quality in Kansas City, Missouri, using data collected during 1998 through 2007 included some upstream sites in Johnson County (Wilkison and others, 2002,

Table 1. Site and drainage area characteristics of biological monitoring sites in Johnson County, Kansas, 2002–10 including estimated watershed area and upstream land use.

[Data from 2005 Kansas Land Cover Patterns (KLCP; Peterson and others, 2010) and Johnson County Automated Information Mapping System (AIMS), Johnson County, written commun., 2006, 2011; mi², square miles; -- no upstream wastewater discharge; <, less than]

Biological monitoring site identifier (fig. 1)	Stream and location	U.S. Geological Survey gaging station number	Drainage area (mi²)	Approximate upstream land use (percent)										General land classification[1]	Distance downstream from nearest wastewater discharge (miles)
				KLCP Level 1						KLCP Level 4					
				Urban	Cropland	Grassland	Woodland	Water	Other	Urban commercial / industrial	Urban residential	Impervious surface (AIMS, 2005)	Impervious surface (AIMS, 2010)		
BI1	Big Bull Creek near Edgerton	6914950	29.1	5.4	34.4	50.2	8.7	0.7	0.6	0.6	2.8	2.1	2.2	Rural	2.9
BL3	Blue River near Stanley (Highway 69)	6893080	45.4	17.3	15.5	54.9	10.9	1.1	0.3	1.3	5.6	3.0	4.2	Rural	--
BL4	Camp Branch at 175th Street	384840094381100	6.9	32.6	4.9	44.5	16.9	0.8	0.3	0.7	8.2	3.0	3.6	Rural	--
BL5	Blue River at Kenneth Road	6893100	65.7	20.8	13.2	49.3	14.4	1.0	0.2	1.6	6.4	3.2	4.4	Rural	--
BR2	Brush Creek at Belinder Street	390127094365800	12.2	96.5	0	0	0	0	0	9.6	79.2	26.0	26.0	Urban	< 0.1[2]
CA1	Captain Creek near 119th Street	385540095032800	41.2	5.2	26.3	50.7	17.2	0.5	0.1	0	1.1	0.6	0.6	Rural	--
CE1	Cedar Creek at Old Highway 56	6892440	13.7	23.8	23.0	37.7	7.8	1.1	6.6	12.9	2.4	6.6	10.4	Rural	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	58.9	24.4	10.8	37.9	24.1	1.0	1.7	6.5	7.3	5.7	7.7	Rural	9.7
IN1b	Indian Creek at Highway 69	6893270	16.1	100	0	0	0	0	0	18.2	60.0	26.3	29.0	Urban	--
IN3a	Indian Creek at College Boulevard	385520094420000	16.5	100	0	0	0	0	0	18.4	59.9	26.3	29.1	Urban	0.6
IN6	Indian Creek at State Line Road	6893390	64.8	98.3	0.3	0.7	0.1	0	0	19.5	57.3	26.1	28.9	Urban	1.4
KI5b	Kill Creek at 127th Street	385355094583600	23.5	18.7	19.7	45.5	15.4	0.7	0	3.9	6.0	4.2	5.4	Rural	5.4
KI6b	Kill Creek at 95th Street	6892360	50.1	16.7	17.1	47.4	17.5	0.7	0.5	2.5	4.0	3.4	4.0	Rural	13.1
LI1	Little Bull Creek near 215th Street	384419094515600	16.6	12.9	25.7	49.5	11.1	0.6	0.2	3.8	2.9	3.8	4.8	Rural	--
LM1a	Little Mill Creek at W 79th Street	385908094445900	4.5	100	0	0	0	0	0	20.6	69.9	30.4	32.6	Urban	--
LM1b	Unnamed Little Mill Creek tributary near W. 83rd Street	385839094444400	1.6	100	0	0	0	0	0	32.4	56.9	35.6	45.1	Urban	--
LM1c	Little Mill Creek at W. 79th Street	385834094445600	1.8	100	0	0	0	0	0	22.9	69.6	30.8	41.5	Urban	--
MI1	Mill Creek at 127th Street	385356094491200	2.3	100	0	0	0	0	0	29.4	58.9	30.0	32.3	Urban	--
MI4	Mill Creek at 87th St Lane	385800094485300	20.4	72.7	0.8	17.8	6.9	0.2	1.6	21.2	29.5	17.7	22.1	Urban	5.8
MI7	Mill Creek at Johnson Drive	6892513	57.9	67.4	1.8	19.2	10.3	0.5	0.7	14.5	28.9	14.1	17.3	Urban	12.7
TO2	Tomahawk Creek near 111th Street	385539094372100	23.5	96.8	0.9	1.9	0.4	0	0	17.2	50.0	21.9	25.7	Urban	--
TU1	Turkey Creek at 67th Street	390027094415600	6.9	100	0	0	0	0	0	33.9	55.9	35.6	38.0	Urban	--

[1]Sites classified as urban have more than 50 percent urban land use and more than 15 percent impervious surface.

[2]Wastewater bypass discharge.

2006, and 2009). Primary sources of nutrients were nonpoint-source runoff and WWTFs, with relative contributions dependent upon annual precipitation. Declines in aquatic community diversity and abundance followed a trend of increasing urbanization and generally were accompanied by similar declines in stream physical habitat quality.

Methods

Study Design

Data describing watershed variables (land use, streamflow, and precipitation), stream-water and streambed-sediment chemistry, riparian and in-stream habitat, algal periphyton, and macroinvertebrates were collected to provide a comprehensive dataset for evaluating stream biological conditions and the environmental variables that may affect them. Sites initially were selected to represent all of the primary watersheds in the county, and to be representative of various land-use types, extent of urbanization, and sources of streamflow, including wastewater discharges, to fully characterize stream condition and important environmental factors. Water, streambed sediment, periphyton, and macroinvertebrates were collected during base-flow conditions in early spring of each sampled year. Samples were collected in early spring to be consistent with previously collected data and to try to precede pulses of spring runoff that may disrupt biological communities. In addition, macroinvertebrate samples collected from small streams in late winter and early spring often have more diversity compared to samples collected in other seasons (Feminella, 1996) because emergence periods of many stream insects occur during that time. Base flow is defined as the sustained low flow of a stream in the absence of direct runoff, and usually originates from groundwater seepage, springs, and wastewater discharges. Because water samples were collected during base flow only, water chemistry data do not show the variability in concentrations that occurs during stormwater runoff (Rasmussen and others, 2008). Habitat assessments were completed at each site in 2007 and 2010 during late summer or early fall before trees started to lose their leaves. The only candidate reference stream located in the county, Captain Creek (Kansas Department of Health and Environment, 2010a), was included in the study. Reference streams are streams designated by the State as being minimally disturbed by human activity. Examples of possible human disturbance include urban or agricultural runoff, municipal or industrial discharges, riparian or in-stream habitat alterations, and changes to hydrologic regime.

Most stream monitoring sites were located at, or near, bridge crossings. Water samples were collected at bridge crossings where available, and at designated stream cross-sections where bridges were not available. Streambed sediment, periphyton, and macroinvertebrate samples were collected from the stream sections (the reaches) located directly upstream from water sampling sites. The reach length for each site was determined so as to include at least two riffle-pool sequences and as many different in-stream and riparian habitat types as possible. Each reach was a minimum of 450 feet (ft) and no more than 900 ft in length. Habitat information was collected primarily at the reach scale, but also incorporated some segment-scale measurements. The stream segment was defined as a section of stream that is relatively homogeneous with respect to physical, chemical, and biological properties and generally bounded by tributary junctions, point-source discharges, or other features that might be expected to change stream properties (Fitzpatrick and others, 1998). The upstream boundary of the segment was defined by a change in stream order (Strahler, 1957) or presence of wastewater discharge.

For most analyses, data collected in 2010 were either compared or combined with data collected in 2003, 2004, and 2007 to evaluate patterns, relations, or trends among variables. Data from previous years were collected generally by following the same protocols as were used in 2010. Biological samples collected during 2003 and 2004 were not collected concurrently with base-flow water and streambed-sediment samples as was done in 2007 and 2010. Therefore, water and streambed-sediment data from 2002 and 2003 are presented to provide information about general stream chemistry at the sites, but they do not represent conditions during biological sampling and were not used in correlation analyses. Previous study designs, data collection, analyses, and results are described in detail by Lee and others (2005), Poulton and others (2007), and Rasmussen and others (2009).

Data Collection and Laboratory Analyses

Land use, hydrology, stream-water and streambed-sediment chemistry, riparian and in-stream habitat, and periphyton and macroinvertebrate community data were collected from 22 stream sites located across Johnson County. Samples were collected from 16 sites in 2003, 2004, 2007, and 2010. The remaining six sites were sampled only in 2007 or 2010, or both. Data types included in collection were either indicators of biological stream condition (macroinvertebrates and periphyton) or measures of factors that could help explain biological stream condition.

Watershed Variables—Land Use, Streamflow, Precipitation

Estimates of land-use percentages were determined for all biological monitoring sites at several different scales. Land-use percentages were determined for the watershed area upstream from each site using data derived from the 2006 National Land Cover Database (NLCD: Fry and others, 2011) and 2005 Kansas Land Cover Patterns (KLCP; Kansas Applied Remote Sensing, 2006; Peterson and others 2010) and included areas where watersheds crossed outside county boundaries. For some analyses, comparison sites generally were classified as urban or rural according to urban land use and impervious surface area. Sites classified as urban had more than 50 percent urban land use and more than 15 percent impervious surface area. Land-use percentages also were calculated at each site for 30-meter buffers on each streambank (fig. 2) for the length of the reach, the segment, and the full extent of the stream upstream from monitoring sites using 2008 data obtained from Johnson County AIMS (Johnson County, written commun., 2006) and derived from true-color orthophotography during leaf-off conditions with a resolution of 0.5 ft. Minor modifications were made to the 2008 AIMS data (Johnson County, written commun., 2011) to best represent 2010 conditions after making comparisons to 2010 imagery. Different scales were used for estimating land use to better characterize land areas that might affect stream conditions. For example, Calhoun and others (2008) documented that algal assemblages were more associated with watershed land use farther from the streams, and macroinvertebrate communities were better associated with land use near the sampled stream reach. Although wider buffer areas have been documented to correlate with better stream quality (as wide as 150 meters, Zelt and Munn, 2009), 30-meter buffers were characterized in this study because of buffer improvement implementation feasibility within a smaller buffer zone, particularly in developed urban areas. Impervious surface areas were estimated using AIMS data supplemented by the other data where watersheds crossed outside the boundaries of Johnson County. The 2005 and 2010 impervious surface data provide the best available quantification of changes in urban land use during the study period. Impervious surface area was calculated by adding total area of all buildings, courtyards, paved and unpaved roads, driveways, parking lots, and airport runways, but not including sidewalks or biking paths. Land use classified as cropland refers to row crops. Stormwater outfalls (fig. 3*A*) adjacent to streams also were used to characterize stream buffers (fig. 2).

USGS streamflow gages were in operation at 7 of the 22 monitoring sites (fig. 1). Streamflow data for these gages were examined for the 3 months before sampling to help interpret macroinvertebrate and periphyton data. Hourly precipitation data, which were collected along with streamflow at USGS gaging sites, also were used to assess patterns before sampling and to compare conditions among sites. Monthly and annual precipitation data from 1999–2010 at the Olathe Johnson County Executive Airport located in central Johnson County, obtained from National Oceanic and Atmospheric Administration (National Oceanic and Atmospheric Administration, 2011), were used to evaluate general precipitation conditions during the study period compared to a longer period-of-record.

Stream-Water and Streambed-Sediment Chemistry

Stream-water and streambed-sediment samples (fig. 3*B*) were collected during March 12–15, 2007, and April 5–9, 2010, on the same day that invertebrate and periphyton samples were collected at each site. Water and streambed-sediment samples were not collected concurrently with biological samples during 2003 and 2004. Water data collected during November 4–7, 2002, and July 14–18, 2003, are included in the study to provide water chemistry information antecedent to the first biological sample collection in March 2003. Streambed-sediment samples were not collected in 2003, but were collected during March 31–April 3, 2004, about 2 weeks after macroinvertebrate samples were collected.

Water samples were collected during base-flow conditions using equal-width-increment (EWI) methods (U.S. Geological Survey, 2006) at sites with adequate stream depth (at least about 0.5 ft) and using grab samples collected at the centroid of flow for other sites. Samples collected using EWI methods were composited in a churn from isokinetic and depth-integrated subsamples. Aliquot samples were processed and preserved on-site according to USGS protocols (U.S. Geological Survey, 2006). Streambed-sediment samples were collected during base-flow conditions from the upper 0.8 in. of deposits using Teflon scooping utensils. The top layer of the finest deposited material, optimally less than 63 micrometers (μm), was removed from 6 to 10 separate depositional zones along the streambed and placed in a glass container, homogenized, split into aliquots for different laboratories, and shipped chilled for analysis (Pope, 2005; Radtke, 2005).

Water samples were analyzed for suspended sediment, dissolved solids, major ions, nutrients, trace elements, fecal-indicator bacteria (*Escherichia coli*, enterococci, and fecal coliform), and pesticide compounds. Suspended-sediment concentration was determined at the USGS Sediment Laboratory in Iowa City, Iowa, according to methods described by Guy (1969). Major ions, nutrients, and fecal-indicator bacteria were analyzed at the Johnson County Environmental Laboratory in Johnson County, Kansas, according to standard methods (American Public Health Association and others, 1995), and replicate samples were sent to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado, and analyzed according to methods presented in Fishman and Friedman (1989).

Streambed-sediment samples were analyzed for total organic carbon, total carbon, major ions, nutrients, trace elements, pesticides including pyrethroids, and organic wastewater compounds. Pyrethroid insecticides were added to the laboratory analysis in 2010 because these synthetic compounds are highly toxic to fish and invertebrates (Hill, 1989) and have become more common in urban and rural areas as a replacement for previously common organophosphate insecticides such as diazinon and chlorpyrifos (Hladik and others, 2009). Analysis for carbon, major ions, nutrients, and trace elements in sediment was performed at the USGS sediment research laboratory in Atlanta, Georgia according to methods described by Horowitz and others (2001). Pyrethroid compounds were analyzed at the USGS research laboratory in Sacramento, Calif., following methods described by Hladik and others (2009). Pesticides and organic wastewater compounds in streambed sediment were analyzed by NWQL according

Figure 2. Example of stream buffer land-use characterization near Mill Creek at 87th Street Lane in Johnson County, Kansas, showing land use and stormwater features within the 30-meter buffer zone.

Figure 3. Photographs showing selected stream-monitoring sites and data-collection activities, including *A*, inventorying stormwater outfalls discharging into streams, *B*, collecting streambed-sediment sample, *C*, assessing streambed substrate using standardized frame, *D*, scrubbing periphyton from cobble surface, and *E*, sorting invertebrate samples.

to methods described by Foreman and others (1995) and Burkhardt and others (2006). Many organic compounds that were analyzed were not detected and, therefore, not included in results discussed in this report; the complete list of organic analytes in sediment is included as appendix 1.

In 2010, all sediment analyses were done only on the particle-size fraction of the sediment sample finer than 63 µm in diameter (silt and clay) to minimize effects of sediment-size differences on chemical concentrations. All samples collected in 2010 were wet-sieved at the laboratory, homogenized, then split into subsamples and shipped to the USGS NWQL and USGS California laboratories for analysis of organic compounds. In 2003 and 2007, samples sent to the Georgia sediment laboratory were sieved before analysis, as in 2010; but analyses performed by NWQL for organic compounds were done on unsieved bulk samples in 2003 and 2007. No adjustments were made to organic compound data to account for effects of differences in particle-size fractions among sampling years; consequently, results for making comparisons between earlier samples collected in 2003 and 2007, and most recent samples collected in 2010, likely contain an unquantified bias.

Riparian and In-Stream Habitat

Riparian and in-stream habitat characteristics were evaluated during September 2007 and October 2010 at each site using methods described in detail by Rasmussen and others (2009) (appendix 2). The protocol used is similar to USEPA's Rapid Habitat Assessment Protocol (RHAP, Barbour and others, 1999) but slightly modified to provide more information about stream types in the study area. A total of 17 habitat variables in 3 general categories (channel conditions and characteristics, bank and riparian conditions, and aquatic habitat availability) were evaluated (fig. 3*C*). Data collection was completed using a combination of field measurements and surveys, aerial imagery, and topographic maps.

Each habitat variable was assigned a score on a scale of 1 to 12 (Rasmussen and others, 2009) and all habitat variables were integrated into 1 total site score by summing each of the individual scores. To simplify comparisons, scores were standardized to a scale of 0 to 100 by dividing each score by the total possible score and multiplying by 100. Four rating categories of relative quality (as described by Rasmussen and others, 2009) were used to evaluate habitat conditions and make comparisons among sites.

Periphyton

Periphyton samples were collected from stream sites during March 12–15, 2007, July 23–26, 2007, and April 5–12, 2010. Because the stream substrates along the study reaches are dominated by gravel and cobble, cobble substrate in riffles and runs was sampled for periphyton at each site. This single habitat sampling approach minimizes periphyton variability among sites caused by sampling of different habitats (Stevenson and Bahls, 1999; Moulton and others, 2002).

Periphyton samples were collected by compositing material from 15 randomly selected cobbles collected from three adjacent riffles at each site. If three riffles were not present, unattached hard substrates (cobbles or woody debris) from run habitats were used. All field sampling equipment was vigorously rinsed three times with stream water. Cobbles were selected and transported from the stream to an on-site processing station. Using a bar-clamp sampler and a new test tube brush at each site, periphyton samples were scraped (scrubbed) from a known area of the cobble surface (device scrubs equivalent areas for each sample) and rinsed into a beaker with filtered stream water (fig. 3*D*). This process was repeated several times until all of the visible periphyton was removed from the sampling area of each cobble.

After all cobbles were scraped, periphytic material was rinsed from the beaker into a graduated cylinder. Sample volume was recorded and the sample was poured into a 1-liter high density polyethylene (HDPE) amber bottle (Stevenson and Bahls, 1999; Moulton and others, 2002; Hambrook-Berkman and Canova, 2007). The sample was vigorously shaken and split into three aliquots. Two aliquots were processed for chlorophyll determination and one for taxonomic identification and enumeration. Chlorophyll samples were processed as described in Hambrook-Berkman and Canova (2007). Samples for taxonomic identification and enumeration were preserved with a 9:1 Lugol's iodine:acetic acid solution. The known areas for all 15 cobbles in a sample were summed to determine total surface area sampled.

Chlorophyll was analyzed at the USGS Kansas Water Science Center, Lawrence, Kans. Total chlorophyll (uncorrected for degradation products) was extracted in heated ethanol (Sartory and Grobbelar, 1986) and analyzed by fluorometry using EPA method 445.0 (Knowlton, 1984; Arar and Collins, 1997). Samples were analyzed in duplicate and results are reported as averages of the duplicates.

BSA Environmental Services, Inc., Beachwood, Ohio, analyzed periphyton samples for taxonomic identification, enumeration, and biovolume of diatoms and soft algae. Diatoms were counted by natural unit as a general category then examined in permanent diatom mounts. Diatom slides were made using the traditional nitric acid digestion method (Patrick Center for Environmental Research, 1988) and a minimum of 400 valves were identified to the lowest possible taxonomic level. The soft algae were enumerated to the lowest possible taxonomic level using membrane-filtered slides (McNabb, 1960) and a minimum of 400 natural units were counted. Biovolume is an estimate of algal biomass and was calculated using mean measured cell dimensions. Biovolume factors for diatoms and soft algae were calculated using methods in Hillebrand and others (1999). Diatom biovolumes were calculated from permanent slides. A mean biovolume measurement per cell was calculated for each sample and that value was used as the biovolume measurement in the general diatom category.

Macroinvertebrates

Macroinvertebrate samples were collected from sites during March 4–13, 2003; February 24–March 3, 2004; March 12–16, 2007; and April 5–9, 2010, following KDHE sampling protocols (Kansas Department of Health and Environment, 2000) with minor adjustments to improve consistency among sites. The KDHE protocol is semiquantitative and uses timed sampling from multiple habitat types. Two independent 100-organism samples were collected and counted onsite by two scientists simultaneously for about 1 hour (fig. 3*E*) and later pooled into one 200-organism sample. Macroinvertebrates were collected using standard 9 in. x 18 in. rectangular-frame kicknets with mesh size approximately 500 µm following physical disturbance of the substrate upstream from the net. Habitat types were sampled according to their relative availability and generally included coarse gravel and cobble in riffles, fine gravel and sand/silt substrates near margins or in runs, leaf packs and coarse detritus accumulations, submerged aquatic vegetation and undercut banks, and large moveable objects like logs or rocks. Habitats such as vegetation and large objects were physically disturbed by the collector and then scooped immediately downstream with the net. Streamside sorting trays and forceps were used to sort organisms. Any organism that appeared different in size, shape, or color compared to organisms previously sorted was included in the sample to maximize diversity. Samples were preserved in 80-percent ethanol and shipped to the USGS NWQL for taxonomic identification and enumeration following methods described by Moulton and others (2000).

Data Analysis

Streamflow Metric Data

Statistical streamflow metrics (table 2) were calculated and used in correlation analysis along with other environmental variables to better understand factors that affect biological conditions. Streamflow variables used in analyses were obtained from several sources including the USGS Streamstats Web site (Perry and others, 2004), calculations for period of record through 2010 (Dave Wolock, U.S. Geological Survey, written commun., 2011) using techniques described by Stewart and others (2006), and The Nature Conservancy's Indicators of Hydrologic Alteration (IHA) method (Richter and others, 1996). More than 100 different streamflow metrics were calculated and a subset of metrics were selected (table 2) that affected stream ecosystems in different ways, differentiated among sites, and represented minimal redundancy.

Periphyton Data

More than 200 periphyton community metrics were calculated using the Algal Data Analysis Software (ADAS) developed for the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program (ADAS, version 2.4.8a released November 30, 2006; T.F. Cuffney, U.S. Geological Survey, written commun., 2009). A subset of about 24 metrics was selected for additional analysis and comparison among sites, and only those metrics are provided

Table 2. Summary of streamflow metrics used in analyses of biological and environmental data for streams in Johnson County, Kansas.

General characteristic	Streamflow metric	Examples of ecosystem effects (Richter and others, 1996)
Magnitude of monthly streamflow conditions (3 months prior to sampling)	Median monthly streamflow, January Median monthly streamflow, February Median monthly streamflow, March	Habitat availability, soil moisture availability, water temperature, dissolved oxygen.
Magnitude and duration of annual streamflow conditions	Mean annual streamflow Base-flow index Minimum 7-day mean streamflow Percentiles of daily flow Minimum daily flow Maximum daily flow Standard deviation of daily flow	Shape and form new habitats, create colonizing sites, flush organic materials into channel, purge invasive species, disperse seeds, duration of stressful conditions.
Frequency and duration of low/high streamflow pulses	Low pulse count High pulse count Low pulse threshold High pulse threshold	Shape river channel, pools, and riffles, determine size of streambed substrate, prevent riparian vegetation from encroaching into channel, flush away waste, exchange nutrients.
Variability and rate of change in streamflow conditions	Rise rate Fall rate Standard deviation (std dev) of the daily flow Coefficient of variability (std dev/mean) Ratio of 75th to 25th percentile 90th minus 10th percentile/50th percentile	Drought stress on plants (falling streamflow), entrapment, tolerance under variable conditions.

in tables contained in this report. Unknown or rare taxa were not deleted and lowest taxonomic levels were used during the ADAS analysis. In addition, only taxa with tolerance values were used in metric calculations, and only diatoms were used for saprobity and trophic metrics. Biovolume, rather than total taxa or cell counts, was used for calculation of periphyton metrics because biovolume is indicative of algal biomass (Lowe and Pan, 1996), and to prevent larger numbers of small taxa (as when using abundance data) from having more effect than smaller numbers of larger taxa. In addition, biovolume was analyzed in a previous report (Rasmussen and others, 2009) so data were comparable. Selected metrics describe oxygen tolerance, saprobity, trophic condition, nitrogen uptake metabolism, and other periphyton attributes; these metrics were used to determine among-site differences (Porter, 2008). The ADAS program uses a common logarithm ($\log_{10}$) base to calculate the Shannon Diversity Index. However, previous studies in Johnson County used a natural logarithm base (ln) for calculations. To allow direct comparison among years, ADAS calculated values were converted to a natural logarithm base by multiplying by 2.3026 (Brower and others, 1998). The percentages of total biovolume that are contributed by *Nitzschia* and *Navicula* were calculated (Stevenson and Rollins, 2007) to indicate contributions to total periphyton biovolume because *Nitzschia* are indicative of ecosystem disturbance and *Navicula* are considered pollution tolerant. Most of the metrics that were used in periphyton analyses were selected because they represent water-quality variables of interest, commonly highlight patterns in data, and are recommended by Stevenson and Rollins (2007), as well as used in USEPA's Rapid Bioassessment Protocols (Barbour and others, 1999).

Nonparametric Wilcoxon signed-rank analysis (Sokal and Rohlf, 1995) was used to test for statistical differences between data sets. Comparisons were made between urban sites and rural sites, and between sites affected by wastewater discharges and sites not affected by wastewater discharges. Each year of data collection included 8–11 urban sites, 8–10 rural sites, and 8–9 sites affected by wastewater discharge. The Wilcoxon analysis tests whether median difference between ranks of paired data values is 0 (the null hypothesis) and the *z*-value represents the test statistic. The probability value (*p*-value) is the probability that the null hypothesis is correct. Lower *p*-values indicate stronger evidence that the paired data values are significantly different. *P*-values less than 0.05 were considered statistically significant in this report.

Macroinvertebrate Data

More than 100 macroinvertebrate community metrics were calculated using the Invertebrate Data Analysis System (IDAS) that was developed for the National Water Quality Assessment Program (NAWQA; IDAS, version 5.0.16 released December 10, 2010, Cuffney and Brightbill, 2011). A smaller subset consisting of 11 metrics was selected for additional evaluation, and only those metrics are provided in tables contained in this report (table 3). They include the four KDHE aquatic-life metrics (Kansas Department of Health and Environment, 2010a), plus those used in Poulton and others (2007) and Rasmussen and others (2009) for multimetric site scoring, which made it possible to make comparisons to previous results. The four aquatic-life metrics include Ephemeroptera-Plecoptera-Trichoptera taxa richness (EPTRich) and Ephemeroptera-Plecoptera-Trichoptera percent abundance (percentage of EPT), which were calculated using IDAS, and Macroinvertebrate Biotic Index (MBI; Davenport and Kelly, 1983) and Kansas Biotic Index (KBI-NO; Huggins and Moffet, 1988) which were calculated as described in these references. The selected metrics represent core metrics used in many State evaluation programs, and those known to be sensitive and reliable for measuring degradation of stream assemblages (table 3). The process for selecting the 11 metrics is described in detail by Poulton and others (2007). During analysis using the IDAS program, the lowest taxonomic levels were used, rare or unknown species were not deleted, and taxonomic ambiguities were resolved by retaining ambiguous data. The Shannon Diversity Index was calculated by using natural logarithms as described in Brower and others (1998).

In addition to comparing sites on the basis of individual metrics, multimetric site scores were calculated to compare degree of biological disturbance or relative conditions. The multimetric scores integrated 10 equally weighted metrics that measure various community facets, including diversity, composition, tolerance, and feeding characteristics, and were calculated using the same methods described in Poulton and others (2007) and also used by Rasmussen and others (2009). Multimetric scores were determined by proportionally scaling each of the 10 metrics among sites, thus transforming each value to numbers between 1 and 100 with 1 representing the poorest biological quality and 100 representing optimum biological quality. The 10 proportionally scaled metrics for each site were summed to determine the multimetric score. The 10-metric scores were used to represent a relative measure of stream-quality condition on the basis of macroinvertebrate communities and to indicate a continuum of biological response to overall human-induced disturbances among the study sites as described by the Biological Condition Gradient conceptual model (Davies and Jackson, 2006). Human-induced disturbances include any physical and chemical stressors that might directly or indirectly affect stream condition. For each of the two sites where replicate macroinvertebrate samples were collected, each of the metrics was calculated by averaging values from the three replicate samples. Multimetric scores were calculated by using the replication mean.

Multimetric scores also were used to compare relative biological effects from human disturbance (least affected, moderately affected, and most affected) as indicated by the 10-metric macroinvertebrate scores and a general knowledge of environmental conditions and sources of human disturbance at the sites. Groups were determined by ranking the sites according to 10-metric scores, and evaluating statistical differences between groups to find logical boundaries for placing sites together that have similar biological conditions (Poulton

Table 3. List of macroinvertebrate metrics, abbreviations, and references used for assessment of biological conditions at monitoring sites in Johnson County, Kansas, 2010.

[KDHE metrics are those used for evaluating the condition of aquatic life in Kansas streams (Kansas Department of Health and Environment, 2010a); KBI-NO, Kansas Biotic Index; X, metric included; --, metric not included; %, percentage; <, less than]

Metric name and reference (if available)	Abbreviation	KDHE metrics	Multimetric score
Macroinvertebrate Biotic Index (Davenport and Kelly, 1983)	MBI	X	X
Kansas Biotic Index (KBI) (Huggins and Moffett, 1988)	KBI-NO	X	X
Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa richness (Klemm and others, 1990)	EPTRich	X	X
Total taxa richness (Barbour and others, 1999)	TRich	--	X
EPT abundance (Barbour and others, 1999)	%EPT	X	--
Percentage of Scrapers (Barbour and others, 1999)	%Sc	--	X
Percentage of Oligochaeta (Lenat, 1993; Kerans and Karr, 1994)	%Olig	--	X
Percentage of Tanytarsini midges (DeShon, 1995)	%Tany	--	X
Percentage of intolerant organisms (KBI < 3), (Huggins and Moffett, 1988)	%Int-KBI	--	X
Percentage of Ephemeroptera and Plecoptera	%EP	--	X
Shannon Diversity Index (Washington, 1984)	SDI	--	X

and others, 2007). Classification results were compared among sites and years of data collection.

The State of Kansas uses four macroinvertebrate metrics, MBI, KBI-NO, EPTRich, and percentage of EPT, for establishing the ability of a stream to support aquatic life and for placement of sites into impairment categories (Kansas Department of Health and Environment, 2010b). Mussel community loss, a fifth State metric of aquatic invertebrate health, is also used if the site is known to have supported at least five mussel species. This metric was not calculated in this report because five mussel species were not found at most sites during previous studies, probably because watersheds were too small to provide suitable habitat. To determine aquatic-life status and relative degree of impairment, these four metric scores were combined into an overall site score representing the mean across all of the metrics included.

Nonparametric Wilcoxon signed-rank analysis (Sokal and Rohlf, 1995) was used to test for statistical differences between data sets, and p-values less than 0.05 were considered statistically significant.

Relating Biological Data to Environmental Variables

Nonparametric statistical analyses were used to determine relations between macroinvertebrate and periphyton communities, water and streambed-sediment quality, habitat measurements, macroinvertebrate and periphyton communities, and watershed variables including land use and streamflow variables. SAS (ver. 9.2) software (Delwiche and Slaughter, 1998) was used to test Spearman rank correlations for monotonic associations between data. Spearman rank-correlation coefficients (rho values) were considered significant when p-values were less than 0.01 and highly significant when p-values were less than 0.001. LOWESS (LOcally WEighted Scatterplot Smoothing; Helsel and Hirsch, 2002) was used to represent general biological response patterns to urbanization. The PRIMER (ver. 6) software (Clarke and Ainsworth, 1993; Clarke and Warwick, 2005; Clarke and Gorley, 2006), which applies nonparametric statistical analyses, was used to evaluate variable similarities and for multidimensional scaling (MDS). The PRIMER software uses nonparametric and permutation approaches to reduce the complexities of multivariate ecological data (many species, metrics, and environmental variables) and graphically displays relations between biological communities, sampling sites, and environmental variables (Clarke and Warwick, 2005). The BEST feature in PRIMER was used to determine the most important environmental variables for explaining biological conditions. BEST uses ranks correlation to determine environmental variables that produce a resemblance matrix similar to the macroinvertebrate matrix (Clarke and Warwick, 2005). Correlations and multivariate analyses were used to characterize relations between variables but do not establish direct causal relations.

Ordinary least squares (OLS) regression analysis was used to develop relations between biological indicator metrics (response variables) and environmental variables (explanatory variables) (Helsel and Hirsch, 2002). A smaller set of potentially suitable explanatory variables was selected after examining scatter plots for linearity of data distribution and meaningful explanatory relations, and Spearman rank correlation coefficients for redundancy among explanatory variables. The selected explanatory variables, which included about 20 descriptors of land use, streamflow, water and streambed-sediment chemistry, in-stream habitat, and riparian buffer conditions, were used in regression model development. Regression models included data from one sample at each site in 2007 and 2010. Variables were transformed when necessary to improve distribution and reduce the risk of violating assumptions of OLS regression. Models were only considered useful when all regression coefficients were statistically significant at *p*-values less than 0.05. Models then were evaluated using diagnostic statistics (R^2, coefficient of determination; RMSE, root mean squared error) and patterns in residual plots.

Quality Assurance and Quality Control

Water and Streambed-Sediment Data

Replicate water and streambed-sediment samples were collected at two different sites in each year of sampling. Relative percent difference (RPD) was used to evaluate differences in analyte concentrations detected in replicate water samples. RPD is calculated as $\{|A-B|/[(A+B)/2]\} \times 100$, where A and B are concentrations in each replicate pair. Most of the quality assurance and quality control information was published in previous reports (Lee and others, 2005; Poulton and others, 2007; Rasmussen and others, 2009). Generally, the RPD between replicate water samples was less than 10 percent with the exception of some nutrients with RPDs ranging to as much as 20 percent, and occasionally larger RPDs when concentrations were near the laboratory reporting level. Replicate pairs of detectable concentrations of nutrients, trace elements, and organic compounds in streambed-sediment samples also had RPDs less than about 10 percent with the exception that the RPD for nitrogen species ranged to as much as 20 percent.

Periphyton Data

Two field-replicate samples for chlorophyll concentration and periphyton community composition, abundance, and biovolume analyses were collected at two sites each year. Coefficient of variation (CV; Sokal and Rohlf, 1995) was used to make comparisons. Concurrent field-replicate sample CVs for periphyton chlorophyll, abundance, and biovolume ranged from 5 percent to 60 percent. High CVs are likely because of the natural variability in periphytic communities (Stevenson, 1997) and the effect of rare taxa that were not present in all samples.

Macroinvertebrate Data

Replicate macroinvertebrate samples were collected at one rural and one urban site each year. Metrics were calculated for each sample individually and were compared using CV values. The mean annual CV across monitoring sites for replicate metric values was less than 20 percent except for percentage of scrapers, percentage of *Oligochaeta*, and percentage of *Tanytarsini* midges, for which the CV ranged from about 30 percent to 100 percent. These metric evaluations were strongly affected by rare taxa that occurred in some replicates but not others. Additionally, variability likely was affected by habitat differences among the sampling locations within each stream reach.

Quality assurance and quality control for macroinvertebrate identification, enumeration, and data entry procedures generally followed those outlined in Moulton and others (2000) and included within-laboratory cross-checking of individual samples and specimens. Current taxonomic keys and voucher specimens are kept on file at the USGS NWQL in Lakewood, Colorado. Other quality-assurance efforts included repeated identification and enumeration procedures by different laboratory technicians and a full comparison of bench sheets for a minimum of 10 percent of the samples.

Assessment of Stream Quality

Environmental Variables

Environmental variables that affect stream quality include watershed variables such as land use (table 1), precipitation, and streamflow, as well as stream-water chemistry, streambed-sediment chemistry, and riparian and in-stream habitat conditions.

Watershed Variables

Precipitation and resulting streamflow conditions can have short-term and long-term effects on biological communities and year-to-year variability can confound data interpretation. The study design calls for samples to be collected in early spring during base flow, that is, allowing adequate time following precipitation such that the stream conditions sampled were not affected by recent runoff. However, during both 2007 and 2010, short periods of recent runoff may have affected biological communities at some sites. Rainfall during the first 3 months of 2010 was about normal compared to those months in previous years (fig. 4). But weather patterns with frequent light-to-moderate rainfall during the spring of 2010 prevented optimal sampling conditions, resulting in a sampling delay of about 2 weeks past the optimal collection period. Although samples were collected during below-normal streamflow, some sites in 2010 were affected by rainfall that occurred in the days and weeks prior to collection. Several sites received 0.5–0.75 in. of rainfall within a few days before sampling.

Regarding precipitation and streamflow conditions during and before sample collections, the year 2003 was the driest year (fig. 4) and streamflow was notably lower during sample collection that year compared to all of the subsequent years (fig. 5). The following year, 2004, had the most total rainfall of the years sampled during March; however, samples were collected in late February and early March 2004 and thus were not affected by the highest streamflow peaks in early March (fig. 5). In 2007, four increasingly larger streamflow pulses occurred at most monitoring sites during the 4 weeks before sample collection, but samples were not collected until about

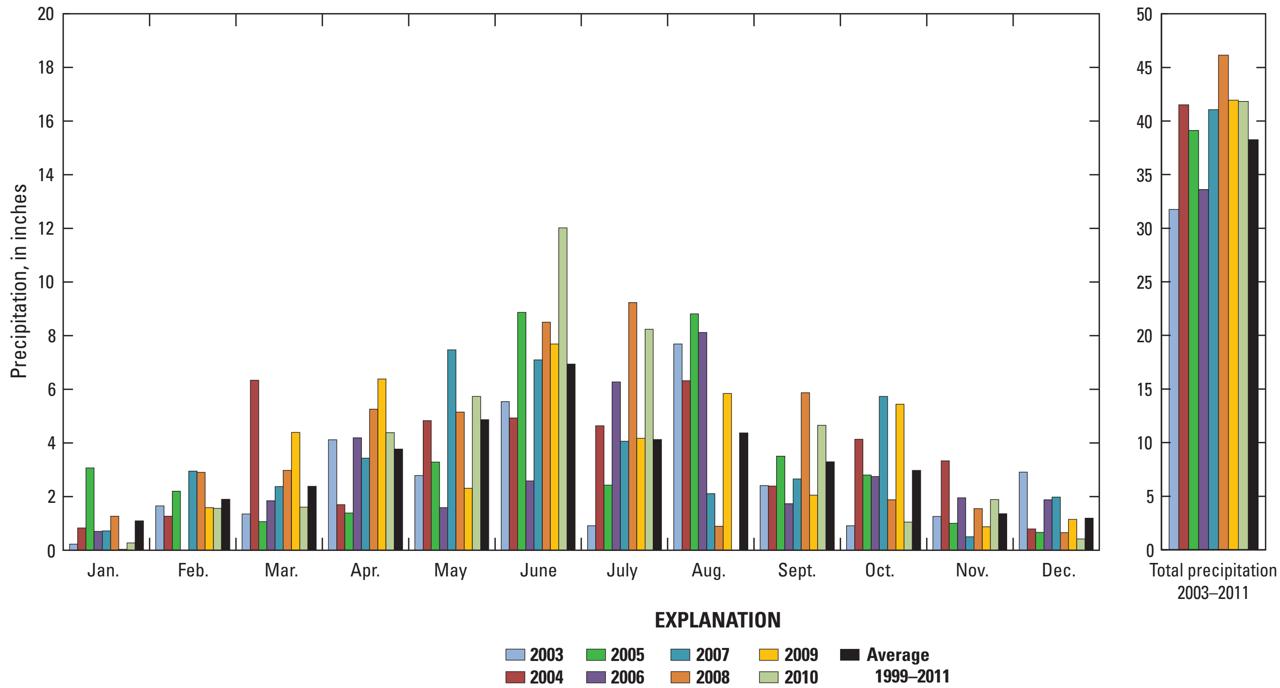

Figure 4. Monthly and annual precipitation in Olathe, Kansas, 2003–10.

1 week after the last peak (fig. 5). In 2010, biological communities may have been affected by rainfall at Indian Creek at State Line Road (IN6), Mill Creek at Johnson Drive (MI7), and possibly other sites where samples may have been collected immediately following a rise in streamflow without adequate time for biological communities to recover (fig. 5). All of the medium and larger runoff events seen in figure 5 likely were large enough to result in entrainment of substrate particles and turbidity values higher than 100 FNU (formazin turbidity units).

Statistical streamflow metrics, used as variables in correlation analysis, were calculated for seven monitoring sites where streamflow data were available (table 4). Twenty streamflow metrics were selected that affected stream ecosystems in different ways, differentiated among sites, and represented minimal redundancy.

Stream-Water Chemistry

Stream-water chemistry is described on the basis of discrete water samples collected during base flow for all years studied and at about the same time biological samples were collected in 2007 and 2010. Base flow water-chemistry data provide some information about water quality at the sites but do not fully describe water quality that likely affects biological communities in the days, weeks, or months prior to sampling. Data qualified by the laboratory as estimated (E) indicates reported values were outside instrument calibration range, analysis did not meet acceptable method-specific criteria, or matrix interference occurred. The precision of estimated values is frequently less than the precision of values reported without this qualifier (Childress and others, 1999). Water-quality constituents not detected at any sites are excluded from tables of results.

Specific conductance is a measure of dissolved ions in stream water and is determined primarily by rock and soil types and weathering rates, the amount of groundwater contributing to streamflow, the amount of urbanization and agriculture, and quality and quantity of discharges from wastewater and industrial sites (Hem, 1992). Road-salt application for de-icing purposes is also a source of dissolved solids, particularly chloride, sodium, and magnesium. Elevated road-salt concentrations in streams have been known to cause acute and chronic toxicity to aquatic organisms (Corsi and others, 2010), and elevated concentrations have been known to persist throughout summer months (Ostendorf and others, 2001). Continuous water-quality monitoring in Johnson County streams indicated that chloride concentrations in urban streams are greater than rural streams year-round and often exceed the EPA recommended chronic freshwater quality criterion of 230 milligrams per liter (mg/L) (U.S. Environmental Protection Agency, 2012) during snowmelt and winter runoff conditions as a result of road-salt application (Rasmussen and others, 2008).

Specific conductance, dissolved solids, and major ions varied largely from site to site. The range in specific conductance is an indication of base-flow variability in dissolved solids and major ions among sites (fig. 6). Specific conductance ranged from 316 microsiemens per centimeter (µs/cm) at the Captain Creek site (CA1) in 2010 to more than 1,500 µs/cm at two Little Mill sites (LM1a and LM1b) and the Turkey Creek (TU1) site in 2007 (appendix 3). Generally, specific

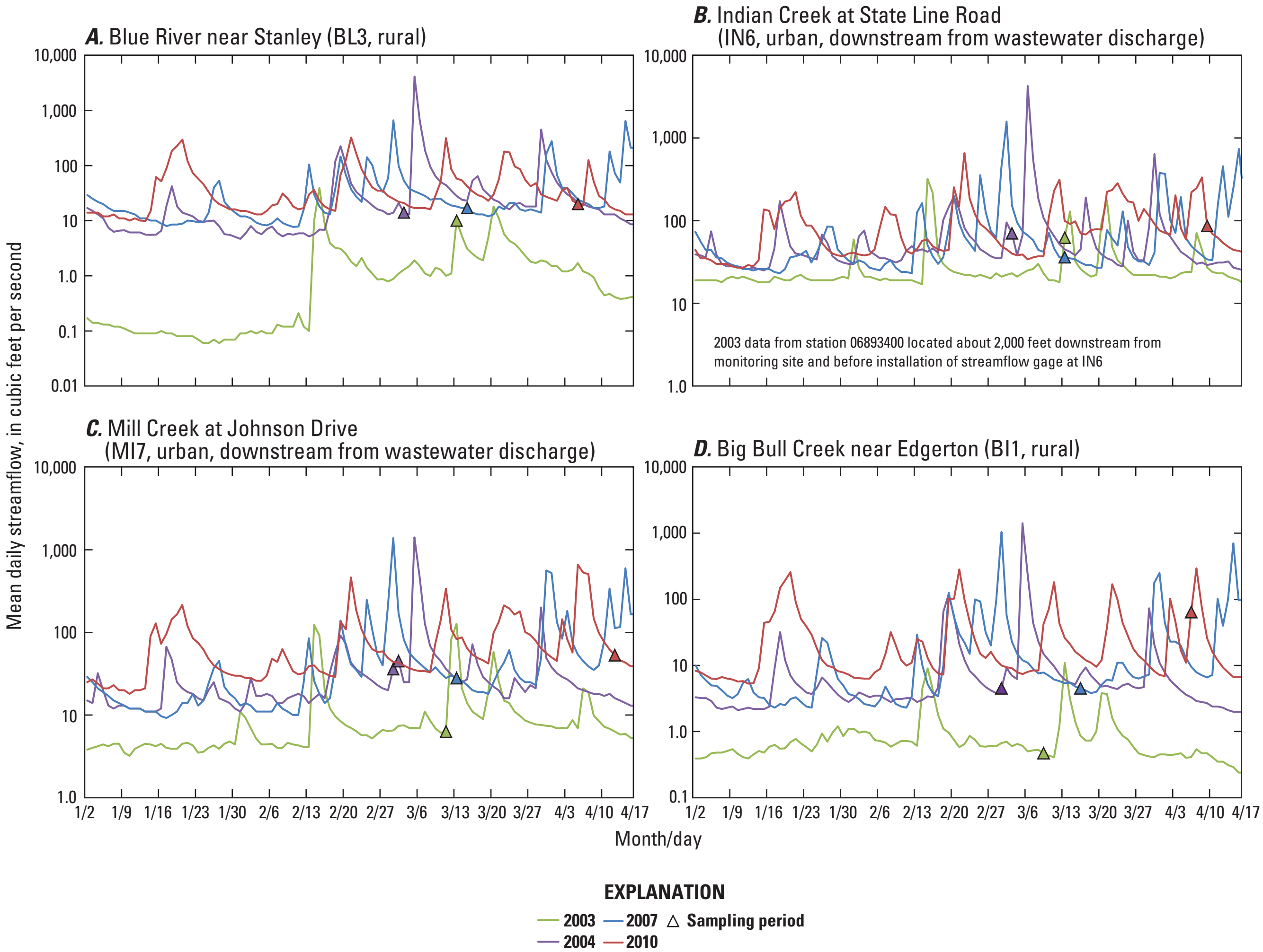

Figure 5. Daily streamflow conditions 3 months before biological sampling in Johnson County, Kansas, and approximate period of sample collection, 2003, 2004, 2007, and 2010.

conductance was highest at urban sites, with the exception of the rural site Cedar Creek at Old Highway 56 (CE1). Although the Cedar Creek site is classified as rural with one-fourth of the drainage area urban land, a large area of commercial and industrial land, including a limestone quarry, is located less than 1 mile upstream from the site on both sides of Cedar Creek. Elevated specific conductance was measured in 2002, 2003, and 2010 at site CE1 and corresponded to high concentrations of dissolved solids (805–1,070 mg/L), sodium (100–150 mg/L), sulfate (307–414 mg/L), and magnesium (24–33 mg/L). The highest specific conductance occurred in 2007 at 18 of the 20 sites with data in 2007 (not sites BI1 or CE1). Higher countywide specific conductance in 2007 likely is related to generally lower precipitation (fig. 4) and more groundwater contribution to base flow. The Big Bull site (BI1) likely had higher specific conductance in 2002 and 2003 because of upstream wastewater discharge that was discontinued in 2007. Chloride concentrations exceeded the chronic criterion of 230 mg/L in 2007 at each of the 3 Little Mill Creek sites (ranging from 253–347 mg/L), and at the Turkey Creek site (TU1, 330 mg/L, appendix 3). Although the winter of 2006–07 received about one-half of the normal snowfall (10.2 in. compared to the annual average of 19.9 in.; National Oceanic and Atmospheric Administration, 2011), freezing precipitation events in January and February 2007 may have resulted in higher use of snowmelt products during the 2–3 months before sampling in 2007.

The highest base-flow nutrient concentrations in water occurred directly downstream from WWTFs. Total nitrogen (calculated by summing nitrate, nitrite, ammonia, and organic nitrogen) and total phosphorus were highest, for each year sampled, at Indian Creek sites IN3a and IN6, which are directly downstream from WWTFs, and at the first Mill Creek site downstream from a WWTF (MI4, table 1, appendix 3, fig. 6). Total nitrogen and total phosphorus at the two Indian Creek sites (IN3a and IN6) demonstrated a pattern of substantial concentrations in the first sample collected followed by sequentially decreasing concentrations in subsequent samples. Reductions in total nitrogen and total phosphorus at the two Indian Creek sites can be attributed to lower contributions

Table 4. Streamflow statistics used in correlation analysis for biological monitoring sites in Johnson County, Kansas, 2002–10.

[mi², square miles; ft³/s, cubic feet per second; (ft³/s)/mi², cubic feet per second per square mile; (ft³/s)/d, cubic feet per second per day]

Streamflow statistic	Biological monitoring site (fig. 1)						
	Big Bull Creek near Edgerton, site BI1 (06914950)	Blue River near Stanley, site BL3 (06893080)	Blue River at Kenneth Road, site BL5 (06893100)	Cedar Creek near DeSoto (83rd Street), site CE6 (06892495)	Indian Creek at State Line Road, site IN6 (06893390)	Kill Creek at 95th Street, site KI6b (06892360)	Mill Creek at Johnson Drive, site MI7 (06892513)
Watershed area, mi²	29.1	45.4	65.7	58.9	64.8	50.1	57.9
Mean daily streamflow/area, (ft³/s)/mi²	0.83	0.83	0.99	0.88	1.7	0.76	1.0
Median monthly streamflow, January, ft³/s	3.9	14	22	17	35	10	15
Median monthly streamflow, February, ft³/s	5	17	22	33	43	10	21
Median monthly streamflow, March, ft³/s	7	19	36	32	46	17	33
Base flow index, unitless	0.107	0.135	0.183	0.256	0.259	0.170	0.221
Standard deviation of baseflow index	0.050	0.053	0.045	0.072	0.024	0.031	0.036
Low pulse count, number of events per year	10	11	10	12	19	7	13
High pulse count, number of events per year	18	18	16	17	33	17	26
Low pulse threshold, ft³/s	1.6	4.0	6.6	9.1	15	4.1	12
High pulse threshold, ft³/s	10	28	44	44	35	25	45
Rise rate, (ft³/s)/d	0.7	1.9	5	4.0	19	2.3	16
Fall rate, (ft³/s)/d	-0.7	-2	-4	-3	-4	-2	-4
Mininum 7-day average streamflow, ft³/s	0.24	0.28	1.89	3.24	18.29	1.43	5.87
Maximum daily streamflow, ft³/s	2,520	5,520	4,830	2,540	5,320	2,450	2,910
Mean daily streamflow, ft³/s	24.2	37.7	65.2	51.8	107	38.3	60.7
Standard deviation of daily streamflow, unitless	117	176	250	152	291	136	171
Coefficient of variability, unitless	4.84	4.68	3.83	2.93	2.70	3.55	2.82
Ratio of 75th to 25th percentile, unitless	7.18	20.2	6.56	5.23	2.85	6.67	3.73
90th minus 10th/50th percentile, unitless	9.83	9.98	6.21	5.05	4.38	8.19	5.62

from the dissolved species, nitrate and orthophosphorus, likely originating from wastewater discharge. Total nitrogen and total phosphorus at the Mill Creek site (MI4) decreased from 2003 onward (fig. 6). Although there were no notable changes in total nitrogen concentrations from 2002 to 2010 at the downstream Cedar Creek site (CE6) or the upstream Kill Creek site (KI5b), both sites had among the highest total phosphorus concentrations in 2002 (0.77 and 0.72 mg/L, respectively), which decreased each year until 2010 when it was 0.14 and 0.17 mg/L, respectively (appendix 3).

Suspended-sediment concentrations ranged from less than 10 mg/L in about one-third of the samples collected (2002–10) to more than 200 mg/L in one sample each from Little Bull Creek in 2003 and Turkey Creek in 2010. Generally, sites downstream from wastewater discharges have been determined to have lower suspended-sediment concentrations during base flow than others sites because of the higher clarity of treated wastewater (Lee and others, 2005). The highest suspended-sediment concentrations at 10 of the sites (50 percent) occurred in 2010 and at 5 sites (25 percent) in 2007. This is likely because the amount of recent rainfall before sample collection was greater during those years. Variability in suspended-sediment concentration among sites and years (including the Little Bull site, LI1, during 2010 with concentrations about triple that of any other site, fig. 6*D*) in this study can be attributed primarily to runoff before sample collection.

Base flow densities of *Escherichia coli* (*E.coli*) bacteria, commonly used as an indicator of pathogens in surface water, ranged from less than 10 colonies per 100 milliliters of water (col/100mL) at the rural Blue River site in 2003 to 4,400 col/100 mL at the rural Captain Creek site in 2010 (appendix 3). Generally, *E. coli* densities were highly variable among both urban and rural sites and among sampling years.

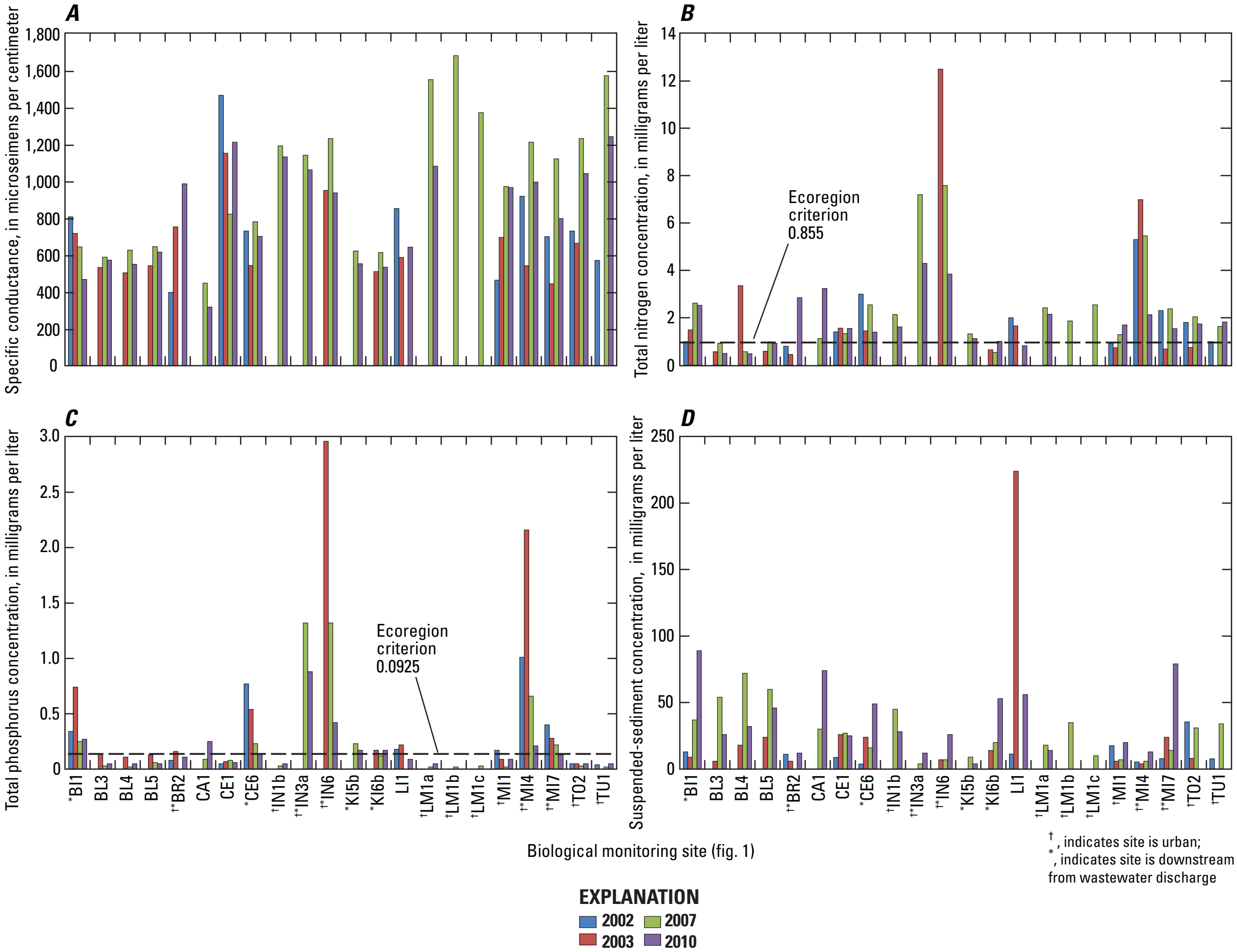

Figure 6. Selected water-quality characteristics during base flow sampling at monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.

Streambed-Sediment Chemistry

Because many compounds are hydrophobic, concentrations of many contaminants in streambed sediment are much greater than concentrations dissolved in the above water column (Horowitz, 1991). Streambed-sediment chemistry is described on the basis of streambed-sediment samples collected during base-flow conditions during years sampled, and at about the same time biological samples were collected in 2007 and 2010. Data were qualified by the laboratory with estimated or left-censored (less-than) values as described by Childress and others (1999). Streambed-sediment constituents that were not detected at any site are not included in tables. Organic compounds in streambed-sediment samples collected in 2003 and 2007 were analyzed from unsieved, bulk samples rather than from sieved samples (fraction finer than 63 microns). Because most compounds are sorbed preferentially to the fine fraction, concentrations in 2003 and 2007 likely are biased low in comparison to concentrations in samples collected in 2010.

The highest concentrations of carbon and nutrients in streambed sediment occurred in 2003 at most sites, followed by concentrations in 2010 (appendix 4, fig. 7). Most sites had increases in total organic carbon from 2007 to 2010, but the net change from 2003 to 2010 was a median decrease in total organic carbon of 23 percent at all except four sites (BL3, IN6, TO2, TU1). Organic carbon affects biogeochemical processes in aquatic systems and in streambed sediment increases adsorption of metals (Horowitz, 1991) and organic compounds (Karickhoff, 1984). However, linear associations between total organic carbon and other constituents analyzed in streambed sediment were apparent only for total nitrogen and total phosphorus (selected scatter plots are shown in appendix 5). Precipitation, and consequently streamflow, was lowest in 2003 compared to the following years (fig. 4), which likely contributed to higher nutrient concentrations downstream from WWTFs. High total organic carbon and nutrient concentrations at the Big Bull Creek site (BI1) in 2003 decreased to at least one-fourth of those concentrations in 2007 and 2010 (fig. 7, appendix 4), likely because of the reduction in

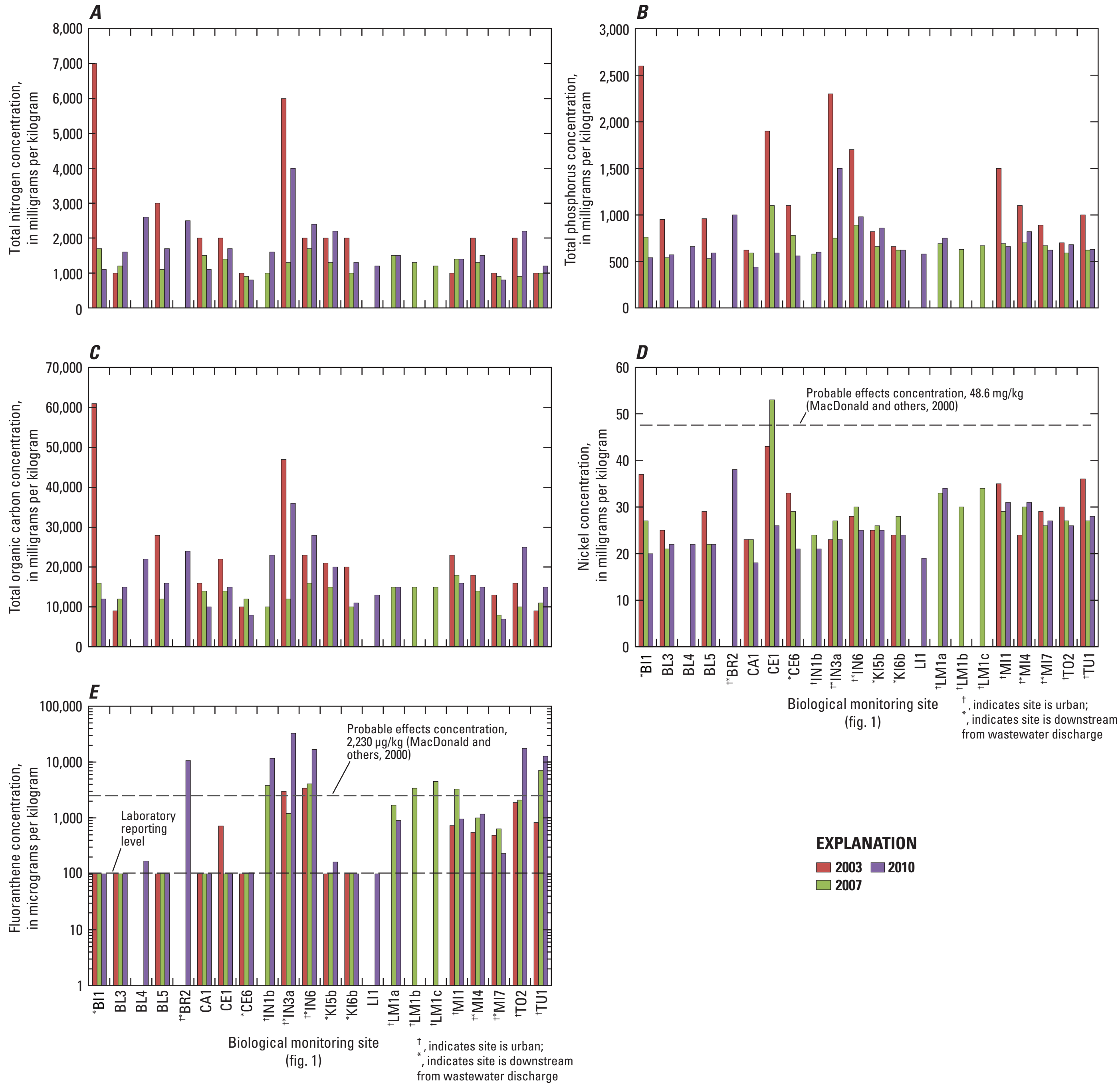

Figure 7. Concentrations of selected sediment-quality constituents in streambed samples collected during base-flow at monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.

upstream wastewater discharge contributions. The city of Gardner's wastewater treatment facility, which had a design flow of 1 million gallons per day (mgd), closed during 2007 and flows subsequently are being pumped to a treatment facility in the Kill Creek watershed. Nutrient concentrations in sediment downstream from the Kill Creek WWTF (KI5b) were slightly higher in 2010 than in previous years (fig. 7). Increases in concentrations at the Kill Creek site would not be expected to be proportional to decreases in concentrations at the Big Bull Creek site because of differences in wastewater treatment processes, receiving stream conditions, and distance of monitoring sites from wastewater discharge sites. During 2010, the highest nutrient concentrations (nitrogen and phosphorus) in sediment occurred at the Indian Creek site directly downstream from Douglas L. Smith WWTF (IN3a, fig. 1).

Trace metals were detected in streambed sediment from all sites. Probable effects concentrations (PECs) have been developed for some trace metals and are shown in appendix 4 (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998). The PEC represents the concentration of a contaminant in streambed sediment that is expected to adversely affect benthic biota. The highest concentrations of trace metals in 2010 occurred at sites on Mill and Indian Creeks (appendix 4). Sites in the Mill Creek watershed had among the highest 2010 aluminum (ranging from 61,000 to 64,000 mg/kg), chromium (60 to 68 mg/kg), and iron (26,000 to 34,000 mg/kg) concentrations. The highest concentrations of zinc occurred at two sites with heavy bridge traffic (IN6 and IN1b). Some metal concentrations showed downward trends across the county from 2003 to 2010. For example, nickel concentrations decreased by at least 20 percent at 6 of the 15 sites for which data were available in 2003, and increased at 1 site (MI4, fig. 7, appendix 4). Zinc concentrations decreased by at least 20 percent at 9 of the 15 sites. However, zinc concentration at Indian Creek at State Line (IN6) increased from 170 mg/kg in 2003 to 500 mg/kg in 2010, exceeding the PEC of 459 mg/kg. Zinc was the only metal to exceed the PEC in 2010. Chromium and nickel at the upstream Cedar Creek site (CE1) exceeded PECs in 2007, and no metals exceeded PECs in 2003. At the Big Bull Creek site (BI1) about 70 percent of the detected constituents in 2003 decreased by at least 20 percent in 2010. Concentrations of trace elements in streambed sediment during the study period were within the range of concentrations reported in a national pilot study of streambed-sediment contaminants in metropolitan streams (Moran and others, 2011).

Of 72 organic compounds analyzed in streambed sediment (appendix 1), 26 were detected (appendix 4) including pesticides, polycyclic aromatic hydrocarbons (PAHs), fuel products, fragrances, preservatives, plasticizers, manufacturing byproducts, flame retardants, and disinfectants. All six PAH compounds analyzed (anthracene, benzo[a]pyrene, fluoranthene, naphthalene, phenanthrene, and pyrene) were detected. PAHs originate from the incomplete combustion of fossil fuels and are common in diesel fuel, crude oil, and gasoline. A frequent source of PAHs in urban areas is coal-tar sealcoats that are applied to parking lots (Mahler and others, 2005). Effects of PAHs on benthic macroinvertebrates include inhibited reproduction, delayed emergence, and higher mortality rates, and effects on fish include fin erosion, liver abnormalities, cataracts, and immune system impairments (U.S. Environmental Protection Agency, 2008). PECs for 4 of the 6 PAH compounds analyzed were exceeded in 2010, in some instances by as much as 14 times (fluoranthene at site IN3a and phenanthrene at site IN1b). Concentrations of PAH compounds commonly exceeded PECs at the most urban sites, Brush Creek (BR2), Indian Creek (IN1b, IN3a, and IN6), Tomahawk Creek (TO2), and Turkey Creek (TU1). For example, fluoranthene was detected at all urban sites each year it was analyzed (fig. 7), but was rarely detected at rural sites. Fluoranthene concentrations exceeded the PEC at 2 of the urban sites in 2003, 6 of them in 2007, and 6 of them in 2010. Higher PAH concentrations in 2010 may have resulted from more recent deposition from stormwater runoff immediately preceding sample collection. Concentrations of PAH compounds during the study period were within the range of concentrations reported in a national pilot study of streambed-sediment contaminants in metropolitan streams (Moran and others, 2011).

Among the organic compounds analyzed in streambed sediment were 26 pesticides, 16 of which were pyrethroid compounds. Only five pesticide compounds analyzed in sediment were detected, including carbazole and four pyrethroid compounds. Carbazole, which also occurs in dyes, lubricants, and explosives, was detected at six sites, all urban, in 2010 (appendix 4). At least one pyrethroid compound was detected at 6 sites, including 3 urban sites and 3 rural sites. Of the 8 detections of pyrethroid compounds at the 6 sites, chronic toxicity guidelines were exceeded at 5 sites (bifenthrin at sites LM1a, MI4, and TU1; cyfluthrin at site BR2; permethrin at site CE6). In a national study of pyrethroid occurrence, bifenthrin, cyfluthrin, and permethrin were detected in 58 percent, 14 percent, and 31 percent of samples, respectively (Hladik and others, 2012).

Riparian and In-Stream Habitat Conditions

Differences in total habitat scores were negligible between 2007 (Rasmussen and others, 2009) and 2010, and only 2010 values are shown in tables and figures. Total habitat scores from 2010 were suboptimal at 17 of the 20 monitoring sites and marginal at the remaining sites (fig. 8, table 5). Variability in total habitat scores was minimal among sites, likely because stream types within the small geographic study area are generally similar. The lowest habitat scores (corresponding with the poorest habitat conditions) occurred at the three most urbanized sites, Brush Creek (BR2), downstream Indian Creek (IN6), and Turkey Creek (TU1). Those sites generally scored lower on most of the individual habitat variables, but also scored particularly low for vegetated buffer length and width. Buffer width is a measure of natural vegetation (including forest, shrubs, and native grasses) extending from the stream bank out into the riparian zone. A wide buffer helps control erosion, promotes nutrient uptake, can produce shading and habitat structure in the channel (if woody species are present), and allows runoff more time to percolate into soils before entering the stream (Barbour and others, 1999). Longitudinal buffer status considers the continuity of the buffer, which is often interrupted by bridge crossings and stormwater drains in urban areas. Additionally, bank stability was highest at two of those sites (BR2 and TU1, fig. 8) because of artificial bank-erosion control features.

The downstream Blue River site (BL5) and the Kill Creek sites (KI5b; KI6b) had the highest total habitat scores (indicating better habitat conditions), followed by the Big Bull site (BI1) and the other two Blue River sites (BL3 and BL4). Land use upstream of all of those sites is primarily rural. These sites generally scored well on in-stream habitat variables related to sediment deposition and habitat diversity

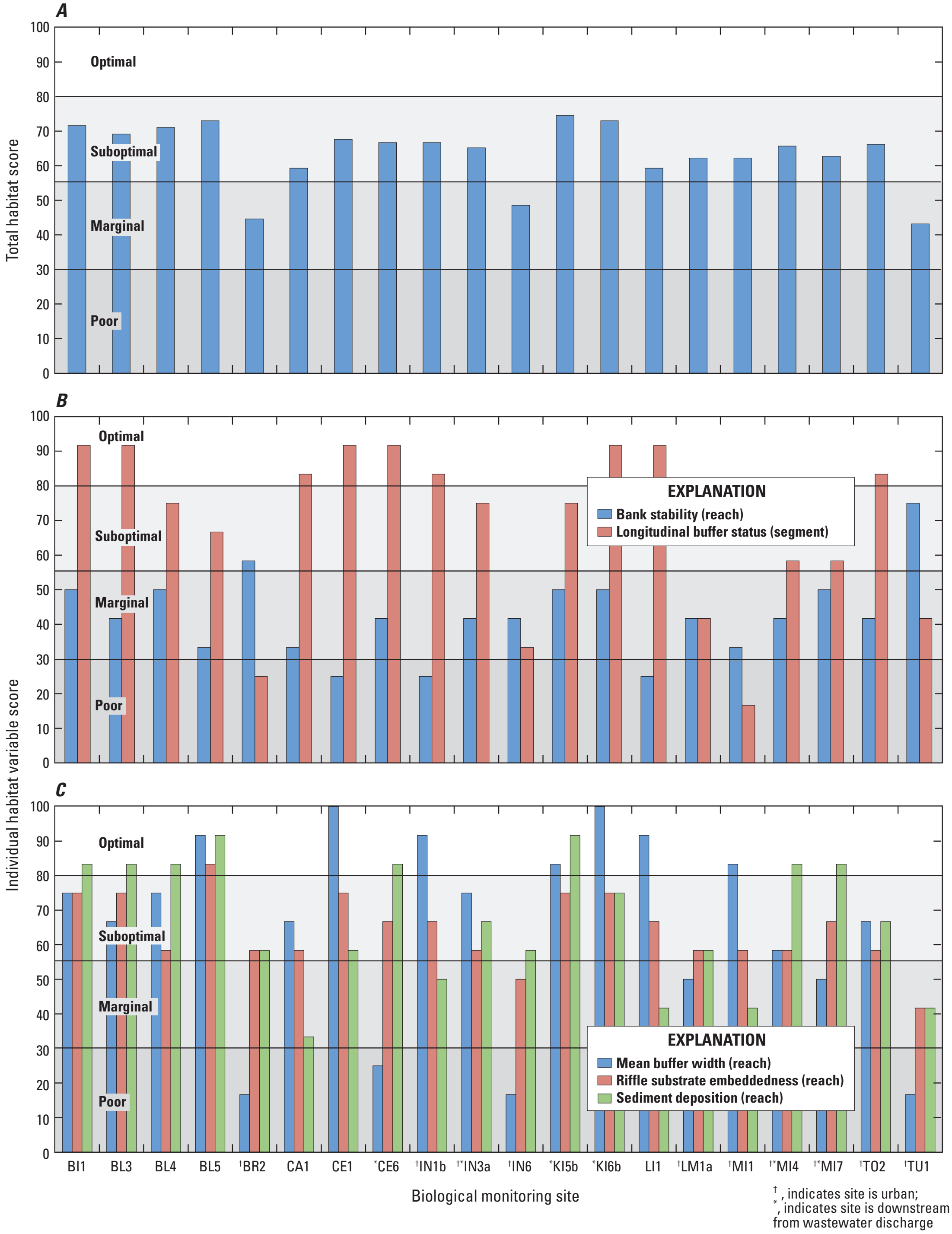

Figure 8. Total habitat score and scores for selected individual habitat variables at biological monitoring sites in Johnson County, Kansas, 2010.

(fig. 8). Excessive sediment deposition makes the streambed unsuitable for many organisms and can lead to substrate embeddedness, which further reduces living space available to macroinvertebrates and fish. Substrate diversity provides cover, protection from high current velocity, feeding sites, and spawning sites in the form of woody debris, leaf packs, root mats, and inundated vegetation.

Biological Variables

Biological variables included in the evaluation of stream quality were periphyton and macroinvertebrate communities. Statistical analyses and emphasis in discussion for this report is on 2010 results with some comparisons to previously collected data, which are described in more detail by Poulton and others (2007) and Rasmussen and others (2009). Differences

Table 5. Results of habitat assessment (standardized to a 0–100 scale) at biological monitoring sites in Johnson County, Kansas, 2010.

[Scores of 80–100 indicate optimal conditions, 55–79 are suboptimal, 30–54 are marginal, and 0–30 are poor; * indicates site is downstream from wastewater treatment facility discharge]

Habitat variable	Biological monitoring site (fig. 1, table 1) and general land-use classification																				Maximum	Minimum
	BI1, rural	BL3, rural	BL4, rural	BL5, rural	BR2, urban	CA1, rural	CE1, rural	CE6*, rural	IN1b, urban	IN3a*, urban	IN6, urban	KI5b*, rural	KI6b*, rural	LI1, rural	LM1a, urban	MI1, urban	MI4*, urban	MI7*, urban	TO2, urban	TU1, urban		
Category 1, channel conditions, characteristics, and assessment scores																						
A. Flow status	58	83	83	83	50	42	75	75	58	75	67	83	75	50	67	42	83	83	75	25	83	25
B. Channel slope and morphological status (reach)	67	67	67	58	42	67	58	25	67	67	75	50	58	33	42	58	67	42	50	58	75	25
C. Sinuosity (segment)	50	42	25	42	25	67	42	58	42	42	33	42	50	50	17	17	17	42	42	17	67	17
D. Pool status (reach)	92	75	83	92	58	92	83	83	83	83	50	83	92	83	83	83	83	75	75	42	92	42
E. Riffle frequency (segment)	58	42	75	50	25	33	58	50	58	58	42	67	42	25	75	92	58	33	50	33	92	25
Category 2, bank, riparian conditions, and assessment scores																						
A. Bank stability (reach)	50	42	50	33	58	33	25	42	25	42	42	50	50	25	42	33	42	50	42	75	75	25
B. Canopy cover (reach)	83	83	92	92	50	50	92	67	92	92	67	75	58	92	92	92	92	75	83	42	92	42
C. Bank/riparian protection (reach)	58	58	25	42	42	42	33	50	33	42	50	58	67	25	50	42	33	58	33	50	67	25
D. Length and extent of buffers (segment)	92	92	75	67	25	83	92	92	83	75	33	75	92	92	42	17	58	58	83	42	92	17
E. Average natural buffer width (reach)	75	67	75	92	17	67	100	25	92	75	17	83	100	92	50	83	58	50	67	17	100	17
F. Percentage (%) altered banks (reach)	83	83	92	83	58	83	83	92	83	67	33	92	92	92	83	92	83	67	75	50	92	33
Category 3, in-stream aquatic habitat availability and assessment scores																						
A. Riffle substrate fouling (reach)	50	58	92	75	50	50	50	75	83	58	33	83	67	42	83	83	83	83	75	50	92	33
B. Velocity/depth combinations (reach)	75	58	75	75	42	67	75	75	75	75	58	75	75	50	75	75	75	58	75	50	75	42
C. Riffle substrate embeddedness (reach)	75	75	58	83	58	58	75	67	67	58	50	75	75	67	58	58	58	67	58	42	83	42
D. Sediment deposition (reach)	83	83	83	92	58	33	58	83	50	67	58	92	75	42	58	42	83	83	67	42	92	33
E. Diversity of epifaunal substrate and cover types (reach)	83	83	75	92	42	92	83	83	83	58	50	83	83	75	67	83	67	58	83	42	92	42
F. Riffle substrate composition (reach)	83	83	83	92	58	50	67	92	58	75	67	100	92	75	75	67	75	83	92	58	100	50
Site score	**72**	**69**	**71**	**73**	**45**	**59**	**68**	**67**	**67**	**65**	**49**	**75**	**73**	**59**	**62**	**62**	**66**	**63**	**66**	**43**	**75**	**43**

between datasets were considered significant (*p*-value less than 0.05) according to Wilcoxon signed-rank analysis (Sokal and Rohlf, 1995).

Algal Periphyton Communities

Periphyton are the attached algae that grow on submerged stream surfaces, such as rocks and woody debris. Periphyton are primary producers and are a key link between abiotic factors, such as sunlight and nutrients, and higher trophic levels, such as macroinvertebrates and fish. Periphytic communities commonly are used as indicators of ecological conditions because they respond rapidly to changes in environmental conditions. As such, physical, chemical, and pollution tolerances and optimal growth conditions have been described for many periphytic algal species (Porter, 2008). Although algal assemblages increasingly are being used as indicators of environmental condition (U.S. Environmental Protection Agency, 2002), the State of Kansas currently (2012) does not use periphyton in biological assessments of water quality. Several States, including Kentucky (Kentucky Division of Water, 1993), Montana (Bahls, 1993), and Oklahoma (Oklahoma Conservation Commission, 1993) use periphyton in their bioassessment programs.

Community Composition

Overall, 129 periphyton taxa were identified from the 20 sites sampled in Johnson County in 2010 (appendix 6), which is about 40 percent greater than the number of taxa identified in 2007 (Rasmussen and others, 2009). This difference likely is because almost twice as many stream sites were sampled in 2010 compared to 2007. Similar to 2007, during 2010 most taxa (109) were in the division Bacillariophyta (diatoms). Eight taxa were in the division Chlorophyta (green algae), six taxa were in the division Cyanophyta (cyanobacteria or blue-green algae), four taxa were in the division Euglenophyta (euglenoids), and one taxon was in the divisions Rhodophyta (red algae) and Streptophyta (green plants). About 80 percent of the periphyton taxa were relatively rare (observed at only 1 or 2 sites, or contributing less than 1 percent to total periphyton abundance or biovolume, or both), which was a large increase compared to about one-half of the taxa classified as rare in 2007. Based on taxa occurrence, among the most common periphyton taxa in 2010 were the diatoms *Amphora pediculus*, *Cocconeis placentula*, *Gomphonema olivaceum*, and *Navicula cryptotenella*. These taxa generally are indicative of eutrophic conditions (Porter, 2008). Diverse communities with abundance or biovolume, or both dominated by few taxa commonly occur in Johnson County streams and streams throughout the Nation (Bahls, 1973; Brown and Olive, 1995; Kutka and Richards, 1996; Rasmussen and others, 2009; Graham and others, 2010).

Periphyton abundance and biovolume at all sites were dominated (greater than 75 percent of total) by diatoms (Bacillariophyta) during 2007 (Rasmussen and others, 2009) and 2010 (appendix 6), with the exception of biovolume at the Tomahawk Creek site (TO2) in 2007. Green algae (Chlorophyta) occurred at 9 out of the 20 sites and contributed from less than 1 percent to 22 percent of total abundance and biovolume. Blue-green algae (Cyanophyta) occurred at seven sites with total abundance and biovolume that ranged from less than 1 to 15 percent. Cyanobacteria generally are considered a nuisance when present because of their potential to produce toxins and disagreeable taste and odor compounds (Graham and others, 2008). Green algae and cyanobacteria blooms in streams are most likely to occur in summer when temperatures are warmer and flows are usually at seasonal lows (Allan, 1995). Cyanobacteria dominance typically indicates enrichment by nutrients and organic pollution (Stevenson and Rollins, 2007).

Periphyton Chlorophyll Concentrations, Abundance, and Biovolume

Chlorophyll is the green pigment that allows photosynthesis to occur and can be used as an indirect measure of algal biomass. Chlorophyll often is used to describe algal communities because it is less time consuming than counting, identifying, and measuring algal cells. Periphyton abundance is the total number of cells present, whereas chlorophyll concentrations and biovolume are indicators of periphyton biomass. Nuisance conditions have been defined for periphyton chlorophyll but not for abundance and biovolume.

Total chlorophyll concentrations in 2010 ranged from 3.2 to 250 milligrams per square meter (mg/m^2; table 6, fig. 9). Nuisance algal conditions have been documented to occur when periphytic chlorophyll concentrations exceed 100 mg/m^2 (Horner and others, 1983; Welch and others, 1988). Six of the 20 sites exceeded this chlorophyll threshold value in 2010, and 4 of 11 sites exceeded the threshold in 2007. With the exception of site TO2 in 2010 and IN6 in 2007, which are both urban, the sites that exceeded the chlorophyll threshold value were rural. Total chlorophyll in 2010 was significantly higher (*z*-value 2.42, *p*-value 0.01) at rural sites (median 95 mg/m^2) than at urban sites (median 37 mg/m^2).

Algal periphyton abundance in 2010 ranged from 0.11 billion cells per meter square (billion cells/m^2) to 18 billion cells/m^2 (table 6, fig. 9). Periphyton abundance during 2010 was not significantly different for urban sites compared to rural sites, or for sites affected by wastewater compared to sites not affected by wastewater. Periphyton biovolume ranged from 30 cubic millimeters per meter square (mm^3/m^2) to 16,000 mm^3/m^2 during 2010 (table 6). The upper range in 2010 was about one-half of the largest biovolume in 2007 (MI7, 32,000 mm^3/m^2). Periphyton biovolume in 2010 was significantly larger (*z*-value 2.2, *p*-value 0.01) at rural sites (median 3,100 mm^3/m^2) than at urban sites (median 860 mm^3/m^2). Larger periphyton biovolume at rural sites was not caused by higher nutrient concentrations since urban sites generally had higher nutrient concentrations than rural sites. It may have been caused by lower light conditions at urban

Table 6. Algal periphyton chlorophyll concentrations, abundance, and biovolume at biological monitoring sites in Johnson County, Kansas, March and July 2007, and April 2010.

[mg/m², milligrams per square meter; mm³/m², cubic millimeters per square meter; *, site is downstream from wastewater treatment facility discharge]

Biological monitoring site identifier (fig. 1)	General land use	Algal periphyton: Chlorophyll concentrations (mg/m²)	Algal periphyton: Abundance (billion cells/m²)	Algal periphyton: Biovolume (mm³/m²)
March 2007				
BI1*	Rural	79	9.6	9,400
BL5	Rural	130	18	13,000
CA1	Rural	110	20	12,000
CE6*	Rural	130	7.9	12,000
IN1b	Urban	77	7.3	4,800
IN3a*	Urban	95	12	3,500
IN6*	Urban	39	6.2	1,100
KI6b*	Rural	16	2.7	1,600
MI7*	Urban	97	15	32,000
TO2	Urban	78	11	62
TU1	Urban	47	4.5	4,500
Minimum		**16**	**2.7**	**62**
Maximum		**130**	**20**	**32,000**
Median		**79**	**10**	**4,800**
July 2007				
BI1*	Rural	16	8.0	1,700
BL5	Rural	19	2.5	1,300
CA1	Rural	7.5	1.9	980
CE6*	Rural	27	4.4	1,500
IN1b	Urban	19	2.3	860
IN3a*	Urban	15	5.8	1,000
IN6*	Urban	120	19	12,000
KI6b*	Rural	13	2.8	2,000
MI7*	Urban	20	6.5	3,300
TO2	Urban	25	2.7	1,800
TU1	Urban	16	2.2	670
Minimum		**7.5**	**1.9**	**670**
Maximum		**120**	**19**	**12,000**
Median		**19**	**2.8**	**1,500**
April 2010				
BI1*	Rural	29	0.71	550
BL3	Rural	170	12	7,100
BL4	Rural	170	18	16,000
BL5	Rural	250	16	9,000
BR2*	Urban	31	6.6	720
CA1	Rural	59	4.0	780
CE1	Rural	81	5.1	2,600
CE6*	Rural	32	2.9	2,200
IN1b	Urban	59	4.5	810
IN3a*	Urban	42	2.8	1,000
IN6*	Urban	59	5.2	2,700
KI5b*	Rural	220	8.7	15,000
KI6b*	Rural	110	8.2	3,700
LI1	Rural	55	1.4	1,200
LM1a	Urban	14	2.9	490
MI1	Urban	59	8.1	1,800
MI4*	Urban	22	2.5	910
MI7*	Urban	6.8	0.19	110
TO2	Urban	150	12	6,800
TU1	Urban	3.2	0.11	30
Minimum		**3.2**	**0.11**	**30**
Maximum		**250**	**18**	**16,000**
Median		**59**	**4.8**	**1,500**

sites, poorer habitat, larger runoff events, or presence of substances inhibiting algae growth at urban sites.

The four most dominant taxa at each site in 2010 contributed 39 to 80 percent of total abundance and 43 to 90 percent of total biovolume (appendixes 7 and 8). The most common taxa based on abundance were *Navicula cryptotenella*, *Nitzschia dissipata*, *Nitzschia inconspicua*, and *Gomphonema olivaceum*. The most common taxa based on biovolume were *Diatoma vulgaris*, *Navicula tripunctata*, *Synedra ulna,* and *Nitzschia linearis*. All of the most common taxa generally were indicative of eutrophic conditions (Porter, 2008).

Periphyton Metrics

Physical, chemical, and pollution tolerances and optimal growth conditions have been described for many species of periphyton, which makes it possible to use these indices as indicators of ecological condition. Periphyton communities in 2010 were evaluated using 24 metrics in 4 categories including oxygen tolerance, saprobity, trophic condition, and nitrogen uptake metabolism, in addition to 3 other common metrics (table 7). The metrics are indicative of a range of conditions from good to poor and provide a basis for evaluating potential stressors on algae communities. Differences among stream sites and between 2007 and 2010 also were evaluated on the basis of percent contribution of diatom indicator taxa to total periphyton biovolume (table 8).

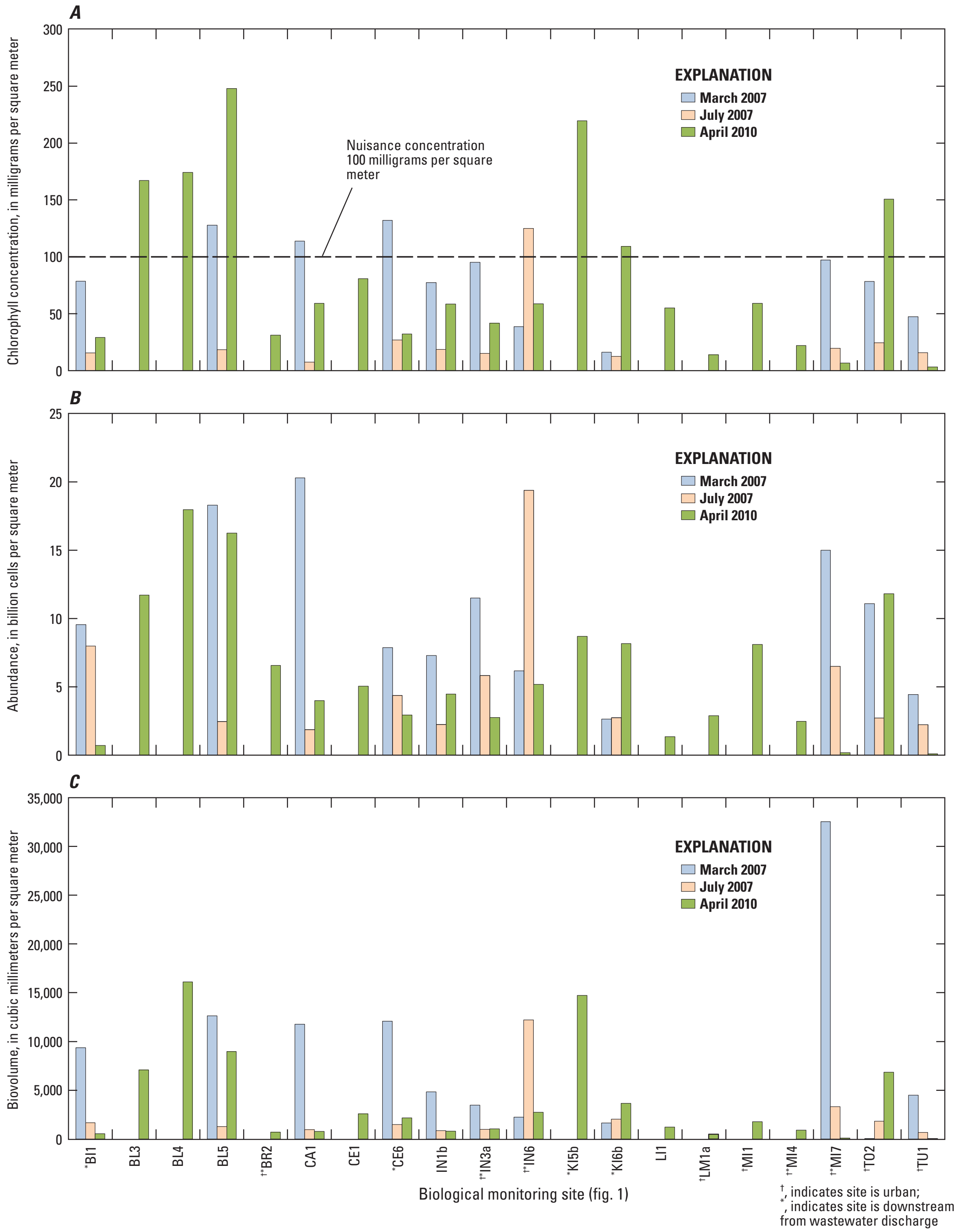

Figure 9. Algal periphyton chlorophyll concentrations, abundance, and biovolume at biological monitoring sites in Johnson County, Kansas, 2007 and 2010.

Oxygen Tolerance

Oxygen tolerance describes the oxygen conditions where organisms often occur, and is expressed using the percentage of diatoms in one or more of five oxygen tolerance categories: very low (less than 10 percent oxygen saturation), low (greater than 30 percent oxygen saturation), moderate (greater than 50 percent oxygen saturation), fairly high (greater than 75 percent oxygen saturation), and always high (near 100 percent oxygen saturation; Cuffney, 2003; Porter, 2008). The percentage of diatoms in the low and moderate categories was summed as discussed as a single oxygen-tolerance metric in this section. Percentage of diatoms that tolerate low and moderate oxygen conditions ranged from 5.7 at the rural Kill Creek site (KI5b) to 52.6 at the urban Mill Creek site (M17),

Table 7. Periphyton metrics, conditions associated with each metric, and metric scores at biological monitoring sites in Johnson County, Kansas, during April 2010.

[%, percent; DO dissolved oxygen; >, greater than; <, less than; BOD, biochemical oxygen demand; mg/L, milligrams per liter; N, nitrogen; *site is downstream from wastewater treatment facility discharge]

Metric	Conditions	Biological monitoring site identifier and general land-use classification										
		BI1*, (rural)	BL3, (rural)	BL4, (rural)	BL5, (rural)	BR2*, (urban)	CA1, (rural)	CE1, (rural)	CE6*, (rural)	IN1b, (urban)	IN3a*, (urban)	IN6*, (urban)
		Oxygen tolerance										
Always high	Nearly 100% DO saturation	0.48	1.09	1.41	4.27	14.3	3.56	0.29	0.76	4.60	3.08	2.74
Fairly high	>75% DO saturation	15.2	56.5	50.0	47.2	10.5	15.9	39.8	73.2	51.5	30.7	43.4
Moderate	>50% DO saturation	41.4	19.1	24.9	33.4	22.4	26.2	33.1	19.8	28.9	29.0	20.7
Low	>30% DO saturation	2.4	0.61	0.13	0.33	22.4	17.6	2.76	0.64	5.03	4.15	5.56
Low plus moderate	>30% and </= 75% DO saturation	43.7	19.8	25.0	33.8	44.8	43.8	35.9	20.5	33.9	33.2	26.3
Very low	About 10% DO saturation or less	0	0.11	0.17	0	0	0	0	0	0	0	0
		Saprobity										
Oligosaprobic	>85% oxygen saturation/BOD<2 mg/L	0.22	0.28	0.25	2.29	12.7	2.97	0.14	0.61	3.39	2.48	1.36
Beta-mesosaprobic	70–85% oxygen saturation/BOD 2–4 mg/L	37.0	62.3	49.7	60.5	14.8	20.6	53.6	77.8	62.9	41.8	51.9
Oligosaprobic plus *beta*-mesosaprobic	>70% oxygen saturation/BOD </= 4 mg/L	37.2	62.6	49.9	62.8	27.5	23.6	53.7	78.5	66.3	44.3	53.3
Alpha-mesosaprobic	25–70% oxygen saturation/BOD 4–13 mg/L	3.55	6.47	5.01	17.6	39.9	26.6	12.7	8.63	19.9	19.9	18.5
Alpha-mesosaprobic/polysaprobic	10–25% oxygen saturation/BOD 13–22 mg/L	17.9	10.2	14.1	6.35	4.20	14.8	9.69	8.66	1.90	3.19	1.80
Polysaprobic	<10% oxygen saturation/BOD>22%	0.85	0.24	0.55	0	0	0	0	0.17	2.73	0.26	0
		Trophic condition										
Oligotrophic	Low nutrient concentrations	0.31	0.20	0.25	1.92	1.28	2.21	0	0.02	0.02	0.14	0
Oligo-mesotrophic	Low to moderate nutrient concentrations	0.07	0.18	0.12	0.18	11.7	1.44	0.34	0	3.39	2.36	1.36
Mesotrophic	Moderate nutrient concentrations	0.15	0	0.07	0.39	1.04	0.21	0.47	0.07	0.83	0.51	1.59
Meso-eutrophic	Moderate to high nutrient concentrations	9.37	35.3	22.3	24.4	3.83	13.7	8.83	55.0	35.6	5.36	3.79
Eutrophic	High nutrient concentrations	31.4	32.1	31.7	50.2	48.1	43.6	56.2	31.0	45.5	56.2	64.6
Hypereutrophic	Very high nutrient concentrations	1.07	0.30	0.68	0.07	0	0	0	0.17	2.73	0.26	0
Ubiquitous	Widespread across nutrient concentrations	17.7	11.6	14.6	9.71	6.92	4.49	10.4	9.51	2.70	2.81	2.31
		Nitrogen uptake metabolism										
Autotroph, low tolerance	Low tolerance for organic N	0.22	1.17	1.53	3.96	12.7	3.33	0.14	0.73	5.05	2.96	2.14
Autotroph, high tolerance	High tolerance for organic N	57.0	73.6	74.8	71.4	42.3	45.1	74.3	87.9	71.2	52.3	59.4
Facultative heterotroph	Needing periodically elevated N	0.84	2.38	0.28	9.75	14.1	2.79	1.13	5.46	10.6	11.2	10.4
Obligate heterotroph	Needing constantly elevated N	1.35	0.36	0	0.07	0.47	12.0	0	0.31	3.14	0.50	0.51

Table 7. Periphyton metrics, conditions associated with each metric, and metric scores at biological monitoring sites in Johnson County, Kansas, during April 2010.—Continued

[%, percent; DO dissolved oxygen; >, greater than; <, less than; BOD, biochemical oxygen demand; mg/L, milligrams per liter; N, nitrogen; *site is downstream from wastewater treatment facility discharge]

Metric	Conditions	Biological monitoring site identifier and general land-use classification								
		KI5b*, (rural)	KI6b*, (rural)	LI1, (rural)	LM1a, (urban)	MI1, (urban)	MI4*, (urban)	MI7*, (urban)	TO2, (urban)	TU1, (urban)
Oxygen tolerance										
Always high	Nearly 100% DO saturation	2.12	3.19	0.71	27.03	1.83	0.99	0.77	1.01	5.60
Fairly high	>75% DO saturation	84.61	51.62	23.7	38.3	39.9	22.25	22.52	62.22	24.25
Moderate	>50% DO saturation	5.6	19.9	8.9	10.1	12.0	31.2	49.0	24.7	23.3
Low	>30% DO saturation	0.09	1.67	1.79	0	2.09	3.88	3.60	0.83	7.08
Low plus moderate	>30% and </= 75% DO saturation	5.7	21.5	10.6	10.1	14.1	35.1	52.6	25.5	30.3
Very low	About 10% DO saturation or less	0	0	0	0	0	0.37	0.32	0.22	0
Saprobity										
Oligosaprobic	>85% oxygen saturation/BOD<2 mg/L	0	3.19	0.69	20.5	1.46	0.40	0.48	0.09	8.75
Beta-mesosaprobic	70–85% oxygen saturation/BOD 2–4 mg/L	88.4	80.4	25.5	46.3	40.4	38.7	28.2	66.8	26.8
Oligosaprobic plus *beta*-mesosaprobic	>70% oxygen saturation/BOD </= 4 mg/L	88.4	83.6	26.2	66.7	41.9	39.1	28.7	66.8	35.5
Alpha-mesosaprobic	25–70% oxygen saturation/BOD 4–13 mg/L	4.50	9.44	3.04	8.67	13.4	13.8	13.8	15.5	28.2
Alpha-mesosaprobic/polysaprobic	10–25% oxygen saturation/BOD 13–22 mg/L	1.17	1.50	5.87	0	0.70	20.2	34.5	9.45	4.01
Polysaprobic	<10% oxygen saturation/BOD>22%	0.03	0	0.04	0	0	0.42	1.06	0	0
Trophic condition										
Oligotrophic	Low nutrient concentrations	0	2.82	0.17	0.53	0	0	0.21	0	0
Oligo-mesotrophic	Low to moderate nutrient concentrations	0	0.08	0.69	20.0	1.46	0.40	0.42	0.18	4.50
Mesotrophic	Moderate nutrient concentrations	0.24	0.59	0.02	0	0.17	0	1.74	0.03	2.29
Meso-eutrophic	Moderate to high nutrient concentrations	71.7	20.4	6.85	33.1	28.10	4.29	8.83	34.3	8.68
Eutrophic	High nutrient concentrations	19.5	53.0	21.9	18.0	25.1	48.4	31.6	44.7	40.6
Hypereutrophic	Very high nutrient concentrations	0.03	0	0.12	0	0.36	1.10	1.06	0	0
Ubiquitous	Widespread across nutrient concentrations	2.69	17.6	5.59	3.88	1.10	19.2	34.4	12.7	7.73
Nitrogen uptake metabolism										
Autotroph, low tolerance	Low tolerance for organic N	2.12	3.19	0.69	23.5	2.00	0.40	0.61	0.46	4.90
Autotroph, high tolerance	High tolerance for organic N	86.2	62.7	33.1	48.0	47.5	51.8	69.8	85.7	48.6
Facultative heterotroph	Needing periodically elevated N	4.12	8.95	0.80	3.96	6.26	5.25	4.71	2.74	7.04
Obligate heterotroph	Needing constantly elevated N	0.03	1.50	0.39	0	0	1.24	1.10	0	0

Table 8. Percentage contribution of diatom indicator taxa or groups of diatom indicator taxa to total periphyton biovolume at biological monitoring sites in Johnson County, Kansas, March and July 2007, and April 2010.

[Eutraphenic (high nutrient) taxa, sum of *Amphora, Cocconeis, Diatoma, Gyrosigma, Meridion, Nitzchia,* and *Synedra* biovolume; Motile taxa, sum of *Gyrosigma, Navicula, Nitzchia,* and *Sururella* biovolume; Low nutrient taxa, sum of *Achnanthes, Cymbella*, and *Encyonema* biovolume; *, site is downstream from wastewater treatment facility discharge]

Biological monitoring site identifier (fig. 1)	General land use	Percentage contributions to total biovolume				
		Eutraphentic (high-nutrient) taxa	*Nitzchia*	*Navicula*	Motile taxa	Oligotraphentic (low-nutrient taxa)
March 2007						
BI1*	Rural	35	6.7	3.2	31	0.4
BL5	Rural	43	17	6.4	36	0
CA1	Rural	8.8	5.1	28	44	0
CE6*	Rural	71	3.4	3.9	13	0
IN1b	Urban	29	22	1.1	45	0
IN3a*	Urban	35	13	10	36	15
IN6*	Urban	40	28	23	28	0.4
KI6b*	Rural	36	9.5	12	32	0.3
MI7*	Urban	65	4.2	1.4	15	0
TO2	Urban	25	1.5	0.5	4.1	0
TU1	Urban	4.1	4.1	1.4	76	0.1
Minimum		**4.1**	**1.5**	**0.5**	**4.1**	**0**
Maximum		**71**	**28**	**28**	**76**	**15**
Median		**35**	**7**	**4**	**32**	**0**
July 2007						
BI1*	Rural	18	15	28	28	0.3
BL5	Rural	49	1.3	15	17	1
CA1	Rural	46	2.7	21	22	0.1
CE6*	Rural	37	13	36	37	9.1
IN1b	Urban	55	4.6	19	19	1.1
IN3a*	Urban	27	8.7	27	27	6.2
IN6*	Urban	20	2.2	2.6	2.6	0.4
KI6b*	Rural	25	10	19	23	34
MI7*	Urban	19	5.8	30	31	0.3
TO2	Urban	18	4.3	18	27	0.7
TU1	Urban	25	23	62	62	0
Minimum		**18**	**1.3**	**2.6**	**2.6**	**0**
Maximum		**55**	**23**	**62**	**62**	**34**
Median		**25**	**6**	**21**	**27**	**1**
April 2010						
BI1*	Rural	31	11	3.7	44	0.3
BL3	Rural	32	20	23	28	0.2
BL4	Rural	50	27	36	32	0.8
BL5	Rural	50	13	23	22	1.9
BR2*	Urban	48	16	27	58	1.3
CA1	Rural	44	13	47	68	2.2
CE1	Rural	56	21	6.7	45	0
CE6*	Rural	31	3.8	21	8.5	0
IN1b	Urban	46	47	6.6	63	0
IN3a*	Urban	56	17	16	54	0.1
IN6*	Urban	65	11	16	45	0
KI5b*	Rural	19	5.7	11	8.2	0
KI6b*	Rural	53	4.1	46	30	2.8
LI1	Rural	22	23	4.1	85	0.2
LM1a	Urban	18	37	2.0	58	0.5
MI1	Urban	25	34	4.8	77	0
MI4*	Urban	48	31	4.9	59	0
MI7*	Urban	32	20	19	40	0.2
TO2	Urban	45	39	4.3	29	0
TU1	Urban	41	20	21	57	0
Minimum		**18**	**3.8**	**2.0**	**8.2**	**0**
Maximum		**65**	**47**	**47**	**85**	**2.8**
Median		**44**	**20**	**16**	**45**	**0**

with a median of 28 percent (table 7). No significant difference occurred between urban and rural site groups, or between wastewater-affected and nonwastewater-affected site groups.

Saprobity

Saprobes are organisms that derive nourishment from nonliving or decaying organic material. The saprobic index combines organism tolerance to the presence of biodegradable organic matter and hypoxic conditions, and was developed to evaluate the sensitivity of diatom communities to organic pollution (Kolkwitz and Marsson, 1908; Van Dam and others, 1994). ADAS uses five saprobity categories representing a gradient of conditions ranging from relatively pristine (oligosaprobic) to highly polluted (polysaprobic): oligosaprobic, *beta*-mesosaprobic, *alpha*-mesosaprobic, *alpha*-mesosaprobic/polysaprobic, and polysaprobic. These categories represent a gradient of conditions ranging from relatively pristine, with higher oxygen concentrations and lower biodegradable organic matter concentrations (oligosaprobic) to highly polluted with lower oxygen and higher organic matter concentrations (polysaprobic, Van Dam and others, 1994; Porter, 2008). The saprobix index was calculated for this section as the summed percentages of diatoms in the oligosaprobic and beta-mesosaprobic categories, which combined are indicative of relatively unpolluted conditions. Percent oligosaprobic and *beta*-mesosaprobic diatoms had a median of 54 and ranged from 23.6 percent at the rural Captain Creek site (CA1) to 88.4 percent at the rural Kill Creek site (KI5b, table 7). No significant difference occurred between urban and rural site groups, or between wastewater-affected and non-wastewater-affected site groups.

Trophic Condition Taxa

Trophic condition is indicative of ecosystem productivity with respect to nutrient concentrations. Oligotrophic systems have low nutrient concentrations and productivity, mesotrophic systems have moderate nutrient concentrations and productivity, and eutrophic systems have high nutrient concentrations and productivity (Graham and others, 2008). ADAS classifies diatoms into seven trophic categories. Diatom communities are indicative of moderate and high nutrient concentrations at all of the monitoring sites (table 7) with no discernible patterns in urban and rural land use, indicating nutrients are available for algae growth in streams throughout the study area.

Nitrogen Uptake Metabolism

Nitrogen uptake metabolism refers to the source of nitrogen required by periphyton or diatoms for growth. High tolerance autotrophs, which require inorganic nitrogen sources such as nitrate or ammonia for growth, comprised the highest percentage of diatoms at all sites, ranging from 33.1 percent at the Little Bull site (LI1) to 87.9 percent at the lower Cedar Creek site (CE6, table 7).

Diatom Indicator to Total Periphyton Biovolume

Eutraphentic (high nutrient) diatoms prefer nutrient-enriched and eutrophic conditions (Stevenson and Rollins, 2007). Eutraphentic diatoms comprised 18 to 65 percent of total periphyton biovolume in spring (April) 2010 (table 8) compared to the larger range of 4.1 to 71 percent that occurred in spring (March) 2007 (Rasmussen and others, 2009). Site IN6 had the fourth highest percent eutraphentic diatoms in spring 2007 (after sites CE6, MI7, and BL5), and the highest percent eutraphentic diatoms in spring 2010. Oligotraphentic (low nutrient) taxa comprised less than 3 percent of periphyton biovolume at all sites in 2010 (table 8), indicating nutrient-enriched conditions occur in both urban and rural streams.

Species of *Nitzchia* typically are considered to be pollution tolerant and species of *Navicula* typically are considered to be indicators of ecosystem disturbance (Stevenson and Rollins, 2007). The largest range for *Nitzchia* as a percentage of total biovolume (3.8 to 47 percent) occurred in 2010 (table 8) when site IN1b (urban, not affected by wastewater) had the highest percent of *Nitzchia* to total biovolume. In 2010, urban sites (median 25 percent) had a significantly higher (z-value 2.3, p-value 0.01) *Nitzchia* percentage contribution than rural sites (median 31 percent), and sites not affected by wastewater (median 23 percent) had significantly higher (z-value 2.6, p-value 0.004) *Nitzchia* percentage than sites affected by wastewater (median 11 percent). Percentage of *Navicula* to total biovolume ranged from 2.0 to 47 in 2010 (table 8). Sites CA1 and KI6b (both rural) had *Navicula* percentages that were higher than 45 percent in 2010. The highest percent *Navicula* of both years (62 percent) occurred at site TU1 (urban, not affected by wastewater) during July 2007.

Motile taxa are indicative of sedimentation because they have the ability to survive by moving to the sediment surface if they become covered by silt (Barbour and others, 1999). The percent of motile taxa biovolume to total biovolume ranged from 8.2 to 85 percent in 2010 (table 8). Site TU1 during 2007 and sites CA1, IN1b, LI1, and MI1 during 2010, all sites not affected by wastewater but inclusive of both urban and rural sites, had the highest motile taxa score (higher than 60 percent). In 2010, percent motile taxa at urban sites (median 57 percent) was significantly higher (z-value 1.8, p-value 0.03) than rural sites (median 31 percent). Percent motile taxa was not significantly different at sites affected by wastewater (median 44 percent) compared to sites not affected by wastewater (median 57 percent). Among sites that were affected by wastewater, urban sites (median 51 percent) had a significantly higher (z-value 2.2, p-value 0.01) percent contribution of motile taxa than rural sites (median 23 percent).

Macroinvertebrate Communities

Aquatic macroinvertebrates are the most often recommended and most widely used indicator organisms for biological assessment (Carter and others, 2007) because they are sensitive to environmental change, have short life cycles, and can integrate the effects of changing environmental conditions. Macroinvertebrate communities commonly are used for assessing biological conditions, long-term monitoring, diagnosis of specific environmental problems, quantification of the success of restoration activities, and development of biological criteria in support of water-quality compliance and regulation (Rosenberg and Resh, 1993).

Community Composition

A total of 181 macroinvertebrate taxa were collected at the Johnson County biological monitoring sites in 2010 (appendix 9), compared to 160 taxa collected in 2007 (Rasmussen and others, 2009). Most taxa were insects (Insecta) in 2010, and about 20 percent were non-insects, mostly mollusks (Bivalvia and Gastropoda), worms (Turbellaria, Enopla, Nematoda, Nematomorpha, and Oligochaeta), leeches (Hirudinea), and crustaceans (Malacostraca). About 22 percent of the insect taxa were in EPT taxa, the three orders of insects typically associated with healthy stream communities (Ephemeroptera, mayflies; Plecoptera, stoneflies; and Trichoptera, caddisflies; referred to as EPT taxa) compared to about 25 percent EPT taxa in 2007 (Rasmussen and others, 2009). In addition to EPT taxa, other aquatic insects including dragonflies and damselflies (Odonata), beetles (Coleoptera), midges (Chironomidae), and true bugs (Hemiptera) were common. Overall, the four most common taxa generally are moderately tolerant or tolerant and were Orthocladiinae midges, the chironomid *Polypedilum* sp., the blackfly *Simulium* sp., and the Naididae family of oligochaetes.

Generally, most rural stream sites contained a larger diversity of macroinvertebrates including insect orders normally associated with healthier communities. More urban sites had none or few of these insects and were dominated by pollution-tolerant insects. This is consistent with a national study of metropolitan areas that found that urban development typically leads to a decline in pollution sensitive species and a shift to species that are more pollution tolerant (Brown and others, 2009).

Macroinvertebrate Metrics

Selected macroinvertebrate metrics (table 9) provide the foundation for the assessment of stream biological conditions. Data collected during 2010 are used to describe current conditions and to evaluate changing conditions by making comparisons to data collected during 2003 and 2004 (Wilkison and others, 2006; Poulton and others, 2007), and 2007 (Rasmussen and others, 2009). Individual metrics are described first starting with the four KDHE aquatic-life status metrics and followed by seven others presented in the order they are listed in table 9. Aquatic-life impairment categories are described, and sites are evaluated and compared on the basis of combined 10-metric scores.

Macroinvertebrate Biotic Index (MBI)

The MBI (Davenport and Kelly, 1983) is a family-level index that is used to evaluate the effects of oxygen-demanding nutrients and organic enrichment on macroinvertebrate communities. Taxa used to calculate the MBI have unitless tolerance values ranging from 1.5 to 11 for some insect and mollusk taxa. Lower tolerance values indicate less tolerance to oxygen-demanding nutrients and organic enrichment and a lesser degree of stream degradation; and higher tolerance values indicate greater tolerance and a higher degree of stream degradation. In 2010, MBI values ranged from 4.60 at Captain Creek (site CA1), a State reference stream, to 7.25 at Turkey Creek (site TU1, table 9). Urban sites (median 6.23) had MBI scores that were significantly greater (z-value 3.87, p-value less than 0.0001) than those for rural sites (median 5.07). For MBI, none of the sites met the KDHE criteria for full support of aquatic life for MBI (less than 4.51, table 9), and none of the urban sites were classified as even partially supporting aquatic life (MBI less than 5.39). Captain Creek (CA1, in 2003) was the only site that attained the “fully supporting” criterion for MBI during the study period. The Mill Creek TMDL for biological impairment established a MBI goal of 4.5 or less as an average for 2006-2015 (Kansas Department of Health and Environment, 2006); however, MBI values for monitoring sites in the Mill Creek watershed have, thus far, failed to achieve the goal. MBI scores ranged from 5.64 to 6.36 in 2010, and from 4.71 to 7.63 in previous years.

Kansas Biotic Index (KBI-NO)

KBI-NO was specifically developed for the State of Kansas and is a genus-level index used to evaluate the effects of nutrients and oxygen demanding substances (Huggins and Moffett, 1988). The KBI-NO uses 10 orders of aquatic insects, and each of the taxa has tolerance values ranging from 0 to 5. Lower tolerance values indicate less tolerance to nutrients and oxygen-demanding substances and correspond to a lesser degree of stream degradation; but higher tolerance values indicate greater tolerance and a higher degree of stream degradation. KBI-NO ranged from 2.45 to 3.46 in 2010 (table 9). The site with the lowest KBI-NO score (indicating best relative condition) in 2010 was CE6 (Cedar Creek), and the site that had the highest was IN3a (Indian Creek). Urban sites (median 3.14) had KBI-NO scores that were significantly greater (z-value 3.2, p-value 0.0008) than those for rural sites (median 2.75). Based on this metric, four sites (CE6, CA1, KI5b, and KI6b) had KBI-NO scores in 2010 that met the KDHE criteria for full support of aquatic life (less than 2.61), compared to 4 sites in 2003 and 2 sites in 2004 and 2007 (table 9). Nine sites had KBI-NO scores that were partially supporting (between 2.61 and 2.99) of aquatic life in 2010, and 7 sites had nonsupporting scores (greater than 2.99).

EPT Taxa Richness (EPTRich)

EPT taxa richness is the number of species belonging to the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Most taxa in these orders generally are intolerant of environmental stressors and higher densities of these species usually are indicative of better water quality (Barbour and others, 1999). EPT taxa richness in 2010 ranged from 1 taxon at Indian Creek (site IN3a) and Turkey Creek (site TU1) to 16 taxa at Blue River near Stanley (site BL3, table 9). Rural sites (median 15 taxa) had significantly higher (z-value 3.9, p-value less than 0.0001) EPT taxa richness than urban sites (median 3). Seven sites (BL3, BL4, CA1, CE6, KI5b, KI6b, and LI1) had EPT taxa richness indicating that site conditions in 2010 fully supported aquatic life (KDHE criterion is greater than 12 EPT taxa), compared to, at most, only one site in previous years (BL4 in 2007). Three sites (BI1, BL5, and CE1) had EPT taxa richness between 8 and 12 in 2010, indicating partial support of aquatic life, and EPT taxa richness at the remaining 10 urban sites indicated nonsupport of aquatic life.

Percentage of EPT (%EPT)

The EPT percentage metric is the number of taxa belonging to the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) calculated as a percentage of the total number of organisms. Because EPT percentage provides information about the relative abundance of three mostly intolerant orders of aquatic insects, large populations of a few species can result in high percentages. Values in 2010 ranged from 0.5 percent at Indian Creek (site IN3a) to 42.8 percent at Captain Creek (site CA1), a State reference stream (table 9). Rural percentage of EPT (median 36.5) was significantly greater (*z*-value 3.7, p-value less than 0.0001) than urban percentage of EPT (median 7.94). A total of 13 sites were classified as not supporting aquatic life in 2010 according to KDHE's criterion (less than 31 percent). The remaining seven sites were partially supporting of aquatic life. Site MI1 in 2003 is the only site that met the full support criterion for this metric during the study.

Total Taxa Richness (TRich)

Total taxa richness is the number of distinct taxa in a sample. The presence of higher numbers of distinct taxa is an indication that the food sources and habitats available at a site can support many species (Barbour and others, 1999). Overall median taxa richness in 2010 was 48 and was the highest of all years sampled (median 77 in 2003, 32 in 2003, and 33 in 2007) and ranged from 22 at Brush Creek (site BR2) to 63 at Cedar Creek (site CE6) and Blue River (site BL3). Rural sites (median 59) had significantly higher (*z*-value 3.6, *p*-value 0.0002) total taxa richness than urban sites (median 32) indicating that urban sites had less diverse macroinvertebrate communities and likely their food sources and habitats also were less diverse than rural sites, on average.

Other Metrics

Aquatic macroinvertebrates commonly are classified into functional feeding groups, which separate taxa according to how they capture or ingest food. Scrapers are a functional feeding group that use their mouthparts to remove (or scrape) periphyton from surfaces. Knowledge about functional feeding groups provides information on community balance, types of food sources, and trophic dynamics (Barbour and others, 1999; Cummins, 1973). Specialized feeders, such as scrapers, are more sensitive organisms and higher densities are generally indicative of healthier streams (Barbour and others, 1996). Percentage of scrapers (%Sc) in 2010 ranged from 0 percent at Brush Creek (BR2) and Turkey Creek (TU1) to 20.4 percent at Cedar Creek (CE6, table 9). Rural percentage of scrapers (median 16 percent) was significantly greater (*z*-value 3.8, *p*-value less than 0.0001) than urban percentage of scrapers (median 3.8 percent).

Many oligochaetes (worms) are pollution tolerant. Percent oligochaetes ranged from 0.4 at Captain Creek (CA1), a State reference site, to 33.3 at Turkey Creek (site TU1, table 9). Percentage oligochaetes (%Olig) was significantly higher (*z*-value 1.7, *p*-value 0.04) for sites that were affected by wastewater (median 11 percent) than for sites that were unaffected by wastewater (median 6.9 percent). Urban sites (median 12 percent) had a significantly higher (*z*-value 3.3, *p*-value 0.0005) percentage of oligochaetes than rural sites (median 4.3 percent). This is the only metric out of the 11 metrics used in previous USGS reports in Johnson County (Poulton and others, 2007; Rasmussen and others, 2009) that was able to effectively differentiate among both wastewater and land-use effects.

Tanytarsini is an intolerant tribe of midges. Percent *Tanytarsini* (%Tany) in 2010 ranged from 0 percent at many sites to 7.6 percent at Brush Creek (site BR2, table 9). No significant differences between site groups were seen with respect to wastewater or land use for this metric.

Percent intolerant organisms (%Int-KBI) is the relative abundance of organisms that have KBI-NO tolerance values less than 3.0. Mean overall percent intolerant organisms in 2010 was 26 percent and ranged from 2.2 at Indian Creek (site IN6) to 48.1 at Captain Creek (site CA1), a State reference stream (table 9). Percent intolerant organisms for rural sites (median 42 percent) was significantly higher (*z*-value 3.5, *p*-value 0.0003) than for urban sites (median 13 percent).

Percentage of Ephemeroptera and Plecoptera (%EP) is a modification of the percentage of EPT metric and omits the Trichoptera to account for the effect of higher relative abundances of tolerant net-spinning caddisflies (*Hydropsychidae*) that often are abundant in macroinvertebrate communities from larger urban streams (Poulton and others, 2007). Percentage of Ephemeroptera and Plecoptera ranged from 0.0 at Brush Creek (site BR2), Indian Creek (site IN3a), Little Mill Creek (LM1a), and Turkey Creek (site TU1) to 34.7 percent at Captain Creek (site CA1), a State reference stream (table 9). Mean percentage of Ephemeroptera and Plecoptera in 2010 was 14 percent. Percentage of Ephemeroptera and Plecoptera was significantly higher (*z*-value 3.8, *p*-value less than 0.0001) for rural sites (median 29 percent) as compared to urban sites (median 0.5 percent).

The Shannon Diversity Index (SDI) is a core metric that measures community diversity and evenness (Washington, 1984). Higher values indicate more diversity and evenness of species and lower values indicate less diversity and less evenness of species. Shannon Diversity Index values in 2010 ranged from 2.6 at Brush Creek (site BR2) to 3.7 at Blue River (site BL3), Captain Creek (site CA1, a State reference site), and Cedar Creek (site CE6, table 9). Overall mean Shannon Diversity Index was 3.3. Rural sites (median 3.54) had significantly higher (*z*-value 3.5, *p*-value 0.0003) Shannon Diversity than urban sites (median 3.03).

Combined 10-Metric Scores

Multimetric scores were developed by integrating 10 selected metrics into 1 overall score as an indicator of the relative biological quality of Johnson County streams (Poulton and others, 2007). Higher scores are indicative of better biological quality and lower scores are indicative of poorer biological quality. Ten-metric scores in 2010 ranged from 165 at Turkey Creek (site TU1) to 777 at Blue River (site BL3, table 9, fig. 10). The four sites with the lowest 10-metric scores (poorest quality) were the urban sites Turkey Creek (site TU1, not affected by wastewater), Indian Creek (sites

Table 9. Macroinvertebrate metric and aquatic-life-support values for biological monitoring sites in Johnson County, Kansas, 2003, 2004, 2007, and 2010.

[MBI, Macroinvertebrate Biotic Index; <, less than; >, greater than; KBI-NO, Kansas Biotic Index; E, Ephemeroptera; P, Plecoptera; T, Trichoptera; --, not determined; Aquatic-life-support criteria from Kansas Department of Health and Environment, 2008; *, site is downstream from wastewater treatment facility discharge]

Biological monitoring site identifier (fig. 1)	Site name	General land classification[1]	Benthic macroinvertebrate metric values: MBI (<4.51 fully supporting, 4.51–5.39 partially supporting, >5.39 nonsupporting)				KBI-NO (<2.61 fully supporting, 2.61–2.99 partially supporting, >2.99 nonsupporting				EPT taxa richness (EPTRich) (>12, fully supporting, 8–12 partially supporting, <8 nonsupporting)				Percent of EPT (abundance) (%EPT) (>48, fully supporting, 31–47 partially supporting, <31 nonsupporting)			
			2003	2004	2007	2010	2003	2004	2007	2010	2003	2004	2007	2010	2003	2004	2007	2010
BI1*	Big Bull Creek near Edgerton	Rural	5.34	5.71	4.91	5.13	3.14	3.11	2.88	2.89	5	4	11	9	30.0	26.5	38.3	33.2
BL3	Blue River near Stanley (Highway 69)	Rural	5.47	5.22	4.92	4.83	2.71	2.68	2.71	2.75	6	9	11	16	24.7	32.8	40.2	39.4
BL4	Camp Branch at 175th Street	Rural	--	--	5.20	5.07	--	--	2.58	2.80	--	--	18	15	--	--	39.7	36.5
BL5	Blue River at Kenneth Road	Rural	5.27	5.36	5.02	5.35	2.78	2.84	2.78	2.85	7	10	11	10	26.5	32.0	33.6	27.9
BR2*	Brush Creek at Belinder Street	Urban	--	--	--	6.99	--	--	--	3.10	--	--	--	2	--	--	--	2.2
CA1	Captain Creek near 119th Street	Rural	4.02	4.98	4.94	4.60	1.61	2.23	2.20	2.50	3	11	10	15	47.7	36.5	41.6	42.8
CE1	Cedar Creek at Old Highway 56	Rural	5.02	5.43	5.05	5.34	2.35	2.50	2.78	2.76	4	8	8	10	35.9	30.0	37.0	23.4
CE6*	Cedar Creek near DeSoto (83 St)	Rural	5.55	6.00	5.69	5.05	3.10	3.10	3.19	2.45	6	7	8	15	31.2	17.6	25.5	33.3
IN1b	Indian Creek at Highway 69	Urban	6.18	6.68	6.10	5.92	2.70	3.25	3.06	3.23	5	4	4	4	17.6	8.0	6.3	12.4
IN3a*	Indian Creek at College Blvd	Urban	7.17	7.14	6.43	6.46	2.79	2.80	3.24	3.46	2	1	1	1	1.6	1.0	8.3	0.5
IN6*	Indian Creek at State Line Road	Urban	7.68	8.12	6.48	6.54	3.76	3.50	3.38	3.41	1	2	3	2	12.0	7.0	17.0	9.6
KI5b*	Kill Creek at 127th Street[2]	Rural	4.87	5.49	5.13	5.34	2.42	2.85	3.13	2.60	4	9	8	14	36.7	26.5	34.1	40.6
KI6b*	Kill Creek at 95th Street	Rural	5.83	5.15	5.14	4.73	2.90	2.81	2.93	2.58	6	7	10	15	11.8	35.6	30.7	40.9
LI1	Little Bull Creek near 215th Street	Rural	--	--	--	5.33	--	--	--	2.99	--	--	--	14	--	--	--	27.8
LM1a	Little Mill Creek at W 79th Street	Urban	--	--	7.49	5.88	--	--	3.33	3.36	--	--	0	2	--	--	0	2.1
LM1b	Unnamed Little Mill Creek tributary near W. 83rd Street	Urban	--	--	6.53	--	--	--	2.93	--	--	--	0	--	--	--	0	--
LM1c	Little Mill Creek at W. 84th Terrace	Urban	--	--	7.63	--	--	--	2.79	--	--	--	1	--	--	--	1.8	--
MI1	Mill Creek at 127th Street	Urban	4.71	5.98	6.33	6.36	3.32	2.94	3.13	3.14	4	3	1	4	53.0	2.8	0.8	3.3
MI4*	Mill Creek at 87th Street Lane	Urban	5.46	6.27	5.77	5.96	2.36	3.32	2.89	2.78	6	5	2	5	27.0	22.8	19.5	13.2
MI7*	Mill Creek at Johnson Drive	Urban	5.83	5.77	5.17	5.64	3.17	3.21	3.20	2.80	5	5	4	7	22.3	23.1	29.9	28.0
TO2	Tomahawk Creek near 111th Street	Urban	5.72	6.10	5.92	6.23	3.29	3.38	3.18	3.29	5	2	4	3	19.9	12.1	10.8	7.9
TU1	Turkey Creek at 67th Street	Urban	5.94	6.44	6.29	7.25	3.19	3.35	3.47	2.96	3	2	2	1	14.2	3.8	5.4	3.5

Table 9. Macroinvertebrate metric and aquatic-life-support values for biological monitoring sites in Johnson County, Kansas, 2003, 2004, 2007, and 2010.—Continued

MBI, Macroinvertebrate Biotic Index; <, less than; >, greater than; KBI-NO, Kansas Biotic Index; E, Ephemeroptera; P, Plecoptera; T, Trichoptera; --, not determined; Aquatic-life-support criteria from Kansas Department of Health and Environment, 2008; *, site is downstream from wastewater treatment facility discharge]

Biological monitoring site identifier (fig. 1)	Site name	General land classification[1]	Benthic macroinvertebrate metric values															
			Total taxa richness (Trich)				Percentage of scrapers (%Sc)				Percentage of Oligochaeta (%Olig)				Percentage of Tanytarsini (%Tany)			
			2003	2004	2007	2010	2003	2004	2007	2010	2003	2004	2007	2010	2003	2004	2007	2010
BI1	Big Bull Creek near Edgerton	Rural	28	28	43	50	12.1	22.6	29.7	14.9	0.8	1.3	0	4.3	0.8	3.5	0.5	2.1
BL3	Blue Rriver near Stanley (Highway 69)	Rural	42	56	58	63	29.8	15.8	26.8	15.5	3.0	2.8	4.2	2.0	0	0.8	1.3	2.8
BL4	Camp Branch at 175th Street	Rural	--	--	57	45	--	--	26.2	15.8	--	--	1.9	1.8	--	--	0.9	0
BL5	Blue River at Kenneth Road	Rural	47	52	46	55	24.8	18.4	31.1	18.4	2.6	1.6	1.2	5.2	0.4	0.8	0	1.2
BR2	Brush Creek at Belinder Street	Urban	--	--	--	22	--	--	--	0	--	--	--	18.5	--	--	--	7.6
CA1	Captain Creek near 119th Street	Rural	24	55	45	62	23.4	23.7	19.6	14.9	4.2	6.2	4.2	0.4	0.9	0.4	0	0
CE1	Cedar Creek at Old Highway 56	Rural	23	47	40	50	41.9	28.3	24.0	19.9	0	0.9	0.5	2.7	0.5	1.8	0.5	1.5
CE6	Cedar Creek near DeSoto (83 St)	Rural	40	50	45	63	19.0	12.2	21.8	20.4	4.1	5.0	4.2	4.4	1.1	3.8	1.2	0.9
IN1b	Indian Creek at Highway 69	Urban	25	34	26	34	27.3	12.6	11.3	3.8	1.4	1.5	4.4	8.6	0.5	0.5	0	1.6
IN3a	Indian Creek at College Blvd	Urban	20	22	23	27	1.6	1.4	3.9	5.1	40.0	29.8	1.7	10.6	0	0	1.7	0
IN6	Indian Creek at State Line Road	Urban	24	26	22	31	5.2	4.9	11.4	0.5	20.6	44.7	3.4	17.2	0	0.3	0	0
KI5b	Kill Creek at 127th Street[2]	Rural	29	47	47	60	38.3	17.1	25.6	15.5	1.2	2.9	7.4	13.6	1.6	6.5	0	1.0
KI6b	Kill Creek at 95th Street	Rural	36	46	46	59	26.4	21.2	30.6	19.9	5.0	3.8	2.6	6.6	1.4	0.4	0.9	0
LI1	Little Bull Creek near 215th Street	Rural	--	--	--	57	--	--	--	10.1	--	--	--	3.1	--	--	--	2.2
LM1a	Little Mill Creek at W 79th Street	Urban	--	--	17	32	--	--	12.8	2.6	--	--	34.6	10.0	--	--	0	0
LM1b	Unnamed Little Mill Creek tributary near W. 83rd Street	Urban	--	--	16	--	--	--	9.5	--	--	--	9.5	--	--	--	0	--
LM1c	Little Mill Creek at W. 84th Terrace	Urban	--	--	17	--	--	--	0	--	--	--	45.6	--	--	--	0	--
MI1	Mill Creek at 127th Street	Urban	24	22	25	51	10.8	2.8	1.6	5.0	1.6	4.2	7.4	9.1	1.2	1.4	0	0.5
MI4	Mill Creek at 87th Street Lane	Urban	21	22	23	41	16.2	9.5	2.3	10.5	0.5	10.0	4.5	13.2	0	0	0	0.5
MI7	Mill Creek at Johnson Drive	Urban	35	30	32	46	18.8	11.8	17.4	8.9	5.9	4.1	1.1	10.7	0	1.4	1.1	0
TO2	Tomahawk Creek near 111th Street	Urban	29	25	33	38	7.4	3.0	5.7	4.2	2.2	2.0	2.2	11.6	0.4	0	0.8	0.5
TU1	Turkey Creek at 67th Street	Urban	24	29	21	29	7.3	12.5	7.5	0	2.8	2.4	10.8	33.3	0.4	0	0	0

Table 9. Macroinvertebrate metric and aquatic-life-support values for biological monitoring sites in Johnson County, Kansas, 2003, 2004, 2007, and 2010.—Continued

[MBI, Macroinvertebrate Biotic Index; <, less than; >, greater than; KBI-NO, Kansas Biotic Index; E, Ephemeroptera; P, Plecoptera; T, Trichoptera; --, not determined; Aquatic-life-support criteria from Kansas Department of Health and Environment, 2008; *, site is downstream from wastewater treatment facility discharge]

Biological monitoring site identifier (fig. 1)	Site name	General land classification[1]	Benthic macroinvertebrate metric values: Percentage of intolerant organisms (KBI-NO < 3) (%Int-KBI)				Percentage of EP (%EP)				Shannon Diversity Index (SDI)				10-metric combined score			
			2003	2004	2007	2010	2003	2004	2007	2010	2003	2004	2007	2010	2003	2004	2007	2010
BI1	Big Bull Creek near Edgerton	Rural	25.1	24.7	27.4	28.2	19.5	19.5	23.0	24.3	2.7	2.9	3.2	3.5	484	527	692	664
BL3	Blue River near Stanley (Highway 69)	Rural	55.3	43.2	31.7	38.2	21.2	23.7	28.9	33.7	3.3	3.6	3.5	3.7	639	734	814	777
BL4	Camp Branch at 175th Street	Rural	--	--	37.3	41.8	--	--	33.6	30.6	--	--	3.6	3.2	--	--	866	620
BL5	Blue River at Kenneth Road	Rural	41.7	40.6	33.6	35.3	25.2	26.2	26.1	19.6	3.3	3.4	3.1	3.4	683	720	691	630
BR2	Brush Creek at Belinder Street	Urban	--	--	--	3.3	--	--	--	0	--	--	--	2.6	--	--	--	299
CA1	Captain Creek near 119th Street	Rural	87.9	66.2	50.7	48.1	47.7	29.5	32.7	34.7	2.0	3.5	3.3	3.7	654	862	756	765
CE1	Cedar Creek at Old Highway 56	Rural	65.9	49.5	24.6	33.8	32.3	21.1	27.9	14.9	2.4	3.3	3.1	3.5	606	755	650	636
CE6	Cedar Creek near DeSoto (83 St)	Rural	27.4	28.1	15.2	41.9	19.0	10.3	14.5	25.8	3.0	3.3	3.2	3.7	594	579	585	751
IN1b	Indian Creek at Highway 69	Urban	48.4	14.8	16.4	12.9	8.8	2.0	1.9	5.4	2.6	3.0	2.9	3.0	510	439	347	384
IN3a	Indian Creek at College Blvd	Urban	35.7	44.1	7.8	7.8	0.3	0	0	0	1.9	2.3	2.6	2.8	118	193	337	251
IN6	Indian Creek at State Line Road	Urban	10.3	13.4	9.7	2.2	0	0.3	2.3	3.0	2.4	2.2	2.3	3.0	117	55	246	278
KI5b	Kill Creek at 127th Street[2]	Rural	60.2	30.1	16.6	47.9	36.7	24.5	23.3	32.2	2.5	3.4	2.6	3.4	695	738	587	666
KI6b	Kill Creek at 95th Street	Rural	37.8	44.6	26.1	44.2	11.4	31.4	22.8	28.7	2.7	3.3	3.2	3.6	586	696	701	733
LI1	Little Bull Creek near 215th Street	Rural	--	--	--	24.3	--	--	--	19.3	--	--	--	3.5	--	--	--	634
LM1a	Little Mill Creek at W 79th Street	Urban	--	--	2.6	10.2	--	--	0	0	--	--	2.4	2.9	--	--	103	293
LM1b	Unnamed Little Mill Creek tributary near W. 83rd Street	Urban	--	--	31.0	--	--	--	0	--	--	--	2.4	--	--	--	274	--
LM1c	Little Mill Creek at W. 84th Terrace	Urban	--	--	7.0	--	--	--	0	--	--	--	2.2	--	--	--	80	--
MI1	Mill Creek at 127th Street	Urban	17.8	29.2	9.0	9.7	50.2	2.3	0.8	1.9	2.1	2.5	2.6	3.5	491	321	239	423
MI4	Mill Creek at 87th Street Lane	Urban	64.7	15.2	24.8	29.0	2.7	1.7	0	0.5	2.0	2.2	2.5	3.3	438	241	310	426
MI7	Mill Creek at Johnson Drive	Urban	32.0	17.0	14.7	35.6	12.1	8.1	19.0	19.1	2.6	2.7	2.9	3.4	434	390	522	520
TO2	Tomahawk Creek near 111th Street	Urban	21.1	13.4	17.2	14.7	10.8	0.5	2.0	0.5	2.7	2.6	2.8	3.2	409	237	393	337
TU1	Turkey Creek at 67th Street	Urban	14.7	12.5	6.5	21.8	0.4	0	0	0	2.3	2.5	2.3	2.9	299	266	197	165

Table 9. Macroinvertebrate metric and aquatic-life-support values for biological monitoring sites in Johnson County, Kansas, 2003, 2004, 2007, and 2010.—Continued

[MBI, Macroinvertebrate Biotic Index; <, less than; >, greater than; KBI-NO, Kansas Biotic Index; E, Ephemeroptera; P, Plecoptera; T, Trichoptera; --, not determined; Aquatic life support criteria from Kansas Department of Health and Environment, 2008; *, site is downstream from wastewater treatment facility discharge]

Biological monitoring site identifier (fig. 1)	Site name	General land classification[1]	Aquatic-life-support status[3]			
			2003	2004	2007	2010
BI1	Big Bull Creek near Edgerton	Rural	1.25	1.00	2.00	2.00
BL3	Blue River near Stanley (Highway 69)	Rural	1.25	2.00	2.00	2.25
BL4	Camp Branch at 175th Street	Rural	--	--	2.50	2.25
BL5	Blue River at Kenneth Road	Rural	1.50	2.00	2.00	1.75
BR2	Brush Creek at Belinder Street	Urban	--	--	--	1.00
CA1	Captain Creek near 119th Street	Rural	2.25	2.25	2.25	2.50
CE1	Cedar Creek at Old Highway 56	Rural	2.00	2.00	2.00	1.75
CE6	Cedar Creek near DeSoto (83 St)	Rural	1.25	1.00	1.25	2.50
IN1b	Indian Creek at Highway 69	Urban	1.25	1.00	1.00	1.00
IN3a	Indian Creek at College Blvd	Urban	1.25	1.25	1.00	1.00
IN6	Indian Creek at State Line Road	Urban	1.00	1.00	1.00	1.00
KI5b	Kill Creek at 127th Street[2]	Rural	2.00	1.50	1.75	2.50
KI6b	Kill Creek at 95th Street	Rural	1.25	1.75	1.75	2.50
LI1	Little Bull Creek near 215th Street	Rural	--	--	--	2.00
LM1a	Little Mill Creek at W 79th Street	Urban	--	--	1.00	1.00
LM1b	Unnamed Little Mill Creek tributary near W. 83rd Street	Urban	--	--	1.25	--
LM1c	Little Mill Creek at W. 84th Terrace	Urban	--	--	1.25	--
MI1	Mill Creek at 127th Street	Urban	1.75	1.25	1.00	1.00
MI4	Mill Creek at 87th Street Lane	Urban	1.50	1.00	1.25	1.25
MI7	Mill Creek at Johnson Drive	Urban	1.00	1.00	1.25	1.25
TO2	Tomahawk Creek near 111th Street	Urban	1.00	1.00	1.00	1.00
TU1	Turkey Creek at 67th Street	Urban	1.00	1.00	1.00	1.25

[1]Urban sites have greater than 50 percent urban land use and greater than 15 percent impervious surface in the upstream drainage area.

[2]Site moved from 135th to 127th Street in 2007.

[3]Mean of scores for four Kansas Department of Health and Environment (KDHE) metrics (MBI, KBI-NO, EPTRich, and %EPT); fully supporting >2.49, partially supporting 1.5–2.49, nonsupporting <1.5.

IN3a and IN6, both affected by wastewater), and Little Mill Creek (LM1a, not affected by wastewater). The four sites with the highest 10-metric scores (best quality) in 2010 were the rural sites Blue River (site BL3, not affected by wastewater), Captain Creek (site CA1, a State reference site, and not affected by wastewater), Cedar Creek (site CE6, affected by wastewater), and Kill Creek (site KI6b, affected by wastewater). Ten-metric scores were significantly higher (z-value 3.9, p-value less than 0.0001) for rural sites (median 654) than urban sites (median 311), indicating that, in general, less disturbed streams are located in rural areas of Johnson County. A notable improvement in the 10-metric score occurred at the Big Bull Creek site (BI1) during 2007 and 2010 compared to scores in 2003 and 2004 (fig. 10), which may be related to reductions in upstream wastewater discharges.

Stream Quality Based on Aquatic-Life-Support Categories

Aquatic-life-support categories are indicative of the ability of a stream to support a certain level of aquatic life. The ranges used for scoring the four metrics (MBI, KBI-NO, EPT Richness, and percentage of EPT) are based on the statewide KDHE database for all streams in Kansas (Kansas Department of Health and Environment, 2010a) and are shown in table 9. Aquatic-life-support status for each site was determined using the mean of individual scores assigned for each of the four KDHE metrics; full support scores, greater than 2.49; partial support scores, 1.5–2.49; nonsupport scores, less than 1.5. Four sites (about 19 percent) in 2010 were fully supporting of aquatic life: Captain Creek (site CA1, a State reference site), Cedar Creek (site CE6), and two Kill Creek sites (KI5b and

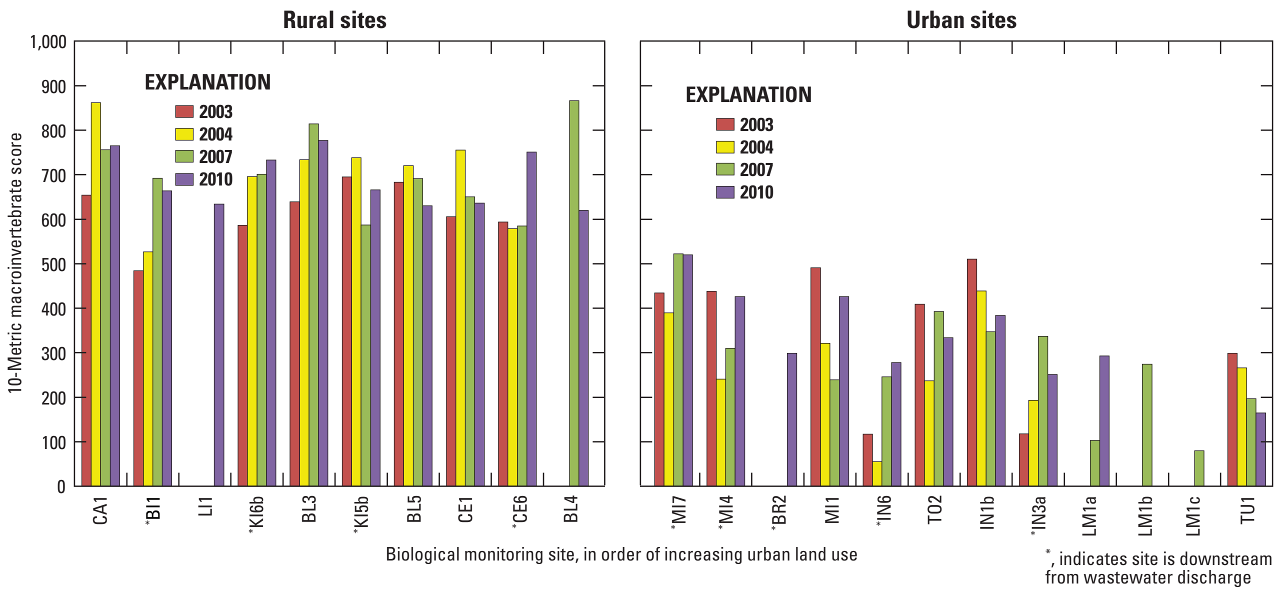

Figure 10. Combined 10-metric macroinvertebrate scores for biological monitoring sites in Johnson County, Kansas, 2003, 2004, 2007, and 2010.

KI6b, table 9, fig. 11). This is a notable difference compared to previous years when no sites were fully supporting (in 2003 and 2004) or just one site was fully supporting (a Blue River tributary in 2007). During 2010 about 29 percent of the sites were partially supporting of aquatic life and about 52 percent of the sites were nonsupporting of aquatic life. All nonsupporting sites were urban. Rural sites (median 2.25) had significantly higher (z-value 4.0, p-value less than 0.0001) aquatic-life-support status scores than urban sites (median 1.00). Figure 11 shows the general pattern that through the years of the study, urban sites' life-support scores either have trended downward, or remained about stable within the nonsupport range. In contrast, most rural sites' scores either were at least partially supporting across the study period, or had become so by 2010.

Aquatic-life-support status for stream sites in Johnson County generally is consistent with anthropogenic disturbance maps developed by KDHE (fig. 12). The maps were developed using geographical databases to identify minimally disturbed watersheds within various ecoregions (Angelo and others, 2010). Ecoregions generally are similar geographical areas defined and differentiated by combining suitable landscape characteristics such as physiography, geology, climate, soils, and vegetation (Angelo and others, 2010). It is within this framework that KDHE developed a watershed anthropogenic disturbance index to rank the State's watersheds and eventually identify candidate reference streams. The index incorporated geographical databases with species (native fishes, mussels, and invertebrates) diversity data, and used cluster analyses and predictive modeling to develop disturbance maps.

Relative to the rest of the State (fig. 12*A*), most Johnson County watersheds fall into the most severe category of disturbance (fig. 12*B*) because of the large proportions of urban and agricultural land use. Streams that have met aquatic-life-support criteria at least once during the study period are located within close upstream proximity to some of the less disturbed areas of the county. Captain Creek, a candidate reference stream located in western Johnson County and considered a minimally disturbed stream in this study, includes a considerable area of highly disturbed land within the lower parts of the watershed.

Comparison of Stream Biological Conditions Among Watersheds

The monitoring sites were divided into three categories of relative biological effects on stream health from human disturbance (least affected, moderately affected, and most affected) as indicated by the annual 10-metric macroinvertebrate scores (fig. 13). Sites were categorized as least affected when scores were less than 315, moderately affected when scores ranged from 315 to 590, and most affected when scores were greater than 590. Based on these categories, seven sites in the rural western and southern parts of the county (BL3, BL4, BL5, CA1, CE1, KI5b, and KI6b) were least affected by disturbance and showed no change in category assignment from 2003 to 2010 (except site BL4 where data were first collected in 2007). Two highly urban sites in northeastern Johnson County (IN6 and TU1) were most affected by human disturbance and also showed no change. Two rural sites (BI1 and CE6) showed improvements in macroinvertebrate metric scores since 2004. Improvement in biological communities at these sites is consistent with improvement in streambed-sediment quality at the same two sites, but improvements may be related to other unknown factors as well. Positive changes in macroinvertebrate community in Big Bull Creek (site BI1) may be related to an upstream wastewater discharge that was discontinued in

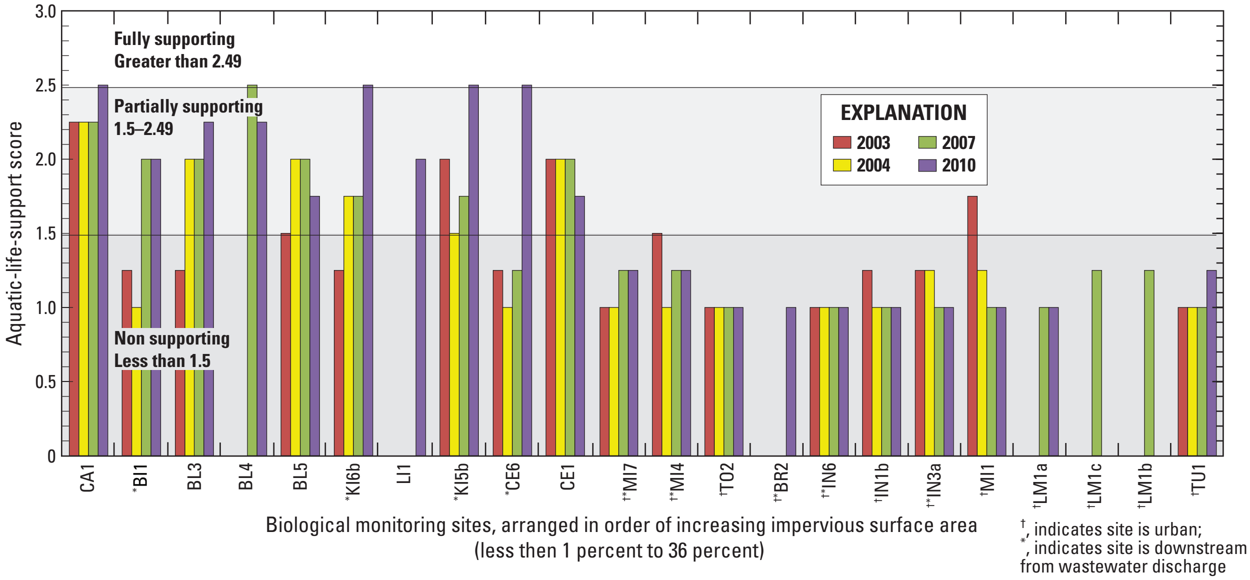

Figure 11. Kansas Department of Health and Environment aquatic-life-support status in relation to percent impervious surface area for biological monitoring sites in Johnson County, Kansas, 2003, 2004, 2007, and 2010.

2007. The reasons for detectable improvements in stream conditions at the Cedar Creek site are unknown. Spatial patterns of relative biological effects indicated by the classification of sampled sites generally were consistent with relative anthropogenic disturbance maps (fig. 12*C*).

Relations Between Stream Biological Conditions and Environmental Variables

Nonparametric Spearman rank correlation coefficients for all combinations of water chemistry, streambed-sediment chemistry, land use, streamflow, habitat, periphyton, and macroinvertebrate variables were computed. Correlations provide an indication of how well the ranges in biological conditions correspond with environmental variables that may affect them. Correlation coefficients (rho values, *p*) shown in table 10 are statistically significant with *p*-values less than 0.01. Highlighted values are highly significant with *p*-values less than 0.001. Data from 2003, 2004, 2007, and 2010 were included in the analysis. Although correlations were calculated for many combinations of variables, table 10 was reduced generally to include only the variables that were most commonly significantly correlated with biological variables. The 10-metric macroinvertebrate score and the most important metrics making up that score were included in the table as biological indicators of stream health. One additional macroinvertebrate metric, percent non-insects, also was included because it was strongly correlated with many environmental variables. There were no strong correlations between environmental factors and periphyton metrics so they were not included in the table. Other studies have determined that nutrient concentrations and, in some cases, environmental factors such as substrate type and light availability were important predictors of algal metrics (Black and others, 2011). Correlations with periphyton metrics may not have been evident in this study because of low variability among sites. In a national study, periphyton metrics were able to differentiate between rural and urban watersheds in most ecoregions of the United States; however, this did not apply to the Northern Plains ecoregion (Porter and others, 2008) in which Johnson County is located.

Watershed impervious surface and land-use variables were significantly (*p*-value less than 0.001) correlated with all invertebrate metrics (table 10). Percentage of impervious surface area and urban land use were negatively correlated with better-quality biological metric indicators. Percentage of cropland (row crops), grassland, and woodland were positively correlated with better-quality biological metric indicators. Although cropland has been shown to negatively affect biological communities in streams because of increased runoff of sediment, nutrients, and pesticides (Cooper, 1993; Waters, 1995), the magnitude of the effects is dependent on the spatial arrangement (Sponseller and others, 2001). The watersheds with the highest percentages of cropland (row crops, ranging from 20–34 percent for Big Bull, Little Bull, Captain, Cedar, and Kill Creeks, table 1) had low percentages of cropland within the stream buffer zones.

Some streamflow metrics were strongly correlated with biological variables and land use and habitat variables (table 10). Of the 3 streamflow metrics retained in the table (base-flow index, ratio of 75th to 25th percentile streamflow, and average daily streamflow), ratio of 75th to 25th percentile streamflow, which is a measure of the magnitude and variability in streamflow conditions, was most strongly correlated with individual invertebrate metrics and the 10-metric score. Higher ratio value indicates more variable streamflow, which decreased with increasing watershed size (table 10). Invertebrate diversity and richness metrics often improve with

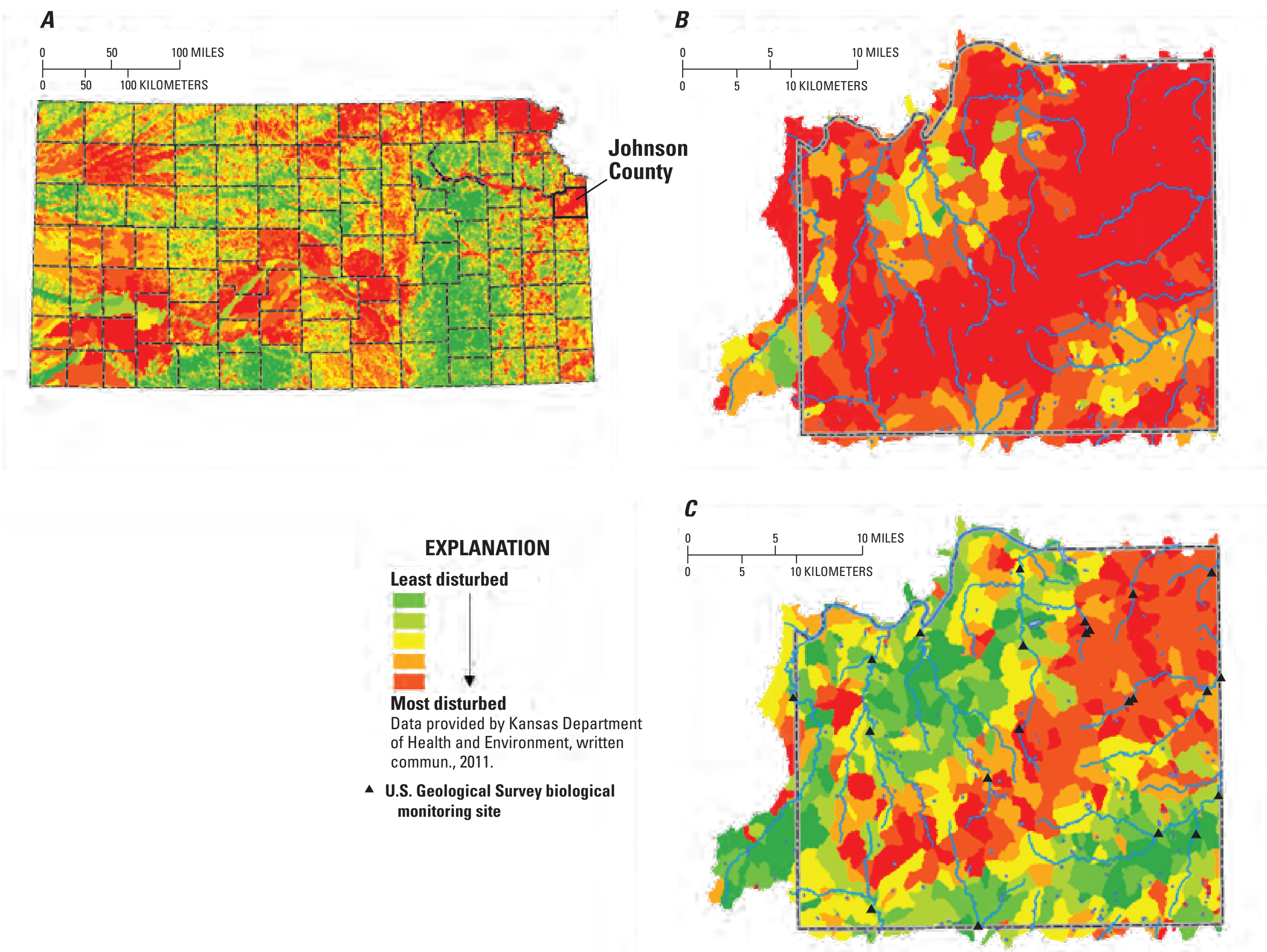

Figure 12. Anthropogenic disturbance maps for watersheds in *A*, Kansas, *B*, Johnson County, and *C*, Johnson County, with watershed disturbance scores range-standardized among themselves.

decreased streamflow variability because it promotes habitat stability (Horowitz, 1978); however, in this study invertebrate diversity and richness measures worsened with decreasing streamflow variability, likely because of the effects of urbanization. As base-flow index (base flow divided by total flow volume) increased, as often occurs when runoff is redistributed from base flow to more flashy stormflow with increasing urbanization (Konrad and Booth, 2005), several invertebrate metric scores worsened. Average daily streamflow, which increased as urbanization increased, was negatively correlated with several individual metrics and the 10-metric score.

Several stream-water and streambed-sediment chemistry variables were correlated with biological variables (table 10). Specific conductance of water and sum of PAH concentrations in streambed sediment were highly negatively correlated (*p*-value less than 0.001) with macroinvertebrate conditions indicated by the 10-metric score and all of the individual metrics that make up the 10-metric score. Specific conductance of water and PAHs in sediment are known to have adverse effects on biological communities at high concentrations (U.S. Environmental Protection Agency, 2008), but both variables also were highly correlated with the land-use variables and, therefore, simply may be redundant indicators of urbanization. Total phosphorus in water did not correlate with any biological or land-use variables, but did correlate with distance downstream from wastewater discharge. Total nitrogen in sediment did not correlate with any other variables including land use. Total nitrogen in water correlated with most of the invertebrate variables, and total phosphorus in sediment correlated with the invertebrate richness metrics and Shannon Diversity Index. When only 2007 data were used (Rasmussen and others 2009), the nutrient relations were weak or not detected, possibly because the dataset was too small to detect significant patterns.

Stream buffer land use variables were closely related to biological conditions (table 10). Urban land use for the full extent of the 30-meter buffer upstream from sampling sites was highly correlated (*p-value* less than 0.001) to all macroinvertebrate metrics. Reach-level urban land use also was highly

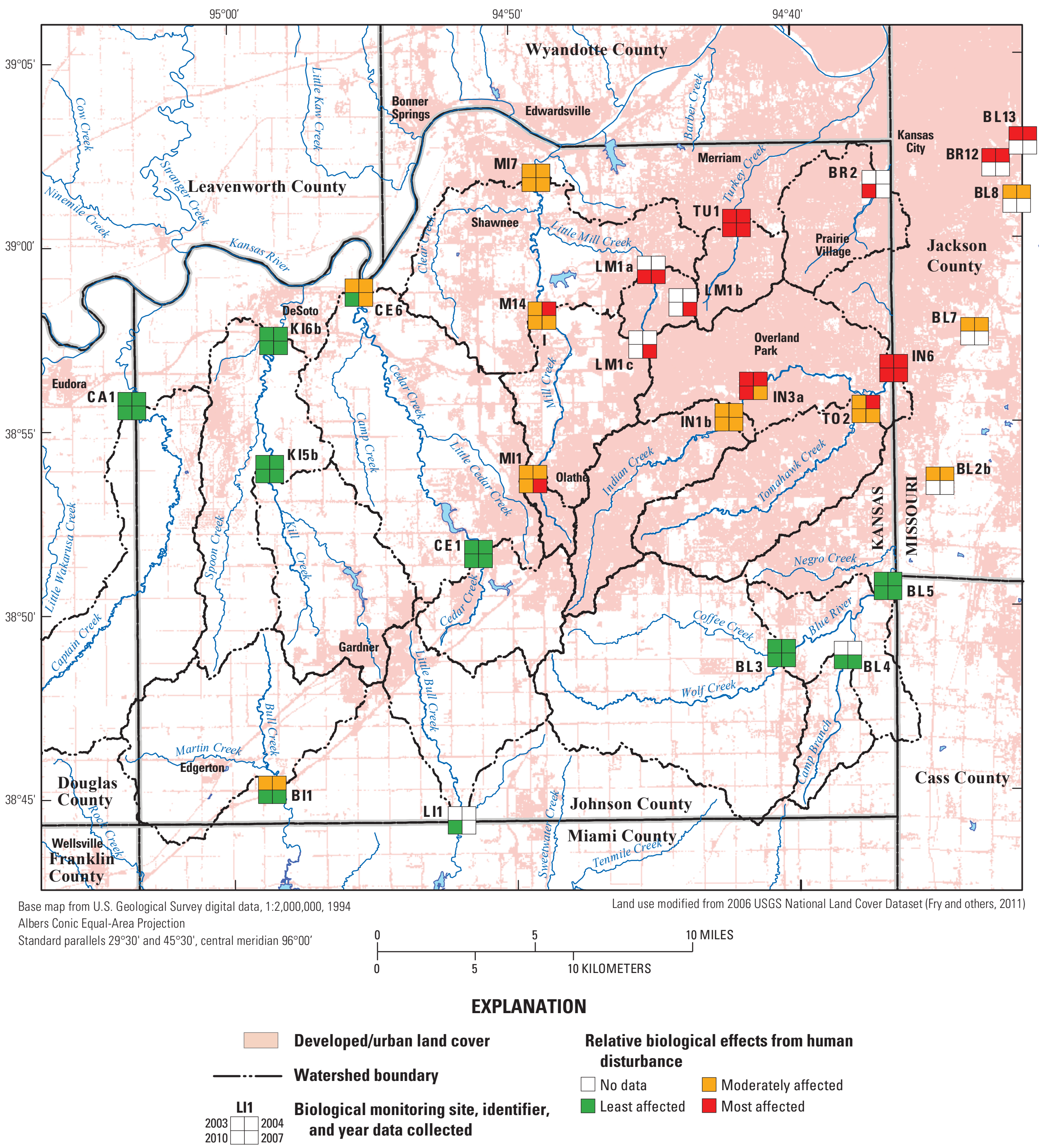

Figure 13. Relative effects from human disturbance on stream health as indicated by 10-metric macroinvertebrate scores at biological monitoring sites in and near Johnson County, Kansas, 2003, 2004, 2007, and 2010.

correlated with most metrics. The segment-level land-use data were useful in explaining relations with macroinvertebrate assemblages except forest land use, which was highly variable among sites. Density of stormwater entry points, determined by dividing the number of stormwater inlets adjacent to the stream in the segment upstream from the sampling site by the length of the segment, was significantly negatively correlated (p-value less than 0.001) with all biological conditions indicated by macroinvertebrate metrics. Density of stormwater outfalls also was positively correlated with specific conductance, total nitrogen and suspended sediment in water, and PAHs in sediment indicating that stormwater outfalls contribute to direct transport of these potentially harmful constituents to stream systems.

Table 10. Spearman correlation matrix for selected biological and environmental variables using data from biological monitoring sites in Johnson County, Kansas, 2003, 2004, 2007, and 2010. Correlation coefficents shown are significant at *p*<0.01. Shading indicates values significant at *p*<0.001.

[<, less than; PAHs, polycyclic aromatic hydrocarbons; MBI, Macroinvertebrate Biotic Index; KBI-NO, Kansas Biotic Index; E, Ephemeroptera; P, Plecoptera; T, Trichoptera; --, correlation not significant]

	Watershed area	Impervious surface, percent	Watershed urban land	Watershed cropland	Watershed grassland	Watershed woodland	Distance from wastewater discharge	Base flow index	Ratio 75th to 25th percentile streamflow	Average daily streamflow	Specific conductance of water	Total nitrogen in water	Total phosphorus in water	Suspended sediment concentration	Total nitrogen in sediment	Total phosphorus in sediment	PAHs in sediment	Total habitat score	Habitat 1C sinuosity	Habitat 1D pool status	Habitat 2D buffer length
Watershed area																					
Impervious surface, percent	-0.50																				
Watershed urban land	-0.57	.95																			
Watershed cropland	0.50	-.91	-.96																		
Watershed grassland	0.57	-.95	-.96	.91																	
Watershed woodland	0.61	-.85	-.84	.79	.86																
Distance from wastewater discharge	-0.46	--	--	--	--	--															
Base-flow index	0.87	.92	.90	-.90	-.90	--	-.54														
Ratio 75th to 25th percentile streamflow	-0.74	-.92	-.84	.83	.97	--	.62	-.91													
Average daily streamflow	0.95	.82	.90	-.90	-.83	--	--	.89	-.84												
Specific conductance of water	-0.51	.84	.84	-.76	-.84	-.79	--	.78	-.88	--											
Total nitrogen in water	--	.43	.42	--	-.50	-.52	--	--	--	--	.52										
Total phosphorus in water	0.56	--	--	--	--	--	-.79	--	--	--	--	.50									
Suspended sediment concentration	--	--	--	--	.42	--	.45	--	--	--	--	--	--								
Total nitrogen in sediment	--	--	--	--	--	--	--	--	--	--	--	--	--	--							
Total phosphorus in sediment	--	--	--	--	-.35	--	-.47	--	--	--	--	.50	--	-.71	.42						
PAHs in sediment	-0.39	.84	.83	-.83	-.85	-.79	--	.68	-.77	.57	.73	.47	--	--	--	--					
Total habitat score	--	-.60	-.57	.60	.57	.54	--	-.65	.72	--	-.50	-.49	--	--	--	--	-.62				
Habitat 1C sinuosity	0.59	-.65	-.74	.74	.64	.64	--	--	--	-.55	-.57	--	--	--	--	--	-.57	.38			
Habitat 1D pool status	--	-.55	-.55	.53	.45	.43	--	-.57	.52	-.52	-.51	--	--	--	--	--	-.59	.49	.52		
Habitat 2D buffer length	--	-.65	-.71	.75	.65	.58	--	-.67	.80	-.85	-.48	--	--	--	--	--	-.59	.62	.79	.44	
Habitat 2E buffer width	--	--	-.31	.35	--	--	--	-.73	.66	-.58	--	-.50	--	--	--	--	-.39	.62	--	.62	.42
Habitat 2F altered banks	--	-.43	-.40	.37	.40	.54	--	--	--	-.53	-.48	-.57	--	--	--	--	-.56	.58	--	.59	.37
Habitat 3C riffle substrate embeddedness	0.38	-.59	-.68	.69	.63	.52	--	-.78	.83	-.54	-.54	-.49	--	--	--	--	-.71	.81	.56	.48	.68
Habitat 3D sediment deposition	0.47	-.47	-.40	.40	.48	.52	-.43	--	--	--	--	--	--	--	--	--	-.46	.72	--	--	--
Habitat 3E substrate cover diversity	--	-.59	-.62	.62	.58	.50	.33	-.55	.72	--	-.58	-.45	--	--	--	-.42	-.63	.53	.61	.65	.60
Habitat 3F riffle substrate composition	0.44	-.40	-.37	.37	--	.56	--	--	--	--	--	--	--	--	--	--	-.43	.71	.30	--	.36
Full extent buffer, agriculture	--	-.47	-.45	.42	.49	.47	--	--	--	--	-.427	--	--	--	--	--	-.48	--	.45	.37	.43
Full extent buffer, forest	--	-.65	-.65	.71	.59	.41	--	-.90	.87	-.99	-.46	--	--	--	--	--	-.58	.53	.58	.60	.68
Full extent buffer, urban	--	.83	.88	-.87	-.86	-.83	--	--	-.68	.67	.74	.48	--	--	--	--	.78	-.52	-.75	-.44	-.78
Segment buffer, agriculture	0.38	-.53	-.51	.48	.49	.78	--	--	--	--	-.50	-.48	--	.41	--	--	-.53	--	.52	--	.41
Segment buffer, forest	-0.37	--	--	--	--	--	.44	--	--	-.98	--	--	--	--	--	--	--	--	--	.42	--
Segment buffer, urban	-0.49	.40	.40	-.37	-.41	-.53	--	--	--	--	.44	.62	--	--	--	--	.48	-.59	--	--	-.39
Segment buffer, roadways	-0.50	.85	.88	-.91	-.86	-.75	--	.78	-.81	.90	.71	--	--	--	--	--	.80	-.56	-.82	-.50	-.84
Reach buffer, forest	--	-.64	-.65	.70	.59	.38	--	-.92	.90	-.98	-.45	--	--	--	--	--	-.57	.51	.57	.59	.67
Reach buffer, urban	-0.52	.88	.92	-.93	-.88	-.77	--	.78	-.81	.90	.74	--	--	--	--	--	.79	-.57	-.81	-.52	-.83
Density of stormwater entry points	-0.51	.89	.91	-.91	-.83	-.84	--	--	--	.73	.80	.42	--	.50	--	--	.80	-.55	-.65	-.48	-.63
Density of septic systems	--	--	--	--	.57	.63	--	--	--	--	--	-.88	--	--	--	--	--	.57	--	--	--
Benthic MBI	--	.77	.78	-.77	-.59	-.71	--	.63	-.67	.56	.79	.52	--	-.42	--	--	.80	-.51	-.50	-.49	-.53
Benthic KBI-NO	--	.59	.59	-.56	-.58	-.52	--	.53	-.70	--	.62	.52	--	-.41	--	--	.62	-.42	-.35	-.46	-.45
Benthic EPT Richness	0.38	-.77	-.77	.74	.79	.78	--	--	.57	--	-.81	-.63	--	.46	--	-.45	-.76	.59	.49	.41	.58
Benthic percent EPT	0.39	-.80	-.80	.78	.80	.75	--	-.57	.64	-.51	-.82	-.48	--	--	--	--	-.77	.48	.49	.40	.50
Benthic total richness	0.37	-.63	-.64	.62	.69	.70	--	--	.51	--	-.82	-.61	--	.43	--	-.53	-.64	.49	.46	--	.51
Benthic percent scrapers	0.33	-.72	-.70	.72	.70	.69	--	--	.58	--	-.58	-.50	--	--	--	--	-.80	.63	.49	.44	.59
Benthic percent intolerant organisms	--	-.65	-.63	.61	.63	.60	--	--	.61	--	-.67	-.57	--	.49	--	--	-.66	.46	.44	.44	.49
Benthic percent EP	0.32	-.80	-.78	.77	.79	.75	--	-.68	.78	-.58	-.86	-.61	--	.42	--	--	-.76	.55	.51	.45	.51
Benthic Shannon Diversity Index	--	-.56	-.58	.56	.62	.60	--	.57	.56	-.50	-.77	-.54	--	.50	--	-.56	-.52	.46	.43	--	.52
Benthic 10-metric score	0.31	-.83	-.82	.79	.83	.79	--	-.57	.76	-.58	-.83	-.57	--	.44	--	--	-.85	.60	.57	.48	.64
Benthic percent non-insects	-0.41	.79	.77	-.77	-.76	-.63	--	.83	--	.75	.59	--	--	--	--	.43	.62	-.43	-.54	--	-.57

Habitat 2E buffer width	Habitat 2F altered banks	Habitat 3C riffle substrate embeddedness	Habitat 3D sediment deposition	Habitat 3E substrate cover diversity	Habitat 3F riffle substrate composition	Full extent buffer, agri-culture	Full extent buffer, forest	Full extent buffer, urban	Segment buffer, agri-culture	Segment buffer, forest	Segment buffer, urban	Segment buffer, roadways	Reach buffer, forest	Reach buffer, urban	Density of stormwater entry points	Density of septic systems	Benthic MBI	Benthic KBI-NO	Benthic EPT Richness	Benthic percent EPT	Benthic total richness	Benthic percent scrapers	Benthic percent intolerant organisms	Benthic percent EP	Benthic Shannon diversity index	Benthic 10-metric score	Benthic percent non-insects
.56																											
.61	.46																										
--	--	.56																									
.57	.57	.61	--																								
--	.41	.54	.83	--																							
--	--	.31	--	.30	--																						
.60	.47	.52	--	.58	--	.39																					
-.30	-.49	-.68	--	-.71	-.32	-.51	-.62																				
--	.44	--	--	.30	--	.60	.39	-.59																			
.62	.36	.52	-.33	.38	--	--	.38	--	.35																		
-.48	-.76	-.51	-.39	-.48	-.41	--	--	.57	-.38	--																	
--	-.33	-.72	-.36	-.63	-.34	-.50	-.70	.92	-.50	--	.31																
.57	.45	-.53	--	.58	--	.40	.99	-.61	--	.32	--	-.70															
--	-.38	-.73	-.37	-.66	-.34	-.46	-.69	.94	-.50	--	.40	.99	-.68														
--	-.43	-.60	-.40	-.46	--	-.45	-.55	.80	-.63	--	.48	.78	-.53	.82													
--	--	--	.59	--	.65	--	--	--	--	--	-.76	--	--	--	--												
-.36	--	-.58	--	-.62	--	-.44	-.56	.77	-.49	--	.50	.51	-.55	.74	.80	--											
-.38	-.41	-.44	--	-.49	--	-.49	-.55	.63	-.37	--	.45	.37	-.54	.58	.60	--	.63										
.33	.53	.60	.44	.55	.39	.42	.46	-.77	.59	--	-.59	-.49	.44	-.73	-.83	.66	-.78	-.59									
--	.42	.52	.35	.55	--	.37	.49	-.77	.48	--	-.48	-.49	.47	-.74	-.87	--	-.93	-.60	.80								
--	.47	.52	.36	.49	.40	.41	.39	-.69	.53	--	-.50	-.38	.37	-.63	-.72	.56	-.61	-.43	.85	.61							
.40	.48	.66	.38	.54	.32	.40	.50	-.71	.51	--	-.48	-.42	.49	-.69	-.74	.65	-.72	-.57	.67	.71	.49						
.37	.43	.44	--	.49	--	.49	.51	-.64	.43	--	-.45	-.42	.49	-.59	-.66	--	-.64	-.88	.60	.63	.42	.63					
.40	.55	.58	.30	.65	--	-.41	.59	-.80	.51	--	-.55	-.47	.56	-.74	-.84	.56	-.91	-.64	.80	.93	.65	.74	--				
--	.44	.50	--	.47	.33	.38	.42	-.63	.45	--	-.44	-.59	.41	-.59	-.69	--	-.53	-.42	.79	.50	.95	.39	.35	.55			
.41	.58	.64	.35	.65	.32	.50	.62	-.84	.56	--	-.57	-.56	.61	-.79	-.83	--	-.87	-.71	.88	.85	.80	.78	.70	.89	.75		
--	--	-.50	--	-.51	--	-.35	-.47	.71	-.43	--	.48	.68	-.43	-.45	.71	--	.79	.41	-.67	-.73	-.54	-.54	-.52	-.70	.47	-.68	

The total habitat score was strongly correlated with the 10-metric macroinvertebrate score and with most of the individual metrics. The most important habitat variables were sinuosity (habitat variable 1C), buffer length (2D), riffle substrate embeddedness (3C), and substrate cover diversity (3E), each of which correlated with all of the invertebrate metrics including the 10-metric score. Stream sinuosity, or meandering, provides more diverse habitat and refuge for invertebrates. It also is highly negatively correlated with urbanization. Buffer length is an indicator of the longitudinal extent of stream buffers and the number of gaps in buffer continuity (Rasmussen and others, 2009). Naturally vegetated buffers with minimal interruptions, such as bridges, stormwater entry points, and development, are associated with healthier streams (Walsh and others, 2005). The two substrate variables measure in-stream habitat characteristics and indicate the importance of in-stream conditions that in some instances may not be directly related to larger watershed factors. Substrate cover diversity describes the number and variety of habitat and cover types, including leaf packs, woody debris, root mats, and overhanging or inundated vegetation, which provide feeding and living locations for a diversity of organisms (Rasmussen and others 2009). Riffle substrate embeddedness is a measure of the amount of packed fine material surrounding rocks and other substrates. Generally, as rocks become embedded, the surface area and living space available to macroinvertebrates and fish decrease (Barbour, 1999). Correlation analysis indicated that if important riparian and in-stream habitat conditions improved, so might invertebrate communities and stream biological quality.

Invertebrate responses to urbanization in Johnson County (as indicated by percent impervious surface), when plotted using LOWESS smoothing, generally showed linear patterns rather than identifiable thresholds (fig. 14). Some early studies in other areas showed that biological conditions generally start to decline when impervious surface exceeds about 10 percent (Klein, 1979; Booth and Jackson, 1997; Paul and Meyer, 2001). Other studies indicate that impervious surface oversimplifies a more complex combination of factors affecting stream biology (Booth and others, 2004) and no threshold exists (Karr and Chu, 2000). The linear responses indicated in this study were consistent with results from a study of invertebrate responses to urban gradients in nine metropolitan areas (Cuffney and others, 2010), which determined that invertebrate assemblages begin to change at low levels of urbanization and usually follow a linear response as hypothesized by Booth and others (2004). Cuffney and others (2010) determined that streams in metropolitan areas that were converted from forest or grassland underwent more degradation of biological assemblages during urbanization than those converted from cropland or pasture. The authors suggested that the apparent lack of resistance to early phases of urbanization in many metropolitan areas may be because biological communities already have been disturbed by changes associated with agriculture. This explanation may apply to watersheds in Johnson County.

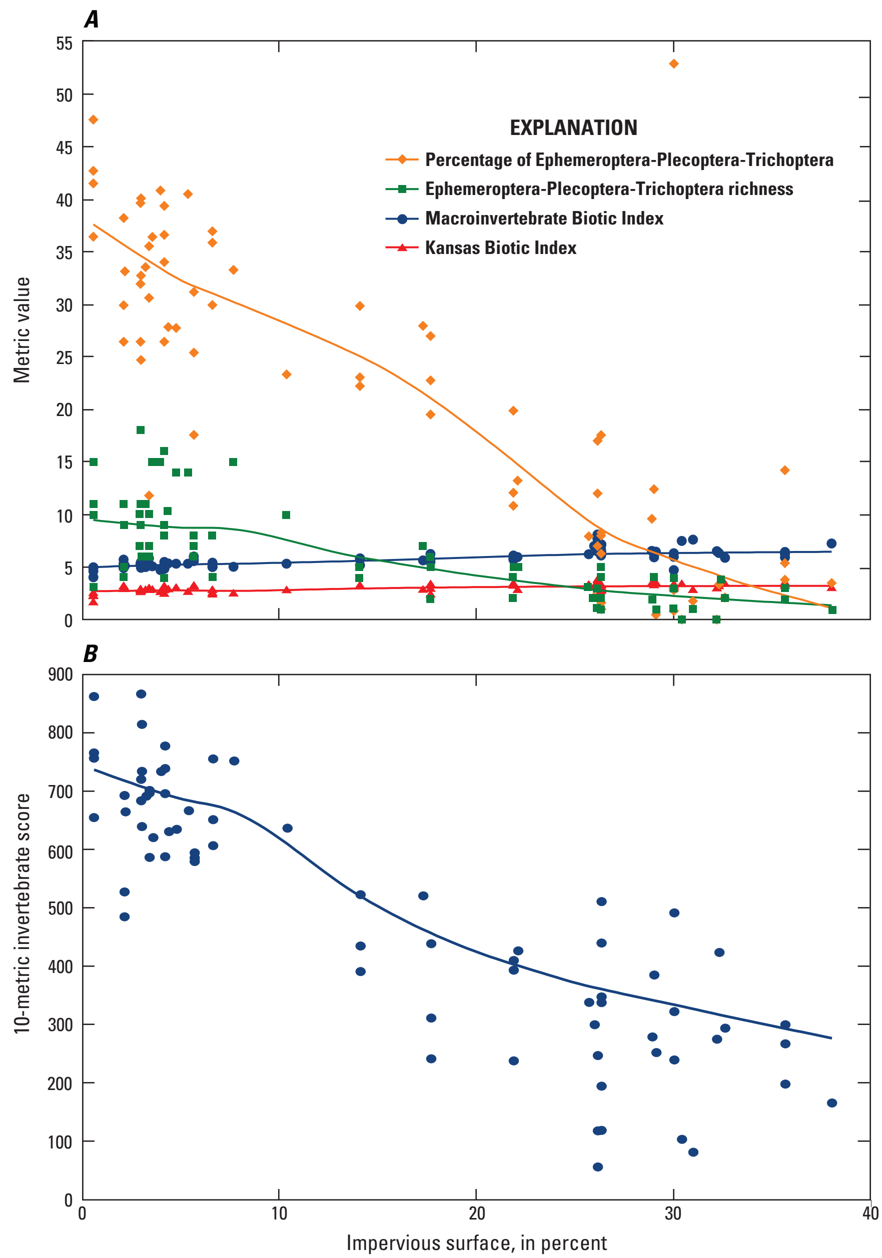

Figure 14. Invertebrate response patterns to urbanization as indicated by percent impervious surface at stream sites in Johnson County, Kansas, 2003, 2004, 2007, and 2010.

Figure 15. Multidimensional scaling of macroinvertebrate abundance at stream biological monitoring sites in Johnson County, Kansas, 2007, 2010.

Nonparametric multidimensional scaling (MDS) is an ordination technique used to represent complex biological relations accurately in a small dimensional space (Clarke and Warwick, 2005). MDS graphs, with axes that have no units, show relative likeness among monitoring sites. MDS graphs of macroinvertebrate abundance data generated using Primer software showed distinct separation of sites according to sample year and rural and urban land use (fig. 15). In 2010 sites were more tightly clustered than in 2007, indicating less overall variability among sites. For both years, variability among rural sites was smaller than among urban sites, as indicated by the smaller rural cluster. Sites in the Mill Creek watershed were most variable both years partly because it is the only watershed that includes headwater stream sites (LM1a in 2010, and LM1a, LM1b, and LM1c in 2007), which would be expected to differ from larger stream sites. In addition, the most downstream Mill Creek site (MI7) plots closely to rural sites indicating that macroinvertebrate assemblages are more similar to those at rural sites than urban sites. Although this site contains the smallest amount of urban land of the urban sites, urban land use is predominant at 68 percent.

Primer's BEST feature determined that 62 percent of the variance in macroinvertebrate communities was explained by the single environmental factor, percent impervious surface. The second best variable was specific conductance of water, but adding that variable only improved the percent of variance explained to 66 percent.

Multiple linear regression (MLR) models were developed for the four macroinvertebrate metrics used by KDHE to determine aquatic-life-support status (MBI, KBI-NO, EPT Richness, and Percent EPT). Although multiple environmental variables were considered as explanatory variables, including those describing land use, streamflow, water and streambed-sediment chemistry, in-stream habitat, and riparian buffer conditions, only measures of urbanization (percent urban land use or impervious surface) were significant for each of the models. Percent impervious surface, as a measure of urban land use, was retained in each of the final models and explained 34 to 67 percent of the variability in biological communities (table 11, fig. 16*A*). In each model, biological quality as indicated by the metric decreases as impervious surface increases. Percent impervious surface explains 76 percent of the variability among sites in the 10-metric invertebrate scores (fig. 16*B*). Impervious surface is highly correlated with biological variables because increasing impervious surface area also increases contaminant-laden stormwater runoff that alters hydrology and stream chemistry (Brabec and others, 2002; Walsh and others, 2005). When measures of upstream urbanization were excluded from models in an attempt to isolate more specific contributing factors, only PAH concentration in streambed sediment or specific conductance of water were significant, individually. Since each of those variables is highly correlated with urban land use (table 10), they represent surrogates for urban land use rather than providing additional information about environmental variables that affect stream biological conditions.

Waite and others (2010) documented that land-use variables are the best predictors of stream biological condition, but that models were improved by including an additional natural variable such as mean annual precipitation or watershed slope. Since this study represents a small geographical area, the physiographic variability among sites may not have been large enough for such natural variables to distinguish among sites.

Results from this study indicate that the cumulative effects of urbanization negatively affect stream quality. Effects of urbanization on Johnson County streams are similar to effects described in national studies that assess effects of urbanization on stream ecology (Brown and others, 2009; Cuffney and others, 2010). Quantification of the primary environmental factors affecting stream quality is made difficult by the complexity of stream systems; however, results indicate that no small subset of environmental variables is causing stream degradation. Although multiple factors are correlated with stream degradation, general urbanization, as indicated by impervious surface area or urban land use, consistently is determined to be the fundamental factor causing change in streams. Individual important environmental factors such as nutrients in water and streambed sediment, specific conductance of water, PAHs in streambed sediment, and some riparian and in-stream habitat variables, serve as surrogates for urbanization and, collectively, contribute to stream impairments. Improvement in any single environmental factor is not likely to result in measurable changes in stream health; however, the cumulative effects of environmental improvements will lead to increasing biological quality.

Management practices that may be most important in protecting the health of streams in Johnson County are minimizing the effects of impervious surfaces, protection of stream corridors, and reduction of sediment, nutrients, and chemicals at their sources and along transport pathways. Healthy stream corridors provide hydrological and physical-habitat conditions to support healthy aquatic communities, as well as provide infiltration and natural filtering opportunities for stormwater runoff. Restoration and protection of riparian areas and wetlands is identified in the Kansas Water Plan (Kansas Water Office, 2009) and Kansas Nonpoint Source Pollution Plan (Kansas Department of Health and Environment, 2010c) as primary components in restoring and maintaining water quality to fully support designated uses. Reduction of sediment, nutrients, and chemicals at their sources (by reducing construction runoff, fertilizer application, and use of household chemicals, as examples) and along the transport pathways (using detention ponds and pervious pavements, for example) results in fewer contaminants requiring filtration and degradation within the riparian areas.

The stream biological monitoring program in Johnson County has made it possible to characterize stream health throughout Johnson County and during various hydrologic conditions, identify sites with the best and worst quality, determine environmental factors most closely related to stream health, and document stream conditions for future comparison and evaluation. Each additional year of data collection provides data under different conditions, identifies new and changing trends, and allows statistical analyses with more confidence. Collectively, this information leads to more informed decisionmaking and expenditure of resources directed toward maintaining healthy stream ecosystems.

Table 11. Multiple linear regression models for biological monitoring sites in Johnson County, Kansas based on data collected in 2003, 2004, 2007, and 2010.

[IMP, percent impervious surface upstream from sampling sites; MBI, macroinvertebrate biotic index; KBI-NO, Kansas biotic index; EPT, Ephemeroptera Plecoptera Trichoptera; n, number of values in sample set; R^2, coefficient of determination; Adj R^2, adjusted coefficient of determination; RMSE, root mean squared error; coefficients and intercepts are statistically significant at $p<0.05$]

Response variable	Regression model	n	R^2	Adj R^2	RMSE
MBI	*MBI* = 0.0504 *IMP* + 5.00	72	0.57	0.57	0.5346
KBI-NO	*KBI-NO* = 0.0175 *IMP* + 2.67	72	0.34	0.34	0.2976
EPT Richness	*EPTRich* = -0.2734 *IMP* + 10.35	72	0.57	0.56	2.956
Percent EPT	*pEPT* = -0.9535 *IMP* + 36.60	72	0.67	0.67	8.253

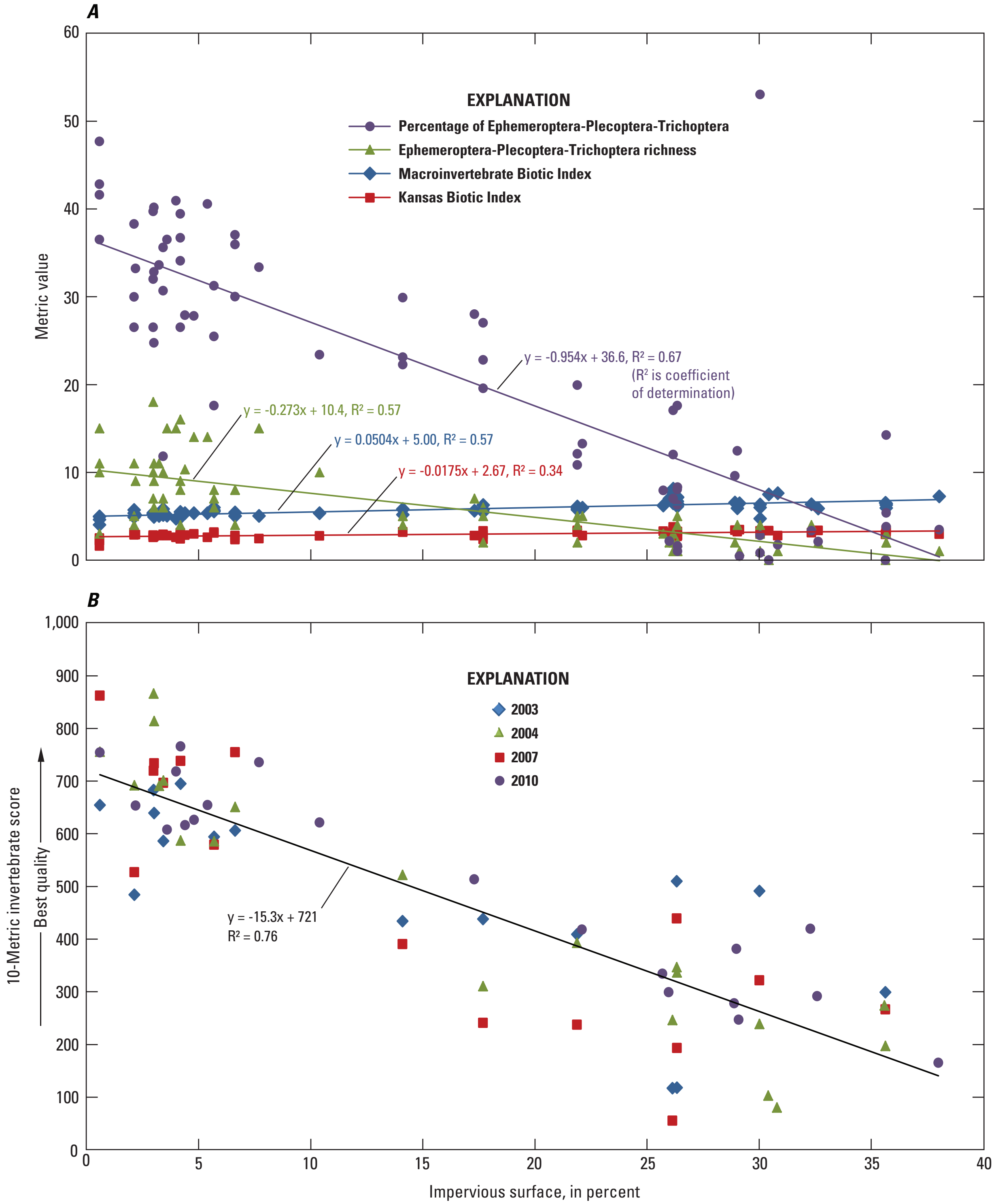

Figure 16. Selected macroinvertebrate metrics (y) plotted against impervious surface area (x) in the watersheds upstream from biological monitoring sites in Johnson County, Kansas, 2003, 2004, 2007, and 2010.

Summary

The purpose of this report is to assess the quality of streams throughout Johnson County from 2002–10. Aquatic biological communities and the environmental variables that may affect them are evaluated. Stream quality is characterized on the basis of watershed land use, streamflow, water and streambed-sediment chemistry, riparian habitat conditions, algal periphyton communities, and macroinvertebrate communities. Water chemistry data represent base-flow conditions only, and do not show the variability in concentrations that occurs during stormwater runoff. Data collected during 2010 are used to describe conditions at the end of the study period and to evaluate changing conditions by making comparisons to previously collected data. This report characterizes stream biological communities and physical and chemical conditions among stream sites and watersheds throughout the county, describes changes during the period 2002–10, evaluates conditions relative to Kansas Department of Health and Environment (KDHE) impairment categories and water-quality standards, and describes environmental factors that are most strongly correlated with biological stream quality.

Constituent concentrations in water during base flow varied across the study area and 2010 conditions were not markedly different from those measured previously (2003, 2004, and 2007). Generally the highest specific conductance, dissolved solids, and major ions in water occurred at urban sites except the upstream Cedar Creek site, which is rural and has a large area of commercial and industrial land less than 1 mile upstream on both sides of the creek. The highest base-flow nutrient concentrations in water occurred downstream from wastewater treatment facilities. Total nitrogen and total phosphorus were highest each year sampled at two Indian Creek sites that are most directly downstream from wastewater discharge, and at the first Mill Creek site downstream from wastewater discharge.

Constituent concentrations in streambed sediment also varied across the study area and some notable changes occurred from previously collected data. High total organic carbon and nutrient concentrations at the Big Bull Creek site in 2003 decreased to at least one-fourth of those concentrations in 2007 and 2010 likely because of the reduction in upstream wastewater discharge contributions. Trace metals were detected in streambed sediment from all sites. The highest concentrations of trace metals in 2010 occurred at sites on Mill and Indian Creeks. The highest concentrations of zinc occurred at two sites on Indian Creek with heavy bridge traffic. Some metals concentrations showed downward trends across the county from 2003 to 2010. For example, nickel concentrations decreased by at least 20 percent at 6 of the 15 sites for which data were available in 2003, and increased at 1 site on Mill Creek. Zinc concentration at Indian Creek at State Line increased from 170 mg/kg in 2003 to 500 mg/kg, exceeding the probable effects concentration (PEC) of 459 mg/kg. Zinc was the only metal to exceed the PEC in 2010. In 2007, chromium and nickel at the upstream Cedar Creek site exceeded PECs, and in 2003, no metals exceeded PECs.

Of 72 organic compounds analyzed in streambed sediment, 26 were detected including pesticides, polycyclic aromatic hydrocarbons (PAHs), fuel products, fragrances, preservatives, plasticizers, manufacturing byproducts, flame retardants, and disinfectants. All 6 PAH compounds analyzed were detected, and PECs for 4 of the 6 PAH compounds analyzed were exceeded in 2010, in some instances by as much as 14 times. Higher PAH concentrations in 2010 may have resulted from more stormwater runoff immediately preceding sample collection. Only five pesticide compounds were detected in streambed sediment, including carbazole and four pyrethroid compounds. At least one pyrethroid compound was detected at six sites including three urban sites and three rural sites. Of the eight detections at the six sites, chronic toxicity guidelines were exceeded at five sites. At the Big Bull Creek site (BI1) about 70 percent of the detected constituents in 2003 decreased by at least 20 percent in 2010.

Total habitat scores from 2010 were suboptimal at 17 of the 20 monitoring sites and marginal at the remaining sites. The variability of habitat scores among sites was small. The lowest habitat scores, corresponding with the poorest habitat condition, occurred at the three most urbanized sites, in part, because of poor riparian buffer conditions. The highest total habitat scores indicating the best habitat condition occurred at rural sites.

Biological quality at nearly all monitoring sites showed some level of impairment. The four most common periphyton taxa in samples from 2010 were taxa that were identified previously as generally indicative of eutrophic conditions. Six of the 20 sites sampled had periphyton chlorophyll concentrations above the defined nuisance threshold in 2010, and 4 of 11 sites exceeded the threshold in 2007. Moreover, periphyton chlorophyll concentration and biomass were significantly higher at rural sites than at urban sites.

Most macroinvertebrate communities metrics reflected a gradient in land use in which the less disturbed streams were located in rural areas of Johnson County. Macroinvertebrate Biotic Index (MBI) is one of four invertebrate metrics used by the KDHE to determine aquatic life support. None of the sites met the KDHE criteria for full support of aquatic life based on MBI scores, and all urban sites were nonsupporting of aquatic life. The Mill Creek TMDL for biological impairment establishes a MBI goal of 4.5 or less as an average for 2006–2015. MBI values for monitoring sites in the Mill Creek watershed have thus far failed to achieve the goal; scores ranged from 5.64 to 6.36 in 2010, showing no improvement from a range of 4.71 to 7.63 in previous years.

Four sites (about 19 percent) in 2010 were fully supporting of aquatic life on the basis of the four metrics used by KDHE to categorize sites. This is a notable difference compared to previous years when no sites were fully supporting (in 2003 and 2004) or just one site was fully supporting (in 2007). About 29 percent of the sites were partially supporting of aquatic life in 2010 and about 52 percent of the sites were nonsupporting of aquatic life. All nonsupporting sites were in urbanized watersheds.

Multimetric scores, developed by integrating 10 selected metrics into 1 overall score as a relative indicator of the biological quality of Johnson County streams, indicated that the 4 sites with the poorest scores were urban sites on Turkey, Indian, and headwater Mill Creeks, and the 4 sites with the best scores were rural sites on the Blue River, and Cedar, Captain, and Kill Creeks. Two of the best sites are affected by upstream wastewater discharges.

Based on general categories of relative disturbance, seven sites in the rural western and southern parts of the County were least affected by disturbance and showed no change from 2003 to 2010. The two most urban sites in northeastern Johnson County were most affected by human disturbance and also showed no change from 2003 to 2010. Two rural sites showed improvements since 2004, including the Big Bull Creek site where wastewater discharges were reduced in 2007. Improvement in biological communities at these sites is consistent with improvement in streambed-sediment quality at the same two sites.

Considering data collected from 2003, 2004, 2007, and 2010, environmental variables that consistently were highly correlated with biological variables were impervious surface area and urban land use. In addition, density of stormwater entry points adjacent to streams was significantly negatively correlated with biological conditions. Specific conductance of water and sum of polycyclic aromatic hydrocarbon (PAH) concentrations in streambed sediment were significantly negatively correlated with biological conditions. Both of those constituents also were highly correlated with the land-use variables and, therefore, likely are redundant indicators of urbanization. Total nitrogen in water and total phosphorus in streambed sediment also were negatively correlated with most of the invertebrate variables, which is a notable difference from previous analyses using smaller datasets when nutrient relations were weak or not detected. The total habitat score was strongly correlated with the 10-metric macroinvertebrate score and with most of the individual metrics. The most important habitat variables, each of which correlated with all of the favorable invertebrate metrics including the 10-metric score, were sinuosity (positive), buffer length (positive), riffle substrate embeddedness (negative), and substrate cover diversity (positive). Density of stormwater entry points was significantly negatively correlated with all biological conditions indicated by macroinvertebrate metrics. Correlation analysis indicated that as important riparian and in-stream habitat conditions improve, so might invertebrate communities and stream biological quality. Invertebrate responses to urbanization in Johnson County showed linear patterns rather than identifiable thresholds.

Primer’s BEST feature determined that 62 percent of the variance in macroinvertebrate communities was explained by the single environmental factor, percent impervious surface. Including the next best variable identified by BEST, specific conductance of water, did not substantially improve the percent of variance explained. Multiple linear regression models developed for each of the four macroinvertebrate metrics used to determine aquatic-life-support status (MBI, KBI-NO, EPT Richness, and Percent EPT) indicated that percent impervious surface, as a measure of urban land use, explained 34 to 67 percent of the variability in biological communities metrics.

The cumulative effects of urbanization negatively affect the quality of Johnson County streams. Effects of urbanization on Johnson County streams are similar to effects described in national studies that assess effects of urbanization on stream health. Results indicate that multiple factors are correlated with stream degradation; however, general urbanization, as indicated by impervious surface area or urban land use, consistently is determined to be the fundamental factor causing change in streams. Individual important environmental factors such as specific conductance of water, PAHs in streambed sediment, in-stream habitat, and riparian buffer conditions, serve as surrogates for urbanization and, collectively, contribute to stream impairments. Improvement in any single environmental factor is not likely to result in a measurable change in stream health; however, the cumulative effects of environmental improvements will lead to increasing biological quality. Management practices that may be most important in protecting health of streams in Johnson County are minimizing effects of impervious surface, protecting stream corridors, and reducing sediment, nutrients, and chemicals at their sources and along transport pathways.

The stream biological monitoring program in Johnson County has made it possible to characterize stream health throughout the county and during various hydrologic conditions, identify sites with the best and worst quality, determine environmental factors most closely related to stream health, and document stream conditions for future comparison and evaluation. Each additional year of data collection provides data under different conditions, identifies new and changing trends, and allows statistical analyses with more confidence. Collectively, this information leads to more informed decision-making and expenditure of resources directed toward maintaining healthy stream ecosystems.

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Appendixes

Appendix 1. Organic compounds analyzed in streambed sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010. (All compounds are reported in micrograms per liter.)

[µg/L, micrograms per liter; CAS, Chemical Abstracts Service; PAH, polycyclic aromatic hydrocarbon; --, not available]

Compound name	General uses or sources (from Burkhardt and others, 2006; Hladik and others, 2009)	CAS[1] number	Laboratory reporting level (µg/L)
1,4-Dichlorobenzene	Moth repellent, fumigant, deodorant	106-46-7	50
1-Methylnaphthalene	Gasoline, diesel fuel, crude oil	90-12-0	50
2,2’,4,4’-Tetrabromodiphenylether	Fire retardant	5436-43-1	50
2,6-Dimethylnaphthalene	Diesel, kerosene	581-42-0	50
2-Methylnaphthalene	Gasoline, diesel fuel, crude oil	91-57-6	50
3-*beta*-Coprostanol	Carnivore fecal indicator	360-68-9	500
3-Methyl-1(H)-indole (Skatole)	Fragrance, odor in feces and coal tar	83-34-1	50
3-*tert*-Butyl-4-hydroxy anisole (BHA)	Antioxidant, general preservative	121-00-6	150
4-Cumylphenol	Nonionic detergent metabolite	599-64-4	50
4-n-Octylphenol	Nonionic detergent metabolite	1806-26-4	50
4-Nonylphenol diethoxylate (NP2EO)	Nonionic detergent metabolite	--	1,000
4-Nonylphenol monoethoxylate (NP1EO)	Nonionic detergent metabolite	104-35-8	500
4-*tert*-Octylphenol	Nonionic detergent metabolite	140-66-9	50
4-*tert*-Octylphenol diethoxylate (OP2EO)	Nonionic detergent metabolite	2315-61-9	50
4-*tert*-Octylphenol monoethoxylate (OP1EO)	Nonionic detergent metabolite	2315-67-5	250
Acetophenone	Fragrance in detergent and tobacco, flavor in beverages	98-86-2	150
Acetyl hexamethyl tetrahydronaphthalene (AHTN)	Common musk fragrance	21145-77-7	50
Anthracene	PAH, wood preservative, tar, diesel, crude oil, combustion product	120-12-7	50
Anthraquinone	Manufacture dye, seed treatment, bird repellent	84-65-1	50
Atrazine	Herbicide	1912-24-9	100
Benzo[a]pyrene	PAH, combustion product	50-32-8	50
Benzophenone	Fixative in perfumes and soaps	119-61-9	50
beta-Sitosterol	Plant sterol	83-46-5	500
beta-Stigmastanol	Plant sterol	19466-47-8	500
bis(2-Ethylhexyl) phthalate	Plasticizer, pesticides	117-81-7	250
Bisphenol A	Polycarbonate resins, antioxidant, flame retardant	80-05-7	50
Bromacil	General use herbicide	314-40-9	500
Camphor	Flavor, odorant, ointments	76-22-2	50
Carbazole	Insecticide, dyes, explosives, lubricants	86-74-8	50
Chlorpyrifos	Insecticide, pest and termite control	2921-88-2	50
Cholesterol	Fecal indicator	57-88-5	250
d-Limonene	Fungicide, antimicrobial, antiviral, fragrance	5989-27-5	50
Diazinon	Insecticide	333-41-5	50
Diethyl phthalate	Plasticizer	84-66-2	100
Fluoranthene	PAH, combustion product, coal tar	206-44-0	50
Hexahydrohexamethylcyclopentabenzopyran (HHCB)	Musk fragrance	1222-05-5	50
Indole	Inert pesticide ingredient, coffee fragrance	120-72-9	100
Isoborneol	Perfume and disinfectant fragrance	124-76-5	50
Isophorone	Solvent for lacquer, plastic, oil, silicon, resins	78-59-1	50
Isopropylbenzene	Manufacture phenol/acetone, fuels, paint thinner	98-82-8	100

Appendix 1. Organic compounds analyzed in streambed sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010. (All compounds are reported in micrograms per liter.)—Continued

[µg/L, micrograms per liter; CAS, Chemical Abstracts Service; PAH, polycyclic aromatic hydrocarbon; --, not available]

Compound name	General uses or sources (from Burkhardt and others, 2006; Hladik and others, 2009)	CAS[1] number	Laboratory reporting level (µg/L)
Isoquinoline	Flavors and fragrances	119-65-3	100
Menthol	Cigarettes, cough drops, liniment, mouthwash	89-78-1	50
Metolachlor	Herbicide, general use pesticide	51218-45-2	50
N,N-diethyl-*meta*-toluamide (DEET)	Insecticide,mosquito repellent	134-62-3	100
Naphthalene	PAH, gasoline, moth repellent	91-20-3	50
p-Cresol	Wood preservative	106-44-5	250
Phenanthrene	PAH, crude oil, tar, diesel fuel, explosives	85-01-8	50
Phenol	Disinfectant, manufacture byproduct	108-95-2	50
Prometon	Herbicide, blacktop application	1610-18-0	50
Pyrene	PAH, coal tar, asphalt, combustion product	129-00-0	50
Tributyl phosphate	Antifoaming agent, flame retardant	126-73-8	50
Triclosan	Disinfectant, antimicrobial	3380-34-5	50
Triphenyl phosphate	Plasticizer, resin, wax, finish, roofing paper, flame retardant	115-86-6	50
Tris(2-butoxyethyl)phosphate	Flame retardant	78-51-3	150
Tris(2-chloroethyl)phosphate	Plasticizer, flame retardant	115-96-8	100
Tris(dichlorisopropyl)phosphate	Flame retardant	13674-87-8	100
Allethrin	Pyrethroid pesticide	584-79-2	0.2
Bifenthrin	Pyrethroid pesticide	82657-04-3	0.2
Cyfluthrin	Pyrethroid pesticide	68359-37-5	0.5
Lambda-Cyhalothrin	Pyrethroid pesticide	91465-08-6	0.2
Cypermethrin	Pyrethroid pesticide	52315-07-8	0.4
Deltamethrin	Pyrethroid pesticide	52918-63-5	0.2
Esfevalerate	Pyrethroid pesticide	66230-04-4	0.2
Fenpropathrin	Pyrethroid pesticide	39515-41-8	0.2
Methoprene	Pyrethroid pesticide	40596-69-8	2.4
Permethrin	Pyrethroid pesticide	52645-53-1	0.2
Phenothrin (Sumithrin)	Pyrethroid pesticide	26002-80-2	0.3
Piperonyl Butoxide	Pyrethroid pesticide	51-03-6	1.6
Resmethrin	Pyrethroid pesticide	10453-86-8	0.5
Tau-Fluvalinate	Pyrethroid pesticide	102851-06-9	0.2
Tefluthrin	Pyrethroid pesticide	13494-80-9	0.2
Tetramethrin	Pyrethroid pesticide	7696-12-0	0.2

[1]This report contains CAS Registry Numbers™, which is a Registered Trademark of the American Chemical Society. CAS recommends the verification of the CASRNs through CAS Client Services℠.

Appendix 2. Summary of variables used to assess stream habitat conditions at biological monitoring sites in Johnson County, Kansas.

[ft/mi, feet per mile; m/km, meters per kilometer; m, meter; mm, millimeter. Each variable was ranked on a scale of 1 (poorest) to 12 (most optimal) on the basis of direct measurements, visual estimation, or examination of specific physical features. The complete field form is available in Rasmussen and others, 2009.]

Variable (and spatial scale)	Description
	Category 1. Channel conditions and characteristics
A. Flow status (reach)	Indicates extent of streambanks and substrate materials exposed during base-flow conditions. Considered optimal when water reaches base of both lower banks and minimal amount of channel substrate is exposed, and poorest when very little water is present in channel and if water present exists mostly as standing pools.
B. Channel slope and morphological status (reach)	Indicates the degree of incision, downcutting, or headcutting that has occurred in the channel. Considered optimal when bank elevations are near the elevation of the active flood plain, the channel cross-section is V- or U-shaped, there is little evidence of lateral or downcutting, the mean bank slope is less than 15 percent, and the mean difference between right and left bank slopes is greater than 5 percent. Poor conditions exist when banks are much higher than the elevation of the active flood plain, the channel is trapezoid-shaped, mean bank slope is greater than 35 percent, and the mean difference between right and left bank slopes is less than 2 percent.
C. Sinuosity (segment)	Describes the meandering of the stream. Conditions for sinousity are optimal when the bends in the stream increase the stream length three to four times compared to a straight line and poorest if the channel is straight as a result of channelization.
D. Pool status (reach)	Indicates pool abundance and mix of deep and shallow pools that are present. Conditions are considered optimal if both deep and shallow pools exist in the reach and more than 30 percent of the pool bottoms are obscured because of depth or turbulence. Poor conditions exist if there are no pools and the entire streambed is visible.
E. Riffle frequency (segment)	Indicates the number of riffles in a segment. Conditions are optimal when elevation declines at least 26 ft/mi (5 m/km) and at least four riffles occur within the segment, and poor if the elevation decreases at less than about 5 ft/mi (1 m/km) and only one shallow riffle occurs.
	Category 2. Bank and riparian conditions
A. Bank stability (reach)	A measure of the left and right bank erosion and potential erosion during periods of increased streamflow. Considered optimal when banks appear stable throughout the reach, less than 5 percent of the banks show evidence of erosion, and more than one-third of the erodible banks on the outside bends are protected by roots or vegetation. Conditions are poor when 60 to 100 percent of the banks have erosional scars.
B. Canopy cover (reach)	Indicates the percentage of the reach that is shaded by overhanging vegetation and other features in the stream channel. Canopy cover is considered optimal when 50–80 percent is shaded and poorest when less than 10 percent or greater than 90 percent is shaded.
C. Bank/ riparian protection (reach)	Indicates how well the streambank and near-stream portion of the riparian zone resist erosion, take up nutrients, and control in-stream scouring. Bank/riparian protection is optimal when more than 90 percent of the streambank surfaces and nearby riparian zones are covered by vegetation and poorest when less than 50 percent of the streambank surfaces are covered by native vegetation.
D. Length and extent of buffers (segment/reach)	Provides an estimate of both the extent of buffers (land covered with natural vegetation such as forests, shrubs, or grasses) and the number of gaps in the longitudinal continuity. Conditions are considered optimal when the mean longitudinal length of buffers that are at least 20 ft (6 m) wide within the segment extends along at least 90 percent of both banks. Conditions are poor when the mean longitudinal length of buffers encompasses less than 70 percent along both banks.
E. Average natural buffer width (reach)	A wider natural buffer allows runoff more time to percolate into soils or be filtered by vegetation before entering the stream. Wider, more vegetated, and less-disturbed riparian zones also produce more organic matter that provides a constant supply of energy to the stream. Conditions are considered optimal when the mean buffer width is larger than 60 ft on both banks and poorest when the mean buffer width is less than 20 ft.
F. Percent altered banks (reach)	Indicates large-scale changes in the shape of the stream channel. Conditions are optimal when no alteration activities are occuring in the reach and past human activities affect less than 10 percent of the total bank and buffer area. Conditions are poor when multiple activities or features are present or more than 70 percent of the bank and buffer area are affected by human activities.

Appendix 2. Summary of variables used to assess stream habitat conditions at biological monitoring sites in Johnson County, Kansas.—Continued

[ft/mi, feet per mile; m/km, meters per kilometer; m, meter; mm, millimeter. Each variable was ranked on a scale of 1 (poorest) to 12 (most optimal) on the basis of direct measurements, visual estimation, or examination of specific physical features. The complete field form is available in Rasmussen and others, 2009.]

Variable (and spatial scale)	Description
	Category 3. Aquatic habitat availablity
A. Substrate fouling (reach)	Estimated amount of periphyton growth and accumulation of fine materials that cover the substrate materials in riffles. Considered optimal when substrate fouling level is 10 percent or less with visible periphyton growth at normal levels and poorest when substrate fouling level is at least 60 percent with visible periphyton growth covering most of the substrate.
B. Velocity/depth combinations (reach)	Visual estimation of the presence of four patterns of velocity and depth—slow-shallow, slow-deep, fast-shallow, and fast-deep. Optimal conditions exist when all four combinations are present, and poor conditions exist when only one is present.
C. Riffle substrate embeddedness (reach)	Indicates the percentage of rock and snag substrates in riffles that are surrounded by or sunken into finer material. Conditions are optimal when mean cobble depth in fine materials is less than 20 percent of total fine-material depth and poor when cobble depth is more that 75 percent of total depth.
D. Sediment deposition (reach)	Estimated amount of sediment that has accumulated in pools and other changes that have occurred to the stream bottom as a result of deposition. Conditions are considered optimal when less than 20 percent of the stream bottom is affected by deposition and little or no island or point-bar deposition is visible. Conditions are poor when thick sediment depositions are visible, more than 80 percent of the stream bottom is affected, and fresh deposits occur along major portions of the overbank areas.
E. Diversity of epifaunal substrate and cover types (reach)	Indicates the number and variety of stream habitat and cover types. Optimal conditions exist when at least seven habitat/cover types are present and at least 70 percent are stable and available for aquatic colonization. Poor conditions exist when one or none of the cover types are present and less that 20 percent are stable or available for colonization.
F. Riffle substrate composition (reach)	Indicates the percentage of cobble, gravel, and finer materials in riffles. Conditions are optimal when the larger substrate classes (cobble and boulder) make up more than 50 percent of the bottom surface and less than 10 percent of the bottom consists of finer substrate sizes (less than 2 mm). Conditions are poor when there is less than 5 percent cobble, and sand and silt make up more than 50 percent of substrate.

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Specific conductance, water, unfiltered, laboratory, microsiemens per centimeter at 25 degrees Celsius (1)	pH, water, unfiltered, laboratory, standard units (0.1)	Temperature, water, degrees Celsius (0.1)	Dissolved oxygen, water, unfiltered, mg/L (0.1)	Turbidity, water, unfiltered, monochrome near infra-red LED light, 780-900 nm, detection angle 90 +/ -2.5 degrees, YSI 6136, formazin nephelometric units (FNU)(0.1)	Chlorophyll, total, water, fluorometric, 650-700 nanometers, in situ sensor, µg/L (0.1)	Residue (dissolved) solids, water, filtered, sum of constituents, mg/L (10)	Suspended solids, water, unfiltered, mg/L (15)	Biochemical oxygen demand, water, unfiltered, 5 days at 20 degrees Celsius, mg/L (2)	Chemical oxygen demand, high level, water, unfiltered, mg/L (10)
BI1	Big Bull Creek near Edgerton	6914950	11/4/2002	1235	806	8.3	6.5	13.0	12	24	500	17	--	--
BI1	Big Bull Creek near Edgerton	6914950	7/14/2003	1000	715	8.0	27.1	3.9	4.6	--	445	6	--	--
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	805	643	7.9	13.2	10.1	29	12	383	39	--	--
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1000	466	7.9	14.3	7.0	61	13	289	72	<20	28
BL3	Blue River near Stanley (Highway 69)	6893080	7/18/2003	830	532	7.9	26.7	1.4	2.9	--	332	3	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1410	587	7.7	15.1	13.9	9.4	3.9	341	15	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1345	571	8.0	15.1	9.8	12	4.1	332	18	<3	<10
BL4	Camp Branch at 175th Street	384840094381100	7/18/2003	755	502	7.7	24.7	3.9	15	--	321	18	--	--
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1245	625	7.7	13.9	13.5	6.4	2.7	365	19	--	--
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1510	549	8.2	15.0	14.5	4.3	3.3	343	5	2	<10
BL5	Blue River at Kenneth Road	6893100	7/18/2003	815	541	7.9	27.3	3.1	33	--	343	27	--	--
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1100	644	7.6	13.1	11.7	20	6.5	381	26	--	--
BL5	Blue River at Kenneth Road	6893100	4/5/2010	1150	615	8.0	14.3	9.8	22	6.2	354	26	<4	<10
BR2	Brush Creek at Belinder Street	390127094365800	11/7/2002	1100	396	7.5	7.1	8.6	18	1.8	238	9	--	--
BR2	Brush Creek at Belinder Street	390127094365800	7/15/2003	935	476	7.9	27.9	7.3	4.5	--	282	6	--	--
BR2	Brush Creek at Belinder Street	390127094365800	4/6/2010	1105	985	7.9	16.8	8.7	11	2.0	595	10	5	<10
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	905	446	7.9	12.7	10.0	25	8.1	282	29	--	--
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	810	316	7.7	10.6	9.5	140	9.3	246	142	20	39
CE1	Cedar Creek at Old Highway 56	6892440	11/4/2002	900	1,460	8.0	4.5	9.5	89	2.9	1,070	4	--	--
CE1	Cedar Creek at Old Highway 56	6892440	7/14/2003	1100	1,180	8.0	26.1	5.3	29	--	841	26	--	--
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	910	820	7.6	12.3	8.3	26	5.1	506	17	--	--
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	825	1,210	E8.0	10.6	9.2	22	2.5	805	24	--	17
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	11/4/2002	1235	729	8.3	7.3	13.2	5.0	1.8	460	3	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	7/14/2003	800	542	7.9	28.7	5.4	18	--	27	27	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1045	779	7.9	13.3	11.7	10	7.8	454	15	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1120	700	E8.0	12.5	9.9	17	2.3	449	24	E2	<10
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1415	1,190	8.1	13.6	17.5	3.1	3.9	661	7	--	--
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1200	1,130	7.8	18.5	6.6	10	4.7	650	12	4	11
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1320	1,140	8.0	15.0	12.5	25	2.3	654	5	--	--
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1400	1,060	7.8	18.8	9.4	3.2	4.4	635	5	3	13
IN6	Indian Creek at State Line Road	6893390	7/17/2003	1150	949	7.5	27.2	5.9	5.1	--	589	10	--	--
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1020	1,230	7.7	11.8	10.0	4.6	3.8	719	8	--	--
IN6	Indian Creek at State Line Road	6893390	4/6/2010	945	936	7.8	16.9	8.0	18	--	543	24	7	20

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Specific conductance, water, unfiltered, laboratory, microsiemens per centimeter at 25 degrees Celsius (1)	pH, water, unfiltered, laboratory, standard units (0.1)	Temperature, water, degrees Celsius (0.1)	Dissolved oxygen, water, unfiltered, mg/L (0.1)	Turbidity, water, unfiltered, monochrome near infra-red LED light, 780-900 nm, detection angle 90 +/- 2.5 degrees, YSI 6136, formazin nephelometric units (FNU)(0.1)	Chlorophyll, total, water, fluorometric, 650-700 nanometers, in situ sensor, µg/L (0.1)	Residue (dissolved) solids, water, filtered, sum of constituents, mg/L (10)	Suspended solids, water, unfiltered, mg/L (15)	Biochemical oxygen demand, water, unfiltered, 5 days at 20 degrees Celsius, mg/L (2)	Chemical oxygen demand, high level, water, unfiltered, mg/L (10)
KI5b alt	Kill Creek at 135th Street	385303094582300	7/15/2003	1235	649	8.3	28.2	8.4	0.2	--	387	4	--	--
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1405	620	8.0	13.2	11.0	6.6	5.3	349	6	--	--
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	945	551	7.9	10.6	9.9	14	3.3	331	13	3	<10
KI6b	Kill Creek at 95th Street	6892360	7/15/2003	1045	509	8.0	28.8	4.7	12	--	312	15	--	--
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1230	612	8.1	13.5	10.4	14	5.9	366	18	--	--
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1145	533	7.7	11.8	9.4	35	5.0	340	38	10	17
LI1	Little Bull Creek near 215th Street	384419094515600	11/4/2002	1435	851	7.9	5.6	7.5	17	3.8	522	7	--	--
LI1	Little Bull Creek near 215th Street	384419094515600	7/14/2003	1140	586	7.7	25.8	3.2	53	--	349	159	--	--
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1215	641	7.9	13.5	8.1	28	6.8	361	55	<15	<10
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	830	1,550	7.8	11.3	8.4	1.4	3.7	918	3	--	--
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1235	1,080	8.1	13.4	11.1	2.6	1.1	667	4	<2	<10
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	750	1,680	7.8	10.8	10.3	3.2	4.9	1,000	13	--	--
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	940	1,370	7.6	11.2	10.3	2.5	4.7	821	10	--	--
MI1	Mill Creek at 127th Street	385356094491200	11/5/2002	820	462	7.6	7.2	9.6	47	6.7	273	19	--	--
MI1	Mill Creek at 127th Street	385356094491200	7/16/2003	1200	695	7.8	24.4	7.2	0.90	--	431	4	--	--
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1150	970	8.1	13.7	14.6	3.3	9.5	604	6	--	--
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1045	965	7.8	11.6	11.8	13	9.6	556	14	4	17
MI4	Mill Creek at 87th Street Lane	385800094485300	11/5/2002	1115	917	8.1	7.7	11.8	8.3	4.0	571	5	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	7/16/2003	1155	540	8.4	27.8	11.2	1.7	--	644	4	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1240	1,210	8.5	15.4	14.8	2.5	4.9	738	6	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1205	994	7.9	11.7	10.7	7.3	5.2	595	8	3	<10
MI7	Mill Creek at Johnson Drive	6892513	11/5/2002	1325	699	8.0	6.7	11.1	0.13	--	427	7	--	--
MI7	Mill Creek at Johnson Drive	6892513	7/16/2003	900	445	8.1	27.6	6.5	17	--	263	28	--	--
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1030	1,120	8.2	12.3	11.6	8.2	2.6	674	13	--	--
MI7	Mill Creek at Johnson Drive	6892513	4/8/2010	1310	797	8.0	12.3	10.5	25	3.5	497	33	7	<10
TO2	Tomahawk Creek near 11th Street	385539094372100	11/6/2002	1120	729	8.1	7.2	9.5	12	2.9	460	6	--	--
TO2	Tomahawk Creek near 11th Street	385539094372100	7/17/2003	925	663	7.8	27.1	5.8	3.1	--	439	5	--	--
TO2	Tomahawk Creek near 11th Street	385539094372100	3/12/2007	1200	1,230	8.1	11.4	13.5	5.0	3.2	724	8	--	--
TO2	Tomahawk Creek near 11th Street	385539094372100	4/6/2010	1415	1,040	7.9	19.2	9.5	8.9	6.4	600	10	4	11
TU1	Turkey Creek at 67th Street	390027094415600	11/7/2002	1105	570	8.1	8.5	14.9	0.38	--	338	5	--	--
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	900	1,570	7.8	8.9	12.0	3.3	4.6	887	6	--	--
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	940	1,240	7.9	10.0	11.0	6.8	1.8	786	9	<2	<10
Minimum value					316	7.5	4.5	1.4	0.1	1.1	27	3	<2	<10
Maximum value					1,680	8.5	28.8	17.5	140.0	24.0	1,070	159	20	39

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Organic carbon, water, filtered, mg/L (0.23)	Organic carbon, water, unfiltered, mg/L (0.5)	Acid neutralizing capacity, water, unfiltered, mg/L as calcium carbonate (4)	Calcium, water, filtered, mg/L (0.1)	Chloride, water, filtered, mg/L (10)	Fluoride, water, filtered, mg/L (0.04)	Iron, water, filtered, µg/L (20)	Magnesium, water, filtered, mg/L (0.1)	Manganese, water, filtered, µg/L (10)	Potassium, water, filtered, mg/L (0.5)
BI1	Big Bull Creek near Edgerton	6914950	11/4/2002	1235	--	--	140	60.1	90	0.5	<10	11.8	20	12
BI1	Big Bull Creek near Edgerton	6914950	7/14/2003	1000	--	--	190	62.7	60	0.7	<10	9.7	1,300	9.0
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	805	--	--	185	79.5	53	0.3	<20	11.4	240	5.1
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1000	8.9	13	152	56.8	29	0.2	110	8.5	220	3.8
BL3	Blue River near Stanley (Highway 69)	6893080	7/18/2003	830	--	--	160	58.1	40	0.4	30	14.2	20	13
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1410	--	--	190	82.2	44	0.2	30	9.4	90	2.9
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1345	4.2	4.4	195	74.2	45	0.2	50	8.6	110	2.4
BL4	Camp Branch at 175th Street	384840094381100	7/18/2003	755	--	--	50	30.3	30	0.6	<20	10.1	70	5.0
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1245	--	--	210	96.3	43	0.2	30	8.1	100	2.1
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1510	3	2.8	214	87.5	36	0.2	40	7.0	50	1.8
BL5	Blue River at Kenneth Road	6893100	7/18/2003	815	--	--	160	60.0	50	0.4	<20	9.7	200	3
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1100	--	--	200	88.9	55	0.2	20	9.2	100	2.6
BL5	Blue River at Kenneth Road	6893100	4/5/2010	1150	3.8	5.0	204	78.1	50	0.2	30	8.2	130	2.4
BR2	Brush Creek at Belinder Street	390127094365800	11/7/2002	1100	--	--	100	41.3	30	0.2	60	5.8	110	3.5
BR2	Brush Creek at Belinder Street	390127094365800	7/15/2003	935	--	--	130	46.3	50	0.3	20	6.1	110	4.0
BR2	Brush Creek at Belinder Street	390127094365800	4/6/2010	1105	4.4	5.2	206	88.3	145	0.3	--	12.4	--	3.6
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	905	--	--	120	61.9	12	0.2	40	10	100	4.3
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	810	8.8	13	130	43.0	6	0.2	210	7.2	170	2.8
CE1	Cedar Creek at Old Highway 56	6892440	11/4/2002	900	--	--	160	101	50	0.7	20	33.3	50	6.1
CE1	Cedar Creek at Old Highway 56	6892440	7/14/2003	1100	--	--	120	99.1	50	0.6	<20	23.9	110	6.0
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	910	--	--	145	80.9	75	0.2	<20	16.2	90	4.3
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	825	5.6	7.3	182	109	94	0.3	<20	28.3	90	4.4
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	11/4/2002	1235	--	--	180	70.9	60	0.4	<10	12.8	<10	6.5
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	7/14/2003	800	--	--	130	50.0	50	0.4	<20	7.2	20	6.0
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1045	--	--	190	95.4	77	0.3	49	11.4	40	4.5
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1120	3.4	3.8	222	93.1	54	0.2	<20	10.8	--	3.0
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1415	--	--	190	110	205	0.2	<20	16.2	140	2.9
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1200	5.6	6.0	164	91.3	191	0.2	40	11.3	220	2.6
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1320	--	--	175	100	177	0.4	<20	15	90	6.9
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1400	5.7	6.2	180	84.2	164	0.4	43	13.8	110	8.6
IN6	Indian Creek at State Line Road	6893390	7/17/2003	1150	--	--	120	56.2	110	0.6	30	13.4	40	13
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1020	--	--	180	107	196	0.4	27	16.2	140	7.6
IN6	Indian Creek at State Line Road	6893390	4/6/2010	945	6.4	7.6	146	67.6	155	0.2	60	10	110	4.8

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Organic carbon, water, filtered, mg/L (0.23)	Organic carbon, water, unfiltered, mg/L (0.5)	Acid neutralizing capacity, water, laboratory, mg/L as calcium carbonate (4)	Calcium, water, filtered, mg/L (0.1)	Chloride, water, filtered, mg/L (10)	Fluoride, water, filtered, mg/L (0.04)	Iron, water, filtered, µg/L (20)	Magnesium, water, filtered, mg/L (0.1)	Manganese, water, filtered, µg/L (10)	Potassium, water, filtered, mg/L (0.5)
KI5b alt	Kill Creek at 135th Street	385303094582300	7/15/2003	1235	--	--	180	63.4	60	0.6	<20	8.8	40	8.0
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1405	--	--	170	78.9	52	0.3	36	9.5	20	3.9
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	945	4.2	5.5	208	77.4	33	0.2	40	8.8	80	2.7
KI6b	Kill Creek at 95th Street	6892360	7/15/2003	1045	--	--	180	61.0	30	0.4	<20	9.6	220	4.0
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1230	--	--	185	84.6	37	0.3	36	10.2	60	4.0
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1145	5.5	6.6	195	75.7	22	0.2	55	9.3	60	2.7
LI1	Little Bull Creek near 215th Street	384419094515600	11/4/2002	1435	--	--	150	43.3	130	0.3	70	9.2	60	11.8
LI1	Little Bull Creek near 215th Street	384419094515600	7/14/2003	1140	--	--	140	40.6	70	0.4	<20	5.8	310	8.0
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1215	3	6.1	215	74.3	52	0.2	40	8.4	390	3.2
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	830	--	--	240	135	311	0.2	<20	17.5	20	2.8
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1235	2.9	3.1	245	115	147	0.2	<20	14.4	30	2.2
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	750	--	--	165	151	347	0.2	<20	18.6	10	3.1
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	940	--	--	190	126	253	0.2	<20	16	40	2.8
MI1	Mill Creek at 127th Street	385356094491200	11/5/2002	820	--	--	90	36.7	50	0.3	30	7.3	<10	4.2
MI1	Mill Creek at 127th Street	385356094491200	7/16/2003	1200	--	--	150	59.2	90	0.5	<20	9.9	40	4.0
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1150	--	--	175	91.2	143	0.4	<20	14.8	60	4.0
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1045	5.6	7.0	161	73.6	157	0.2	23	11	70	3.7
MI4	Mill Creek at 87th Street Lane	385800094485300	11/5/2002	1115	--	--	160	71.9	110	0.4	10	16.8	40	6.5
MI4	Mill Creek at 87th Street Lane	385800094485300	7/16/2003	1155	--	--	160	74.5	140	0.5	<20	12.5	10	8.0
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1240	--	--	190	115	178	0.4	31	20.6	50	5.6
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1205	3.9	4.4	220	101	128	0.2	<20	15.3	60	3.2
MI7	Mill Creek at Johnson Drive	6892513	11/5/2002	1325	--	--	160	68.5	80	0.3	10	11.5	40	4.0
MI7	Mill Creek at Johnson Drive	6892513	7/16/2003	900	--	--	120	44.3	40	0.3	<20	6.2	40	4.0
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1030	--	--	200	118	158	0.3	27	17.4	90	4.2
MI7	Mill Creek at Johnson Drive	6892513	4/8/2010	1310	3.8	4.9	210	93.5	82	0.2	24	11.9	70	2.9
TO2	Tomahawk Creek near 11th Street	385539094372100	11/6/2002	1120	--	--	200	82.1	46	0.3	40	15.3	50	3.2
TO2	Tomahawk Creek near 11th Street	385539094372100	7/17/2003	925	--	--	160	63.8	60	0.4	<20	13	40	3.0
TO2	Tomahawk Creek near 11th Street	385539094372100	3/12/2007	1200	--	--	200	113	204	0.2	<20	17.6	130	2.8
TO2	Tomahawk Creek near 11th Street	385539094372100	4/6/2010	1415	5.4	6.0	161	77.0	179	0.2	27	10.9	160	2.3
TU1	Turkey Creek at 67th Street	390027094415600	11/7/2002	1105	--	--	120	58.1	70	0.2	50	8.0	120	2.5
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	900	--	--	200	134	330	0.2	<20	16.2	240	3.9
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	940	3.4	3.5	240	128	194	0.2	<20	15.4	220	3.0
Minimum value					2.9	2.8	50	30	6	0.2	10	5.8	10	1.8
Maximum value					9	13	245	151	347	0.7	210	33	1,300	13.0

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

[USGS, U.S. Geological Survery; ( ), laboratory reporting level; mg/L, milligrams per liter; µg/L, micrograms per liter; mL, milliliters; E, estimated; <, less than; --, not determined; nm, nanometers; LED, light-emitting diode; YSI, Yellow Springs Instrument, Yellow Springs, Ohio; FNU, Formazine Nephelometric Unit]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Silica, water, filtered, mg/L (0.2)	Sodium, water, filtered, mg/L (0.1)	Sulfate, water, filtered, mg/L (0.18)	Zinc, water, filtered, µg/L (2)	Zinc, water, unfiltered, recoverable, µg/L (2)	Ammonia plus organic nitrogen, water, filtered, mg/L as nitrogen (0.2)	Ammonia plus organic nitrogen, water, unfiltered, mg/L as nitrogen (0.2)	Ammonia, water, filtered, mg/L as nitrogen (0.02)	Nitrate plus nitrite, water, filtered, mg/L as nitrogen (0.02)	Nitrite, water, filtered, mg/L as nitrogen(0.02)
BI1	Big Bull Creek near Edgerton	6914950	11/4/2002	1235	3.6	73.0	117	--	--	0.4	0.9	<.02	<.1	<.02
BI1	Big Bull Creek near Edgerton	6914950	7/14/2003	1000	9.1	60.0	68.0	--	--	1.0	1.4	0.4	0.09	0.02
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	805	6.5	32.8	56.0	8.3	4.7	0.7	1.1	0.11	1.52	0.03
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1000	8.0	21.9	32.0	E4.5	8.0	0.9	2	0.2	0.52	0.04
BL3	Blue River near Stanley (Highway 69)	6893080	7/18/2003	830	8.1	78.3	43.0	--	--	0.4	0.5	0.1	0.07	<.02
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1410	3.1	23.2	38.0	5.4	2.2	0.4	0.6	0.04	0.32	<.02
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1345	1.6	25.5	28.0	5.7	5.2	<.2	0.4	<.02	0.09	<.02
BL4	Camp Branch at 175th Street	384840094381100	7/18/2003	755	9.6	39.7	133	--	--	0.4	0.4	0.11	2.95	0.07
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1245	1.5	24.1	44.0	1.9	2.5	0.4	0.5	0.08	0.07	<.02
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1510	3.4	20.8	30.0	E3.9	<4	<.2	0.3	<.02	0.18	<.02
BL5	Blue River at Kenneth Road	6893100	7/18/2003	815	9.3	25.2	46.0	--	--	0.5	0.5	0.09	0.09	<.02
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1100	3.6	27.9	41.0	8.0	2.8	0.5	0.6	0.03	0.38	<.02
BL5	Blue River at Kenneth Road	6893100	4/5/2010	1150	3.8	27.6	30.0	5.1	E3.1	0.3	0.9	<.02	0.02	0.02
BR2	Brush Creek at Belinder Street	390127094365800	11/7/2002	1100	3.6	24.0	43.2	--	--	0.3	0.4	0.02	0.4	0.02
BR2	Brush Creek at Belinder Street	390127094365800	7/15/2003	935	5.0	30.3	32.0	--	--	0.3	0.4	0.05	<.05	<.02
BR2	Brush Creek at Belinder Street	390127094365800	4/6/2010	1105	11.8	75.9	76.0	9.9	9.0	0.5	1.1	0.1	1.75	0.09
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	905	8.6	16.9	49.0	2.8	3.2	0.5	0.8	0.09	0.32	<.02
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	810	12.0	9.8	24.0	E2.5	16	1.5	2.9	0.1	0.34	0.02
CE1	Cedar Creek at Old Highway 56	6892440	11/4/2002	900	3.9	150	414	--	--	0.4	0.4	<.02	1	<.02
CE1	Cedar Creek at Old Highway 56	6892440	7/14/2003	1100	4.5	102	402	--	--	0.5	0.5	0.2	1.06	0.06
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	910	5.0	58.0	146	4.8	6.6	0.7	0.7	0.07	0.63	0.03
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	825	5.4	100	307	E4.2	6.4	0.6	1.1	<.02	E.45	<.02
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	11/4/2002	1235	7.5	53.7	98.4	--	--	0.4	0.4	<.02	2.6	<.02
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	7/14/2003	800	5.4	42.3	64.0	--	--	0.4	0.6	0.07	0.85	0.02
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1045	2.7	48.6	77.0	5.4	7.3	0.7	0.7	0.03	1.85	0.03
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1120	7.1	38.3	56.0	E3.1	E3.3	0.3	0.6	<.02	E.79	<.02
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1415	4.1	106	86.0	5.3	5.4	0.7	0.7	0.09	1.44	0.03
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1200	3.8	98.6	61.0	15	15	1.0	0.9	0.1	0.71	0.06
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1320	7.9	103	95.0	26	25	1.3	1.4	0.15	5.8	0.08
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1400	9.8	84.3	84.0	21	20	1.1	1.4	0.07	2.9	0.1
IN6	Indian Creek at State Line Road	6893390	7/17/2003	1150	9.8	90.3	125	--	--	1.3	1.8	0.5	10.7	0.26
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1020	8.3	113	107	22	22	2.2	2.4	0.66	5.18	0.15
IN6	Indian Creek at State Line Road	6893390	4/6/2010	945	6.4	86.0	62.0	15	22	0.8	1.8	0.19	2.05	0.14

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Silica, water, filtered, mg/L (0.2)	Sodium, water, filtered, mg/L (0.1)	Sulfate, water, filtered, mg/L (0.18)	Zinc, water, filtered, µg/L (2)	Zinc, water, unfiltered, recoverable, µg/L (2)	Ammonia plus organic nitrogen, water, filtered, mg/L as nitrogen (0.2)	Ammonia plus organic nitrogen, water, unfiltered, mg/L as nitrogen (0.2)	Ammonia, water, filtered, mg/L as nitrogen (0.02)	Nitrate plus nitrite, water, filtered, mg/L as nitrogen (0.02)	Nitrite, water, filtered, mg/L as nitrogen(0.02)
KI5b alt	Kill Creek at 135th Street	385303094582300	7/15/2003	1235	6.7	45.0	60.0	--	--	0.3	0.5	0.05	0.24	<.02
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1405	1.6	34.5	55.0	9.4	6.7	0.4	0.7	0.03	0.62	0.02
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	945	5.7	27.1	34.0	7.7	9.5	0.5	0.7	<.02	0.42	<.02
KI6b	Kill Creek at 95th Street	6892360	7/15/2003	1045	9.8	23.1	47.0	--	--	0.3	0.6	0.02	<.05	<.02
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1230	1.4	29.0	64.0	3.7	4.5	0.3	0.5	<.02	0.03	<.02
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1145	8.8	19.2	46.0	E3.5	6.0	0.6	0.6	<.02	0.41	<.02
LI1	Little Bull Creek near 215th Street	384419094515600	11/4/2002	1435	7.0	104	70.0	--	--	0.6	0.9	<.02	1.1	0.02
LI1	Little Bull Creek near 215th Street	384419094515600	7/14/2003	1140	7.2	56.0	38.0	--	--	0.6	1.1	0.1	0.56	0.03
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1215	3.0	34.2	32.0	6.8	6.1	0.6	0.8	<.02	0.02	0.02
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	830	3.6	152	101	4.4	5.3	0.7	0.7	0.19	1.72	0.04
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1235	8.6	86.3	77.0	9.5	8.1	0.3	0.2	<.02	1.95	<.02
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	750	5.07	166	98.7	4.7	7.6	0.6	0.6	<.02	1.26	0.02
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	940	3.48	133	99.5	7.7	6.5	0.7	0.6	<.02	1.95	0.03
MI1	Mill Creek at 127th Street	385356094491200	11/5/2002	820	3.0	34.4	45.7	--	--	0.4	0.5	0.11	0.4	0.03
MI1	Mill Creek at 127th Street	385356094491200	7/16/2003	1200	6.0	56.8	65.0	--	--	0.3	0.5	0.06	0.23	<.02
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1150	3.3	88.3	96.0	5.6	6.6	0.8	0.9	0.13	0.39	<.02
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1045	3.9	101	56.0	6.7	10	1.1	1.2	0.04	0.5	<.02
MI4	Mill Creek at 87th Street Lane	385800094485300	11/5/2002	1115	6.9	73.1	117	--	--	0.4	0.5	<.02	4.8	0.02
MI4	Mill Creek at 87th Street Lane	385800094485300	7/16/2003	1155	6.3	93.6	112	--	--	0.4	0.5	0.04	6.49	0.05
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1240	5.9	104	142	15	10	1.2	1.0	0.09	4.46	0.12
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1205	7.5	75.9	88.0	5.5	4.6	0.6	0.7	<.02	1.43	<.02
MI7	Mill Creek at Johnson Drive	6892513	11/5/2002	1325	6.8	46.8	74.1	--	--	0.2	0.4	<.02	1.9	<.02
MI7	Mill Creek at Johnson Drive	6892513	7/16/2003	900	4.4	27.6	40.0	--	--	0.3	0.4	0.03	0.28	<.02
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1030	5.1	88.0	111	7.2	5.9	0.7	0.6	0.05	1.78	0.04
MI7	Mill Creek at Johnson Drive	6892513	4/8/2010	1310	8.6	52.5	57.0	5.2	6.0	0.3	0.6	<.02	0.94	<.02
TO2	Tomahawk Creek near 11th Street	385539094372100	11/6/2002	1120	6.7	40.4	98.4	--	--	0.4	0.6	0.02	1.2	0.02
TO2	Tomahawk Creek near 11th Street	385539094372100	7/17/2003	925	3.9	42.4	82.0	--	--	0.4	0.4	0.07	0.34	<.02
TO2	Tomahawk Creek near 11th Street	385539094372100	3/12/2007	1200	3.9	106	97.0	2.7	3.8	0.7	0.8	0.06	1.24	0.02
TO2	Tomahawk Creek near 11th Street	385539094372100	4/6/2010	1415	2.5	96.5	61.0	8.4	11	0.8	1.1	0.12	0.64	0.04
TU1	Turkey Creek at 67th Street	390027094415600	11/7/2002	1105	3.1	37.9	47.3	--	--	0.2	0.6	0.03	0.4	0.02
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	900	7.6	159	85.0	10	11	0.7	0.7	0.66	0.93	0.04
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	940	11.9	101	70.0	16	20	<.2	0.4	<.02	1.42	<.02
Minimum value					1.4	9.8	24.0	1.9	2.2	0.2	0.2	<.02	0.02	0.02
Maximum value					12.0	166	414	26	25	2.2	2.9	0.66	10.70	0.26

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Total nitrogen, water, mg/L as nitrogen (0.01)	Orthophosphate, water, filtered, mg/L as phosphorus (0.01)	Phosphorus, water, filtered, mg/L (0.02)	Phosphorus, water, unfiltered, mg/L (0.05)	Suspended-sediment concentration, mg/L (1)	*Escherichia coli*, water, colonies per 100 milliliters	Fecal coliform, water, colonies per 100 mL (10)	Enterococci, colonies per 100 mL (10)	1-Naphthol, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L	2-Chloro-2',6'-diethylacetanilide, water, filtered, recoverable, µg/L
BI1	Big Bull Creek near Edgerton	6914950	11/4/2002	1235	<1	0.22	0.25	0.34	13	20	10	49	--	--
BI1	Big Bull Creek near Edgerton	6914950	7/14/2003	1000	1.49	0.62	0.61	0.74	9.2	120	100	20	<.09	<.005
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	805	2.62	0.14	0.16	0.25	37	80	90	160	<.09	<.006
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1000	2.52	0.05	0.12	0.27	89	530	600	200	<.04	<.010
BL3	Blue River near Stanley (Highway 69)	6893080	7/18/2003	830	0.57	0.07	0.09	0.14	6.1	<10	10	40	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1410	0.92	<.01	0.02	0.03	54	63	60	21	<.09	<.006
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1345	0.49	<.01	0.02	<.05	26	<100	50	100	0.04	<.010
BL4	Camp Branch at 175th Street	384840094381100	7/18/2003	755	3.35	<.01	0.06	0.11	18	80	260	110	--	--
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1245	0.57	<.01	<.01	0.02	72	20	10	<4	<.09	<.006
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1510	0.48	<.01	<.01	<.05	32	100	30	100	<.04	<.010
BL5	Blue River at Kenneth Road	6893100	7/18/2003	815	0.59	0.09	0.11	0.13	24	20	20	620	<.09	<.005
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1100	0.98	<.01	<.01	0.06	60	20	20	21	<.09	<.006
BL5	Blue River at Kenneth Road	6893100	4/5/2010	1150	0.92	<.01	0.02	0.05	46	100	30	100	--	--
BR2	Brush Creek at Belinder Street	390127094365800	11/7/2002	1100	0.8	0.04	0.05	0.08	11	620	700	386	--	--
BR2	Brush Creek at Belinder Street	390127094365800	7/15/2003	935	<.45	0.06	0.1	0.16	5.6	90	200	50	<.09	<.005
BR2	Brush Creek at Belinder Street	390127094365800	4/6/2010	1105	2.85	0.04	0.08	0.11	12	2,140	280	250	<.04	<.010
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	905	1.12	0.02	0.03	0.09	30	73	110	85	<.09	<.006
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	810	3.24	0.02	0.06	0.25	74	4,400	2,300	2,600	<.04	<.010
CE1	Cedar Creek at Old Highway 56	6892440	11/4/2002	900	1.4	0.03	0.05	0.05	8.8	30	40	195	--	--
CE1	Cedar Creek at Old Highway 56	6892440	7/14/2003	1100	1.56	0.01	0.03	0.07	26	220	520	710	<.09	<.005
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	910	1.33	0.02	0.04	0.08	27	110	40	25	<.09	<.006
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	825	<1.55	<.01	0.01	0.06	25	180	150	150	<.04	<.010
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	11/4/2002	1235	3	0.72	0.76	0.77	3.8	10	10	41	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	7/14/2003	800	1.45	0.45	0.43	0.54	24	50	70	10	<.09	<.005
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1045	2.55	0.15	0.2	0.23	16	41	70	38	<.09	<.006
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1120	<1.39	E.07	0.1	0.14	49	187	180	97	<.04	<.010
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1415	2.14	<.01	0.01	0.03	45	20	30	16	<.09	<.006
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1200	1.61	<.01	0.02	<.05	28	262	210	31	<.04	<.010
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1320	7.2	1.2	1.24	1.32	4	90	70	20	<.09	<.006
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1400	4.3	0.56	0.74	0.88	12	96	110	41	<.04	<.010
IN6	Indian Creek at State Line Road	6893390	7/17/2003	1150	12.5	2.76	2.91	2.96	6.9	230	500	10	<.09	<.005
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1020	7.58	1.1	1.17	1.32	7	140	70	16	<.09	<.006
IN6	Indian Creek at State Line Road	6893390	4/6/2010	945	3.85	0.28	0.33	0.42	26	1,110	800	600	<.04	<.010

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

[USGS, U.S. Geological Survery; ( ), laboratory reporting level; mg/L, milligrams per liter; µg/L, micrograms per liter; mL, milliliters; E, estimated; <, less than; --, not determined; nm, nanometers; LED, light-emitting diode; YSI, Yellow Springs Instrument, Yellow Springs, Ohio; FNU, Formazine Nephelometric Unit]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Total nitrogen, water, mg/L as nitrogen (0.01)	Orthophosphate, water, filtered, mg/L as phosphorus (0.01)	Phosphorus, water, filtered, mg/L (0.02)	Phosphorus, water, unfiltered, mg/L (0.05)	Suspended-sediment concentration, mg/L (1)	*Escherichia coli*, water, colonies per 100 m/L	Fecal coliform, water, colonies per 100 mL (10)	Enterococci, colonies per 100 mL (10)	1-Naphthol, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L	2-Chloro-2',6'-diethylacetanilide, water, filtered, recoverable, µg/L
KI5b alt	Kill Creek at 135th Street	385303094582300	7/15/2003	1235	0.74	0.62	0.63	0.72	4.8	120	150	<10	--	--
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1405	1.32	0.21	0.23	0.23	9	20	<10	12	<.09	<.006
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	945	1.12	0.07	0.14	0.17	4	373	260	170	<.04	<.010
KI6b	Kill Creek at 95th Street	6892360	7/15/2003	1045	<.65	0.08	0.11	0.17	14	10	60	<10	--	--
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1230	0.53	0.07	0.09	0.12	20	31	<10	48	<.09	<.006
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1145	1.01	0.05	0.11	0.17	53	638	350	310	<.04	<.010
LI1	Little Bull Creek near 215th Street	384419094515600	11/4/2002	1435	2	0.1	0.12	0.18	11	--	120	300	--	--
LI1	Little Bull Creek near 215th Street	384419094515600	7/14/2003	1140	1.66	0.01	0.08	0.22	220	700	500	90	<.09	<.005
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1215	0.82	0.01	0.04	0.09	56	520	530	100	<.04	<.010
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	830	2.42	<.01	<.01	0.02	18	10	<10	21	<.09	<.006
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1235	2.15	0.01	0.02	<.05	14	408	370	20	E.009	<.010
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	750	1.86	<.01	<.01	0.02	35	41	30	16	<.088	<.006
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	940	2.55	<.01	<.01	0.03	10	31	30	97	<.088	<.006
MI1	Mill Creek at 127th Street	385356094491200	11/5/2002	820	0.9	0.09	0.1	0.17	18	1,300	2,000	E10000	--	--
MI1	Mill Creek at 127th Street	385356094491200	7/16/2003	1200	0.73	0.06	0.07	0.09	5.6	190	400	120	--	--
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1150	1.29	<.01	<.01	0.02	7	110	140	21	<.09	<.006
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1045	1.7	<.01	0.04	0.09	20	988	1,000	1,200	<.04	<.010
MI4	Mill Creek at 87th Street Lane	385800094485300	11/5/2002	1115	5.3	1	0.97	1.01	5.4	490	210	--	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	7/16/2003	1155	6.99	1.08	1.17	2.16	4.5	80	100	<10	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1240	5.46	0.62	0.64	0.66	6	20	30	<4	<.09	<.006
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1205	2.13	0.09	0.17	0.21	13	443	330	180	<.04	<.010
MI7	Mill Creek at Johnson Drive	6892513	11/5/2002	1325	2.3	0.35	0.39	0.4	7.9	40	<10	52	--	--
MI7	Mill Creek at Johnson Drive	6892513	7/16/2003	900	0.68	0.18	0.19	0.28	24	130	200	<10	<.09	<.005
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1030	2.38	0.19	0.2	0.22	14	20	30	12	<.09	<.006
MI7	Mill Creek at Johnson Drive	6892513	4/8/2010	1310	1.54	0.06	0.08	0.13	79	680	530	160	<.04	<.010
TO2	Tomahawk Creek near 11th Street	385539094372100	11/6/2002	1120	1.8	0.03	0.03	0.05	35	480	730	340	--	--
TO2	Tomahawk Creek near 11th Street	385539094372100	7/17/2003	925	0.74	0.02	0.03	0.05	7.9	50	130	<10	<.09	<.005
TO2	Tomahawk Creek near 11th Street	385539094372100	3/12/2007	1200	2.04	<.01	<.01	0.03	31	210	190	44	<.09	<.006
TO2	Tomahawk Creek near 11th Street	385539094372100	4/6/2010	1415	1.74	<.01	0.02	<.05	--	504	260	10	<.04	<.010
TU1	Turkey Creek at 67th Street	390027094415600	11/7/2002	1105	1	0.02	0.02	0.04	7.7	230	220	41	--	--
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	900	1.63	0.01	<.01	0.02	34	122	20	16	<.09	<.006
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	940	1.82	0.02	0.04	<.05	220	1,140	400	1,300	<.04	<.010
Minimum value					0.48	0.01	0.01	0.02	3.8	<10	<10	<10	0.04	0
Maximum value					12.5	2.76	2.91	2.96	220	4,400	2,300	2,600	0.04	0

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable, µg/L (0.014)	2,6-Diethylaniline, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L	2-Ethyl-6-methylaniline, water, filtered, recoverable, µg/L	3,4-Dichloroaniline, water, filtered, recoverable, µg/L (0.004)	4-Chloro-2-methylphenol, water, filtered, recoverable, µg/L	Acetochlor, water, filtered, recoverable, µg/L	Alachlor, water, filtered, recoverable, µg/L (0.008)	Atrazine, water, filtered, recoverable, µg/L (0.007)	Benfluralin, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.014)	Carbaryl, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.2)
BI1	Big Bull Creek near Edgerton	6914950	11/4/2002	1235	E.083	<.006	--	--	--	<.006	<.004	0.230	<.01	<.04
BI1	Big Bull Creek near Edgerton	6914950	7/14/2003	1000	E.221	<.006	E.007	0.044	<.006	0.57	<.004	3.520	<.01	<.04
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	805	E.092	<.006	<.010	E.010	<.005	0.008	0.012	0.508	<.01	<.06
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1000	E.046	<.006	<.010	<.004	<.003	0.011	<.008	0.077	<.01	<.06
BL3	Blue River near Stanley (Highway 69)	6893080	7/18/2003	830	--	--	--	--	--	--	--	--	--	<1.0
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1410	E.012	<.006	<.010	<.004	<.005	<.006	<.005	0.015	<.01	<.06
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1345	E.019	<.006	<.010	<.004	<.003	<.010	<.008	0.019	<.01	<.06
BL4	Camp Branch at 175th Street	384840094381100	7/18/2003	755	--	--	--	--	--	--	--	--	--	<1.0
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1245	E.009	<.006	<.010	<.004	<.005	<.006	<.005	0.008	<.01	<.06
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1510	<.016	<.006	<.010	E.008	<.003	<.010	<.008	0.011	<.01	<.06
BL5	Blue River at Kenneth Road	6893100	7/18/2003	815	E.036	<.006	<.004	0.096	<.006	<.006	<.004	0.152	<.01	<.04
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1100	E.012	<.006	<.010	<.004	<.005	<.006	<.005	0.014	<.01	<.06
BL5	Blue River at Kenneth Road	6893100	4/5/2010	1150	--	--	--	--	--	--	--	--	--	--
BR2	Brush Creek at Belinder Street	390127094365800	11/7/2002	1100	<.006	<.006	--	--	--	<.006	<.004	0.008	<.01	E.006
BR2	Brush Creek at Belinder Street	390127094365800	7/15/2003	935	E.025	<.006	<.004	0.017	E.008	<.006	<.004	0.083	<.01	<.04
BR2	Brush Creek at Belinder Street	390127094365800	4/6/2010	1105	<.014	<.006	<.010	<.004	<.003	<.010	<.008	0.014	E.003	E.01
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	905	E.024	<.006	<.010	<.004	<.005	<.006	<.005	0.091	<.01	<.06
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	810	E.032	<.006	<.010	<.005	<.003	0.011	0.009	0.050	<.01	<.06
CE1	Cedar Creek at Old Highway 56	6892440	11/4/2002	900	E.054	<.006	--	--	--	<.006	<.004	0.209	--	--
CE1	Cedar Creek at Old Highway 56	6892440	7/14/2003	1100	E.099	<.006	<.004	0.045	<.006	<.008	0.007	0.724	--	--
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	910	E.014	<.006	<.010	<.004	<.005	<.008	<.005	0.025	<.01	<.06
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	825	E.032	<.006	<.010	<.006	E.008	E.010	<.008	0.036	<.01	E.01
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	11/4/2002	1235	E.048	<.006	--	--	--	<.006	<.004	0.194	<.01	E.03
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	7/14/2003	800	E.055	<.006	<.004	0.029	E.009	<.006	0.005	0.235	<.01	E.02
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1045	E.019	<.006	<.010	E.030	<.005	0.008	<.005	0.102	<.01	<.06
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1120	E.035	<.006	<.010	E.013	<.004	<.010	<.008	0.062	<.02	<.06
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1415	E.011	<.006	<.010	<.004	<.005	<.006	<.005	0.027	<.01	E.01
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1200	E.022	<.006	<.010	E.284	E.007	<.010	<.008	0.032	0.02	E.02
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1320	E.028	<.006	<.010	E.037	<.005	<.006	<.005	0.114	<.01	E.01
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1400	E.042	<.006	<.010	E.340	<.005	<.010	<.016	0.065	0.02	<.06
IN6	Indian Creek at State Line Road	6893390	7/17/2003	1150	E.092	<.006	<.004	0.146	<.006	<.006	<.004	0.376	<.01	<.04
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1020	E.018	<.006	<.010	E.029	<.005	<.006	<.005	0.074	<.01	<.06
IN6	Indian Creek at State Line Road	6893390	4/6/2010	945	E.030	<.006	<.010	E.028	E.007	<.010	<.008	0.037	0.02	E.04

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable, µg/L (0.014)	2,6-Diethylaniline, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L	2-Ethyl-6-methylaniline, water, filtered, recoverable, µg/L	3,4-Dichloroaniline, water, filtered, recoverable, µg/L (0.004)	4-Chloro-2-methylphenol, water, filtered, recoverable, µg/L	Acetochlor, water, filtered, recoverable, µg/L	Alachlor, water, filtered, recoverable, µg/L (0.008)	Atrazine, water, filtered, recoverable, µg/L (0.007)	Benfluralin, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.014)	Carbaryl, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.2)
KI5b alt	Kill Creek at 135th Street	385303094582300	7/15/2003	1235	--	--	--	--	--	--	--	--	--	<1.0
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1405	E.015	<.006	<.010	E.014	<.005	<.006	<.005	0.030	<.01	<.06
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	945	E.026	<.006	<.010	E.010	<.003	<.010	<.008	0.031	<.01	<.06
KI6b	Kill Creek at 95th Street	6892360	7/15/2003	1045	0.036	--	--	--	--	--	--	0.223	--	<1.0
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1230	E.017	<.006	<.010	E.008	<.005	<.006	<.005	0.043	<.01	<.06
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1145	E.025	<.006	<.010	E.004	<.003	<.011	<.008	0.032	<.01	<.06
LI1	Little Bull Creek near 215th Street	384419094515600	11/4/2002	1435	E.039	<.006	--	--	--	<.006	<.004	0.106	<.01	<.04
LI1	Little Bull Creek near 215th Street	384419094515600	7/14/2003	1140	E.084	<.006	<.004	0.018	<.006	<.006	<.004	0.290	<.01	E.02
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1215	E.034	<.006	<.010	<.004	<.003	E.009	<.008	0.039	<.01	<.06
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	830	E.008	<.006	<.010	E.007	<.005	<.006	<.005	0.014	E.004	<.06
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1235	E.016	<.006	<.010	E.008	E.007	E.009	<.008	0.018	0.02	E.07
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	750	E.007	<.006	<.010	E.005	<.005	<.006	<.005	0.013	<.01	<.06
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	940	E.008	<.006	<.010	E.007	E.005	<.006	<.005	0.014	E.004	<.06
MI1	Mill Creek at 127th Street	385356094491200	11/5/2002	820	E.039	<.006	--	--	--	<.010	<.004	0.119	<.01	E.13
MI1	Mill Creek at 127th Street	385356094491200	7/16/2003	1200	--	--	--	--	--	--	--	--	--	<1.0
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1150	E.024	<.006	<.010	E.047	<.005	<.006	<.005	0.120	<.01	<.06
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1045	E.021	<.006	<.010	E.029	E.006	E.009	<.008	0.031	0.02	E.04
MI4	Mill Creek at 87th Street Lane	385800094485300	11/5/2002	1115	E.056	<.006	--	--	--	<.006	<.008	0.118	<.01	<.04
MI4	Mill Creek at 87th Street Lane	385800094485300	7/16/2003	1155	--	--	--	--	--	--	--	--	--	<1.0
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1240	E.024	<.006	<.010	E.015	<.005	<.006	<.005	0.091	<.01	<.06
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1205	E.021	<.006	<.010	E.019	E.004	E.008	<.008	0.029	0.02	E.01
MI7	Mill Creek at Johnson Drive	6892513	11/5/2002	1325	E.024	<.006	--	--	--	<.006	<.004	0.051	<.01	<.04
MI7	Mill Creek at Johnson Drive	6892513	7/16/2003	900	E.039	<.006	<.004	0.080	E.007	<.006	0.006	0.118	<.01	<.04
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1030	E.015	<.006	<.010	<.006	<.005	<.006	<.005	0.042	<.01	<.06
MI7	Mill Creek at Johnson Drive	6892513	4/8/2010	1310	E.017	<.006	<.010	E.010	E.003	<.010	<.008	0.022	<.01	E.01
TO2	Tomahawk Creek near 11th Street	385539094372100	11/6/2002	1120	<.008	<.006	--	--	--	<.006	<.004	0.012	<.01	<.04
TO2	Tomahawk Creek near 11th Street	385539094372100	7/17/2003	925	E.034	<.006	<.004	0.269	E.007	<.006	<.004	0.071	<.01	E.01
TO2	Tomahawk Creek near 11th Street	385539094372100	3/12/2007	1200	<.014	<.006	<.010	<.004	<.005	<.006	<.005	0.017	<.01	<.06
TO2	Tomahawk Creek near 11th Street	385539094372100	4/6/2010	1415	<.027	<.006	<.010	<.004	<.003	<.010	<.008	0.033	E.005	E.01
TU1	Turkey Creek at 67th Street	390027094415600	11/7/2002	1105	<.006	<.006	--	--	--	<.006	<.004	0.007	<.01	E.01
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	900	<.014	<.006	<.010	<.004	<.005	<.006	<.005	0.027	<.01	E.01
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	940	E.017	<.006	<.010	E.011	<.004	E.010	<.008	0.018	<.02	E.03
Minimum value					0.04	0	0	0.02	0	0.01	<.004	0.007	<.01	<.06
Maximum value					0.04	0	0	0.27	0	0.57	0.01	3.520	0.02	E.13

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	DCPA, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L	Desulfinylfipronil, water, filtered, recoverable, µg/L (0.012)	Desulfinylfipronil amide, water, filtered, recoverable, µg/L (0.029)	Diazinon, water, filtered, recoverable, µg/L	Dichlorvos, water, filtered, recoverable, µg/L (0.02)	Dieldrin, water, filtered, recoverable, µg/L	Fipronil sulfide, water, filtered, recoverable, µg/L (0.013)	Fipronil sulfone, water, filtered, recoverable, µg/L (0.024)	Fipronil, water, filtered, recoverable, µg/L (0.04)	Hexazinone, water, filtered, recoverable, µg/L	Malathion, water, filtered, recoverable, µg/L
BI1	Big Bull Creek near Edgerton	6914950	11/4/2002	1235	<.003	0.0088	<.009	<.005	<1.00	<.005	<.010	<.0125	E.009	--	<.03
BI1	Big Bull Creek near Edgerton	6914950	7/14/2003	1000	<.003	0.0085	E.011	<.005	<.01	<.005	0.0066	0.0079	<.008	<.013	<.027
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	805	<.003	E.008	E.006	<.005	<.01	<.009	E.009	E.006	E.011	<.026	<.016
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1000	<.008	E.006	<.029	<.005	<.02	<.009	<.013	<.024	E.015	<.008	<.016
BL3	Blue River near Stanley (Highway 69)	6893080	7/18/2003	830	--	--	--	<.5	<1.00	--	--	--	--	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1410	<.003	<.012	<.029	<.005	<.01	<.009	<.013	<.024	<.016	<.026	<.016
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1345	<.008	E.006	<.029	<.005	<.02	<.009	<.013	<.024	<.018	<.008	<.016
BL4	Camp Branch at 175th Street	384840094381100	7/18/2003	755	--	--	--	<.5	<1.00	--	--	--	--	--	--
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1245	<.003	E.007	E.005	<.005	<.01	<.009	E.009	E.005	E.007	<.026	<.016
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1510	<.008	E.006	<.029	<.005	<.02	<.009	E.011	<.024	<.018	<.008	<.016
BL5	Blue River at Kenneth Road	6893100	7/18/2003	815	<.003	<.004	<.009	E.005	<.01	<.005	<.005	<.005	<.007	<.013	<.027
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1100	<.003	E.007	E.005	<.005	<.01	<.009	E.009	E.005	E.007	<.026	<.016
BL5	Blue River at Kenneth Road	6893100	4/5/2010	1150	--	--	--	--	--	--	--	--	--	--	--
BR2	Brush Creek at Belinder Street	390127094365800	11/7/2002	1100	0.0042	<.004	<.009	0.018	<1.00	<.005	E.004	0.0052	<.009	--	<.03
BR2	Brush Creek at Belinder Street	390127094365800	7/15/2003	935	<.003	<.004	<.009	0.067	<.01	<.005	0.0064	<.005	E.012	<.013	<.027
BR2	Brush Creek at Belinder Street	390127094365800	4/6/2010	1105	<.008	E.008	<.029	<.005	<.02	0.0326	0.0136	0.0334	E.068	<.008	<.016
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	905	<.003	<.012	<.029	<.005	<.01	<.009	<.013	<.024	<.016	<.026	<.016
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	810	<.008	<.012	<.029	<.005	E.01	<.009	<.013	<.024	<.018	<.008	<.016
CE1	Cedar Creek at Old Highway 56	6892440	11/4/2002	900	<.003	<.004	<.009	<.005	<1.00	<.005	<.005	<.005	<.007	--	<.027
CE1	Cedar Creek at Old Highway 56	6892440	7/14/2003	1100	<.003	<.004	<.009	E.003	<.01	<.005	<.005	<.005	<.007	<.013	<.027
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	910	<.003	<.012	<.029	<.005	<.01	<.009	<.013	<.024	<.016	<.026	<.016
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	825	<.008	E.002	<.029	<.005	<.02	<.009	<.013	<.024	E.004	<.008	<.016
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	11/4/2002	1235	<.003	0.01	<.009	0.011	<1.00	<.005	<.008	0.0111	E.043	--	<.027
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	7/14/2003	800	<.003	0.0085	<.009	0.097	<.01	<.005	E.004	<.009	E.015	<.013	<.027
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1045	<.003	E.007	E.005	<.005	<.01	<.009	E.009	E.006	E.012	<.026	<.016
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1120	<.008	E.003	E.002	<.005	E.01	<.009	E.001	E.009	E.011	<.008	<.016
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1415	<.003	E.010	E.012	<.005	<.01	<.009	E.008	E.013	E.034	<.026	<.016
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1200	<.008	E.009	E.008	<.005	<.02	<.009	E.007	E.014	E.024	<.008	<.016
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1320	<.003	E.012	E.012	<.005	<.01	<.009	E.009	E.017	E.073	E.014	<.016
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1400	<.008	0.0274	E.018	<.005	<.02	<.009	E.013	E.020	E.129	<.008	<.016
IN6	Indian Creek at State Line Road	6893390	7/17/2003	1150	<.003	0.0154	<.009	0.060	<.01	<.005	0.0066	<.025	E.071	<.013	<.027
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1020	<.003	E.010	E.010	<.015	<.01	<.009	E.008	E.015	E.061	<.026	<.016
IN6	Indian Creek at State Line Road	6893390	4/6/2010	945	<.008	E.012	E.007	0.020	<.02	<.009	E.008	E.015	E.083	<.008	<.016

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

[USGS, U.S. Geological Survery; ( ), laboratory reporting level; mg/L, milligrams per liter; µg/L, micrograms per liter; mL, milliliters; E, estimated; <, less than; --, not determined; nm, nanometers; LED, light-emitting diode; YSI, Yellow Springs Instrument, Yellow Springs, Ohio; FNU, Formazine Nephelometric Unit]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Dimethyl tetrachloroterephthalate, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L	Desulfinylfipronil, water, filtered, recoverable, µg/L (0.012)	Desulfinylfipronil amide, water, filtered, recoverable, µg/L (0.029)	Diazinon, water, filtered, recoverable, µg/L	Dichlorvos, water, filtered, recoverable, µg/L (0.02)	Dieldrin, water, filtered, recoverable, µg/L	Fipronil sulfide, water, filtered, recoverable, µg/L (0.013)	Fipronil sulfone, water, filtered, recoverable, µg/L (0.024)	Fipronil, water, filtered, recoverable, µg/L (0.04)	Hexazinone, water, filtered, recoverable, µg/L	Malathion, water, filtered, recoverable, µg/L
KI5b alt	Kill Creek at 135th Street	385303094582300	7/15/2003	1235	--	--	--	<.5	<1.00	--	--	--	--	--	--
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1405	<.003	E.008	E.006	<.005	<.01	<.009	E.009	E.006	E.008	<.026	<.016
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	945	<.008	E.006	E.005	<.005	<.02	<.009	E.005	E.010	E.021	<.008	<.016
KI6b	Kill Creek at 95th Street	6892360	7/15/2003	1045	--	--	--	<.5	<1.00	--	--	--	--	--	--
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1230	<.003	E.007	E.006	<.005	<.01	<.009	E.009	E.005	E.007	<.026	<.016
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1145	<.008	E.004	<.029	<.005	<.02	E.002	E.004	<.024	E.009	<.008	<.016
LI1	Little Bull Creek near 215th Street	384419094515600	11/4/2002	1435	<.003	<.004	<.009	<.005	<1.00	<.005	<.005	<.005	<.007	--	<.03
LI1	Little Bull Creek near 215th Street	384419094515600	7/14/2003	1140	<.003	<.004	<.009	0.019	<.01	<.005	<.005	<.005	<.007	<.013	<.027
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1215	<.008	E.006	<.029	<.005	<.02	<.009	<.013	<.024	<.018	<.008	<.016
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	830	<.003	E.010	E.008	<.005	<.013	<.009	E.010	E.010	E.023	<.026	<.016
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1235	<.008	0.0262	E.012	<.005	<.02	<.009	E.010	E.018	E.125	<.008	<.016
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	750	<.003	E.007	E.010	<.005	<.013	<.009	E.008	E.011	E.023	<.026	<.016
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	940	<.003	E.009	E.008	<.005	<.013	<.009	E.009	E.009	E.025	<.026	<.016
MI1	Mill Creek at 127th Street	385356094491200	11/5/2002	820	<.003	<.004	<.009	<.015	<1.00	<.005	<.005	<.005	<.010	--	<.04
MI1	Mill Creek at 127th Street	385356094491200	7/16/2003	1200	--	--	--	<.5	<1.00	--	--	--	--	--	--
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1150	<.003	E.006	E.005	<.005	<.013	<.009	E.009	E.006	E.009	<.026	<.016
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1045	<.008	0.0182	E.007	<.005	<.02	<.009	E.009	E.011	E.035	<.008	<.016
MI4	Mill Creek at 87th Street Lane	385800094485300	11/5/2002	1115	<.003	<.008	<.009	0.007	<1.00	<.005	<.005	0.0093	E.023	--	<.027
MI4	Mill Creek at 87th Street Lane	385800094485300	7/16/2003	1155	--	--	--	<.5	<1.00	--	--	--	--	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1240	<.003	E.007	E.008	<.005	<.01	<.009	E.007	E.010	E.024	<.026	<.016
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1205	<.008	E.008	E.005	<.005	<.02	E.002	E.005	E.011	E.035	<.008	<.016
MI7	Mill Creek at Johnson Drive	6892513	11/5/2002	1325	<.003	0.0049	<.009	0.009	<1.00	<.005	<.005	<.012	E.014	--	<.027
MI7	Mill Creek at Johnson Drive	6892513	7/16/2003	900	<.003	0.0062	<.009	0.050	<.01	<.005	<.005	<.008	E.009	<.013	<.027
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1030	<.003	E.006	E.008	<.005	<.01	<.009	E.006	<.024	E.013	<.026	<.016
MI7	Mill Creek at Johnson Drive	6892513	4/8/2010	1310	<.008	E.007	E.005	<.005	<.02	<.009	E.006	E.011	E.039	<.008	<.016
TO2	Tomahawk Creek near 11th Street	385539094372100	11/6/2002	1120	<.003	<.008	<.009	0.020	<1.00	<.005	<.005	0.0108	E.025	--	<.027
TO2	Tomahawk Creek near 11th Street	385539094372100	7/17/2003	925	<.003	0.0122	E.008	0.057	<.01	<.005	0.0054	<.015	E.018	<.013	<.027
TO2	Tomahawk Creek near 11th Street	385539094372100	3/12/2007	1200	<.003	E.009	E.009	<.005	<.01	<.009	E.007	<.024	E.032	<.026	<.016
TO2	Tomahawk Creek near 11th Street	385539094372100	4/6/2010	1415	E.002	0.0195	E.029	<.005	<.02	<.009	0.0143	0.0453	E.081	<.008	<.016
TU1	Turkey Creek at 67th Street	390027094415600	11/7/2002	1105	E.002	<.004	<.009	0.017	<1.00	<.005	0.0051	<.005	<.007	--	E.015
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	900	<.003	0.0145	E.008	<.005	E.05	<.009	E.007	E.009	E.069	<.026	<.016
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	940	<.008	E.009	E.004	<.005	E.01	E.005	E.006	E.011	E.032	<.008	<.016
Minimum value					<.003	<.004	<.009	<.005	<.01	<.005	<.005	<.008	<.008	<.008	<.016
Maximum value					0.004	0.027	E.029	0.097	E.01	0.03	0.01	0.05	E.129	E.014	E.015

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Metalaxyl, water, filtered, recoverable, µg/L	Metolachlor, water, filtered, recoverable, µg/L (0.014)	Metribuzin, water, filtered, recoverable, µg/L (0.016)	Myclobutanil, water, filtered, recoverable, µg/L	Pendimethalin, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.012)	Prometon, water, filtered, recoverable, µg/L (0.012)	Simazine, water, filtered, recoverable, µg/L (0.01)	Tebuthiuron, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.02)	Terbuthylazine, water, filtered, recoverable, µg/L	Triazine screen, water, filtered, enzyme link immuno sorbent assay, recoverable, µg/L as atrazine	Trifluralin, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.012)
BI1	Big Bull Creek near Edgerton	6914950	11/4/2002	1235	--	0.028	<.006	--	<.022	0.02	0.009	<.02	--	<.10	<.009
BI1	Big Bull Creek near Edgerton	6914950	7/14/2003	1000	<.005	0.043	<.006	<.008	<.022	0.03	0.021	E.05	E.005	4.3	<.009
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	805	<.007	0.024	0.0449	<.033	<.02	0.01	E.007	<.02	<.008	0.64	<.009
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1000	<.007	0.016	<.012	<.010	<.012	E.006	<.006	<.03	<.006	<.10	<.018
BL3	Blue River near Stanley (Highway 69)	6893080	7/18/2003	830	--	E.036	--	--	--	<.5	--	--	--	0.32	--
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1410	<.007	E.009	<.012	<.033	<.02	E.009	<.006	<.02	<.008	<.10	<.009
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1345	<.007	0.033	<.012	<.010	<.012	0.03	<.006	<.03	<.006	<.10	<.018
BL4	Camp Branch at 175th Street	384840094381100	7/18/2003	755	--	E.091	--	--	--	<.5	--	--	--	0.24	--
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1245	<.007	E.006	<.012	<.033	<.02	E.01	0.008	<.02	<.008	<.10	<.009
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1510	<.007	E.009	<.012	<.010	<.012	E.007	E.007	<.03	<.006	<.10	<.018
BL5	Blue River at Kenneth Road	6893100	7/18/2003	815	<.005	0.039	<.006	0.0084	<.022	0.04	E.004	<.02	<.010	0.21	<.009
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1100	<.007	E.008	E.010	<.033	<.02	<.01	E.005	<.02	<.008	<.10	<.009
BL5	Blue River at Kenneth Road	6893100	4/5/2010	1150	--	--	--	--	--	--	--	--	--	<.10	--
BR2	Brush Creek at Belinder Street	390127094365800	11/7/2002	1100	--	E.010	<.006	--	E.013	0.04	<.005	<.02	--	<.10	E.001
BR2	Brush Creek at Belinder Street	390127094365800	7/15/2003	935	<.005	0.017	<.006	0.0382	<.022	0.35	<.006	<.02	<.010	0.14	<.009
BR2	Brush Creek at Belinder Street	390127094365800	4/6/2010	1105	<.007	E.012	<.012	<.048	0.043	0.02	<.006	<.03	<.006	<.10	E.006
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	905	<.007	0.011	<.012	<.033	<.02	<.01	E.005	<.02	<.008	<.10	<.009
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	810	E.018	0.018	<.012	<.010	<.012	E.008	<.008	<.03	<.006	<.10	<.018
CE1	Cedar Creek at Old Highway 56	6892440	11/4/2002	900	--	0.021	<.006	--	<.022	E.01	0.016	E.01	--	--	<.009
CE1	Cedar Creek at Old Highway 56	6892440	7/14/2003	1100	<.005	0.192	<.006	<.008	<.022	0.04	<.025	<.02	E.003	0.91	<.009
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	910	<.007	0.020	<.012	<.033	<.02	E.009	0.008	0.1	<.008	<.10	<.009
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	825	<.007	0.089	<.012	<.010	<.012	0.03	<.008	E.02	<.006	<.10	<.018
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	11/4/2002	1235	--	0.087	<.006	--	<.022	0.04	0.033	0.02	--	0.19	<.009
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	7/14/2003	800	0.0122	0.043	<.006	0.0187	<.022	0.14	0.012	<.02	<.010	0.37	<.009
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1045	<.007	0.014	<.012	<.033	<.02	0.01	0.034	0.04	<.008	0.16	<.009
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1120	<.007	0.051	<.012	<.010	<.027	0.01	0.02	<.03	<.006	<.10	<.018
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1415	<.007	E.007	<.012	<.033	0.040	0.02	0.01	<.02	<.008	<.10	<.009
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1200	<.008	0.022	<.012	<.042	0.041	0.07	<.010	<.03	<.006	<.10	E.008
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1320	<.007	0.019	<.012	<.033	0.028	0.02	0.009	<.02	<.008	0.11	<.009
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1400	<.007	0.023	<.013	<.020	0.033	0.03	<.008	<.03	<.006	0.11	E.007
IN6	Indian Creek at State Line Road	6893390	7/17/2003	1150	<.005	0.106	<.006	<.008	<.022	0.03	<.010	<.02	<.010	0.41	<.009
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1020	<.007	0.013	<.012	<.033	<.021	0.01	0.009	<.02	<.008	0.14	<.009
IN6	Indian Creek at State Line Road	6893390	4/6/2010	945	<.016	0.020	<.012	<.017	0.049	0.04	<.008	<.03	<.007	<.10	E.014

Appendix 3. Results of laboratory analysis for dissolved solids, major ions, nutrients, trace elements, suspended sediment, fecal-indicator bacteria, and organic compounds in water from biological monitoring sites in Johnson County, Kansas, 2002, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Metalaxyl, water, filtered, recoverable, µg/L	Metolachlor, water, filtered, recoverable, µg/L (0.014)	Metribuzin, water, filtered, recoverable, µg/L (0.016)	Myclobutanil, water, filtered, recoverable, µg/L	Pendimethalin, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.012)	Prometon, water, filtered, recoverable, µg/L (0.012)	Simazine, water, filtered, recoverable, µg/L (0.01)	Tebuthiuron, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.02)	Terbuthylazine, water, filtered, recoverable, µg/L	Triazine screen, water, filtered, enzyme link immuno sorbent assay, recoverable, µg/L as atrazine	Trifluralin, water, filtered (0.7 micron glass fiber filter), recoverable, µg/L (0.012)
KI5b alt	Kill Creek at 135th Street	385303094582300	7/15/2003	1235	--	E.008	--	--	--	<.5	--	--	--	0.68	--
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1405	<.007	<.010	<.012	<.033	<.02	0.02	<.006	<.02	<.008	<.10	<.009
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	945	<.007	E.010	<.012	<.010	<.012	E.007	<.006	<.03	<.006	<.10	<.018
KI6b	Kill Creek at 95th Street	6892360	7/15/2003	1045	--	<.5	--	--	--	<.5	--	<.03	--	0.55	--
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1230	<.007	E.006	<.012	<.033	<.02	0.02	E.004	<.02	<.008	<.10	<.009
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1145	<.007	0.015	<.012	<.010	<.012	E.006	<.006	<.03	<.006	<.10	<.018
LI1	Little Bull Creek near 215th Street	384419094515600	11/4/2002	1435	--	0.015	<.006	--	<.022	0.08	<.005	<.02	--	0.37	<.009
LI1	Little Bull Creek near 215th Street	384419094515600	7/14/2003	1140	<.005	0.017	<.006	<.008	<.022	0.06	0.013	<.02	0.619	0.64	<.009
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1215	<.007	0.024	<.012	<.010	<.012	E.007	<.006	<.03	0.0083	<.10	<.018
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	830	<.007	E.006	<.012	<.033	<.02	0.05	0.015	<.02	<.008	<.10	E.005
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1235	<.007	E.011	<.012	<.010	0.038	0.01	0.019	E.02	<.006	<.10	E.008
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	750	<.007	E.005	<.012	<.033	0.022	0.04	0.036	0.027	<.008	<.1	<.009
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	940	<.007	E.006	<.012	<.033	<.02	0.02	E.007	0.024	<.008	<.1	E.004
MI1	Mill Creek at 127th Street	385356094491200	11/5/2002	820	--	0.060	<.006	--	<.022	0.02	<.005	0.06	--	0.2	<.009
MI1	Mill Creek at 127th Street	385356094491200	7/16/2003	1200	--	E.210	--	--	--	<.5	--	--	--	0.67	--
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1150	<.007	0.012	<.012	<.033	<.02	0.03	0.008	<.02	<.008	0.16	<.009
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1045	<.007	0.019	<.012	E.008	<.028	0.05	<.007	0.03	<.006	<.10	E.007
MI4	Mill Creek at 87th Street Lane	385800094485300	11/5/2002	1115	--	0.075	<.006	--	<.022	0.02	<.005	0.12	--	0.18	<.009
MI4	Mill Creek at 87th Street Lane	385800094485300	7/16/2003	1155	--	E.035	--	--	--	<.5	--	--	--	0.54	--
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1240	<.007	0.012	<.012	<.033	<.02	0.02	<.006	0.02	<.008	0.14	<.009
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1205	<.007	E.012	<.012	<.010	<.027	0.04	E.007	E.02	<.006	<.10	E.008
MI7	Mill Creek at Johnson Drive	6892513	11/5/2002	1325	--	0.029	<.006	--	<.022	0.02	0.008	0.05	--	<.10	<.009
MI7	Mill Creek at Johnson Drive	6892513	7/16/2003	900	<.005	0.015	<.006	0.0099	<.022	0.06	0.02	E.03	<.010	0.2	<.009
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1030	<.007	E.008	<.012	<.033	<.02	0.01	0.008	0.02	<.008	<.10	<.009
MI7	Mill Creek at Johnson Drive	6892513	4/8/2010	1310	<.007	E.011	<.012	<.010	0.023	0.02	0.009	<.03	<.006	<.10	E.002
TO2	Tomahawk Creek near 11th Street	385539094372100	11/6/2002	1120	--	E.008	<.006	--	<.022	E.01	<.005	<.02	--	<.10	<.009
TO2	Tomahawk Creek near 11th Street	385539094372100	7/17/2003	925	<.005	E.012	<.006	0.0231	<.022	0.04	<.005	<.02	<.010	0.12	<.009
TO2	Tomahawk Creek near 11th Street	385539094372100	3/12/2007	1200	<.007	E.006	<.012	<.033	<.036	E.010	0.011	<.02	<.008	<.10	E.010
TO2	Tomahawk Creek near 11th Street	385539094372100	4/6/2010	1415	<.007	0.022	<.012	<.014	0.081	E.008	<.015	<.03	<.006	<.10	E.015
TU1	Turkey Creek at 67th Street	390027094415600	11/7/2002	1105	--	E.009	<.006	--	<.022	0.02	<.005	0.06	--	0.27	<.009
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	900	0.088	E.008	<.012	<.033	<.056	0.03	<.012	<.02	<.008	<.10	E.012
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	940	<.007	E.010	<.012	<.010	<.029	0.01	E.008	E.03	0.0282	<.10	E.008
Minimum value					<.005	E.008	<.006	<.008	<.022	<.01	<.005	<.02	<.006	<.10	<.009
Maximum value					0.088	0.19	0.04	0.038	0.081	0.35	0.04	0.12	0.62	4.30	E.015

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.

[USGS, U.S. Geological Survery; mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available; <, less than]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Carbon (inorganic plus organic), mg/kg (1,000)	Organic carbon, mg/kg (1,000)	Total nitrogen, mg/kg (100)	Phosphorus, mg/kg (100)	Aluminum, mg/kg (1)	Antimony, mg/kg	Arsenic, mg/kg (0.1)	Barium, mg/kg (1)	Beryllium, mg/kg (0.1)	Cadmium, mg/kg	Calcium, mg/kg	Chromium, mg/kg (1)	Cobalt, mg/kg (1)
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)											33			4.98		111	
BI1	Big Bull Creek near Edgerton	6914950	3/31/2003	915	63,000	61,000	7,000	2,600	68,000	0.6	12.0	730	2	0.8	21,000	69	21
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	810	17,000	16,000	1,700	760	59,000	1.0	10.0	640	2	0.3	--	67	13
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1130	11,000	12,000	1,100	540	52,000	0.8	7.4	600	2	0.2	9,000	51	9
BL3	Blue River near Stanley (Highway 69)	6893080	4/3/2003	1045	13,000	9,000	1,000	950	54,000	0.4	6.2	550	2	0.3	30,000	52	12
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1345	14,000	12,000	1,200	540	55,000	0.7	6.6	640	2	0.2	--	56	9
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1420	21,000	15,000	1,600	570	53,000	0.9	7.3	620	2	0.2	24,000	52	10
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1250	22,000	16,000	1,600	590	57,000	0.8	7.4	640	2	0.3	--	58	11
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1520	39,000	22,000	2,600	660	50,000	0.8	6.8	580	1	0.4	59,000	51	10
BL5	Blue River at Kenneth Road	6893100	4/3/2003	930	32,000	28,000	3,000	960	55,000	1.0	10.0	610	2	0.6	30,000	54	13
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1050	15,000	12,000	1,100	530	54,000	0.8	7.2	640	2	0.2	--	56	9
BL5	Blue River at Kenneth Road	6893100	4/6/2010	850	21,000	16,000	1,700	590	55,000	0.8	6.7	620	2	0.3	24,000	54	10
BR2	Brush Creek at Belinder	390127094365800	4/6/2010	1030	31,000	24,000	2,500	1,000	63,000	1.4	14.0	600	2	1.3	29,000	75	15
CA1	Captain Creek near 119th Street	385540095032800	3/31/2003	1245	22,000	16,000	2,000	620	51,000	0.3	7.2	560	1	0.4	25,000	46	10
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	910	16,000	14,000	1,500	590	58,000	0.7	8.0	670	2	0.2	--	60	12
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	1510	11,000	10,000	1,100	440	52,000	0.8	6.7	600	2	0.1	7,000	47	9
CE1	Cedar Creek at Old Highway 56	6892440	4/1/2003	1300	66,000	22,000	2,000	1,900	42,000	1.0	21.0	410	2	0.8	12,000	56	16
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	915	24,000	14,000	1,400	1,100	100,000	1.6	19.0	1,100	3	0.7	--	120	20
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	835	33,000	15,000	1,700	590	51,000	1.0	8.6	560	2	0.5	62,000	56	10
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/1/2003	1100	11,000	10,000	1,000	1,100	64,000	0.4	5.3	680	2	0.7	10,000	61	13
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1050	14,000	12,000	900	780	63,000	0.9	8.8	680	2	0.4	--	65	13
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1100	9,000	8,000	80	560	55,000	0.9	6.9	590	2	0.4	11,000	53	9
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1420	13,000	10,000	1,000	580	54,000	0.8	8.6	680	2	0.3	--	57	13
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1330	33,000	23,000	1,600	600	48,000	1.4	7.4	590	1	1.8	42,000	52	11
IN3a	Indian Creek at College Blvd	385520094420000	4/2/2003	1300	51,000	47,000	6,000	2,300	46,000	0.9	5.9	620	1	0.9	25,000	49	10
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1325	15,000	12,000	1,300	750	56,000	0.8	8.9	690	2	0.3	--	59	14
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1230	48,000	36,000	4,000	1,500	49,000	1.5	7.0	590	1	1.3	42,000	53	10
IN6	Indian Creek at State Line Road	6893390	4/2/2003	1100	29,000	23,000	2,000	1,700	47,000	0.7	8.7	600	1	0.7	25,000	51	13
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1035	19,000	16,000	1,700	890	59,000	0.9	9.5	700	2	0.4	--	65	14
IN6	Indian Creek at State Line Road	6893390	4/6/2010	1515	38,000	28,000	2,400	980	51,000	1.5	8.8	560	2	2.3	36,000	56	12

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[USGS, U.S. Geological Survery; mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available; <, less than]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Carbon (inorganic plus organic), mg/kg (1,000)	Organic carbon, mg/kg (1,000)	Total nitrogen, mg/kg (100)	Phosphorus, mg/kg (100)	Aluminum, mg/kg (1)	Antimony, mg/kg	Arsenic, mg/kg (0.1)	Barium, mg/kg (1)	Beryllium, mg/kg (0.1)	Cadmium, mg/kg	Calcium, mg/kg	Chromium, mg/kg (1)	Cobalt, mg/kg (1)
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)											33			4.98		111	
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1410	17,000	15,000	1,300	660	57,000	0.8	9.3	630	2	0.3	--	64	11
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	1310	22,000	20,000	2,200	860	56,000	0.9	9.1	600	2	0.3	13,000	56	11
KI5b alt	Kill Creek at 135th Street	385303094582300	3/31/2003	1200	25,000	21,000	2,000	820	45,000	0.5	7.2	550	1	0.6	30,000	44	13
KI6b	Kill Creek at 95th Street	6892360	3/31/2003	1040	37,000	20,000	2,000	660	48,000	0.5	5.7	510	1	0.4	47,000	47	10
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1235	13,000	10,000	1,000	620	68,000	0.8	6.9	690	2	0.4	--	66	11
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1200	12,000	11,000	1,300	620	56,000	0.9	7.5	580	2	0.3	12,000	62	9
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1320	13,000	13,000	1,200	580	51,000	0.8	7.6	620	1	0.3	10,000	50	9
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	825	19,000	15,000	1,500	690	64,000	0.9	11.0	680	2	0.7	--	70	15
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1200	16,000	15,000	1,500	750	64,000	1.1	14.0	670	2	0.7	14,000	66	16
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	920	18,000	15,000	1,300	630	63,000	0.9	10.0	680	2	0.4	--	67	12
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	720	18,000	15,000	1,200	670	64,000	1.0	10.0	690	2	0.4	--	71	16
MI1	Mill Creek at 127th Street	385356094491200	4/1/2003	1200	35,000	23,000	1,000	1,500	42,000	1.3	20.0	580	1	0.9	50,000	48	16
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1155	24,000	18,000	1,400	690	58,000	1.2	11.0	660	2	0.6	--	68	11
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1450	18,000	16,000	1,400	660	62,000	1.2	12.0	670	2	0.7	19,000	68	12
MI4	Mill Creek at 87th Street Lane	385800094485300	4/1/2003	1000	59,000	18,000	2,000	1,100	40,000	0.6	6.4	400	1	0.6	100,000	40	9
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1245	20,000	14,000	1,300	700	60,000	0.9	9.5	630	2	0.3	--	66	12
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1305	21,000	15,000	1,500	820	61,000	1.2	9.8	620	2	0.6	27,000	65	12
MI7	Mill Creek at Johnson Drive	6892513	4/1/2003	900	15,000	13,000	1,000	890	57,000	0.6	7.9	650	2	0.6	16,000	56	12
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1045	11,000	8,000	900	670	58,000	0.8	8.6	680	2	0.3	--	59	11
MI7	Mill Creek at Johnson Drive	6892513	4/9/2010	1000	8,000	7,000	80	620	62,000	1.0	6.9	640	2	0.5	11,000	60	10
TO2	Tomahawk Creek near 111th Street	385539094372100	4/2/2003	1200	23,000	16,000	2,000	700	56,000	0.8	10.0	580	2	0.8	28,000	53	14
TO2	Tomahawk Creek near 111th Street	385539094372100	3/12/2007	1205	13,000	10,000	900	590	56,000	0.8	9.1	650	2	0.3	--	58	13
TO2	Tomahawk Creek near 111th Street	385539094372100	4/6/2010	1420	37,000	25,000	2,000	680	54,000	1.4	7.6	600	2	1.0	48,000	57	12
TU1	Turkey Creek at 67th Street	390027094415600	4/2/2003	900	31,000	9,000	1,000	1,000	44,000	1.3	19.0	610	1	0.7	70,000	47	21
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	905	14,000	11,000	1,000	620	55,000	0.9	9.4	670	2	0.7	--	58	13
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	1010	21,000	15,000	1,200	630	56,000	1.3	9.0	650	2	1.3	26,000	61	12
Minimum value					8,000	7,000	80	440	40,000	0.3	5.3	400	1	0.1	7,000	40	9
Maximum value					66,000	61,000	7,000	2,600	100,000	1.6	21.0	1,100	3	2.3	100,000	120	21

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Copper, mg/kg (1)	Iron, mg/kg (1,000)	Lead, mg/kg (1)	Lithium, mg/kg (1)	Magnesium, mg/kg	Manganese, mg/kg (10)	Mercury, mg/kg (0.01)	Molybdenum, mg/kg (1)	Nickel, mg/kg (1)	Potassium, mg/kg	Selenium, mg/kg (0.1)	Silver, mg/kg (0.5)	Sodium, mg/kg
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)					149		128				1.06		48.6				
BI1	Big Bull Creek near Edgerton	6914950	3/31/2003	915	25	36,000	34	40	7,000	3,200	0.03	<1	37	15,000	1.3	0.5	4,000
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	810	20	27,000	26	32	--	810	<0.01	1	27	--	0.7	<0.5	--
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1130	15	21,000	22	28	4,000	670	0.03	1	20	17,000	0.5	<.5	7,000
BL3	Blue River near Stanley (Highway 69)	6893080	4/3/2003	1045	16	25,000	24	30	5,000	650	<.01	<1	25	15,000	0.4	<.5	6,000
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1345	17	23,000	17	29	--	590	<.01	<1	21	--	0.3	<.5	--
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1420	16	23,000	20	28	5,000	1,000	0.02	<1	22	17,000	0.4	<.5	7,000
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1250	19	25,000	20	31	--	780	<.01	<1	26	--	0.5	<.5	--
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1520	16	22,000	21	28	5,000	1,700	0.02	<1	22	16,000	0.5	<.5	7,000
BL5	Blue River at Kenneth Road	6893100	4/3/2003	930	20	26,000	26	33	5,000	880	0.02	<1	29	15,000	0.8	<.5	6,000
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1050	17	22,000	19	28	--	660	<.01	<1	22	--	0.4	<.5	--
BL5	Blue River at Kenneth Road	6893100	4/6/2010	850	17	23,000	21	29	5,000	1,100	0.02	<1	22	17,000	0.4	<.5	7,000
BR2	Brush Creek at Belinder	390127094365800	4/6/2010	1030	37	31,000	60	40	8,000	800	0.13	1	38	20,000	1.0	<.5	7,000
CA1	Captain Creek near 119th Street	385540095032800	3/31/2003	1245	15	21,000	21	26	5,000	640	0.01	<1	23	13,000	0.7	<.5	5,000
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	910	17	25,000	22	31	--	700	0.10	<1	23	--	0.5	<.5	--
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	1510	13	20,000	20	27	4,000	600	0.01	<1	18	16,000	0.4	<.5	8,000
CE1	Cedar Creek at Old Highway 56	6892440	4/1/2003	1300	20	42,000	38	29	8,000	1,100	0.03	1	43	12,000	1.7	<.5	4,000
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	915	38	51,000	46	54	--	1,100	0.10	2	53	--	1.4	<.5	--
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	835	17	23,000	25	27	8,000	960	0.02	1	26	17,000	0.9	<.5	7,000
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/1/2003	1100	17	27,000	20	33	7,000	600	0.02	<1	33	19,000	0.4	<.5	8,000
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1050	20	29,000	25	34	--	710	0.11	<1	29	--	0.5	<.5	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1100	16	23,000	20	28	5,000	530	0.02	1	21	18,000	0.3	<.5	7,000
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1420	18	24,000	25	28	--	770	0.02	<1	24	--	0.4	<.5	--
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1330	22	21,000	49	26	5,000	1,100	0.03	1	21	16,000	0.5	<.5	8,000
IN3a	Indian Creek at College Blvd	385520094420000	4/2/2003	1300	33	21,000	30	25	5,000	540	0.05	1	23	14,000	0.8	2.3	7,000
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1325	20	25,000	26	30	--	830	0.06	<1	27	--	0.4	<.5	--
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1230	28	22,000	41	27	6,000	940	0.06	1	23	16,000	0.7	0.6	8,000
IN6	Indian Creek at State Line Road	6893390	4/2/2003	1100	23	25,000	33	28	5,000	690	0.04	<1	28	14,000	0.7	1.4	6,000
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1035	22	28,000	26	35	--	930	0.04	1	30	--	0.5	<.5	--
IN6	Indian Creek at State Line Road	6893390	4/6/2010	1515	26	23,000	60	30	6,000	970	0.04	1	25	17,000	0.5	<.5	7,000

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[USGS, U.S. Geological Survery; mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available; <, less than]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Copper, mg/kg (1)	Iron, mg/kg (1,000)	Lead, mg/kg (1)	Lithium, mg/kg (1)	Magnesium, mg/kg	Manganese, mg/kg (10)	Mercury, mg/kg (0.01)	Molybdenum, mg/kg (1)	Nickel, mg/kg (1)	Potassium, mg/kg	Selenium, mg/kg (0.1)	Silver, mg/kg (0.5)	Sodium, mg/kg
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)					149		128				1.06		48.6				
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1410	19	26,000	22	30	--	710	0.02	<1	26	--	0.4	<.5	--
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	1310	25	25,000	23	29	5,000	950	0.04	1	25	17,000	0.6	0.5	6,000
KI5b alt	Kill Creek at 135th Street	385303094582300	3/31/2003	1200	16	21,000	23	24	4,000	720	0.01	<1	25	14,000	0.8	<.5	6,000
KI6b	Kill Creek at 95th Street	6892360	3/31/2003	1040	17	23,000	23	27	6,000	450	0.03	<1	24	13,000	0.6	<.5	5,000
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1235	23	29,000	22	35	--	460	0.03	<1	28	--	0.6	0.5	--
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1200	19	27,000	23	29	5,000	530	0.02	1	24	17,000	0.4	<.5	7,000
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1320	15	21,000	23	25	4,000	720	0.02	<1	19	17,000	0.4	<.5	7,000
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	825	23	32,000	31	36	--	820	0.20	1	33	--	0.5	<.5	--
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1200	24	34,000	36	37	6,000	1,100	0.03	1	34	19,000	0.5	<.5	7,000
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	920	22	30,000	28	35	--	840	<.01	1	30	--	0.5	<.5	--
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	720	24	33,000	30	36	--	880	0.01	1	34	--	0.5	<.5	--
MI1	Mill Creek at 127th Street	385356094491200	4/1/2003	1200	23	34,000	73	22	4,000	1,100	0.11	1	35	13,000	0.7	<.5	5,000
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1155	27	28,000	61	30	--	690	0.08	1	29	--	0.7	<.5	--
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1450	23	30,000	44	33	6,000	790	0.03	1	31	18,000	0.5	<.5	7,000
MI4	Mill Creek at 87th Street Lane	385800094485300	4/1/2003	1000	18	20,000	24	25	8,000	980	0.04	1	24	12,000	0.5	0.5	6,000
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1245	21	28,000	27	33	--	820	0.02	1	30	--	1.1	<.5	--
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1305	25	28,000	30	35	7,000	1,000	0.03	1	31	19,000	0.7	<.5	7,000
MI7	Mill Creek at Johnson Drive	6892513	4/1/2003	900	19	26,000	25	30	6,000	760	0.01	<1	29	17,000	0.4	<.5	7,000
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1045	19	26,000	22	30	--	680	0.02	1	26	--	0.4	<.5	--
MI7	Mill Creek at Johnson Drive	6892513	4/9/2010	1000	20	26,000	22	33	6,000	520	0.04	1	27	19,000	0.3	<.5	7,000
TO2	Tomahawk Creek near 111th Street	385539094372100	4/2/2003	1200	19	28,000	28	36	6,000	1,300	0.02	<1	30	16,000	0.4	<.5	7,000
TO2	Tomahawk Creek near 111th Street	385539094372100	3/12/2007	1205	18	26,000	23	32	--	740	<.01	1	27	--	0.3	<.5	--
TO2	Tomahawk Creek near 111th Street	385539094372100	4/6/2010	1420	24	24,000	35	32	6,000	1,400	0.03	1	26	17,000	0.5	<.5	7,000
TU1	Turkey Creek at 67th Street	390027094415600	4/2/2003	900	20	31,000	45	25	6,000	1,800	0.01	2	36	15,000	0.6	<.5	6,000
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	905	21	26,000	33	27	--	840	0.01	1	27	--	0.3	<.5	--
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	1010	26	25,000	48	29	6,000	860	0.03	1	28	18,000	0.4	<.5	8,000
Minimum value					13	20,000	17	22	4,000	450	0.01	<1	18	12,000	0.3	0.5	4,000
Maximum value					38	51,000	73	54	8,000	3,200	0.20	2	53	20,000	1.7	2.3	8,000

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[USGS, U.S. Geological Survery; mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available; <, less than]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Strontium, mg/kg (1)	Sulfur, mg/kg	Thallium, mg/kg (50)	Tin, mg/kg	Titanium, mg/kg (50)	Uranium, mg/kg	Vanadium, mg/kg (1)	Zinc, mg/kg (1)	1-Methylnaphthalene, µg/kg (50)	2,6-Dimethylnaphthalene, µg/kg(50)	2-Methylnaphthalene, µg/kg (50)	3-*beta*-Coprostanol, µg/kg (500)	3-Methyl-1H-indole, µg/kg (50)
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)												459					
BI1	Big Bull Creek near Edgerton	6914950	3/31/2003	915	160	1,000	<50	--	3,700	<50	100	190	<50	52	<50	800	220
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	810	140	400	<50	--	4,500	<50	89	100	<20	E5.9	<20	E83	<20
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1130	130	300	<50	1	4,200	<50	73	70	<100	E35	<100	<1,000	E17
BL3	Blue River near Stanley (Highway 69)	6893080	4/3/2003	1045	170	<1,000	<50	--	3,300	<50	69	99	<50	<50	<50	210	53
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1345	140	300	<50	--	4,400	<50	76	73	<70	E23	<70	<700	E41
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1420	170	600	<50	1	4,100	<50	75	74	<154	E87	<154	<1,540	E69
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1250	150	400	<50	--	4,100	<50	80	78	<40	E32	<40	E97	148
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1520	190	800	<50	<1	3,500	<50	70	89	<246	E220	<246	<2,460	E159
BL5	Blue River at Kenneth Road	6893100	4/3/2003	930	150	1,000	<50	--	3,600	<50	78	110	<50	<50	<50	200	120
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1050	140	300	<50	--	4,200	<50	77	71	<70	E14	<70	E182	E43
BL5	Blue River at Kenneth Road	6893100	4/6/2010	850	150	400	<50	<1	3,900	<50	76	74	<114	E110	<114	<1,140	E45
BR2	Brush Creek at Belinder	390127094365800	4/6/2010	1030	210	1,600	<50	4	3,800	<50	98	250	E38	E33	E47	E83,900	E18
CA1	Captain Creek near 119th Street	385540095032800	3/31/2003	1245	210	<1,000	<50	--	3,000	<50	67	100	<50	E11	<50	250	71
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	910	150	300	<50	--	4,600	<50	83	80	<30	<30	<30	<300	<30
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	1510	130	200	<50	<1	4,200	<50	68	58	<64	E5.6	<64	<640	E9.5
CE1	Cedar Creek at Old Highway 56	6892440	4/1/2003	1300	420	1,000	<50	--	2,100	<50	84	180	<50	86	<50	990	210
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	915	390	1,600	<50	--	6,900	<50	160	200	<40	E11	<40	<400	E12
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	835	310	1,200	<50	1	3,500	<50	75	110	<67	E5.6	<67	<670	E9.8
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/1/2003	1100	160	<1,000	<50	--	3,900	<50	89	140	<50	<50	<50	<200	E17
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1050	160	300	<50	--	4,300	<50	94	98	<30	<30	<30	<300	<30
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1100	140	200	<50	2	4,800	<50	81	73	<242	<242	<242	<2,420	<242
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1420	160	500	<50	--	4,200	<50	78	110	E23	E20	E29	E211	E28
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1330	230	1,800	<50	1	3,700	<50	69	440	E25	89	E39	<725	73
IN3a	Indian Creek at College Blvd	385520094420000	4/2/2003	1300	200	3,000	<50	--	3,200	<50	60	230	<50	280	<50	10,000	450
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1325	150	600	<50	--	4,300	<50	82	100	<30	E4.9	E5.8	E2,190	161
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1230	230	2,400	<50	2	3,600	<50	70	370	<220	226	<220	E6,560	E183
IN6	Indian Creek at State Line Road	6893390	4/2/2003	1100	160	1,000	<50	--	3,100	<50	68	170	<50	55	<50	5,500	160
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1035	160	600	<50	--	4,300	<50	88	130	<85	E17	<85	E12,900	458
IN6	Indian Creek at State Line Road	6893390	4/6/2010	1515	250	3,200	<50	2	3,600	<50	74	500	E46	149	E69	E6,380	E84

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Strontium, mg/kg (1)	Sulfur, mg/kg	Thallium, mg/kg (50)	Tin, mg/kg	Titanium, mg/kg (50)	Uranium, mg/kg	Vanadium, mg/kg (1)	Zinc, mg/kg (1)	1-Methylnaphthalene, µg/kg (50)	2,6-Dimethylnaphthalene, µg/kg(50)	2-Methylnaphthalene, µg/kg (50)	3-*beta*-Coprostanol, µg/kg (500)	3-Methyl-1H-indole, µg/kg (50)
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)												459					
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1410	140	300	<50	--	4,300	<50	85	88	<50	E12	<50	E160	E23
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	1310	130	400	<50	2	4,100	<50	82	89	<162	E28	<162	E3,690	E40
KI5b alt	Kill Creek at 135th Street	385303094582300	3/31/2003	1200	150	1,000	<50	--	3,100	<50	61	100	<50	<50	<50	220	90
KI6b	Kill Creek at 95th Street	6892360	3/31/2003	1040	200	1,000	<50	--	3,100	<50	67	100	<50	<50	<50	<200	<50
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1235	160	300	<50	--	4,300	<50	100	97	<30	E5.1	<30	E57	<30
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1200	140	400	<50	2	5,100	<50	85	78	<78	<78	<78	<775	E4.0
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1320	130	300	<50	<1	4,000	<50	71	70	<77	E29	<77	<770	E15.
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	825	160	600	<50	--	4,400	<50	97	180	<40	E14	<40	<400	E14
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1200	160	700	<50	2	4,200	<50	99	190	<182	<182	<182	<1,820	E31
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	920	150	400	<50	--	4,300	<50	93	140	<65.0	<65.0	<65	<650	<65
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	720	150	400	<50	--	4,400	<50.0	99	150	<70.0	E7.58	<70	<700	E19
MI1	Mill Creek at 127th Street	385356094491200	4/1/2003	1200	220	1,000	<50	--	2,500	<50	74	230	E2.6	E3.0	E6.6	<200	E18
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1155	180	600	<50	--	4,000	<50	89	170	142	E87	265	E239	E38
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1450	170	500	<50	2	4,200	<50	97	180	<153	E14	<153	<1,530	E9.9
MI4	Mill Creek at 87th Street Lane	385800094485300	4/1/2003	1000	360	<1,000	<50	--	2,300	<50	50	130	<50	130	<50	1,200	200
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1245	180	500	<50	--	4,400	<50	88	110	E46	E29	52	E248	E45
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1305	190	700	<50	2	4,200	<50	89	150	<120	E20	<120	E1,280	E10
MI7	Mill Creek at Johnson Drive	6892513	4/1/2003	900	140	<1,000	<50	--	3,500	<50	78	130	<50	<50	<50	210	77
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1045	160	300	<50	--	4,200	<50	86	93	<40	E19	<40	E286	E24
MI7	Mill Creek at Johnson Drive	6892513	4/9/2010	1000	150	300	<50	1	4,300	<50	93	91	<173	E19	<173	<1,730	E20
TO2	Tomahawk Creek near 111th Street	385539094372100	4/2/2003	1200	170	1,000	<50	--	3,300	<50	74	160	E13	70	E16	<200	1,000
TO2	Tomahawk Creek near 111th Street	385539094372100	3/12/2007	1205	150	500	<50	--	4,300	<50	81	89	<50	E20	<50	E153	E33
TO2	Tomahawk Creek near 111th Street	385539094372100	4/6/2010	1420	240	2,100	<50	2	3,800	<50	77	260	E36	E154	E42	<1,080	E74
TU1	Turkey Creek at 67th Street	390027094415600	4/2/2003	900	230	<1,000	<50	--	2,600	<50	70	140	<50	<50	<50	<200	<50
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	905	160	400	<50	--	4,100	<50	81	160	E46	E19	72	<250	E7.6
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	1010	200	1,400	<50	2	4,100	<50	85	300	<137	E28	<137	<1,370	E14
Minimum value					130	200	<50	<1	2,100	<50	50	58	<50	<50	<50	<200	<30
Maximum value					420	3,200	<50	4	6,900	<50	160	500	142	280	265	10,000	1,000

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

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Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	4-Nonylphenol monoethoxylate (sum of all isomers), µg/kg (500)	4-Nonylphenol (sum of all isomers), µg/kg (750)	4-Nonylphenol diethoxylate (sum of all isomers), µg/kg (1,000)	4-*tert*-Octylphenol monoethoxylate, µg/kg (250)	4-*tert*-Octylphenol, µg/kg (50)	9,10-Anthraquinone, µg/kg (50)	Acetophenone, µg/kg (150)	Acetyl hexamethyl tetrahydro naphthalene, µg/kg (50)	Anthracene, µg/kg (50)	Benzo[a]pyrene, µg/kg (50)	*beta*-Sitosterol, µg/kg (500)
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)													845	1,450	
BI1	Big Bull Creek near Edgerton	6914950	3/31/2003	915	<500	<500	<500	<100	<50	<50	<50	<50	<50	<50	28,000
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	810	<250	<380	<500	<120	<20	<20	<80	<20	<25	<20	E820
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1130	<1,000	<1,500	<2,000	<500	<100	<100	<300	<100	<100	<100	E6,400
BL3	Blue River near Stanley (Highway 69)	6893080	4/3/2003	1045	<500	<500	<500	<100	<50	<50	<50	<50	<50	<50	4,000
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1345	<700	E499	<1,400	<350	<70	<70	<210	<70	<70	<70	E5,700
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1420	<1,540	<2,300	<3,070	<768	<154	E72	<460	<150	<150	<150	E11,000
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1250	<400	<600	<800	<200	<40	E20	<120	<40	E10	E20	E3,200
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1520	<2,460	<3,700	<4,930	<1,230	<246	<250	<740	<250	<250	E50	E21,000
BL5	Blue River at Kenneth Road	6893100	4/3/2003	930	<500	<500	<500	<100	<50	<50	<50	<50	<50	<50	9,900
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1050	<700	<1,050	<1,400	<350	<70	<70	<210	<70	<70	E20	E3,800
BL5	Blue River at Kenneth Road	6893100	4/6/2010	850	<1,140	<1,710	<2,280	<570	<114	<110	<340	<110	<110	E20	E9,000
BR2	Brush Creek at Belinder	390127094365800	4/6/2010	1030	<1,380	<2,070	<2,760	<690	<138	E1,500	<410	<140	170	E1,900	E12,000
CA1	Captain Creek near 119th Street	385540095032800	3/31/2003	1245	<500	<500	<500	<100	<50	<50	<50	<50	<50	<50	5,600
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	910	<300	<450	<600	<150	<30	<30	<90	<30	<30	<30	E1,000
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	1510	<640	<960	<1,280	<320	<64	<60	E40	<60	<60	<60	<640
CE1	Cedar Creek at Old Highway 56	6892440	4/1/2003	1300	E460	<500	E940	<100	<50	130	<50	E50	E40	220	5,100
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	915	<400	<600	<800	<200	<40	<40	<120	<40	<40	E9.7	E1,100
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	835	<670	<1,000	<1,340	<335	<67	<70	<200	<70	<70	<70	<840
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/1/2003	1100	<500	<500	<500	<100	<50	<50	<50	E50	<50	<50	2,600
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1050	<300	<450	<600	<150	<30	E12	<90	<30	<30	<30	E1,200
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1100	<2,420	<3,620	<4,830	<1210	<242	<242	<720	<240	<240	E20	<3,300
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1420	<650	<975	<1,300	<325	<65	597	<200	<70	190	990	E3,200
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1330	<720	<1,090	<1,450	<362	<72	<72	E90	<70	440	E10,000	E6,500
IN3a	Indian Creek at College Blvd	385520094420000	4/2/2003	1300	1,500	E950	E4,200	<100	<50	580	<50	930	160	1,100	9,800
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1325	E640	E429	E249	E34	E13	109	<90	E20	E40	200	E2,000
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1230	E1,370	<3310	E2,290	E121	<220	E3140	E200	E20	320	E2,800	E15,000
IN6	Indian Creek at State Line Road	6893390	4/2/2003	1100	1,100	1,600	E1,400	<100	<50	590	<50	210	230	1,300	8,300
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1035	E1,290	E517	<1,700	<425	<85	483	<260	E10	290	980	E5,300
IN6	Indian Creek at State Line Road	6893390	4/6/2010	1515	<1,380	<2060	<2,750	<688	<138	E8390	E120	E10	510	E7,800	E13,400

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[USGS, U.S. Geological Survery; mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available; <, less than]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	4-Nonylphenol monoethoxylate (sum of all isomers), µg/kg (500)	4-Nonylphenol (sum of all isomers), µg/kg (750)	4-Nonylphenol diethoxylate (sum of all isomers), µg/kg (1,000)	4-*tert*-Octylphenol monoethoxylate, µg/kg (250)	4-*tert*-Octylphenol, µg/kg (50)	9,10-Anthraquinone, µg/kg (50)	Acetophenone, µg/kg (150)	Acetyl hexamethyl tetrahydro naphthalene, µg/kg (50)	Anthracene, µg/kg (50)	Benzo[a]pyrene, µg/kg (50)	*beta*-Sitosterol, µg/kg (500)
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)													845	1,450	
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1410	<500	<750	<1,000	<250	<50	<50	<150	<50	<50	E6.4	E2,400
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	1310	<1,620	<2440	<3,250	<812	<162	<162	<490	<160	<160	<160	E11,000
KI5b alt	Kill Creek at 135th Street	385303094582300	3/31/2003	1200	<500	<500	<500	<100	<50	<50	<50	<50	<50	<50	5,800
KI6b	Kill Creek at 95th Street	6892360	3/31/2003	1040	<500	<500	<500	<100	<50	E28	<50	<50	E50	60	16,000
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1235	<300	<450	<600	<150	<30	<30	<90	<30	<30	<30	E1,100
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1200	<780	<1,160	<1,550	<388	<78	<78	<230	<80	<80	<80	<780
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1320	<770	<1,160	<1,540	<385	<77	E29	<230	<80	<80	E20	<770
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	825	<400	<600	<800	<200	<40	378	E10	<40	110	500	E1,800
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1200	<1,820	<2,730	<3,640	<910	<182	E251	<550	<180	E40	E280	<2,100
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	920	<650	<975	<1,300	<325	<65	388	<195	<65	154	429	E1,300
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	720	<700	<1,050	<1,400	<350	<70	551	<210	<70	219	1,130	E2,430
MI1	Mill Creek at 127th Street	385356094491200	4/1/2003	1200	<500	<500	E83	<100	<50	110	<50	<50	50	280	1,600
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1155	<1,000	<1,500	<2,000	<500	<100	622	<300	<100	230	1,100	E8,600
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1450	<1,530	<2,300	<3,060	<765	<153	E172	<460	<153	E50	240	<1,500
MI4	Mill Creek at 87th Street Lane	385800094485300	4/1/2003	1000	E490	E1.8	E700	<100	<50	110	E10	E50	E20	190	6,200
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1245	<450	<675	<900	<225	<45	185	E40	<40	140	310	E3,400
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1305	<1,200	<1,800	<2,400	<600	<120	E224	E140	<120	E40	300	<1,300
MI7	Mill Creek at Johnson Drive	6892513	4/1/2003	900	<500	<500	E120	<100	<50	91	<50	<50	E32	170	3,300
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1045	<400	<600	<800	<200	<40	143	E20	<40	E30	160	E2,600
MI7	Mill Creek at Johnson Drive	6892513	4/9/2010	1000	<1,730	<2,600	<3,460	<865	<173	E53	E120	<170	E10	E60	<2,100
TO2	Tomahawk Creek near 111th Street	385539094372100	4/2/2003	1200	E620	562	E590	<100	<50	310	<50	<50	100	700	4,500
TO2	Tomahawk Creek near 111th Street	385539094372100	3/12/2007	1205	<500	<750	<1,000	<250	<50	397	E50	<50	110	580	E2,700
TO2	Tomahawk Creek near 111th Street	385539094372100	4/6/2010	1420	<1,080	<1,620	<2,160	<540	<108	E4220	E210	<110	280	E3,700	E7,300
TU1	Turkey Creek at 67th Street	390027094415600	4/2/2003	900	<500	<500	<500	<100	<50	210	<50	<50	80	350	850
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	905	<190	<375	E207	<125	<25	915	<80	<20	510	1,200	E2,600
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	1010	<1,370	<2,060	<2,740	<685	<137	E1420	E80	<140	190	E2,400	<1,400
Minimum value					<190	<375	<500	<100	<25	<30	<50	<30	<30	<30	<640
Maximum value					1,500	1,600	E4,200	E121	E13	915	E210	930	510	1,300	28,000

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	*beta*-Stigmastanol, µg/kg (500)	Bis(2-ethylhexyl) phthalate, µg/kg (250)	Bisphenol A, µg/kg (100)	Carbazole, µg/kg (50)	Cholesterol, µg/kg (250)	*cis*-Chlordane, µg/kg	*cis*-Nonachlor, µg/kg	Dieldrin, µg/kg	D-Limonene, µg/kg (50)	Estrone, µg/kg	Fluoranthene, µg/kg (50)	Heptachlor, µg/kg	Hexachlorobenzene, µg/kg
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)															2,230		
BI1	Big Bull Creek near Edgerton	6914950	3/31/2003	915	2,000	--	<100	<50	12,000	<3.0	<3.0	<3.0	E15	<250	<50	<3.0	<3.0
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	810	E150	<120	--	<20	E470	--	--	--	<20	--	<20	--	--
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1130	E860	<500	E27	<100	E3,700	--	--	--	<100	--	E30	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	4/3/2003	1045	570	--	<100	<50	3,000	<1.0	<1.0	<1.0	<50	<250	<50	<1.0	<1.0
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1345	E1300	E150	--	<70	E2,100	--	--	--	<70	--	E20	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1420	E1500	<770	E300	E15	E7,300	--	--	--	E70	--	E80	--	--
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1250	E360	<200	--	E11	E1,300	--	--	--	<40	--	84	--	--
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1520	E3,100	<1,200	E680	<250	E22,000	--	--	--	E150	--	E170	--	--
BL5	Blue River at Kenneth Road	6893100	4/3/2003	930	1,000	--	<100	<50	4,100	E.56	<2.0	E.64	<50	<250	<50	<2.0	<2.0
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1050	E880	E170	--	<70	E1,600	--	--	--	E33	--	E39	--	--
BL5	Blue River at Kenneth Road	6893100	4/6/2010	850	E1,500	<570	E93	E11	E6900	--	--	--	<114	--	E80	--	--
BR2	Brush Creek at Belinder	390127094365800	4/6/2010	1030	E2,700	E1,000	E220	360	E92,000	--	--	--	<138	--	E11,000	--	--
CA1	Captain Creek near 119th Street	385540095032800	3/31/2003	1245	640	--	<100	<50	3,000	<1.0	<1.0	1	<50	<250	<50	<1.0	<1.0
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	910	E240	<150	--	<30	E500	--	--	--	E100	--	<30	--	--
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	1510	<640	<320	E13	<64	<320	--	--	--	<64	--	<64	--	--
CE1	Cedar Creek at Old Highway 56	6892440	4/1/2003	1300	E460	--	<100	E50	4,000	<2.0	<2.0	<2.0	<50	<250	720	<2.0	<2.0
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	915	<400	<200	--	<40	E640	--	--	--	<40	--	E24	--	--
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	835	<670	<340	E7.6	<70	E1,900	--	--	--	<70	--	<67	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/1/2003	1100	E240	--	<100	<50	2,800	<1.0	<1.0	<1.0	<50	<250	64	<1.0	<1.0
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1050	E190	<150	--	E4.3	E440	--	--	--	<30	--	E30	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1100	<2400	<1,200	E140	<240	<1,200	--	--	--	<242	--	E100	--	--
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1420	E370	E190	E30	300	E1,100	--	--	--	<70	--	4,000	--	--
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1330	E510	E1,700	E330	E1,100	E4,200	--	--	--	<73	--	E1,200	--	--
IN3a	Indian Creek at College Blvd	385520094420000	4/2/2003	1300	1,100	--	E100	310	30,000	2.5	<2.0	<2.0	<50	<250	3,000	<2.0	<2.0
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1325	E350	230	E20	60	E5,600	--	--	--	E32	--	1,200	--	--
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1230	E1,700	E1,100	E550	840	E15,000	--	--	--	<220	--	E33,000	--	--
IN6	Indian Creek at State Line Road	6893390	4/2/2003	1100	1,200	--	<100	300	10,000	6.7	1.0	6	<50	<250	3,400	<1.0	<1.0
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1035	E1,500	620	--	270	E9,300	--	--	--	<90	--	4,100	--	--
IN6	Indian Creek at State Line Road	6893390	4/6/2010	1515	E2,300	E5,300	E250	E1,200	E13,000	--	--	--	<138	--	E17,000	--	--

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	*beta*-Stigmastanol, µg/kg (500)	Bis(2-ethylhexyl) phthalate, µg/kg (250)	Bisphenol A, µg/kg (100)	Carbazole, µg/kg (50)	Cholesterol, µg/kg (250)	*cis*-Chlordane, µg/kg	*cis*-Nonachlor, µg/kg	Dieldrin, µg/kg	D-Limonene, µg/kg (50)	Estrone, µg/kg	Fluoranthene, µg/kg (50)	Heptachlor, µg/kg	Hexachlorobenzene, µg/kg
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)															2,230		
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1410	E450	<250	--	<50	E1,100	--	--	--	<50	--	E40	--	--
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	1310	E2,100	<810	E270	E15	E10,000	--	--	--	E124	--	<160	--	--
KI5b alt	Kill Creek at 135th Street	385303094582300	3/31/2003	1200	760	--	<100	<50	3,300	<2.0	<2.0	<2.0	<50	E11	<50	<2.0	<2.0
KI6b	Kill Creek at 95th Street	6892360	3/31/2003	1040	2,300	--	E24	<50	2,100	<1.0	<1.0	E.70	E200	<250	70	<1.0	<1.0
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1235	E170	<150	--	<30	E640	--	--	--	<30	--	<30	--	--
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1200	<780	<390	<80	<80	<390	--	--	--	<80	--	<80	--	--
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1320	E630	<390	E500	E7.1	E2,500	--	--	--	<80	--	E73	--	--
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	825	E230	250	--	180	E770	--	--	--	<40	--	1,700	--	--
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1200	<1,800	<910	<180	E70	<910	--	--	--	<182	--	E900	--	--
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	920	<650	E226	--	240	E385	--	--	--	<65	--	3,370	--	--
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	720	<700	369	<70	316	E1,110	--	--	--	<70	--	4,460	--	--
MI1	Mill Creek at 127th Street	385356094491200	4/1/2003	1200	E170	--	<100	E40	820	5.7	1.5	3	<50	<250	730	E1.2	E.37
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1155	E1,000	810	--	300	E1,600	--	--	--	E46	--	3,300	--	--
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1450	<1,500	E490	E130	E60	E3,800	--	--	--	<153	--	E960	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	4/1/2003	1000	E370	--	<100	E40	4,600	2.6	<1.0	2	<50	<250	550	<1.0	<1.0
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1245	E440	E100	--	120	E1,300	--	--	--	E30	--	1,000	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1305	<1200	<600	E170	E80	E4,100	--	--	--	E60	--	E1,200	--	--
MI7	Mill Creek at Johnson Drive	6892513	4/1/2003	900	E440	--	<100	E31	2,100	E.63	<1.0	E.42	<50	<250	490	<1.0	<1.0
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1045	E320	E130	--	60	E1,200	--	--	--	E20	--	640	--	--
MI7	Mill Creek at Johnson Drive	6892513	4/9/2010	1000	<1,700	<870	E120	E20	E4,000	--	--	--	<173	--	E230	--	--
TO2	Tomahawk Creek near 111th Street	385539094372100	4/2/2003	1200	960	--	140	140	4,000	E.83	<1.0	<1.0	E42	<250	1,900	<1.0	<1.0
TO2	Tomahawk Creek near 111th Street	385539094372100	3/12/2007	1205	E390	E240	--	180	E1,000	--	--	--	<50	--	2,000	--	--
TO2	Tomahawk Creek near 111th Street	385539094372100	4/6/2010	1420	<1,100	E570	E180	9,710	E3,600	--	--	--	<110	--	E18,000	--	--
TU1	Turkey Creek at 67th Street	390027094415600	4/2/2003	900	E100	--	<100	60	610	2.3	<1.0	E.78	<50	<250	830	<1.0	<1.0
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	905	E230	E110	--	760	E380	--	--	--	<20	--	7,100	--	--
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	1010	E680	E890	<140	410	E4,500	--	--	--	<140	--	E13,000	--	--
Minimum value					<400	<150	<100	<30	<390	<1.0	<1.0	<1.0	<30	<250	<30	<1.0	<1.0
Maximum value					2,300	810	140	9,710	30,000	6.7	1.5	5.5	E200	E11	7,100	E1.2	E.37

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Hexahydrohexamethyl cyclopentabenzopyran, µg/kg (50)	Indole, µg/kg (100)	Isophorone, µg/kg (50)	Isopropylbenzene, µg/kg (50)	Naphthalene, µg/kg (50)	*para*-cresol, µg/kg (250)	Phenanthrene, µg/kg (50)	Phenol, µg/kg (50)	PCBs, µg/kg	p,p'-DDE, µg/kg	p,p'-DDT, µg/kg
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)									561		1,170				
BI1	Big Bull Creek near Edgerton	6914950	3/31/2003	915	<50	120	<50	<50	<50	1,000	E20	270	<150	<3.0	<6.0
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	810	E5.4	87	<20	<50	<20	E50	<20	E42	--	--	--
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1130	<100	E220	<100	<200	<100	<500	<100	<164	--	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	4/3/2003	1045	<50	E45	<50	<50	<50	E32	E11	<100	<50	<1.0	<2.0
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1345	<70	E50	<70	<140	<70	E130	<70	E234	--	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1420	<154	E570	<150	<310	<153	E222	<153	<153	--	--	--
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1250	<40	237	<40	<80	<40	6,440	64	E170	--	--	--
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1520	<250	E900	<250	<493	<250	<1,232	E80	<250	--	--	--
BL5	Blue River at Kenneth Road	6893100	4/3/2003	930	<50	120	<50	<50	E11	110	E20	E72	<100	E.90	<4.0
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1050	<70	<150	<70	<140	<70	E92	<70	E222	--	--	--
BL5	Blue River at Kenneth Road	6893100	4/6/2010	850	<114	E550	E9.3	<230	<114	<570	E42	<224	--	--	--
BR2	Brush Creek at Belinder	390127094365800	4/6/2010	1030	E20	E330	<140	<280	<140	<690	E2,310	<210	--	--	--
CA1	Captain Creek near 119th Street	385540095032800	3/31/2003	1245	<50	240	<50	<50	E10	E72	E14	E50	<50	<1.0	<2.0
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	910	<30	E44	<30	<60	<30	<150	<30	<30	--	--	--
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	1510	<64	E100	<64	<130	<64	<320	<64	<212	--	--	--
CE1	Cedar Creek at Old Highway 56	6892440	4/1/2003	1300	<50	400	<50	<50	E23	2,300	370	120	E14	E.56	<4.0
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	915	<40	<50	<40	<80	E9.2	E40	E20	<40	--	--	--
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	835	<70	<134	E2.5	<134	<67	<340	<70	<90	--	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/1/2003	1100	<50	53	<50	<50	<50	E51	<50	<100	<50	<1.0	<2.0
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1050	E5.7	E60	<30	<60	E2.8	<150	<30	E23	--	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1100	<240	E200	<240	<483	<241	<1,210	<241	<763	--	--	--
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1420	<60	420	<70	<130	E50	E62	1,760	E143	--	--	--
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1330	<73	E410	<72	<150	151	E330	E16,600	<150	--	--	--
IN3a	Indian Creek at College Blvd	385520094420000	4/2/2003	1300	<50	540	<50	<50	130	6,300	1,500	480	<100	E.77	<4.0
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1325	90	130	<30	<60	<30	441	380	E224	--	--	--
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1230	372	E920	<220	<441	E120	E550	E6,340	<552	--	--	--
IN6	Indian Creek at State Line Road	6893390	4/2/2003	1100	<50	160	<50	<50	97	930	1,500	160	E22	3	E5.0
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1035	E75	380	<90	<170	E34	1,660	1,650	E122	--	--	--
IN6	Indian Creek at State Line Road	6893390	4/6/2010	1515	140	E790	<140	<280	E205	E630	E16,800	<160	--	--	--

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available; <, less than]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Hexahydrohexamethyl cyclopentabenzopyran, µg/kg (50)	Indole, µg/kg (100)	Isophorone, µg/kg (100)	Isopropylbenzene, µg/kg (50)	Naphthalene, µg/kg (50)	*para*-cresol, µg/kg (250)	Phenanthrene, µg/kg (50)	Phenol, µg/kg (50)	PCBs, µg/kg	p,p'-DDE, µg/kg	p,p'-DDT, µg/kg
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)									561		1,170				
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1410	<50	330	<50	<100	<50	E60	E20	E102	--	--	--
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	1310	E55	E670	<162	<320	<162	<812	<162	<162	--	--	--
KI5b alt	Kill Creek at 135th Street	385303094582300	3/31/2003	1200	<50	220	<50	<50	<50	E100	<50	E80	<100	<2.0	<4.0
KI6b	Kill Creek at 95th Street	6892360	3/31/2003	1040	<50	230	<50	<50	130	E80	E34	E80	<50	<1.0	<2.0
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1235	<30	E53	<30	<60	<30	E10	<30	<30	--	--	--
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1200	<80	<160	E2.5	<160	<80	<390	<80	<282	--	--	--
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1320	<80	E180	<80	<154	<80	<390	E30	<100	--	--	--
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	825	<40	E60	<40	<80	E33	E43	760	E54	--	--	--
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1200	<182	<360	<182	<364	<182	<910	280	<314	--	--	--
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	920	<65	E20	<65	<130	E25	E39	1,600	E55	--	--	--
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	720	<70	E69	<70	<140	<70	E107	1,570	E104	--	--	--
MI1	Mill Creek at 127th Street	385356094491200	4/1/2003	1200	<50	140	<50	<50	E23	E21	330	E22	E18	6	E4.8
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1155	<100	E190	<100	<200	210	E154	1,670	E350	--	--	--
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1450	<153	E222	<153	<310	<153	<760	321	<290	--	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	4/1/2003	1000	<50	240	<50	<50	E20	2,000	260	220	<50	E.50	<2.0
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1245	<50	100	<40	<90	E44	E130	860	E751	--	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1305	E12	E140	E22	<240	<120	<600	332	<572	--	--	--
MI7	Mill Creek at Johnson Drive	6892513	4/1/2003	900	<50	84	<50	<50	E18	680	270	E91	<50	E.26	<2.0
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1045	<40	E52	<40	<80	E20	E60	263	E191	--	--	--
MI7	Mill Creek at Johnson Drive	6892513	4/9/2010	1000	E20	E140	<173	<350	<173	<860	E100	<1,160	--	--	--
TO2	Tomahawk Creek near 111th Street	385539094372100	4/2/2003	1200	<50	520	<50	<50	E50	2,000	970	510	<50.000	E.46	<2.0
TO2	Tomahawk Creek near 111th Street	385539094372100	3/12/2007	1205	<50	E71	<50	<100	E30	E100	890	E200	--	--	--
TO2	Tomahawk Creek near 111th Street	385539094372100	4/6/2010	1420	<110	E350	E8.5	<220	E110	E420	E9,670	<440	--	--	--
TU1	Turkey Creek at 67th Street	390027094415600	4/2/2003	900	<50	60	<50	E9.1	E20	E9.8	390	<100	E52	<1.0	<2.0
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	905	<30	110	<20	<50	130	E22	3,640	E110	--	--	--
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	1010	<140	E200	<140	<274	<140	<680	2,260	<270	--	--	--
Minimum value					<30	<50	<30	<50	<50	<150	<50	<30	<50	2.7	<2.0
Maximum value					372	540	E8.5	E9.1	210	6,440	3,640	510	E52	6.2	E4.8

Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Pyrene, µg/kg (50)	trans-Chlordane, µg/kg	trans-Nonachlor, µg/kg	Triclosan, µg/kg (50)	Percent organic carbon	Bifenthrin, ug/kg (0.2)	Cyfluthrin, ug/kg (0.5)	Permethrin, ug/kg (0.2)	Resmethrin, ug/kg (0.5)
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)					1,520					0.494 *	2.16 *	19.6 *	
BI1	Big Bull Creek near Edgerton	6914950	3/31/2003	915	<50	<3.0	<3.2	E25	--	--	--	--	--
BI1	Big Bull Creek near Edgerton	6914950	3/14/2007	810	<20	--	--	<20	--	--	--	--	--
BI1	Big Bull Creek near Edgerton	6914950	4/5/2010	1130	E20	--	--	<100	1.19	<0.2	<0.5	<0.2	<0.5
BL3	Blue River near Stanley (Highway 69)	6893080	4/3/2003	1045	<50	<1.0	<1.0	<50	--	--	--	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	3/14/2007	1345	E20	--	--	<70	--	--	--	--	--
BL3	Blue River near Stanley (Highway 69)	6893080	4/5/2010	1420	E60	--	--	<153	1.94	<0.2	<0.5	<0.2	<0.5
BL4	Camp Branch at 175th Street	384840094381100	3/14/2007	1250	60	--	--	<40	--	--	--	--	--
BL4	Camp Branch at 175th Street	384840094381100	4/5/2010	1520	E124	--	--	<250	--	--	--	--	--
BL5	Blue River at Kenneth Road	6893100	4/3/2003	930	<50	E.51	E.75	<50	--	--	--	--	--
BL5	Blue River at Kenneth Road	6893100	3/14/2007	1050	E32	--	--	<70	--	--	--	--	--
BL5	Blue River at Kenneth Road	6893100	4/6/2010	850	E50	--	--	<114	2.43	<0.2	<0.5	<0.2	<0.5
BR2	Brush Creek at Belinder	390127094365800	4/6/2010	1030	E7,320	--	--	<160	4.01	<0.2	3.7	<0.2	<0.5
CA1	Captain Creek near 119th Street	385540095032800	3/31/2003	1245	<50	<1.0	<1.0	<50	--	--	--	--	--
CA1	Captain Creek near 119th Street	385540095032800	3/14/2007	910	<30	--	--	<30	--	--	--	--	--
CA1	Captain Creek near 119th Street	385540095032800	4/9/2010	1510	<64	--	--	<64	1.17	<0.2	<0.5	<0.2	<0.5
CE1	Cedar Creek at Old Highway 56	6892440	4/1/2003	1300	560	<2.0	<2.0	E26	--	--	--	--	--
CE1	Cedar Creek at Old Highway 56	6892440	3/15/2007	915	E20	--	--	<40	--	--	--	--	--
CE1	Cedar Creek at Old Highway 56	6892440	4/9/2010	835	<70	--	--	<70	2.87	<0.2	<0.5	2.9	10.3
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/1/2003	1100	E30	<1.0	<1.3	<50	--	--	--	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	3/15/2007	1050	E20	--	--	<30	--	--	--	--	--
CE6	Cedar Creek near DeSoto (83rd Street)	6892495	4/9/2010	1100	E80	--	--	<241	1.33	<0.2	<0.5	29.8	<0.5
IN1b	Indian Creek at Highway 69	6893270	3/12/2007	1420	2,750	--	--	<60	--	--	--	--	--
IN1b	Indian Creek at Highway 69	6893270	4/6/2010	1330	E8,380	--	--	<72	3.27	<0.2	<0.5	<0.2	<0.5
IN3a	Indian Creek at College Blvd	385520094420000	4/2/2003	1300	1,800	3.5	<2.0	140	--	--	--	--	--
IN3a	Indian Creek at College Blvd	385520094420000	3/12/2007	1325	860	--	--	74	--	--	--	--	--
IN3a	Indian Creek at College Blvd	385520094420000	4/6/2010	1230	E20,300	--	--	<240	4.75	<0.2	<0.5	<0.2	<0.5
IN6	Indian Creek at State Line Road	6893390	4/2/2003	1100	2,700	5.6	7.9	160	--	--	--	--	--
IN6	Indian Creek at State Line Road	6893390	3/12/2007	1035	3,040	--	--	114	--	--	--	--	--
IN6	Indian Creek at State Line Road	6893390	4/6/2010	1515	E13,100	--	--	<140	3.52	<0.2	<0.5	<0.2	<0.5

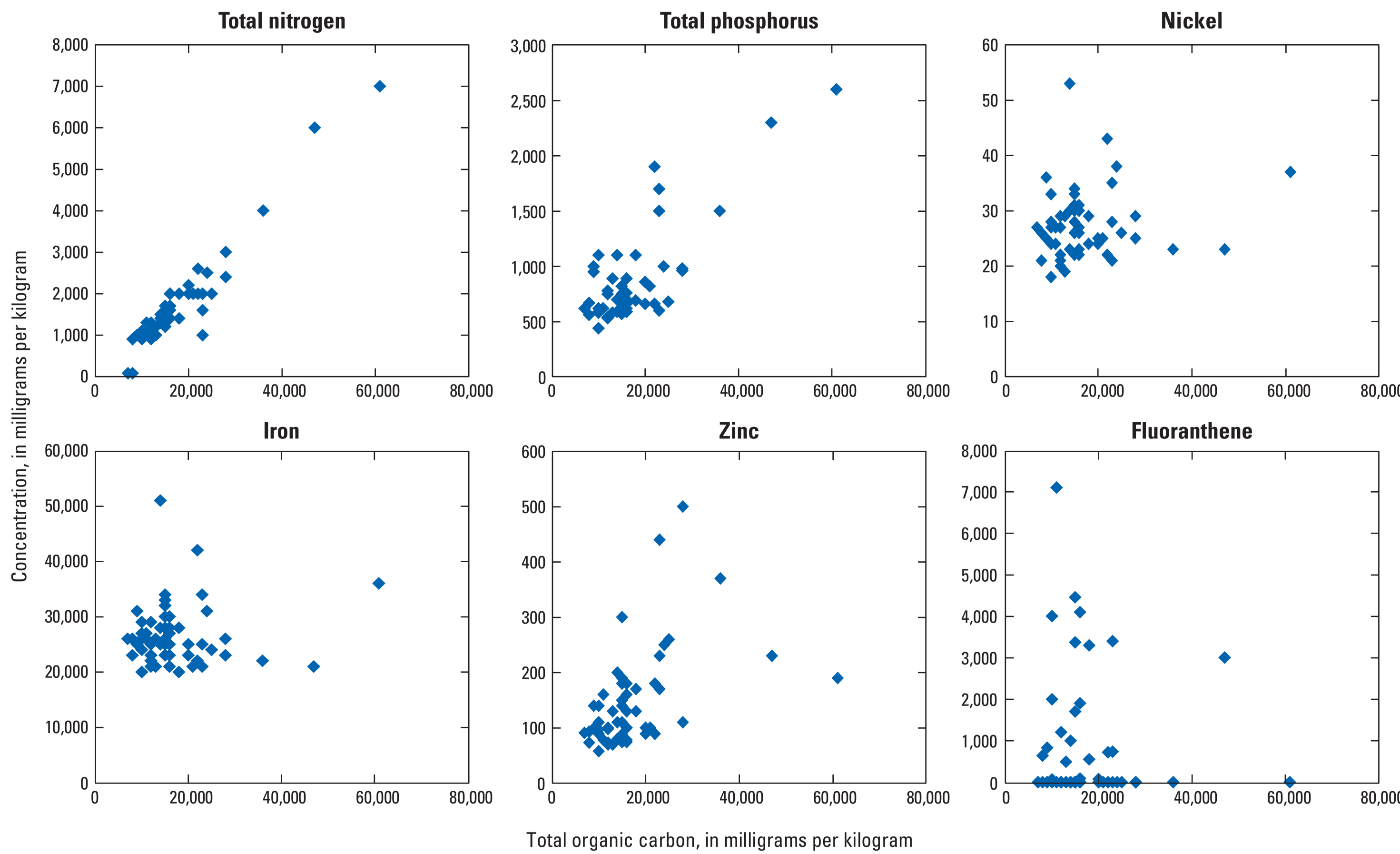
Appendix 4. Results of laboratory analysis for carbon, nutrients, trace elements and organic compounds in streambed-sediment samples from biological monitoring sites in Johnson County, Kansas, 2003, 2007, and 2010.—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram, ( ) laboratory reporting level; M, presence verified but not quantified; E, estimated; --, not available]

Biological monitoring site identifier	Site name	USGS identification number	Date of sample collection (month/day/year)	Sample time (24-hour time)	Pyrene, µg/kg (50)	trans-Chlordane, µg/kg	trans-Nonachlor, µg/kg	Triclosan, µg/kg (50)	Percent organic carbon	Bifenthrin, ug/kg (0.2)	Cyfluthrin, ug/kg (0.5)	Permethrin, ug/kg (0.2)	Resmethrin, ug/kg (0.5)
Probable effects concentrations (MacDonald and others, 2000; U.S. Environmental Protection Agency, 1998)					1,520					0.49*	2.16*	19.6*	
KI5b	Kill Creek at 127th Street	6892359	3/15/2007	1410	E30	--	--	<50	--	--	--	--	--
KI5b	Kill Creek at 127th Street	6892359	4/9/2010	1310	E40	--	--	<162	2.36	0.2	<0.5	<0.2	<0.5
KI5b alt	Kill Creek at 135th Street	385303094582300	3/31/2003	1200	<50	<2.0	<2.0	<50	--	--	--	--	--
KI6b	Kill Creek at 95th Street	6892360	3/31/2003	1040	54	<1.0	<1.0	<50	--	--	--	--	--
KI6b	Kill Creek at 95th Street	6892360	3/15/2007	1235	<30	--	--	<30	--	--	--	--	--
KI6b	Kill Creek at 95th Street	6892360	4/9/2010	1200	<80	--	--	<80	1.23	<0.2	<0.5	<0.2	<0.5
LI1	Little Bull Creek near 215th Street	384419094515600	4/5/2010	1320	E60	--	--	<80	1.28	<0.2	<0.5	<0.2	<0.5
LM1a	Little Mill Creek at W. 79th Street	385908094445900	3/13/2007	825	1,250	--	--	<40	--	--	--	--	--
LM1a	Little Mill Creek at W. 79th Street	385908094445900	4/8/2010	1200	E750	--	--	<182	1.54	2.3	<0.5	<0.2	<0.5
LM1b	Unnamed Little Mill tributary near W. 83rd Street	385839094444400	3/13/2007	920	2,520	--	--	<65	--	--	--	--	--
LM1c	Little Mill Creek at 84th Terrace	385834094445600	3/13/2007	720	3,390	--	--	<70	--	--	--	--	--
MI1	Mill Creek at 127th Street	385356094491200	4/1/2003	1200	610	13.0	5.3	<50	--	--	--	--	--
MI1	Mill Creek at 127th Street	385356094491200	3/13/2007	1155	2,440	--	--	<100	--	--	--	--	--
MI1	Mill Creek at 127th Street	385356094491200	4/8/2010	1450	E700	--	--	<153	1.57	<0.2	<0.5	<0.2	<0.5
MI4	Mill Creek at 87th Street Lane	385800094485300	4/1/2003	1000	440	3.0	5.9	E20	--	--	--	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	3/13/2007	1245	960	--	--	<40	--	--	--	--	--
MI4	Mill Creek at 87th Street Lane	385800094485300	4/8/2010	1305	E841	--	--	<120	1.92	0.7	<0.5	1.3	<0.5
MI7	Mill Creek at Johnson Drive	6892513	4/1/2003	900	400	E.53	E.95	E6.0	--	--	--	--	--
MI7	Mill Creek at Johnson Drive	6892513	3/13/2007	1045	463	--	--	<40	--	--	--	--	--
MI7	Mill Creek at Johnson Drive	6892513	4/9/2010	1000	E174	--	--	<173	0.77	<0.2	<0.5	<0.2	<0.5
TO2	Tomahawk Creek near 111th Street	385539094372100	4/2/2003	1200	1,100	E.82	E.70	<50	--	--	--	--	--
TO2	Tomahawk Creek near 111th Street	385539094372100	3/12/2007	1205	1,480	--	--	<50	--	--	--	--	--
TO2	Tomahawk Creek near 111th Street	385539094372100	4/6/2010	1420	E13,000	--	--	<110	3.69	<0.2	<0.5	<0.2	<0.5
TU1	Turkey Creek at 67th Street	390027094415600	4/2/2003	900	680	2.0	1.2	<50	--	--	--	--	--
TU1	Turkey Creek at 67th Street	390027094415600	3/12/2007	905	5,340	--	--	<20	--	--	--	--	--
TU1	Turkey Creek at 67th Street	390027094415600	4/8/2010	1010	E8,510	--	--	<140	1.67	2.1	<0.5	<0.2	<0.5
Minimum value					<30	<1.0	<1.0	<20	0.77	<0.2	<0.5	<0.2	<0.5
Maximum value					5,340	13	7.9	160	4.75	2.3	3.7	30	10

*Chronic toxicity threshold concentrations for pyrethroid compounds from Moran (2011).

Appendix 5. Scatter plots showing general relations between total organic carbon concentrations and selected constituents in streambed sediment at monitoring sites in Johnson County, Kansas, 2002–10.



Appendix 6. Periphyton taxa identified and the number of biological monitoring sites where each taxa occurred in Johnson County, Kansas streams during April 2010.

[Bacillariophyta, diatoms; Chlorophyta, green algae; Chrysophyta, golden algae; Cynophyta, blue-green algae or cyanobacteria; Euglenophyta, euglenoids; Rhodophyta, red algae; Streptophyta, green plants; sp., species; var., variety]

Division	Taxon	Number of sites
Bacillariophyta	*Achnanthes rupestoides*	1
	Achnanthes saccula	1
	Achnanthidium exiguum	1
	Achnanthidium minutissimum	16
	Amphora sp.	1
	Amphora aequalis	1
	Amphora holsatica	1
	Amphora inariensis	10
	Amphora libyca	1
	Amphora montana	1
	Amphora ovalis	5
	Amphora pediculus	18
	Aulacoseira alpigena	1
	Aulacoseira italica	1
	Caloneis bacillum	10
	Cocconeis pediculus	2
	Cocconeis placentula	16
	Craticula sp.	1
	Cyclostephanos	3
	Cyclostephanos invisitatus	1
	Cyclotella meneghiniana	5
	Cyclotella ocellata	3
	Cymbella amphicephala	2
	Cymbella prostrata	6
	Cymbella turgidula	3
	Diatoma moniliformis	1
	Diatoma vulgaris	9
	Diploneis puella	1
	Encyonema minutum	1
	Encyonema silesiacum	4
	Eunotia bilunaris	1
	Fragilaria bidens	1
	Fragilaria capucina	7
	Fragilaria capucina var. *rumpens*	4
	Fragilaria capucina var. *vaucheriae*	10
	Frustulia vulgaris	1
	Geissleria sp.	1
	Gomphonema sp.	2
	Gomphonema affine	2
	Gomphonema angustatum	6
	Gomphonema angustum	1
	Gomphonema gracile	2
	Gomphonema insigne	1
	Gomphonema micropus	1
	Gomphonema olivaceum	19
	Gomphonema parvulum	7
	Gomphonema parvulum var. *exilissimum*	1
	Gomphonema pumilum var. *elegans*	1
	Gyrosigma acuminatum	7
	Gyrosigma wansbeckii	1
	Hantzschia amphioxys	1
	Hippodonta capitata	1
	Luticola mutica	1
	Mayamaea sp.	3
	Mayamaea aliena	1
	Mayamaea atomus	1
	Melosira varians	9
	Meridion circulare	7
	Navicula sp.	13
	Navicula capitatoradiata	12
	Navicula cryptotenella	18
	Navicula decussis	1
	Navicula detenta	1
	Navicula goeppertiana	1
	Navicula gregaria	19
	Navicula ingenua	4
	Navicula lundii	2
	Navicula margalithii	4
	Navicula menisculus	13
	Navicula pygmaea	1
	Navicula salinarum	6
	Navicula subminuscula	12
	Navicula tripunctata	14
	Navicula trivialis	5
	Nitzschia sp.	2
	Nitzschia acicularis	1
	Nitzschia agnita	5
	Nitzschia amphibia	11
	Nitzschia capitellata	1
	Nitzschia clausii	2
	Nitzschia dissipata	20
	Nitzschia dubia	9

Appendix 6. Periphyton taxa identified and the number of biological monitoring sites where each taxa occurred in Johnson County, Kansas streams during April 2010.—Continued

[Bacillariophyta, diatoms; Chlorophyta, green algae; Chrysophyta, golden algae; Cynophyta, blue-green algae or cyanobacteria; Euglenophyta, euglenoids; Rhodophyta, red algae; Streptophyta, green plants; sp., species; var., variety]

Division	Taxon	Number of sites
Bacillariophyta—Continued	*Nitzschia flexa*	1
	Nitzschia gracilis	1
	Nitzschia homburgiensis	1
	Nitzschia inconspicua	20
	Nitzschia intermedia	5
	Nitzschia linearis	13
	Nitzschia palea	9
	Nitzschia sociabilis	7
	Nitzschia sublinearis	2
	Planothidium frequentissimum	1
	Planothidium lanceolatum	14
	Psammothidium sp.	18
	Psammothidium ventralis	1
	Puncticulata bodanica	1
	Reimeria sinuata	9
	Rhoicosphenia curvata	20
	Sellaphora pupula	2
	Staurosirella pinnata	1
	Stephanodiscus parvus	5
	Surirella sp.	1
	Surirella angusta	7
	Surirella brebissonii	20
	Synedra acus	3
	Synedra ulna	17
	Tabularia fasciculata	12
	Thalassiosira sp.	1
	Tryblionella apiculata	4
Chlorophyta	*Bulbochaete* sp.	1
	Chlamydomonas sp.	1
	Closterium sp.	1
	Mougeotia sp.	1
	Oedogonium sp.	1
	Pyramimonas tetrarhynchus	1
	Ulothrix sp.	1
	Ulothrix tenerrima	4
Cyanophyta	*Chroococcus turgidus*	1
	Gloeocapsopsis sp.	1
	Lyngbya sp.	2
	Phormidium sp.	1
	Phormidium aerugineo-caeruleum	3
	Phormidium taylori	1
Euglenophyta	*Strombomonas* sp.	1
	Trachelomonas sp.	4
	Trachelomonas similis	1
	Trachelomonas volvocina	12
Rhodophyta	*Audouinella* sp.	5
Streptophyta	*Klebsormidium subtile*	1

Appendix 7. Four most dominant periphyton taxa on the basis of abundance and the percentage contribution of each taxon to total abundance at biological monitoring sites in Johnson County, Kansas, during April 2010.

[sp., species; var., variety; total percentage does not always equal sum of species percentages because of rounding effects]

Biological monitoring site identifier (fig. 1)	Four most dominant taxa (percentage of total algal abundance)	Total percentage of sample comprising four most dominant taxa
BI1	*Surirella brebissonii* (17), *Nitzschia dissipata* (15), *Cocconeis placentula* (9), *Audouinella* sp. (9)	51
BL3	*Surirella brebissonii* (20), *Nitzschia dissipata* (14), *Navicula* sp. (10), *Navicula tripunctata (7)*	51
BL4 replicate 1	*Navicula cryptotenella* (39), *Navicula tripunctata* (15), *Nitzschia dissipata* (8), *Gomphonema olivaceum* (8)	71
BL4 replicate 2	*Navicula dissipata* (22), *Gomphonema olivaceum* (10), *Navicula cryptonella* (9), *Navicula menisculus* (9)	51
BL5	*Nitzschia dissipata* (14), *Gomphonema olivaceum* (9), *Navicula menisculus* (8), *Navicula tripunctata* (7)	39
BR2	*Amphora pediculus* (31), *Psammothidium* sp. (19), *Nitzschia amphibia* (17), *Nitzschia inconspicua* (8)	76
CA1	*Navicula subminuscula* (25), *Nitzschia dissipata* (17), *Navicula inconspicua* (10), *Nitzschia menisculus* (10)	61
CE1	*Nitzschia inconspicua* (23), *Surirella brebissonii* (13), *Gomphonema olivaceum* (12), *Fragilaria capucina* var. *vaucheriae* (9)	58
CE6	*Diatoma vulgaris* (26), *Lyngbya* sp. (15), *Navicula tripunctata* (9), *Nitzschia dissipata* (8)	58
IN1b	*Nitzschia inconspicua* (28), *Psammothidium* sp. (26), *Nitzschia dissipata* (13), *Amphora pediculus* (8)	76
IN3a replicate 1	*Psammothidium* sp. (20), *Navicula ingenua* (12), *Amphora pediculus* (11), *Nitzschia inconspicua* (11)	55
IN3a replicate 2	*Nitzschia inconspicua* (23), *Psammothidium* sp. (26), *Nitzschia dissipata* (8), *Surirella brebissonii* (8)	56
IN6	*Amphora pediculus* (14), *Psammothidium* sp. (12), *Rhoicosphenia curvata* (11), *Nitzschia dissipata* (6)	43
KI5b	*Diatoma vulgaris* (33), *Navicula tripunctata* (10), *Navicula cryptonella* (10), *Gomphonema olivaceum* (8)	61
KI6b	*Navicula cryptotenella* (32), *Nitzschia inconspicua* (15), *Navicula tripunctata* (12), *Navicula subminuscula* (12)	71
LI1	*Nitzschia inconspicua* (27), *Surirella brebissonii* (25), *Psammothidium* sp. (8), *Nitzschia linearis* (5)	65
LM1a	*Psammothidium* sp. (45), *Nitzschia dissipata* (15), *Nitzschia inconspicua* (12), *Achnanthidium minutissimum* (8)	80
MI1	*Nitzschia inconspicua* (32), *Nitzschia dissipata* (22), *Psammothidium* sp. (9), *Surirella brebissonii* (8)	70
MI4	*Nitzschia inconspicua* (36), *Mayamaea atomus* (10), *Gomphonema olivaceum* (10), *Surirella brebissonii* (9)	65
MI7	*Nitzschia inconspicua* (12), *Gomphonema olivaceum* (9), *Surirella brebissonii* (9), *Psammothidium* sp. (8)	39
TO2	*Nitzschia dissipata* (25), *Gomphonema olivaceum* (21), *Achnanthidium minutissimum* (7), *Tabularia fasciculata* (6)	59
TU1	*Psammothidium* sp. (25), *Nitzschia amphibia* (15), *Navicula gregaria* (8), *Nitzschia dissipata* (8)	57

Appendix 8. Four most dominant periphyton taxa on the basis of biovolume and the percentage contribution of each taxon to total biovolume at biological monitoring sites in Johnson County, Kansas, during April 2010.

[sp., species; total percentage does not always equal sum of species percentages because of rounding effects]

Biological monitoring site identifier (fig. 1)	Four most dominant taxa (percentage of total algal abundance)	Total percentage of sample comprising four most dominant taxa
BI1	*Surirella brebissonii* (32), *Cocconeis placentula* (21), *Synedra ulna* (17), *Nitzschia dissipata* (6)	76
BL3	*Diatoma vulgaris* (17), *Surirella brebissonii* (15), *Nitzschia linearis* (15), *Navicula tripunctata* (15)	62
BL4 replicate 1	*Navicula tripunctata* (31), *Nitzschia intermedia* (20), *Navicula cryptotenella* (15), *Nitzschia linearis* (14)	80
BL4 replicate 2	*Synedra ulna* (36), *Navicula tripunctata* (15), *Gomphonema olivaceum* (10), *Nitzschia linearis* (8)	69
BL5	*Navicula tripunctata* (12), *Diatoma vulgaris* (12), *Cocconeis placentula* (11), *Melosira varians* (10)	45
BR2	*Navicula gregaria* (22), *Surirella brebissonii* (19), *Psammothidium* sp. (12), *Nitzschia amphibia* (9)	61
CA1	*Navicula margalithii* (14), *Navicula subminuscula* (12), *Nitzschia dissipata* (11), *Navicula meniscus* (11)	48
CE1	*Surirella brebissonii* (21), *Cocconeis placentula* (12), *Synedra ulna* (10), *Gomphonema olivaceum* (9)	51
CE6	*Diatoma vulgaris* (52), *Navicula tripunctata* (17), *Synedra ulna* (9), *Melosira varians* (5)	83
IN1b	*Nitzschia dissipata* (34), *Rhoicosphenia curvata* (9), *Surirella brebissonii* (8), *Gyrosigma acuminatum* (8)	59
IN3a replicate 1	*Surirella brebissonii* (20), *Mougeotia* sp. (19), *Nitzschia dubia* (10), *Navicula tripunctata* (9)	59
IN3a replicate 2	*Surirella brebissonii* (16), *Gyrosigma acuminatum* (15), *Melosira varians* (15), *Nitzschia dubia* (8)	54
IN6	*Surirella brebissonii* (23), *Rhoicosphenia curvata* (16), *Melosira varians* (10), *Navicula tripunctata* (7)	55
KI5b	*Diatoma vulgaris* (66), *Navicula tripunctata* (8), *Nitzschia linearis* (5), *Surirella brebissonii* (4)	84
KI6b	*Navicula tripunctata* (26), *Navicula cryptotenella* (18), *Diatoma vulgaris* (17), *Cocconeis placentula* (9)	69
LI1	*Surirella brebissonii* (63), *Nitzschia dubia* (16), *Synedra ulna* (6), *Nitzschia linearis* (5)	90
LM1a	*Nitzschia dissipata* (33), *Psammothidium* sp. (20), *Surirella brebissonii* (20), *Achnanthidium minutissimum* (4)	77
MI1	*Surirella brebissonii* (37), *Nitzschia dissipata* (28), *Nitzschia inconspicua* (6), *Gomphonema olivaceum* (5)	76
MI4	*Surirella brebissonii* (25), *Synedra ulna* (19), *Nitzschia intermedia* (14), *Gomphonema olivaceum* (7)	66
MI7	*Synedra ulna* (34), *Navicula margalithii* (11), *Nitzschia dubia* (7), *Nitzschia linearis* (6)	58
TO2	*Nitzschia linearis* (21), *Gomphonema olivaceum* (18), *Nitzschia dissipata* (13), *Tabularia fasciculata* (11)	63
TU1	*Surirella brebissonii* (23), *Navicula gregaria* (7), *Rhoicosphenia curvata* (7), *Nitzschia amphibia* (7)	43

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Cnidaria	Hydrozoa	Hydroida	Hydridae	--	*Hydra*	*Hydra* sp.	2	1	0	0
Platyhelminthes	Turbellaria	--	--	--	--	*Turbellaria*	10	7	12	14
Nematoda	--	--	--	--	--	*Nematoda*	3	3	1	2
Nemertea	Enopla	Haplonemertea	Tetrastemmatidae	--	*Prostoma*	*Prostoma* sp.	0	0	1	2
Nematomorpha	Gordioida	--	--	--	--	*Nematomorpha*	0	0	2	5
Nematomorpha	Gordioida	--	--	--	--	*Gordioida*	1	0	0	0
Bryozoa	--	--	--	--	--	*Bryozoa*	1	0	0	0
Mollusca	Gastropoda	Mesogastropoda	Hydrobiidae	--	--	*Hydrobiidae*	0	0	3	2
Mollusca	Gastropoda	Basommatophora	Ancylidae	--	--	*Ancylidae*	1	0	0	0
Mollusca	Gastropoda	Basommatophora	Ancylidae	--	*Ferrissia*	*Ferrissia* sp.	1	1	3	6
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	--	--	*Lymnaeidae*	0	0	1	1
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Lymnaeinae	*Fossaria*	*Fossaria* sp.	9	7	5	8
Mollusca	Gastropoda	Basommatophora	Physidae	Physinae	*Physa*	*Physa* sp.	0	15	17	14
Mollusca	Gastropoda	Basommatophora	Physidae	Physinae	*Physella*	*Physella* sp.	15	0	0	0
Mollusca	Gastropoda	Basommatophora	Planorbidae	--	--	*Planorbidae*	3	0	0	0
Mollusca	Gastropoda	Basommatophora	Planorbidae	--	*Gyraulus*	*Gyraulus* sp.	1	0	0	0
Mollusca	Gastropoda	Basommatophora	Planorbidae	--	*Micromenetus*	*Micromenetus* sp.	0	0	1	0
Mollusca	Gastropoda	Basommatophora	Planorbidae	--	*Micromenetus*	*Micromenetus dilataus* (Gould)	1	1	0	0
Mollusca	Gastropoda	Basommatophora	Planorbidae	--	*Planorbella*	*Planorbella* sp.	2	7	2	1
Mollusca	Bivalvia	--	--	--	--	*Bivalvia*	1	1	0	0
Mollusca	Bivalvia	Veneroida	Corbiculidae	--	*Corbicula*	*Corbicula* sp.	9	9	13	10
Mollusca	Bivalvia	Veneroida	Sphaeriidae			*Sphaeriidae*	2	2	0	0
Mollusca	Bivalvia	Veneroida	Sphaeriidae	Pisidiinae	*Pisidium*	*Pisidium* sp.	2	2	0	3
Mollusca	Bivalvia	Veneroida	Sphaeriidae	Sphaeriinae	*Musculium*	*Musculium* sp.	8	8	5	8
Mollusca	Bivalvia	Veneroida	Sphaeriidae	Sphaeriinae	*Sphaerium*	*Sphaerium* sp.	1	2	3	5
Annelida						*Annelida*	0	0	0	1
Annelida	Oligochaeta	--	--	--	--	*Megadrile*	5	0	8	5
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae	--	--	*Lumbriculidae*	0	0	2	0
Annelida	Oligochaeta	Tubificida	Naididae	--	--	*Naididae*	12	12	4	18
Annelida	Oligochaeta	Tubificida	Naididae	--	*Dero*	*Dero* sp.	1	0	0	0

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Annelida	Oligochaeta	Tubificida	Tubificidae	--	--	*Tubificidae*	11	14	19	17
Annelida	Oligochaeta	Tubificida	Tubificidae	--	*Branchiura*	*Branchiura sowerbyi* Beddard	1	0	2	3
Annelida	Oligochaeta	Tubificida	Tubificidae	--	*Quistadrilus*	*Quistadrilus multisetosus* (Smith)	0	0	3	1
Annelida	Oligochaeta	Enchytraeida	Enchytraeidae	--	--	*Enchytraeidae*	2	1	1	2
Annelida	Hirudinea	--	--	--	--	*Hirudinea*	1	1	0	0
Annelida	Hirudinea	Rhynchobdellae	Glossiphoniidae	--	--	*Glossiphoniidae*	0	0	0	1
Annelida	Hirudinea	Rhynchobdellae	Glossiphoniidae	--	*Helobdella*	*Helobdella* sp.	1	0	0	1
Annelida	Hirudinea	Rhynchobdellae	Glossiphoniidae	--	*Helobdella*	*Helobdella stagnalis* (Linnaeus)	1	1	3	2
Annelida	Hirudinea	Rhynchobdellae	Glossiphoniidae		*Placobdella*	*Placobdella* sp.	0	0	0	4
Annelida	Hirudinea	Rhynchobdellae	Glossiphoniidae	--	*Placobdella*	*Placobdella multilineata Moore*	0	0	1	1
Annelida	Hirudinea	Rhynchobdellae	Glossiphoniidae	--	*Placobdella*	*Placobdella ornata* (Verrill)	1	0	1	0
Annelida	Hirudinea	Rhynchobdellae	Piscicolidae	--	--	*Piscicolidae*	1	0	0	2
Annelida	Hirudinea	Rhynchobdellae	Piscicolidae	--	*Piscicola*	*Piscicola* sp.	0	0	2	0
Annelida	Hirudinea	Arhynchobdellae	Erpobdellidae	--	--	*Erpobdellidae*	15	13	20	15
Annelida	Hirudinea	Arhynchobdellae	Hirudinidae	--	*Haemopis*	*Haemopis* sp.	0	0	0	1
Arthropoda	Arachnida	--	--	--	--	*Acari*	1	4	0	4
Arthropoda	Malacostraca	Decapoda	Cambaridae	--	--	*Cambaridae*	3	4	9	9
Arthropoda	Malacostraca	Decapoda	Cambaridae	Cambarinae	*Orconectes*	*Orconectes* sp.	2	4	7	11
Arthropoda	Malacostraca	Isopoda	Asellidae	--	*Caecidotea*	*Caecidotea* sp.	1	0	7	7
Arthropoda	Malacostraca	Isopoda	Asellidae	--	*Lirceus*	*Lirceus* sp.	3	4	6	2
Arthropoda	Malacostraca	Amphipoda	Crangonyctidae	--	*Crangonyx*	*Crangonyx* sp.	4	4	6	4
Arthropoda	Malacostraca	Amphipoda	Hyalellidae	--	*Hyalella*	*Hyalella* sp.	0	0	0	16
Arthropoda	Malacostraca	Amphipoda	Hyalellidae	--	*Hyalella*	*Hyalella azteca* (Saussure)	5	7	11	0
Arthropoda	Insecta	Collembola	--	--	--	*Collembola*	1	0	6	9
Arthropoda	Insecta	Ephemeroptera	--	--	--	*Ephemeroptera*	0	0	1	1
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	--	--	*Leptophlebiidae*	0	0	1	0

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	--	*Leptophlebia*	*Leptophlebia* sp.	3	4	6	3
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	--	*Tricorythodes*	*Tricorythodes* sp.	1	0	0	2
Anthropoda	Insecta	Ephemeroptera	Ephemeridae	--	*Hexagenia*	*Hexagenia* sp.	0	4	0	0
Arthropoda	Insecta	Ephemeroptera	Caenidae	--	*Caenis*	*Caenis* sp.	7	11	12	13
Arthropoda	Insecta	Ephemeroptera	Baetidae	--	--	*Baetidae*	0	0	1	1
Arthropoda	Insecta	Ephemeroptera	Baetidae	--	*Acerpenna*	*Acerpenna* sp.	0	0	2	0
Arthropoda	Insecta	Ephemeroptera	Baetidae	--	*Acerpenna*	*Acerpenna pygmaea* (Hagen)	1	1	4	9
Arthropoda	Insecta	Ephemeroptera	Baetidae	--	*Baetis*	*Baetis intercaalaris McDunnough*	1	0	0	0
Arthropoda	Insecta	Ephemeroptera	Baetidae	--	*Callibaetis*	*Callibaetis* sp.	0	3	0	0
Arthropoda	Insecta	Ephemeroptera	Baetidae	--	*Centroptilium/ Procloeon*	*Centroptilium/Pro-cloeon*	0	0	1	0
Arthropoda	Insecta	Ephemeroptera	Baetidae	--	*Centroptilum*	*Centroptilum* sp.	0	0	0	4
Arthropoda	Insecta	Ephemeroptera	Baetidae	--	*Fallceon*	*Fallceon quilleri* (Dodds)	1	0	5	7
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	--	--	*Heptageniidae*	0	8	0	0
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Plauditus*	*Plauditus* sp.	0	0	0	4
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	--	*Stenacron*	*Stenacron* sp.	2	0	0	0
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	--	*Stenacron*	*Stenacron interpunc-tatum* (Say)	10	10	12	15
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	--	*Stenonema*	*Stenonema* sp.	1	0	0	0
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	--	*Stenonema*	*Stenonema femoratum* (Say)	14	11	12	11
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	--	*Stenonema*	*Stenonema termina-tum* (Walsh)	1	0	0	0
Arthropoda	Insecta	Ephemeroptera	Isonychiidae	--	*Isonychia*	*Isonychia* sp.	0	2	1	0
Arthropoda	Insecta	Odonata	Calopterygidae	--	*Calopteryx*	*Calopteryx* sp.	0	0	1	2
Arthropoda	Insecta	Odonata	Calopterygidae	--	*Calopteryx*	*Calopteryx maculata* (Beauvois)	6	4	9	17
Arthropoda	Insecta	Odonata	Calopterygidae	--	*Hetaerina*	*Hetaerina americana* (Fabricius)	1	0	1	1

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Arthropoda	Insecta	Odonata	Coenagrionidae	--	--	*Coenagrionidae*	1	4	5	9
Arthropoda	Insecta	Odonata	Coenagrionidae		*Hetaerina*	*Hetaerina* sp.	0	0	0	2
Arthropoda	Insecta	Odonata	Coenagrionidae	--	*Argia*	*Argia* sp.	13	14	15	16
Arthropoda	Insecta	Odonata	Coenagrionidae	--	*Argia*	*Argia apicalis* (Say)	1	0	3	0
Arthropoda	Insecta	Odonata	Coenagrionidae	--	*Argia*	*Argia plana Calvert*	1	0	5	2
Arthropoda	Insecta	Odonata	Coenagrionidae	--	*Argia*	*Argia translata Hagen*	11	0	11	13
Arthropoda	Insecta	Odonata	Coenagrionidae	--	*Enallagma*	*Enallagma* sp.	10	10	14	17
Arthropoda	Insecta	Odonata	Coenagrionidae	--	*Ischnura*	*Ischnura* sp.	3	9	6	11
Arthropoda	Insecta	Odonata	Aeshnidae	--	*Basiaeschna*	*Basiaeschna janata* (Say)	0	1	4	2
Arthropoda	Insecta	Odonata	Aeshnidae	--	*Nasiaeschna*	*Nasiaeschna pentacantha* (Rambur)	0	4	4	4
Arthropoda	Insecta	Odonata	Gomphidae	--	*Arigomphus*	*Arigomphus* sp.	0	0	0	1
Arthropoda	Insecta	Odonata	Aeshnidae	--	*Gomphidae*	*Gomphidae*	0	0	0	2
Arthropoda	Insecta	Odonata	Corduliidae	--	*Epitheca*	*Epitheca princeps Hagen*	1	3	2	0
Arthropoda	Insecta	Odonata	Corduliidae	--	*Somatochlora*	*Somatochlora* sp.	0	2	0	0
Arthropoda	Insecta	Odonata	Gomphidae	--	*Dromogomphus*	*Dromogomphus* sp.	0	0	0	1
Arthropoda	Insecta	Odonata	Gomphidae	--	*Progomphus*	*Progomphus* sp.	0	0	0	1
Arthropoda	Insecta	Odonata	Libellulidae	--	*Erythemis*	*Erythemis* sp.	0	0	0	1
Arthropoda	Insecta	Odonata	Libellulidae	--	--	*Libellulidae*	1	3	1	0
Arthropoda	Insecta	Odonata	Libellulidae	--	*Libellula*	*Libellula* sp.	2	3	2	2
Arthropoda	Insecta	Odonata	Libellulidae	--	*Plathemis*	*Plathemis lydia* (Drury)	1	1	1	2
Arthropoda	Insecta	Plecoptera	--	--	--	*Plecoptera*	0	0	2	1
Arthropoda	Insecta	Plecoptera	Capniidae	Capniinae	*Allocapnia*	*Allocapnia* sp.	6	7	7	1
Arthropoda	Insecta	Plecoptera	Capniidae	Capniinae	*Allocapnia*	*Allocapnia granulata* (Claassen)	1	0	2	0
Arthropoda	Insecta	Plecoptera	Capniidae	Capniinae	*Allocapnia*	*Allocapnia vivipara* (Claassen)	3	0	4	1
Arthropoda	Insecta	Plecoptera	Leuctridae	Leuctrinae	*Zealeuctra*	*Zealeuctra* sp.	0	0	1	0

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Arthropoda	Insecta	Plecoptera	Leuctridae	Leuctrinae	*Zealeuctra*	*Zealeuctra claasseni* (Frison)	0	0	1	0
Arthropoda	Insecta	Plecoptera	Nemouridae	Amphinemurinae	*Amphinemura*	*Amphinemura* sp.	0	0	1	6
Arthropoda	Insecta	Plecoptera	Perlidae	--	--	*Perlidae*	1	1	4	1
Arthropoda	Insecta	Plecoptera	Perlidae	Acroneuriinae	*Perlesta*	*Perlesta* sp.	0	2	0	9
Arthropoda	Insecta	Plecoptera	Perlodidae	--	--	*Perlodidae*	1	0	0	0
Arthropoda	Insecta	Plecoptera	Perlodidae	Isoperlinae	*Isoperla*	*Isoperla* sp.	2	1	6	8
Arthropoda	Insecta	Plecoptera	Perlodidae	Perlodinae	*Hydropera*	*Hydroperla* sp.	0	1	1	0
Arthropoda	Insecta	Hemiptera	Belostomatidae	Belostomatinae	*Belostoma*	*Belostoma flumineum* (Say)	3	2	2	0
Anthropoda	Insecta	Hemiptera	Corixidae	--	--	*Corixidae*	0	3	0	0
Anthropoda	Insecta	Hemiptera	Corixidae	Corixinae	*Palmacorixa*	*Palmacorixa* sp.	0	3	0	0
Arthropoda	Insecta	Hemiptera	Corixidae	Corixinae	*Sigara*	*Sigara* sp.	8	7	6	3
Arthropoda	Insecta	Hemiptera	Corixidae	Corixinae	*Trichocorixa*	*Trichocorixa* sp.	3	4	5	5
Arthropoda	Insecta	Hemiptera	Gerridae	Gerrinae	*Aquarius*	*Aquarius* sp.	0	0	0	2
Arthropoda	Insecta	Hemiptera	Gerridae	Gerrinae	*Aquarius*	*Aquarius remigis* (Say)	0	0	1	1
Arthropoda	Insecta	Hemiptera	Nepidae	--	*Ranatra*	*Ranatra kirkaldyi Torre-Bueno*	0	0	1	0
Arthropoda	Insecta	Hemiptera	Nepidae	Ranatrinae	*Ranatra*	*Ranatra nigra Herrich-Schaeffer*	0	1	0	0
Arthropoda	Insecta	Hemiptera	Notonectidae	--	*Notonecta*	*Notonecta* sp.	1	0	0	0
Arthropoda	Insecta	Hemiptera	Pleidae		*Neoplea striola*	*Neoplea striola* (Fieber)	0	0	0	1
Arthropoda	Insecta	Hemiptera	Veliidae	Microveliinae	*Microvelia*	*Microvelia* sp.	0	0	11	12
Arthropoda	Insecta	Megaloptera	Corydalidae	Corydalinae	*Corydalus*	*Corydalus cornutus* (Linnaeus)	3	0	3	2
Arthropoda	Insecta	Megaloptera	Sialidae	--	*Sialis*	*Sialis* sp.	2	2	0	0
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Hydroptila*	*Hydroptila* sp.	1	1	0	3
Arthropoda	Insecta	Trichoptera	Hydroptilidae			*Hydroptilidae*	0	0	0	1
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	--	*Rhyacophila*	*Rhyacophila* sp.	0	0	0	1
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	--	*Rhyacophila*	*Rhyacophila lobifera Betten*	1	4	10	2

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Arthropoda	Insecta	Trichoptera	Philopotamidae	Chimarrinae	*Chimarra*	*Chimarra* sp.	0	0	2	3
Arthropoda	Insecta	Trichoptera	Hydropsychidae	--	--	*Hydropsychidae*	0	1	0	0
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae	*Cheumato-psyche*	*Cheumatopsyche* sp.	10	16	16	16
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae	*Hydropsyche*	*Hydropsyche* sp.	2	5	0	2
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae	*Hydropsyche*	*Hydropsyche betteni Ross*	6	0	6	11
Arthropoda	Insecta	Trichoptera	Polycentropodi-dae	Polycentropodi-nae	--	*Cernotina/Polycentro-pus* sp.	1	0	0	0
Arthropoda	Insecta	Trichoptera	Polycentropodi-dae	Polycentropodi-nae	*Nyctiophylax*	*Nyctiophylax* sp.	0	0	0	1
Arthropoda	Insecta	Trichoptera	Polycentropodi-dae	Polycentropodi-nae	*Polycentropus*	*Polycentropus* sp.	0	0	1	2
Arthropoda	Insecta	Trichoptera	Phryganeidae	Phryganeinae	*Ptilostomis*	*Ptilostomis* sp.	0	1	1	1
Arthropoda	Insecta	Trichoptera	Limnephilidae	--	--	*Limnephilidae*	0	0	1	0
Arthropoda	Insecta	Trichoptera	Limnephilidae	Dicosmoecinae	*Ironoquia*	*Ironoquia* sp.	0	0	6	13
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilinae	*Pycnopsyche*	*Pycnopsyche* sp.	2	3	4	2
Arthropoda	Insecta	Trichoptera	Limnephilidae			*Leptoceridae*	0	0	0	1
Arthropoda	Insecta	Trichoptera	Limnephilidae	Leptocerinae	*Ceraclea*	*Ceraclea* sp.	0	0	0	1
Arthropoda	Insecta	Trichoptera	Limnephilidae	Leptocerinae	*Triaenodes*	*Triaenodes* sp.	0	0	0	3
Arthropoda	Insecta	Trichoptera	Helicopsychidae	--	*Helicopsyche*	*Helicopsyche borealis* (Hagen)	1	1	0	4
Arthropoda	Insecta	Lepidoptera	Pyralidae	Nymphylinae	*Petrophila*	*Petrophila* sp.	0	0	0	1
Arthropoda	Insecta	Coleoptera	--	--	--	*Coleoptera*	1	0	3	1
Arthropoda	Insecta	Coleoptera	Carabidae	--	--	*Carabidae*	1	0	0	0
Arthropoda	Insecta	Coleoptera	Dytiscidae			*Dytiscidae*	0	0	1	0
Arthropoda	Insecta	Coleoptera	Dytiscidae	Colymbetinae	*Agabus*	*Agabus* sp.	1	4	4	4
Arthropoda	Insecta	Coleoptera	Dytiscidae	Colymbetinae	*Copelatus*	*Copelatus* sp.	0	0	0	1
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hydroporinae	--	*Hydroporini*	2	6	5	3
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hydroporinae	*Neoporus*	*Neoporus* sp.	4	7	10	5
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hydroporinae	*Uvarus*	*Uvarus* sp.	0	0	1	0
Arthropoda	Insecta	Coleoptera	Dytiscidae	Laccophilinae	*Laccophilus*	*Laccophilus* sp.	0	1	1	1

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Arthropoda	Insecta	Coleoptera	Gyrinidae	--	*Dineutus*	*Dineutus assimilis* (Kirby)	0	1	2	1
Arthropoda	Insecta	Coleoptera	Gyrinidae	--	*Gyrinus*	*Gyrinus* sp.	0	1	1	1
Arthropoda	Insecta	Coleoptera	Haliplidae	--	*Haliplus*	*Haliplus* sp.	0	0	0	5
Arthropoda	Insecta	Coleoptera	Haliplidae	--	*Peltodytes*	*Peltodytes* sp.	5	7	14	9
Arthropoda	Insecta	Coleoptera	Staphylinidae	--	--	*Staphylinidae*	0	0	1	1
Arthropoda	Insecta	Coleoptera	Hydrophilidae	--	*Berosus*	*Berosus* sp.	0	2	0	0
Arthropoda	Insecta	Coleoptera	Hydrophilidae	--	*Cymbiodyta*	*Cymbiodyta* sp.	1	1	1	0
Arthropoda	Insecta	Coleoptera	Hydrophilidae	--	*Enochrus*	*Enochrus* sp.	1	0	1	1
Arthropoda	Insecta	Coleoptera	Hydrophilidae		*Paracymus*	*Paracymus* sp.	0	0	1	1
Arthropoda	Insecta	Coleoptera	Hydrophilidae	--	*Tropisternus*	*Tropisternus* sp.	0	2	3	0
Arthropoda	Insecta	Coleoptera	Hydrophilidae	--	*Tropisternus*	*Tropisternus lateralis* (Fabricius)	0	0	0	1
Arthropoda	Insecta	Coleoptera	Hydrophilidae		*Laccobius*	*Laccobius* sp.	0	0	0	1
Arthropoda	Insecta	Coleoptera	Scirtidae	--	--	*Scirtidae*	1	0	1	1
Arthropoda	Insecta	Coleoptera	Dryopidae	--	*Helichus*	*Helichus basalis LeConte*	3	1	3	4
Arthropoda	Insecta	Coleoptera	Elmidae	--	*Dubiraphia*	*Dubiraphia* sp.	1	1	0	3
Arthropoda	Insecta	Coleoptera	Elmidae		*Macronychus*	*Macronychus glabratus* (Say)	0	0	0	4
Arthropoda	Insecta	Coleoptera	Elmidae	--	*Stenelmis*	*Stenelmis* sp.	9	14	15	15
Arthropoda	Insecta	Coleoptera	Elmidae	--	*Stenelmis*	*Stenelmis crenata* (Say)	0	0	0	2
Arthropoda	Insecta	Coleoptera	Elmidae	--	*Stenelmis*	*Stenelmis sexlineata Sanderson*	6	0	11	14
Arthropoda	Insecta	Coleoptera	Curculionidae	--	--	*Curculionidae*	0	0	2	0
Arthropoda	Insecta	Diptera	--	--	--	*Nematocera*	0	0	0	1
Arthropoda	Insecta	Diptera	Ceratopogonidae	--	--	*Ceratopogonidae*	0	0	4	8
Arthropoda	Insecta	Diptera	Chironomidae	--	--	*Chironomidae*	8	9	7	11
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	--	*Chironominae*	2	1	1	5
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	--	*Chironomini*	2	1	0	3
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	--	*Endochironomus*	0	0	0	0

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	--	*Phaenopsectra/ Tribelos* sp.	1	11	0	5
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Axarus*	*Axarus* sp.	2	0	1	0
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Chironomus*	*Chironomus* sp.	8	13	12	10
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae		*Bezzia/Palpomyia* sp.	0	0	0	3
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Cryptochi-ronomus*	*Cryptochironomus* sp.	2	9	4	12
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Cryptotendi-pes*	*Cryptotendipes* sp.	0	1	0	3
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Dicrotendipes*	*Dicrotendipes* sp.	6	8	8	16
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Harnischia*	*Harnischia* sp.	0	0	0	1
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Nilothauma*	*Nilothauma* sp.	0	0	0	2
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Glyptotendi-pes*	*Glyptotendipes* sp.	2	6	1	1
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Microtendipes*	*Microtendipes* sp.	3	5	3	3
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Paraclado-pelma*	*Paracladopelma* sp.	1	0	1	0
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Paralauter-vorniella*	*Paralauterborni-ella nigrohalterale* (Malloch)	0	0	0	2
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Paratendipes*	*Paratendipes* sp.	3	5	3	12
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Phaenopsec-tra*	*Phaenopsectra* sp.	4	0	7	10
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Polypedilum*	*Polypedilum* sp.	11	14	12	19
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Saetheria*	*Saetheria* sp.	0	0	0	1
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Stenochirono-mus*	*Stenochironomus* sp.	0	0	0	4
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Stictochirono-mus*	*Stictochironomus* sp.	6	8	11	4
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Tribelos*	*Tribelos* sp.	2	0	3	4
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Pseudochi-ronomus*	*Pseudochironomus* sp.	2	3	0	1
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	--	*Tanytarsini*	1	0	1	0

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	--	*Micropsectra/Tanytarsus* sp.	3	9	0	0
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Cladotanytarsus*	*Cladotanytarsus* sp.	0	1	0	1
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Micropsectra*	*Micropsectra* sp.	3	0	0	0
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Paratanytarsus*	*Paratanytarsus* sp.	1	7	5	2
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Rheotanytarsus*	*Rheotanytarsus* sp.	0	1	4	3
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Tanytarsus*	*Tanytarsus* sp.	7	0	4	10
Arthropoda	Insecta	Diptera	Chironomidae	Diamesinae	*Diamesa*	*Diamesa* sp.	1	0	4	6
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	--	*Orthocladiinae*	15	0	13	10
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	--	*Cricotopus/Orthocladius* sp.	2	16	12	18
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Corynoneura*	*Corynoneura* sp.	3	5	1	1
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Cricotopus*	*Cricotopus* sp.	5	0	14	11
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Cricotopus*	*Cricotopus bicinctus group*	6	10	14	10
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Cricotopus*	*Cricotopus (Isocladius)* sp.	1	0	0	0
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Diplocladius*	*Diplocladius cultriger Kieffer*	1	0	0	0
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Eukiefferiella*	*Eukiefferiella* sp.	3	3	6	10
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Hydrobaenus*	*Hydrobaenus* sp.	12	13	11	3
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Limnophyes*	*Limnophyes* sp.	1	0	0	0
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Nanocladius*	*Nanocladius* sp.	5	4	1	2
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Parakiefferiella*	*Parakiefferiella* sp.	2	0	0	0
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Parametriocnemus*	*Parametriocnemus* sp.	2	6	4	1
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Paratrichocladius*	*Paraphaenocladius* sp.	0	1	0	0
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Psectrocladius*	*Psectrocladius* sp.	1	0	1	0

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

[--, data not available; sp., species]

Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Rheocricotopus*	*Rheocricotopus* sp.	0	2	0	1
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Smittia*	*Smittia* sp.	0	0	1	1
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Thienemanniella*	*Thienemanniella* sp.	3	8	7	1
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	*Tvetenia*	*Tvetenia* sp.	1	0	0	0
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	--	*Tanypodinae*	1	0	1	15
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	*Natarsia*	*Natarsia* sp.	3	2	4	5
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	--	*Pentaneurini*	3	1	0	1
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	--	*Thienemannimyia gp.* sp. (Coffman and Ferrington, 1996)	11	15	16	17
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	*Ablabesmyia*	*Ablabesmyia* sp.	3	0	1	8
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	*Labrundinia*	*Labrundinia* sp.	0	0	1	0
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	*Procladius*	*Procladius* sp.	4	11	8	3
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	*Psectrotanypus*	*Psectrotanypus* sp.	0	0	0	1
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	*Tanypus*	*Tanypus* sp.	0	0	1	0
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	*Zavrelimyia*	*Zavrelimyia* sp.	0	3	5	0
Arthropoda	Insecta	Diptera	Simuliidae	--	--	*Simuliidae*	6	10	3	2
Arthropoda	Insecta	Diptera	Simuliidae	--	*Simulium*	*Simulium* sp.	13	15	19	19
Arthropoda	Insecta	Diptera	Tipulidae	--	--	*Tipulidae*	1	0	0	0
Arthropoda	Insecta	Diptera	Tipulidae	Tipulinae	*Tipula*	*Tipula* sp.	2	7	13	13
Arthropoda	Insecta	Diptera	Tipulidae	Limoniinae	*Helius*	*Helius* sp.	0	0	0	1
Arthropoda	Insecta	Diptera	Tipulidae	Limoniinae	*Hexatoma*	*Hexatoma* sp.	1	0	1	3
Arthropoda	Insecta	Diptera	Tipulidae	Limoniinae	*Limonia*	*Limonia* sp.	0	0	0	3
Arthropoda	Insecta	Diptera	--	--	--	*Brachycera*	1	0	1	1
Arthropoda	Insecta	Diptera	Empididae	--	--	*Empididae*	1	0	0	0
Arthropoda	Insecta	Diptera	Empididae	Clinocerinae	*Clinocera*	*Clinocera* sp.	1	0	3	1
Arthropoda	Insecta	Diptera	Empididae	Clinocerinae	*Trichoclinocera*	*Trichoclinocera* sp.	0	0	0	1

Appendix 9. Macroinvertebrate taxa identified and the number of biological monitoring sites where each occurred in Johnson County, Kansas streams, 2003, 2004, 2007, and 2010.—Continued

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Phylum	Class	Order	Family	Subfamily	Genus	Taxa reported as	Number of sites in 2003	Number of sites in 2004	Number of sites in 2007	Number of sites in 2010
Arthropoda	Insecta	Diptera	Empididae	Hemerodromiinae	*Hemerodromia*	*Hemerodromia* sp.	0	0	0	1
Arthropoda	Insecta	Diptera	Muscidae	--	--	*Muscidae*	0	1	0	0
Arthropoda	Insecta	Diptera	Stratiomyidae	Stratiomyinae	*Stratiomys*	*Stratiomys* sp.	1	0	0	0
Arthropoda	Insecta	Diptera	Stratiomyidae	Stratiomyinae	*Odontomyia*	*Odontomyia* sp.	0	0	0	1
Arthropoda	Insecta	Diptera	Tabanidae	--	--	*Tabanidae*	1	1	1	3
Arthropoda	Insecta	Diptera	Tabanidae		*Chrysops*	*Chrysops* sp.	0	0	0	2
Arthropoda	Insecta	Diptera	Tabanidae	--	*Tabanus*	*Tabanus* sp.	4	2	6	5

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Rasmussen and others—**Quality of Streams in Johnson County, Kansas, 2002–10**—Scientific Investigations Report 2012–5279