

Prepared in cooperation with the U.S. Environmental Protection Agency

Occurrence and Variability of Mining-Related Lead and Zinc in the Spring River Flood Plain and Tributary Flood Plains, Cherokee County, Kansas, 2009–11



Scientific Investigations Report 2013–5028

Cover. Chat piles (mine tailings) in the Tar Creek Basin, Cherokee County, Kansas (photograph by Eric Looper, U.S. Geological Survey).

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By Kyle E. Juracek

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Conversion Factors, Abbreviations, and Datum

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
millimeter (mm)	0.03937	inch (in.)
Area		
acre	4,047	square meter (m ²)
acre	0.4047	hectare (ha)
acre	0.004047	square kilometer (km ²)
square foot (ft ²)	0.09290	square meter (m ²)
square mile (mi ²)	259.0	hectare (ha)
square mile (mi ²)	2.590	square kilometer (km ²)
Mass		
gram (g)	0.03527	ounce (oz)
milligram per kilogram (mg/kg)	1.0	part per million (ppm)
pound (lb)	0.4536	kilogram (kg)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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Occurrence and Variability of Mining-Related Lead and Zinc in the Spring River Flood Plain and Tributary Flood Plains, Cherokee County, Kansas, 2009–11

By Kyle E. Juracek

Abstract

Historical mining activity in the Tri-State Mining District (TSMD), located in parts of southeast Kansas, southwest Missouri, and northeast Oklahoma, has resulted in a substantial ongoing input of cadmium, lead, and zinc to the environment. To provide some of the information needed to support remediation efforts in the Cherokee County, Kansas, superfund site, a 4-year study was begun in 2009 by the U.S. Geological Survey that was requested and funded by the U.S. Environmental Protection Agency. A combination of surficial-soil sampling and coring was used to investigate the occurrence and variability of mining-related lead and zinc in the flood plains of the Spring River and several tributaries within the superfund site. Lead- and zinc-contaminated flood plains are a concern, in part, because they represent a long-term source of contamination to the fluvial environment.

Lead and zinc contamination was assessed with reference to probable-effect concentrations (PECs), which represent the concentrations above which adverse aquatic biological effects are likely to occur. The general PECs for lead and zinc were 128 and 459 milligrams per kilogram, respectively. The TSMD-specific PECs for lead and zinc were 150 and 2,083 milligrams per kilogram, respectively.

Typically, surficial soils in the Spring River flood plain had lead and zinc concentrations that were less than the general PECs. Lead and zinc concentrations in the surficial-soil samples were variable with distance downstream and with distance from the Spring River channel, and the largest lead and zinc concentrations usually were located near the channel. Lead and zinc concentrations larger than the general or TSMD-specific PECs, or both, were infrequent at depth in the Spring River flood plain. When present, such contamination typically was confined to the upper 2 feet of the core and frequently was confined to the upper 6 inches.

Tributaries with few or no lead- and zinc-mined areas in the basin—Brush Creek, Cow Creek, and Shawnee Creek—generally had flood-plain lead and zinc concentrations (surficial soil, 6- and 12-inch depth) that were substantially less than the general PECs. Tributaries with extensive lead- and zinc-mined

areas in the basin—Shoal Creek, Short Creek, Spring Branch, Tar Creek, Turkey Creek, and Willow Creek—had flood-plain lead concentrations (surficial soil, 6- and 12-inch depth) that frequently or typically exceeded the general and TSMD-specific PECs. Likewise, the tributaries with extensive lead- and zinc-mined areas in the basin had flood-plain zinc concentrations (surficial soil, 6- and 12-inch depth) that frequently or typically exceeded the general PEC. With the exception of Shoal and Willow Creeks, zinc concentrations typically exceeded the TSMD-specific PEC. The largest flood-plain lead and zinc concentrations (surficial soil, 6- and 12-inch depth) were measured for Short and Tar Creeks. Lead and zinc concentrations in the surficial-soil samples collected from the tributary flood plains varied longitudinally in relation to sources of mining-contaminated sediment in the basins. Lead and zinc concentrations also varied with distance from the channel; however, no consistent spatial trend was evident. For the surficial-soil samples collected from the Spring River flood plain and tributary flood plains, both the coarse (larger than 63 micrometers) and fine particles (less than 63 micrometers) contained substantial lead and zinc concentrations.

Introduction

For about 100 years (1850–1950), the Tri-State Mining District (TSMD) in parts of southeast Kansas, southwest Missouri, and northeast Oklahoma (fig. 1) was one of the primary sources of lead and zinc ore in the world (Brosius and Sawin, 2001). Mining activity in the TSMD ended in the 1970s. The historical mining activity in the TSMD has resulted in a substantial ongoing input of cadmium, lead, and zinc to the environment (Juracek, 2006; Juracek and Becker, 2009). Recent studies by the U.S. Geological Survey (USGS), in cooperation with the U.S. Fish and Wildlife Service (USFWS) and the Kansas Department of Health and Environment (KDHE), documented cadmium, lead, and zinc concentrations in sediment that far exceeded background levels as well as probable-effects guidelines for toxic aquatic biological effects (Pope, 2005; Juracek, 2006). For these

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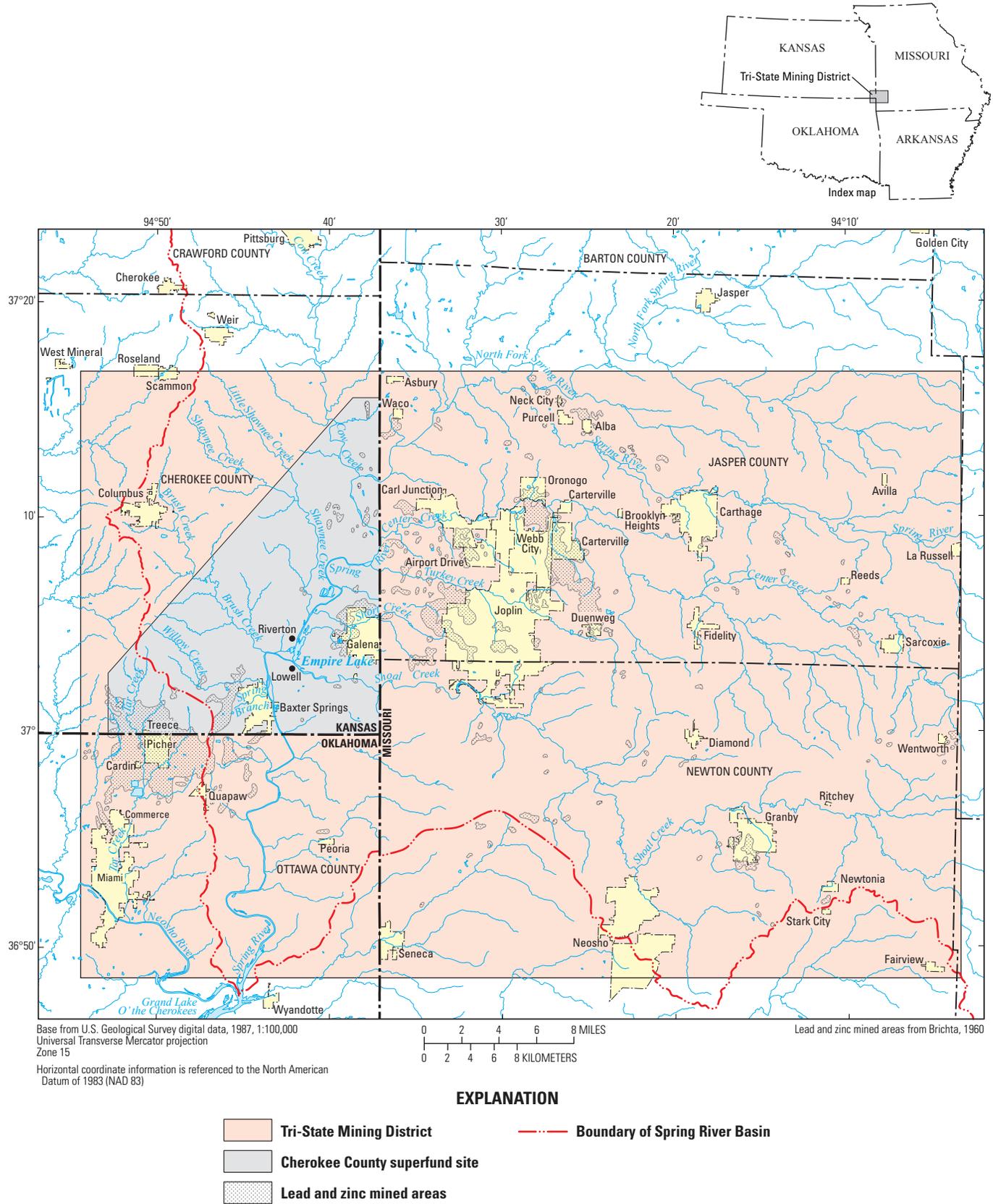


Figure 1. Location of the Spring River system, the Cherokee County superfund site, and lead- and zinc-mined areas in the Tri-State Mining District, Kansas, Missouri, and Oklahoma.

studies, the USGS sampled deposited sediment in the Spring River and its tributaries, Tar Creek, and Empire Lake in Cherokee County, Kansas. Sediment quality is an important environmental concern because sediment may be a sink for some water-quality constituents and a source of constituents to the overlying water column and biota (Baudo and others, 1990; Zoumis and others, 2001; Luoma and Rainbow, 2008). Once in the food chain, sediment-derived constituents may pose an even greater concern because of bioaccumulation (that is, the accumulation of constituents in biological tissues of living organisms) (Smol, 2002).

The ongoing mining-related input of cadmium, lead, and zinc to the environment has resulted in contamination that has adversely affected biota including mussels (Angelo and others, 2007), waterfowl (Beyer and others, 2004; van der Merwe and others, 2011), and fish (Wildhaber and others, 1998, 1999, 2000). In recent years, a shellfish consumption advisory was issued in Kansas (Kansas Department of Health and Environment, 2006, 2012) and a fish consumption advisory was issued in Oklahoma (Oklahoma Department of Environmental Quality, 2008) because of cadmium or lead contamination, or both. Human health problems and risks also have been attributed to mining-related contamination (Neuberger and others, 1990; Malcoe and others, 2002). In response to concern about the mining-related environmental contamination, southeast Cherokee County was listed on the U.S. Environmental Protection Agency's (USEPA) National Priority List as a superfund hazardous waste site in 1983 (U.S. Environmental Protection Agency, 2004).

Mining-related contamination is not confined to stream channels and lake beds in Cherokee County (Juracek, 2006). During floods, contaminated sediment is carried out of the channels and deposited on the adjoining flood plains. Flood-plain contamination is an important environmental concern because of the potentially toxic effects of the contaminated sediment on wildlife. Moreover, the contaminated flood plains are a potential concern because the stored sediment may be remobilized and reintroduced into the aquatic environment (for example, by floods and channel-bank erosion). Given the importance of flood-plain contamination as an issue for environmental restoration, an understanding of the magnitude and extent of the contamination is needed.

A 4-year study by USGS, which was requested and funded by USEPA, was begun in 2009 to investigate the occurrence and variability of mining-related cadmium, lead, and zinc in the Spring River flood plain and tributary flood plains located in the Cherokee County, Kansas, superfund site (fig. 1). The specific objectives of the study were to:

1. Determine the concentrations of cadmium, lead, and zinc in the Spring River flood plain and tributary flood plains;
2. Determine how flood-plain contamination along the Spring River and tributary streams varies with distance downstream, with distance from the channel, and in relation to particle size; and

3. Determine the depth of contamination in the Spring River flood plain and tributary flood plains.

Information on contamination of the Spring River flood plain and tributary flood plains provided by this study, in combination with previous studies on in-channel and lakebed sediment contamination, will assist USEPA in the development of a comprehensive remediation plan for Cherokee County.

Previous Investigations

Several previous studies have examined the effects of lead and zinc mining on water and sediment quality in or near Cherokee County, Kansas. Barks (1977) investigated the effects of abandoned lead and zinc mines and tailings piles on water and sediment quality in the vicinity of Joplin, Missouri. Water from abandoned lead and zinc mines in the area, some of which discharges at the surface, was determined to have average dissolved zinc concentrations of 9,400 micrograms per liter ($\mu\text{g/L}$). Mine-water discharges increased the dissolved zinc concentrations in receiving streams from a baseline of about 40 $\mu\text{g/L}$ to about 500 $\mu\text{g/L}$ during low-flow conditions. In runoff from tailings areas, dissolved zinc concentrations averaged 16,000 $\mu\text{g/L}$. Runoff from one tailings area during a summer storm contained maximum dissolved cadmium, lead, and zinc concentrations of 1,400 $\mu\text{g/L}$, 400 $\mu\text{g/L}$, and 200,000 $\mu\text{g/L}$, respectively. The mining activity also resulted in increased zinc concentrations in stream-bottom sediment from a baseline of about 100 micrograms per gram ($\mu\text{g/g}$) to about 2,500 $\mu\text{g/g}$ and increased lead concentrations in stream-bottom sediment from a baseline of about 20 $\mu\text{g/g}$ to about 450 $\mu\text{g/g}$ (Barks, 1977). The bottom-sediment samples, described as sandy, were not sieved to isolate the silt-clay fraction before analyses to determine trace-element concentrations. Spring River tributaries sampled as part of the Barks (1977) study included Center Creek, Short Creek, and Turkey Creek (fig. 1).

An extensive study of the effects of abandoned lead and zinc mines on hydrology and surface-water and groundwater quality in Cherokee County, Kansas, and adjacent areas, was completed by Spruill (1987). Water from mines located mostly in the vicinity of Galena, Kansas (fig. 1) had respective median concentrations of 180 $\mu\text{g/L}$, 240 $\mu\text{g/L}$, and 37,600 $\mu\text{g/L}$ for dissolved cadmium, lead, and zinc. Of the four streams sampled that were affected by lead and zinc mining and provide flow directly or indirectly to Empire Lake (that is, Center Creek, Shoal Creek, Short Creek, and Turkey Creek; fig. 1), Short Creek had the largest concentrations of dissolved cadmium (170 $\mu\text{g/L}$) and zinc (25,000 $\mu\text{g/L}$) (Spruill, 1987).

Ferrington and others (1989) completed a study to determine the occurrence and biological effects of cadmium, lead, manganese, and zinc in the Short Creek/Empire Lake aquatic system in Cherokee County, Kansas. As part of this study, bottom sediment was sampled at multiple sites within the Spring River and Shoal Creek arms as well as the

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main body of Empire Lake. Bottom sediment throughout Empire Lake was found to have increased concentrations of all four trace elements. The largest concentrations of cadmium, lead, and zinc were detected in two samples collected from the Spring River arm near the mouth of Short Creek (fig. 1). At this location, mean concentrations of cadmium, lead, and zinc were about 129 $\mu\text{g/g}$, 1,600 $\mu\text{g/g}$, and 23,000 $\mu\text{g/g}$, respectively (Ferrington and others, 1989). The bottom-sediment samples were not sieved to isolate the silt-clay fraction prior to analyses to determine trace-element concentrations. Overall, the results indicated substantial transport and accumulation of sediment-associated trace elements in Empire Lake. No statistically significant relations between trace-element concentrations and benthic macroinvertebrate species richness or abundance were determined. It was concluded that the primary biological effect of large cadmium, lead, and zinc concentrations in the bottom sediment of Empire Lake was a reduction of aquatic macroinvertebrate abundance, and presumably overall biological productivity of the reservoir system (Ferrington and others, 1989).

A study to determine concentrations of trace elements and organic compounds in sediment and biota of the Spring River system, including Empire Lake, was completed by USFWS in 1992. As part of the study, two bottom-sediment samples were collected from a site in both the Spring River and Shoal Creek arms upstream from the main body of Empire Lake. Cadmium concentrations in the bottom sediment averaged about 26 $\mu\text{g/g}$ for the sampling site in the Spring River arm and about 23 $\mu\text{g/g}$ for the sampling site in the Shoal Creek arm. For lead, the respective average sediment concentrations for the Spring River and Shoal Creek sites were 165 and 230 $\mu\text{g/g}$. Average zinc concentrations in the sediment for the Spring River and Shoal Creek sites were 3,580 and 3,300 $\mu\text{g/g}$, respectively (U.S. Fish and Wildlife Service, 1992). It is uncertain if the bottom-sediment samples were sieved to isolate the silt-clay fraction before analyses to determine trace-element concentrations.

Davis and Schumacher (1992) conducted an appraisal of surface-water quality in the Spring River Basin of southwest Missouri and southeast Kansas using existing water-quality data collected from the early 1960s to September 1987 by USGS and KDHE. Results indicated that several Spring River tributaries, including Brush, Center, Cow, Turkey, and Short Creeks (fig. 1), are significantly affected by lead-zinc or coal mining. The effect of the contaminated tributaries on the water quality of the Spring River was revealed by a comparison of the water-quality data collected at the Spring River sampling stations located near Waco, Missouri (upstream from the tributary inflows), and Baxter Springs, Kansas (downstream from the tributary inflows) (fig. 1). Increased median concentrations of several water-quality constituents were documented including an increase of dissolved zinc from 30 to 310 $\mu\text{g/L}$. The largest single source of dissolved zinc to the Spring River was determined to be Short Creek. Davis and Schumacher (1992) also concluded that baseline water-quality

conditions for the study area were best represented by the Spring River near Waco, Missouri, and Shoal Creek near Galena, Kansas.

A study by Pope (2005) provided an assessment of streambed sediment quality along the main stem and major tributaries of both the Spring River and Tar Creek within the boundary of the Cherokee County, Kansas, superfund site (fig. 1). All sediment samples were collected to a depth of 0.8 inch (in.) and sieved to isolate the less than 63-micrometers (μm) fraction (silt- and clay-size particles) for analysis. Concentrations ranged from 0.6 to 460 milligrams per kilogram (mg/kg) for cadmium, 22 to 7,400 mg/kg for lead, and 100 to 45,000 mg/kg for zinc, with respective median concentrations of 13, 180, and 1,800 mg/kg. The largest concentrations were measured at sampling sites in the Short Creek, Tar Creek, and Spring Branch basins. Proceeding downstream along the 22-mile length of the Spring River within the study area, it was determined that sediment concentrations of cadmium, lead, and zinc increased about 18, 7, and 17 times, respectively.

Juracek (2006) investigated mining-related sediment contamination in Empire Lake, Kansas (fig. 1). All bottom-sediment samples were sieved to isolate the less than 63- μm fraction for analysis. Cadmium concentrations ranged from 7.3 to 76 mg/kg with a median concentration of 29 mg/kg. Lead concentrations ranged from 100 to 950 mg/kg with a median concentration of 270 mg/kg. Zinc concentrations ranged from 1,300 to 13,000 mg/kg with a median concentration of 4,900 mg/kg. In general, the cadmium, lead, and zinc concentrations were one to two orders of magnitude larger than estimated local background concentrations with the largest concentrations in the older sediment that corresponded to when the mines were in operation. Despite a decrease in concentrations with time, the concentrations of cadmium, lead, and zinc in the most recently deposited bottom sediment still exceeded probable-effects guidelines (U.S. Environmental Protection Agency, 1997; MacDonald and others, 2000) for toxic aquatic biological effects.

Angelo and others (2007) investigated the effects of historical lead and zinc mining activity on mussel populations in the Spring River Basin. As part of the study, mussel species diversity, densities, and concentrations of cadmium, lead, and zinc in streambed sediment and mussel soft tissue were determined at selected sites along the Spring River and tributary streams. Mussels were not found in the downstream reaches of Center, Shoal, Short, and Turkey Creeks. Also, mussel diversity and density were substantially reduced in the Spring River downstream from Center and Turkey Creeks. Angelo and others (2007) concluded that the historical lead and zinc mining activity continues to adversely affect environmental quality and impede the recovery of mussel populations in much of the Spring River Basin.

MacDonald and others (2010) completed an ecological risk assessment to investigate risks to benthic invertebrates exposed to contaminants in aquatic habitats within the TSMD. Specifically, the assessment was focused on the survival,

growth, and reproduction of amphipods, midges, and mussels as affected by exposure to contaminants in surface water, sediment, and pore water. Cadmium, lead, and zinc were identified as the principal contaminants of interest in the TSMD. It was determined that exposure to contaminated surface water, sediment, and pore water posed increased risks to benthic invertebrates throughout a large part of the TSMD (MacDonald and others, 2010).

Purpose and Scope

The purpose of this report is to present the results of the USGS study to assess the magnitude, extent, and variability of mining-related contamination in the Spring River flood plain and tributary flood plains located in the Cherokee County, Kansas, superfund site. In 2009, surficial-soil samples were collected at 30 sites in the Spring River flood plain. In 2009 and 2010, a total of 34 cores were collected along 6 transects in the Spring River flood plain. In 2011, surficial-soil samples and cores were collected at more than 50 sites along transects in several tributary flood plains. All surficial-soil samples and cores were analyzed for cadmium, lead, and zinc concentrations. Cadmium, lead, and zinc are the trace elements that were of primary interest in this study because they are the major contaminants introduced into the environment as a result of the historical mining activity (Juracek, 2006). In this report, background trace element concentrations were defined as concentrations that were minimally affected by historical lead and zinc mining.

Results presented in this report will provide some of the information required by USEPA for the development of a comprehensive remediation plan for Cherokee County. From a national perspective, the methods and results presented in this report provide guidance and perspective for future studies concerned with the issues of sediment-associated contaminant transport and deposition in fluvial environments.

Description of the Spring River Basin

The Spring River Basin drains about 2,500 square miles (mi^2) of southwest Missouri, southeast Kansas, and northeast Oklahoma (Seaber and others, 1987) (fig. 1). Principal tributaries to the Spring River in Cherokee County include Brush Creek, Cow Creek, Center Creek, Shawnee Creek, Shoal Creek, Short Creek, Turkey Creek, and Willow Creek (fig. 1). Several of the tributaries drain areas that were substantially affected by historical lead and zinc mining.

The Spring River Basin overlaps two physiographic provinces as defined by Fenneman (1938, 1946). The southeast two-thirds of the basin is located in the Springfield Plateau Section of the Ozark Plateaus Province. This part of the basin is underlain by limestone of Mississippian age (Fenneman, 1938). The northwest one-third of the basin, including the Kansas part of the basin located west of the Spring River, is located in the Osage Plains Section of the Central Lowland

Province. This part of the basin is underlain by shale with interbedded sandstone and limestone of Pennsylvanian age (Fenneman, 1938). Topographically, the basin is typified by gently rolling uplands dissected by streams.

The lead and zinc ores in the TSMD occur in the cherty limestones of Mississippian age. The ores possibly resulted from hydrothermal (that is, hot, metal-bearing) solutions that originated as sedimentary brines (Leach and others, 2010) and moved into the porous and permeable cherty limestones. The solutions deposited sphalerite (zinc sulfide), galena (lead sulfide) and other associated minerals.

Several major soil associations are present within the Spring River Basin. Soils in the Missouri part of the basin are described by Allgood and Persinger (1979). Information on soils in the Kansas part of the basin is provided by the U.S. Department of Agriculture, Soil Conservation Service (1973, 1985).

The climate in the Spring River Basin is characterized as subhumid continental (Stringer, 1972). Long-term, mean annual precipitation at Joplin, Missouri (period of record 1948–2011) is about 43 in. (High Plains Regional Climate Center, 2012) (fig. 1).

Land use in the Spring River Basin is predominantly a mix of cropland, grassland, and woodland (Davis and Schumacher, 1992). Historically, numerous sites within the basin were mined for coal, lead, and zinc (Brichta, 1960; Marcher and others, 1984). The distribution of lead- and zinc-mined lands within the basin is shown in figure 1.

Methods

The objectives of this study were accomplished using available and newly collected information. Available information included sediment chemistry data from previous investigations. New information was obtained through the collection and analysis of surficial-soil samples and cores from the Spring River flood plain and tributary flood plains in the Cherokee County superfund site.

Flood-Plain Surficial-Soil Sampling and Analysis

Site Selection

The selection of surficial-soil sampling sites for the Spring River flood plain involved multiple steps. First, all 1- mi^2 sections that were located mostly (that is, at least 50 percent) or completely in the Spring River flood plain were identified using USGS 1:24,000-scale topographic quadrangle maps. Second, the selected sections were divided into quadrants. Third, for each section, a quadrant was randomly selected for sampling. The random-selection process involved the use of coin flips to determine if the quadrant was north or south and east or west. Using this process, either the

northwest, northeast, southwest, or southeast quadrant was selected for each section. If the randomly selected quadrant for a section was unusable, either because it was located mostly out of the flood plain or because access permission from the land owner was not granted, the next quadrant was selected using a clockwise rotation. A total of 30 surficial-soil sampling sites were selected (fig. 2A). Typically, the flood-plain soil was sampled at the center of each randomly selected quadrant. However, for a few quadrants, the soil was sampled off center either because the center of the quadrant was under water or because access permission from the land owner was not granted. The latitude and longitude coordinates for the center of each sampling site, obtained using global positioning system (GPS) technology, are provided in table 1–1 in the appendix at the back of this report.

Tributary streams for which flood-plain surficial soils were sampled included Brush Creek, Cow Creek, Shawnee Creek, Shoal Creek, Short Creek, Spring Branch, Tar Creek, Turkey Creek, and Willow Creek (fig. 1). Tar Creek is not a direct tributary of the Spring River. It flows into the Neosho River, which subsequently joins the Spring River at Grand Lake O' the Cherokees in Oklahoma. Tar Creek was included because it drains a part of Cherokee County that was substantially affected by historical lead and zinc mining activity (fig. 1). Along each stream, one to three transects were established for the purpose of sampling (figs. 2A–2U). A total of 20 transects were established. Along each transect, two to four sampling sites were selected. The distance between successive sampling sites (when two or more sites were sampled on the same side of the stream) ranged from about 10 to about 300 feet (ft) as determined by flood-plain width, number of sites, and site conditions. A total of 59 surficial-soil sampling sites were selected. The latitude and longitude coordinates for the center of each sampling site, obtained using GPS technology, are provided in table 1–1 at the back of this report.

Sample Collection and Preparation

The Spring River flood-plain surficial-soil samples were collected in the fall of 2009. The tributary flood-plain surficial-soil samples were collected in the spring of 2011. All flood-plain surficial-soil samples were collected to a depth of about 1 in. At each Spring River flood-plain site, the soil was sampled at the selected center location and typically at a distance (hereafter referred to as the sampling radius) of 100 ft north, south, east, and west of the center. This sampling method is referred to as the five-point sampling technique. For the tributary flood-plain sites, the five-point sampling technique was used with a sampling radius that ranged from 5 to 50 ft as determined by the width of flood plain available for sampling and the number of sampling sites per transect.

At each sampling site, an equal volume of soil was collected at the five locations using a 5-in. long section of cellulose acetate butyrate transparent tubing (2.625-in. inside

diameter) that was pushed by hand into the soil. The tubing was thoroughly cleaned with a clean paper towel prior to each reuse. For each site, the soil from the five locations was combined in a plastic bag and transported back to the USGS laboratory in Lawrence, Kansas, for subsequent sample preparation.

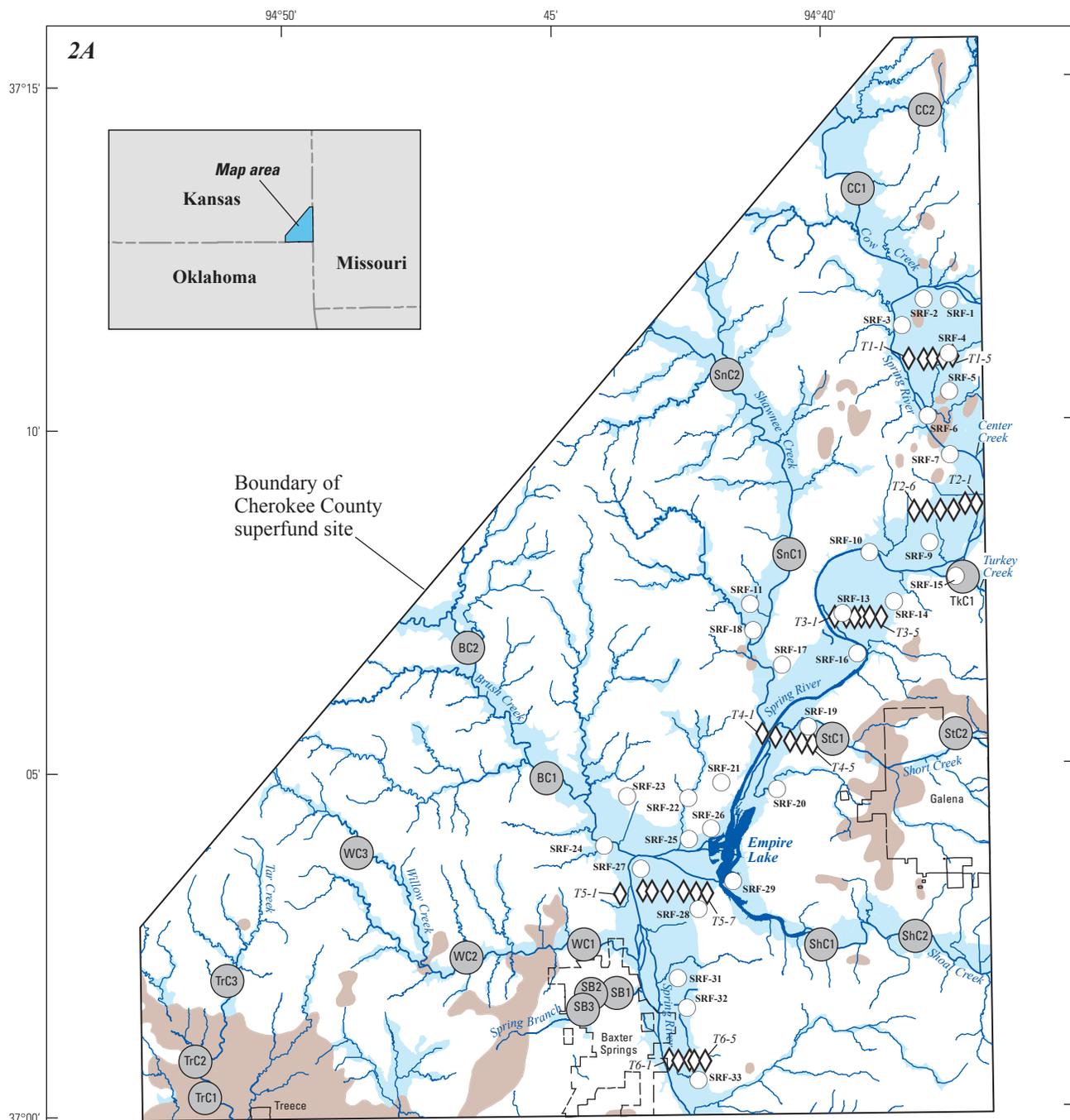
Following air drying, each bulk sample was spread out on a clean plastic sheet and all visible organics (for example, plant fragments, seed pods, and roots) were removed using stainless steel tweezers. Each sample was disaggregated using a rubber-tipped pestle until the entire sample passed through a 4-millimeter (mm) stainless steel sieve. Then, each disaggregated sample was placed in a glass bowl and homogenized using a plastic spoon to provide a composite sample for each site. All utensils used in sample preparation were thoroughly cleaned with deionized water and wiped dry with a clean paper towel before each reuse.

The composite sample for each site was split into three subsamples of approximately equal size by successively removing random scoops of the sample using a plastic spoon and placing it into three separate plastic bags. The scooping continued until the entire sample was redistributed into the three subsamples. Respectively, subsamples *a*, *b*, and *c* were used for chemical analyses, particle-size analysis, and archival.

Chemical Analyses

The flood-plain surficial-soil samples were analyzed for cadmium, lead, and zinc using x-ray fluorescence (XRF) (U.S. Environmental Protection Agency, 2007). The Spring River flood-plain samples were analyzed at the USEPA field office in Galena, Kansas. The tributary flood-plain samples were analyzed at the USEPA office in Kansas City, Kansas. All samples were analyzed as bulk samples. Subsequently, all samples were wet sieved using deionized water to isolate the less than 63- μm fraction (silt and clay). The less than 63- μm fraction for each sample was dried and analyzed for cadmium, lead, and zinc using XRF. All bulk and less than 63- μm samples collected from the Spring River flood plain were analyzed using a handheld XRF instrument. All bulk and less than 63- μm samples collected from the tributary flood plains were analyzed using a stationary XRF instrument.

To assess comparability of results with other recently completed studies in Cherokee County, Kansas [see studies by Pope (2005) and Juracek (2006) in the Previous Investigations section of this report], a split-replicate sample from three Spring River flood-plain surficial-soil sampling sites (SRF-2, SRF-5, and SRF-10) and six tributary flood-plain surficial-soil sampling sites (BC2-1, SB2-2, SnC2-1, StC1-2, TrC1-3, and WC2-1) were analyzed by combustion and various spectroscopic methods (table 1). For each site, the composite sample was split to provide the original and split-replicate samples. Besides cadmium, lead, and zinc, the nine split-replicate samples were analyzed for 22 additional trace elements, nutrients (total nitrogen and total phosphorus)



Base from U.S. Geological Survey digital data, 1987, 1:100,000
 Universal Transverse Mercator projection
 Zone 15
 Horizontal coordinate information is referenced to the North American
 Datum of 1983 (NAD 83)

0 1 2 3 4 MILES
 0 1 2 3 4 KILOMETERS

Lead and zinc mined areas from Brichta, 1960
 Approximate flood-plain extent from Federal
 Emergency Management Agency (2008)

EXPLANATION

- Lead and zinc mined areas
- Approximate flood-plain extent
- U.S. Geological Survey surficial-soil sampling site in the Spring River flood plain and site identifier
- U.S. Geological Survey surficial-soil sampling and coring transect in tributary flood plain and transect identifier. See figures 2B–2U for location of sampling sites along each transect
- U.S. Geological Survey coring site in Spring River flood plain and site identifier—First two characters, T1–T6, represent the transect identifiers

Figure 2. Location of surficial-soil sampling sites and coring sites in the Spring River flood plain and tributary flood plains, Cherokee County, Kansas. (Note: Because the tributary streams are shown as linear, rather than two-dimensional, features in figures 2B–2U, the sampling sites are closer to the channels than they appear.)

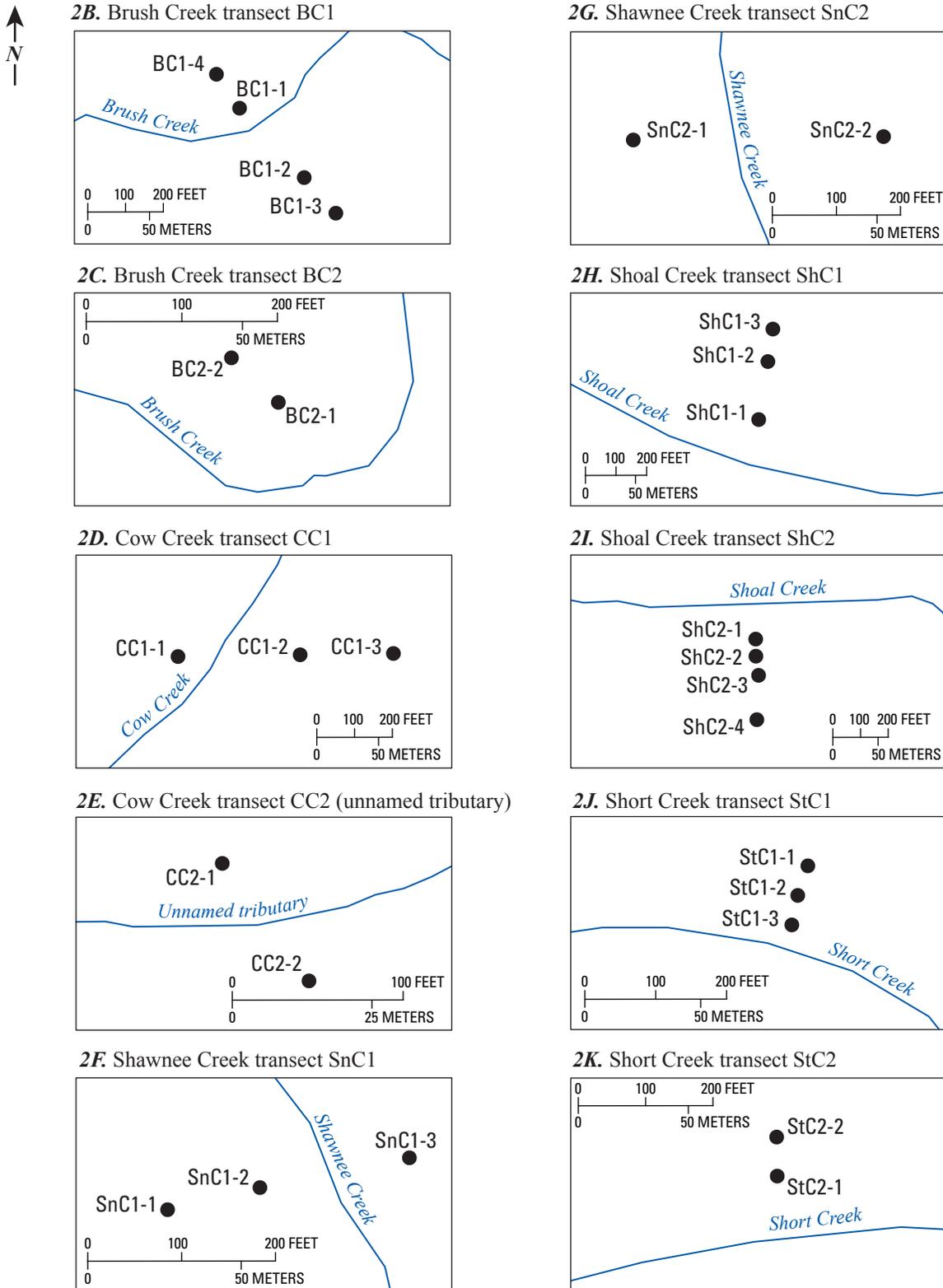


Figure 2. Location of surficial-soil sampling sites and coring sites in the Spring River flood plain and tributary flood plains, Cherokee County, Kansas. (Note: Because the tributary streams are shown as linear, rather than two-dimensional, features in figures 2B–2U, the sampling sites are closer to the channels than they appear.)—Continued

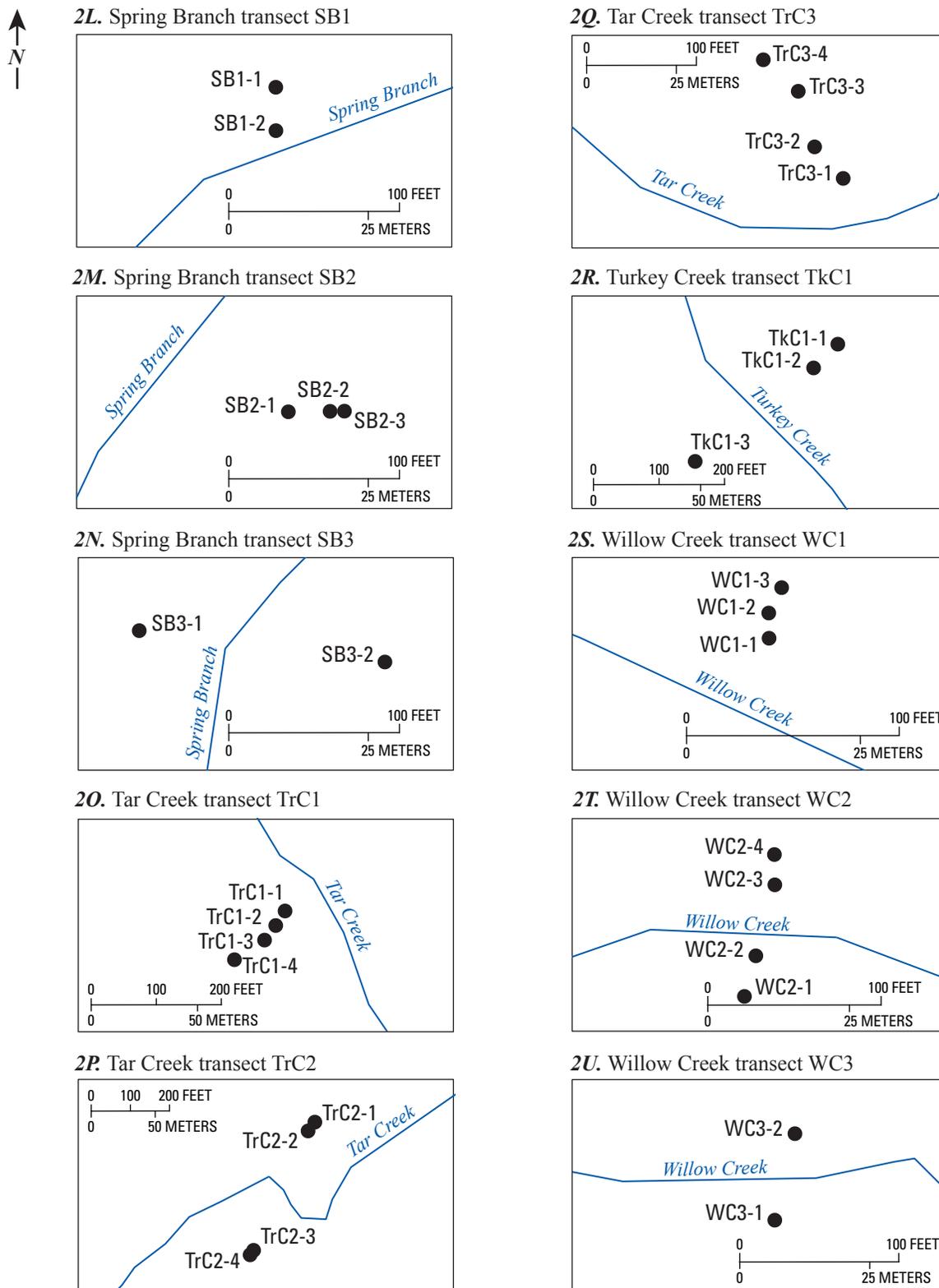


Figure 2. Location of surficial-soil sampling sites and coring sites in the Spring River flood plain and tributary flood plains, Cherokee County, Kansas. (Note: Because the tributary streams are shown as linear, rather than two-dimensional, features in figures 2B–2U, the sampling sites are closer to the channels than they appear.)—Continued

and organic and total carbon (table 1). The nine samples were analyzed as bulk samples and as the less than 63- μ m fraction. Analyses of the nine samples by combustion and various spectroscopic methods were performed at the USGS Sediment Trace Element Partitioning Laboratory in Atlanta, Georgia. Analyses of samples for total nitrogen and carbon concentrations were performed using the methods described by Horowitz and others (2001). Analyses for total phosphorus and trace elements were performed using the methods described by Fishman and Friedman (1989), Arbogast (1996), and Briggs and Meier (1999). The spectroscopic methods used provided total (at least 95 percent of the element present) rather than total-recoverable concentrations. For cadmium, lead, and zinc, analysis of two duplicate samples (that is, two original samples were split and both halves were analyzed) indicated that the analytical variability for the spectroscopic methods was about 10 percent or less. Data for the additional constituents are presented but not discussed (see tables 1–3 and 1–5 at the back of this report).

Particle-Size Analysis

A particle-size analysis was completed for each surficial-soil sample to determine the percentage of sand, silt, and clay in each sample. The particle-size determinations were completed by ARDL, Inc., Mt. Vernon, Illinois, using hydrometer analyses following American Society for Testing and Materials method D422 (American Society for Testing and Materials International, 2007).

Flood-Plain Coring and Analysis

Site Selection

Spring River flood-plain coring sites were selected to be representative of conditions throughout the Cherokee County, Kansas, superfund site as affected by tributary inputs. Coring sites were established along six transects that generally were oriented perpendicular to the Spring River. The six transect locations (fig. 2A) were as follows: (1) between the Missouri State line and the Center Creek confluence (transect T1), (2) between the Center and Turkey Creek confluences (transect T2), (3) between the Turkey and Short Creek confluences (transect T3), (4) between the Short Creek confluence and Empire Lake (transect T4), (5) between Empire Lake and the Willow Creek confluence (transect T5), and (6) downstream from the Spring Branch confluence near the Oklahoma State line (transect T6). Along each transect, five to seven coring sites were selected at an approximately equal distance interval that ranged from about 800 ft for transects T3 and T6 to about 1,300 ft for transect T5 (fig. 2A). The distance interval varied among transects as dictated by flood-plain width, number of sites per transect, site conditions, and property access. The latitude and longitude coordinates for each coring site, obtained using GPS technology, are provided in table 1–2 at the back of this report.

Tributary flood-plain coring sites were collocated with the surficial-soil sampling sites. At each site, the core was collected at or near the center of where the five-point surficial-soil sample

Table 1. Chemical analyses performed on surficial-soil and core samples from the Spring River flood plain and tributary flood plains, Cherokee County, Kansas, 2009–11.

[Number in parentheses is the detection limit or method reporting limit for each constituent. mg/kg, milligrams per kilogram; %, percent dry weight]

Analyses using x-ray fluorescence methods ¹			
Cadmium (50–150 mg/kg)	Lead (10–100 mg/kg)	Zinc (10–100 mg/kg)	
Analyses using combustion and various spectroscopic methods ²			
Aluminum (0.1%)	Chromium (1.0 mg/kg)	Molybdenum (1.0 mg/kg)	Sulfur (0.01%)
Antimony (0.1 mg/kg)	Cobalt (1.0 mg/kg)	Nickel (1.0 mg/kg)	Thallium (50 mg/kg)
Arsenic (0.1 mg/kg)	Copper (1.0 mg/kg)	Nitrogen, total (100 mg/kg)	Tin (1.0 mg/kg)
Barium (1.0 mg/kg)	Iron (0.1%)	Phosphorus, total (50 mg/kg)	Titanium (0.01%)
Beryllium (0.1 mg/kg)	Lead (1.0 mg/kg)	Selenium (0.1 mg/kg)	Uranium (50 mg/kg)
Cadmium (0.1 mg/kg)	Lithium (1.0 mg/kg)	Silver (0.5 mg/kg)	Vanadium (1.0 mg/kg)
Carbon, organic (0.1%)	Manganese (10.0 mg/kg)	Strontium (1.0 mg/kg)	Zinc (1.0 mg/kg)
Carbon, total (0.1%)			

¹The detection limit varies depending on several factors including the constituent of interest, the type of detector used, the type and strength of excitation source, count time used to irradiate the sample, physical matrix effects, chemical matrix effects, and interelement spectral interferences (U.S. Environmental Protection Agency, 2007).

²Carbon and nitrogen analyzed by combustion. Antimony, arsenic, and selenium analyzed by hydride generation inductively coupled plasma-atomic emission spectroscopy (ICP-AES). Cadmium, lead, and silver analyzed by flame atomic absorption. Remaining constituents analyzed by ICP-AES (Fishman and Friedman, 1989; Arbogast, 1996; Briggs and Meier, 1999; Horowitz and others, 2001).

was collected. Thus, the latitude and longitude coordinates for each core were the same as for the surficial-soil sample collected at each site (table 1–1 at the back of this report).

Core Collection and Preparation

The Spring River flood-plain cores were collected in the fall of 2009 and the spring of 2010 using a truck- or tractor-mounted Geoprobe® GH-40 direct-push system. A total of 34 cores were collected. Cores collected along transects T1, T3, and T6 were pushed to a depth of 16 ft or refusal. Cores collected along transects T2, T4, and T5 were pushed to a depth of 8 ft or refusal. Coring sites are shown in figure 2A. Each core was collected in 4-ft increments by successive core runs using a 1.5-in. diameter by 4-ft long core barrel with an acetate liner. The coring equipment was thoroughly washed with a laboratory detergent solution and rinsed with tap water and deionized water prior to each core run. A new acetate liner was used for each core run. Following collection, the cores were placed in cardboard core boxes, transported to a secure storage facility, and laid out on tables. Approximately one-third of the liner was removed to allow the cores to air dry. Also, about one-third of each core was removed with a stainless steel knife to expose the inner material for geologic description and chemical analysis. Compaction affected all collected cores as evidenced by the fact that the length of each recovered core was always less than the depth of penetration. Depth measurements along each core were adjusted to account for compaction, which was assumed to be uniform for each core. The adjusted depth intervals were computed for each core using the ratio of the length of recovered core to the depth of penetration.

The tributary flood-plain cores were collected in the spring of 2011 using a 24-in. hand-push corer. A core was collected at 54 sampling sites. At five sites, a core was not collected typically because shallow rock was encountered, which prevented penetration of the corer. Each core was collected to a depth of 15 in. or refusal. A new 1-in. diameter butyrate liner was used for each site. Compaction affected all collected cores. Following collection, the cores were segmented to remove the 6- and 12-in. depth intervals for subsequent chemical analysis. Identification of the 6- and 12-in. depth intervals for each core required that compaction be accounted for as described previously. Each core was cut at the adjusted depth intervals to expose the estimated 6- and 12-in. depths. For a few cores, shallower depth intervals were used because refusal was encountered before the target depth (15 in.) was achieved. A total of 105 core segments were obtained from the 54 cores. The core segments were air dried.

Chemical Analysis

All flood-plain cores were analyzed for cadmium, lead, and zinc using XRF (U.S. Environmental Protection Agency,

2007). The Spring River core samples were analyzed at the USEPA field office in Galena, Kansas. The tributary core samples were analyzed at the USEPA office in Kansas City, Kansas. All core samples were analyzed as bulk samples. Generally, for the Spring River cores, the top 2-in. interval of each core was analyzed. Then, the remainder of each core was analyzed about every one-third of a foot (adjusted for compaction as necessary). All Spring River core samples were analyzed using a handheld XRF instrument. For the tributary cores, the 6- and 12-in. depths (adjusted for compaction as necessary) were analyzed using a stationary XRF instrument.

Quality Control

Samples Collected from the Spring River Flood Plain

Quality control for the XRF chemical analysis of the Spring River flood-plain surficial-soil samples involved several parts. To determine the analytical variability of the XRF method, 10 bulk samples and 11 less than 63- μ m samples were analyzed 3 times. Additional verification was provided by the analysis of split-replicate samples (three sampling sites) using spectroscopic methods. Within-site variability of the surficial soils was assessed using sequential five-point replicate samples (three sampling sites) and a 17-point sampling technique (three sampling sites) to determine the representativeness of the five-point sampling technique. In the 17-point technique, the soil was sampled at the selected center location and at a sampling radius of 50 and 100 ft north, northeast, east, southeast, south, southwest, west, and northwest of the center. Finally, the accuracy of the XRF method was evaluated using standard reference samples and blank samples, which were repeatedly analyzed before, during, and after the analysis of the surficial-soil and core samples.

The evaluation of XRF analytical variability was constrained by some results that were less than the XRF limit of detection (LOD). For cadmium, concentrations in the bulk samples were less than the XRF LOD for at least 2 of the 3 analyses for 8 of the 10 samples. For the remaining two samples, XRF-measured cadmium concentrations were within ± 3 and ± 35 percent of the mean concentration for each sample. Similarly, cadmium concentrations for the less than 63- μ m samples were less than the XRF LOD for at least 2 of the 3 analyses for 10 of the 11 samples. For the remaining sample, XRF-measured cadmium concentrations were within ± 37 percent of the mean concentration. For lead, XRF analytical variability for the bulk and less than 63- μ m samples ranged from ± 2 to ± 38 percent (nine samples) and ± 2 to ± 18 percent (four samples), respectively. For zinc, XRF analytical variability for the bulk and less than 63- μ m samples ranged from ± 2 to ± 33 percent (10 samples) and ± 3 to ± 27 percent (eight samples), respectively.

A comparison of cadmium concentrations for the bulk and less than 63- μm samples determined by XRF and spectroscopic methods was not possible because the cadmium concentrations were less than the XRF LOD for all three samples (SRF-2, SRF-5, and SRF-10). Lead and zinc concentrations for the three bulk samples determined by spectroscopic methods averaged 55 and 28 percent larger, respectively (table 2). A comparison of lead concentrations in the less than 63- μm samples was constrained because concentrations were less than the XRF LOD for two of the three samples. For the remaining sample, the lead concentration determined by spectroscopic methods was 51 percent larger. Zinc concentrations for the less than 63- μm samples determined by spectroscopic methods averaged 80 percent larger (table 2). A complete list of results for the three split-replicate samples analyzed by combustion and spectroscopic methods is provided in table 1–3 at the back of this report.

Within-site variability was assessed to determine the representativeness of the five-point sampling technique. At three sampling sites (SRF-1, SRF-3, and SRF-7), a sequential five-point replicate sample was collected immediately next to the original five-point sample. Also, at three sampling sites (SRF-4, SRF-9, and SRF-29), an additional sample was collected using the 17-point sampling technique.

An assessment of within-site variability for cadmium using the five-point bulk samples was not possible because the cadmium concentrations for all original, sequential-replicate, and 17-point samples were less than the XRF LOD. On average, the lead and zinc concentrations in the three sequential-replicate bulk samples were within ± 11 and ± 15 percent of the concentrations in the three original bulk samples, respectively. For lead, the average variability for the sequential-replicate samples was computed using only two sampling sites because the lead concentration was less than the XRF LOD for one of the original bulk samples. On average, the lead and zinc concentrations for the three 17-point bulk samples were within ± 27 and ± 23 percent of the concentrations in the three five-point bulk samples, respectively.

An assessment of within-site variability using the less than 63- μm samples was constrained by measured concentrations less than the XRF LOD. For cadmium, an assessment was not possible because the results for all five-point and 17-point samples were less than the XRF LOD. Likewise, for lead, an assessment was not possible using the original and sequential-replicate five-point samples because all results were less than the XRF LOD. For the comparison using the five- and 17-point samples, all results were less than the XRF LOD for two of the three sampling sites. For the remaining sampling site, the lead concentration for the 17-point sample was 43 percent larger than the five-point sample. On average, zinc concentrations for the sequential-replicate five-point samples were within ± 57 percent of the concentrations in the original five-point samples. On average, zinc concentrations for the 17-point samples were within

± 10 percent of the concentrations in the five-point samples. For zinc, the average variability for the 17-point samples was computed using only two sampling sites because the zinc concentration was less than the XRF LOD for one of the five-point less than 63- μm samples.

Quality control for the XRF analysis of the Spring River flood-plain cores involved two parts. To determine the analytical variability of the XRF method, two or three intervals of each core typically were analyzed two or three times. The accuracy of the XRF method also was evaluated using standard reference samples and blank samples which were repeatedly analyzed before, during, and after the analysis of the cores.

Repeat analyses were completed for 75 core intervals. Analytical variability for each trace element only was computed using the core intervals for which all results were larger than the XRF LOD. For cadmium (50 core intervals used), XRF-measured concentrations were on average within ± 14 percent of the mean concentration for each core interval. XRF-measured concentrations of lead (33 core intervals used) were on average within ± 15 percent of the mean concentration for each core interval. For zinc (51 core intervals used), XRF-measured concentrations were on average within ± 10 percent of the mean concentration for each core interval.

Results for the analysis of standard reference samples using XRF are provided in table 1–4 at the back of this report. A target goal for acceptable results of analysis of reference samples was within ± 10 percent of the most probable value (MPV) for the constituent, except when constituent concentrations were near or less than method reporting limits. For the reference sample with a cadmium MPV of 500 mg/kg, cadmium concentrations were within ± 10 percent of the MPV for 89 percent of the results (47 analyses). Only 1 of 42 results was within ± 10 percent for the reference sample with a cadmium MPV of 28.2 mg/kg. Cadmium concentrations for the remaining 41 results averaged 50 percent larger than the MPV. For the reference sample with a cadmium MPV of 1.12 mg/kg, analytical precision could not be determined for eight of nine results because the MPV was less than the XRF LOD (table 1–4).

The analytical precision of XRF for lead also was assessed using three standard reference samples. For the reference sample with a lead MPV of 2,700 mg/kg, lead concentrations were within ± 10 percent of the MPV for 95 percent of the results (43 analyses). Lead concentrations were within ± 10 percent of the MPV for 87 percent of the results (47 analyses) for the reference sample with a lead MPV of 500 mg/kg. For the reference sample with a lead MPV of 27 mg/kg, analytical precision could not be determined for five of nine results because the measured concentration was less than the XRF LOD. The remaining four results ranged from about 4 percent larger to about 33 percent less than the MPV (table 1–4).

The analytical precision of XRF for zinc was assessed using two standard reference samples. For the reference sample with a zinc MPV of 3,800 mg/kg, zinc concentrations

Table 2. Cadmium, lead, and zinc concentrations for three surficial-soil samples collected from the Spring River flood plain and six surficial-soil samples collected from the tributary flood plains, Cherokee County, Kansas, and analyzed by x-ray fluorescence (XRF) and spectroscopic methods (SM).

[mg/kg, milligrams per kilogram; <, less than; LOD, limit of detection; --, not determined]

Sample identifier (figs. 2A–2U)	Concentrations in bulk sample (mg/kg)			Concentrations in less than 63-micrometer fraction (mg/kg)		
	XRF ¹	SM	Difference (percent)	XRF ¹	SM	Difference (percent)
Cadmium ²						
Spring River sampling sites						
SRF-2	<LOD	0.8	--	<21.8	0.7	--
SRF-5	<LOD	0.3	--	<8.6	0.4	--
SRF-10	<12.0	5.7	--	<16.6	7.4	--
Tributary sampling sites						
BC2-1	<12.8	0.5	--	<12.3	0.9	--
SB2-2	<13.1	24	--	<13.3	22	--
SnC2-1	<12.9	0.1	--	<11.8	0.2	--
StC1-2	48	80	67	28	78	179
TrC1-3	54	100	85	<9.4	93	--
WC2-1	<13.2	9.9	--	<13.0	8.9	--
Lead ²						
Spring River sampling sites						
SRF-2	20	28	40	<25.6	25	--
SRF-5	14	30	114	<15.4	26	--
SRF-10	83	91	10	93	140	51
Tributary sampling sites						
BC2-1	55	24	-56	24	36	50
SB2-2	598	670	12	651	740	14
SnC2-1	47	28	-40	12	35	192
StC1-2	4,897	5,600	14	3,284	6,100	86
TrC1-3	4,278	8,300	94	2,016	8,000	297
WC2-1	261	260	-0.4	174	280	61
Zinc ²						
Spring River sampling sites						
SRF-2	91	110	21	50	110	120
SRF-5	46	60	30	43	67	56
SRF-10	704	940	34	732	1,200	64
Tributary sampling sites						
BC2-1	133	170	28	127	250	97
SB2-2	3,149	3,400	8	2,940	3,500	19
SnC2-1	54	75	39	35	97	177
StC1-2	10,700	11,000	3	5,436	11,000	102
TrC1-3	15,300	26,000	70	6,896	26,000	277
WC2-1	1,511	1,700	13	1,290	1,600	24

¹The limit of detection (LOD) for XRF analyses varies depending on several factors. See footnote on table 1 for more information.

²For samples SRF-2 (bulk sample only) and SRF-10 (bulk sample and <63-micrometer sample), the reported concentration estimated using XRF was computed as the average of three XRF analyses that were done for each sample. For all tributary samples, the reported concentration was the average of three XRF analyses that were done for each sample.

were within ± 10 percent of the MPV for 91 percent of the results (43 analyses). For the reference sample with a zinc MPV of 46 mg/kg, 33 percent of the results (9 analyses) were within ± 10 percent of the MPV (table 1–4).

A total of 41 blank samples were analyzed before, during, and after the XRF analyses of the surficial-soil and core samples. Lead and zinc concentrations were less than the XRF LOD for all 41 samples. Cadmium concentrations were less than the XRF LOD for 38 of 41 samples.

The variability described in the preceding paragraphs likely was caused, in part, by the use of a handheld (as opposed to stationary) XRF instrument for the chemical analyses of the surficial-soil and core samples.

Samples Collected from the Tributary Flood Plains

Quality control for the XRF chemical analysis of the tributary flood-plain surficial-soil and core samples involved several parts. Each tributary surficial-soil and core sample was analyzed multiple times until three results were obtained that were within 10 percent of the mean concentration. To assess analytical variability of the XRF method, the first three results for each sample were used. Additional verification was provided by the analysis of split-replicate samples (six sampling sites) using spectroscopic methods. Within-site variability of the surficial soils was assessed using sequential five-point replicate samples (six sampling sites) and the 17-point sampling technique (five sampling sites) to determine the representativeness of the five-point sampling technique. In the 17-point technique, the soil was sampled at the selected center location and at 100 and 50 percent of the site-specific sampling radius north, northeast, east, southeast, south, southwest, west, and northwest of the center. Finally, the accuracy of the XRF method was evaluated using standard reference samples and blank samples that were repeatedly analyzed before, during, and after the analysis of the surficial-soil and core samples.

The evaluation of XRF analytical variability for the surficial-soil samples was constrained by cadmium results that were less than the XRF LOD. Cadmium concentrations in the bulk surficial-soil samples were less than the XRF LOD for at least 2 of the 3 analyses for 53 of the 70 samples. For the remaining 17 samples, XRF-measured cadmium concentrations ranged from 0 to ± 29 percent of the mean concentration for each sample with an average variability of ± 11 percent. Cadmium concentrations for the less than 63- μm samples were less than the XRF LOD for all three analyses for 66 of the 70 samples. For the remaining four samples, XRF-measured cadmium concentrations ranged from ± 7 to ± 42 percent of the mean concentration. For lead, analytical variability for the bulk samples ranged from ± 1 to ± 12 percent with an average variability of ± 4 percent (70 samples). Analytical variability for lead concentrations in the less than 63- μm samples ranged from ± 1 to ± 33 percent with an average

variability of ± 8 percent (69 samples). For zinc, analytical variability for the bulk samples ranged from 0 to ± 12 percent with an average variability of ± 3 percent (70 samples). Analytical variability for zinc concentrations in the less than 63- μm samples ranged from ± 1 to ± 25 percent with an average variability of ± 3 percent (70 samples).

The evaluation of XRF analytical variability for the core samples also was constrained by cadmium results that were less than the XRF LOD. For cadmium, analytical variability ranged from 0 to ± 28 percent from the mean concentration for each sample with an average variability of ± 10 percent (21 samples). Analytical variability for lead ranged from ± 1 to ± 42 percent with an average variability of ± 9 percent (100 samples). For zinc, analytical variability ranged from 0 to ± 26 percent with an average variability of ± 4 percent (104 samples).

A comparison of cadmium concentrations for the bulk and less than 63- μm surficial-soil samples determined by XRF and spectroscopic methods was constrained because most of the concentrations were less than the XRF LOD. For two bulk samples, cadmium concentrations determined by spectroscopic methods averaged 76 percent larger (table 2). Lead concentrations for the bulk samples determined by spectroscopic methods ranged from 56 percent smaller to 94 percent larger. For the less than 63- μm samples, lead concentrations determined by spectroscopic methods ranged from 14 to 297 percent larger (table 2). Zinc concentrations for the bulk samples determined by spectroscopic methods ranged from 3 to 70 percent larger. For the less than 63- μm samples, zinc concentrations determined by spectroscopic methods ranged from 19 to 277 percent larger (table 2). Overall, including the results for both the Spring River and tributary flood plains, lead and zinc concentrations determined by spectroscopic methods typically were larger. A complete list of results for the six split-replicate samples analyzed by combustion and spectroscopic methods is provided in table 1–5 at the back of this report.

Within-site variability was assessed to determine the representativeness of the five-point sampling technique. A sequential five-point replicate sample was collected immediately next to the original five-point sample at six sampling sites (BC2-2, CC1-3, SB2-1, TrC1-2, TkC1-3, and WC1-1). A 17-point sample was collected at five sampling sites (BC1-2, CC1-2, ShC2-1, SB2-3, and TrC3-1).

An assessment of within-site variability for cadmium using the five-point bulk samples was constrained because the cadmium concentrations for five of the six sequential-replicate sampling sites, and all five of the 17-point sampling sites, were less than the XRF LOD. For the single site with detectable cadmium concentrations, the sequential-replicate sample had a cadmium concentration that was 3 percent larger. On average, the lead and zinc concentrations in the six sequential-replicate bulk samples were within ± 8 and ± 4 percent of the concentrations in the six original five-point bulk samples, respectively. On average, the lead and zinc concentrations for the five 17-point bulk samples were within ± 11 and

±14 percent of the concentrations in the five original five-point bulk samples, respectively.

An assessment of within-site variability using the less than 63- μm samples was not possible for cadmium because the cadmium concentrations for all original, sequential-replicate, and 17-point samples were less than the XRF LOD. On average, lead and zinc concentrations in the six sequential-replicate less than 63- μm samples were within ± 10 and ± 15 percent of the concentrations in the six original less than 63- μm samples, respectively. On average, the lead and zinc concentrations for the five 17-point less than 63- μm samples were within ± 19 and ± 13 percent of the concentrations in the five original less than 63- μm samples, respectively. For lead, the average variability for the 17-point samples was computed using only four sampling sites because the lead concentration was less than the XRF LOD for one of the original less than 63- μm samples.

Results for the analysis of standard reference samples using XRF are provided in table 1–4 at the back of this report. A target goal for acceptable results of analysis of reference samples was within ± 10 percent of the MPV for the constituent, except when constituent concentrations were near or less than method reporting limits. For the reference sample with a cadmium MPV of 500 mg/kg, cadmium concentrations were within ± 10 percent of the MPV for 92 percent of the results (36 analyses). Only 24 percent of the results (34 analyses) were within ± 10 percent for the reference sample with a cadmium MPV of 28.2 mg/kg. For the reference sample with a cadmium MPV of 1.12 mg/kg, analytical precision could not be determined because the MPV was less than the XRF LOD (table 1–4).

The analytical precision of XRF for lead also was assessed using three standard reference samples. For the reference sample with a lead MPV of 2,700 mg/kg, lead concentrations were within ± 10 percent of the MPV for 100 percent of the results (36 analyses). Lead concentrations were within ± 10 percent for 81 percent of the results (36 analyses) for the reference sample with a lead MPV of 500 mg/kg. For the reference sample with a lead MPV of 27 mg/kg, only 8 percent of the results (36 analyses) were within ± 10 percent (table 1–4).

The analytical precision of XRF for zinc was assessed using two standard reference samples. For the reference sample with a zinc MPV of 3,800 mg/kg, zinc concentrations were within ± 10 percent of the MPV for only 14 percent of the results (36 analyses); however, 100 percent of the results were within ± 13 percent of the MPV. For the reference sample with a zinc MPV of 46 mg/kg, none of the results (36 analyses) were within ± 10 percent. On average, the results were 45 percent less than the MPV (table 1–4).

A total of 24 blank samples were analyzed before, during, and after the XRF analyses of the surficial-soil and core samples. Cadmium, lead, and zinc concentrations were less than the XRF LOD for all 24 samples.

Sediment-Quality Guidelines

The USEPA has adopted nonenforceable sediment-quality guidelines (SQGs) in the form of level-of-concern concentrations for several trace elements (U.S. Environmental Protection Agency, 1997). These level-of-concern concentrations were derived from biological-effects correlations made on the basis of paired onsite and laboratory data to relate incidence of adverse biological effects in aquatic organisms to dry-weight sediment concentrations. Two such level-of-concern guidelines adopted by USEPA are referred to as the threshold-effects level (TEL) and the probable-effects level (PEL). The TEL is assumed to represent the concentration below which toxic aquatic biological effects rarely occur. In the range of concentrations between the TEL and PEL, toxic effects occasionally occur. Toxic effects usually or frequently occur at concentrations above the PEL.

USEPA cautions that the TEL and PEL guidelines are intended for use as screening tools for possible hazardous levels of chemicals and are not regulatory criteria. This cautionary statement is made because, although biological-effects correlation identifies level-of-concern concentrations associated with the likelihood of adverse organism response, the comparison may not demonstrate that a particular chemical is solely responsible. In fact, biological-effects correlations may not indicate direct cause-and-effect relations because sediment may contain a mixture of chemicals that contribute to the adverse effects to some degree. Thus, for any given site, these guidelines may be over- or underprotective (U.S. Environmental Protection Agency, 1997).

MacDonald and others (2000) developed consensus-based SQGs for several trace elements that were computed as the geometric mean of several previously published SQGs. The consensus-based SQGs consist of a threshold-effect concentration (TEC) and a probable-effect concentration (PEC). The TEC represents the concentration below which adverse effects are not expected to occur, whereas the PEC represents the concentration above which adverse effects are expected to occur more often than not. An evaluation of the reliability of the SQGs indicated that most of the individual TECs and PECs provide an accurate basis for predicting the presence or absence of sediment toxicity (MacDonald and others, 2000).

A comparison of the two sets of trace-element SQGs indicated some differences (table 3). The largest difference was for the zinc PEL and PEC. In this case, the PEC (459 mg/kg) was about 69 percent larger than the PEL (271 mg/kg).

In 2009, TSMD-specific PECs for cadmium, lead and zinc were developed. The TSMD-specific PECs represent sediment concentrations predicted to reduce the survival of the amphipod *Hyalella azteca* (a species known to be sensitive

to trace element contamination) by 10 percent relative to reference conditions in the TSMD (Ingersoll and others, 2009). In this study, both the general PECs provided by MacDonald and others (2000) and the TSMD-specific PECs provided by Ingersoll and others (2009) were used to assess sediment quality. A comparison of the PECs is provided in table 3.

Background Information for Trace Elements

Trace elements are important determinants of sediment quality because of their potential toxicity to living organisms (Forstner and Wittman, 1981; Smol, 2002; Luoma and Rainbow, 2008). Trace elements may be defined as elements that typically are found in the environment in relatively low (less than 0.1 percent) concentrations (Pais and Jones, 1997; Adriano, 2001). Using this definition, the majority of the elements analyzed in this study may be considered trace elements. Exceptions, which are some of the abundant rock-forming elements, include aluminum and iron (Adriano, 2001).

Trace elements in sediment and soil originate naturally from the rock within a basin. In addition to natural sources (for example, ore deposits), elevated concentrations of trace elements may be attributable to several human-related sources including fertilizers, liming materials, pesticides, irrigation water, animal and human wastes, coal-combustion residues, leaching from landfills, mining, metal-smelting industries, and automobile emissions (Forstner and Wittman, 1981; Davies, 1983; Adriano, 2001; Luoma and Rainbow, 2008).

The health of living organisms is dependent on a sufficient intake of various trace elements. Many elements, such as cobalt, copper, iron, manganese, and zinc, are essential for plants, animals, and humans. Other elements, such as arsenic and chromium, are required by animals and humans but are not essential for plants. Nonessential elements for plants, animals, and humans include cadmium, mercury, and lead (Lide, 1993; Pais and Jones, 1997; Adriano, 2001; Marmiroli and Maestri, 2008).

Toxicity is a function of several factors including the type of organism, availability of a trace element in the environment, and its potential to bioaccumulate once in the food chain. The daily intake of trace elements by animals and humans may be classified as deficient, optimal, or toxic. Most, if not all, trace elements may be toxic in animals and humans if the concentrations are sufficiently large (Pais and Jones, 1997; Smol, 2002; Luoma and Rainbow, 2008). Information on the bioaccumulation index (Pais and Jones, 1997) for cadmium, lead, and zinc is provided in table 3. The bioaccumulation index indicates the relative potential of a trace element to bioaccumulate in organisms.

Flood-Plain Occurrence of Mining-Related Lead and Zinc

This section describes the occurrence of lead and zinc in surficial-soil samples and cores collected from the Spring River flood plain and tributary flood plains. Cadmium data (provided in tables 1–6 through 1–8 at the back of this report) are not discussed because the XRF results either were less than the XRF LOD or at relatively small concentrations that were of questionable accuracy. In the following sections, the mean lead and zinc concentrations determined by XRF were used for all samples that were analyzed three times (that is, selected Spring River flood-plain samples and all tributary flood-plain samples). If one or two of the three XRF results for a sample were less than the LOD, the final result was reported as less than the largest value that was measured. Sediment quality was assessed with reference to general and TSMD-specific PECs (table 3).

For perspective in the following sections, it is helpful to know the background concentrations of lead and zinc for the study area. Based on an analysis of streambed-sediment samples collected at sites minimally affected by historical lead and zinc mining within the Cherokee County superfund site, Pope (2005) estimated the background sediment concentrations of lead and zinc to be 20 and 100 mg/kg, respectively. Nationally, Horowitz and others (1991) estimated the background concentrations of lead and zinc in sediment to be 23 and 88 mg/kg, respectively.

Table 3. Sediment-quality guidelines (SQGs) and associated bioaccumulation index for cadmium, lead, and zinc.

[Values in milligrams per kilogram. Shading indicates guidelines to which sediment concentrations were compared in this report. USEPA, U.S. Environmental Protection Agency; TEL, threshold-effects level; PEL, probable-effects level; TEC, threshold-effect concentration; PEC, probable-effect concentration]

Trace element	USEPA (1997) ¹		MacDonald and others (2000) ¹		Ingersoll and others (2009) ²	Bio-accumulation index ³
	TEL	PEL	TEC	PEC	PEC	
Cadmium	0.676	4.21	0.99	4.98	11.1	Moderate
Lead	30.2	112	35.8	128	150	Moderate
Zinc	124	271	121	459	2,083	High

¹General sediment-quality guidelines.

²Sediment-quality guidelines specific to the Tri-State Mining District.

³Bioaccumulation index information for trace elements from Pais and Jones (1997).

Spring River

Of the 30 surficial-soil sites sampled in the Spring River flood plain, lead concentrations larger than the PECs were only measured for two sites—SRF-15 and SRF-19. Site SRF-15, located near the Turkey Creek confluence (fig. 3), had lead concentrations in the bulk and less than 63- μ m samples of 310 and 314 mg/kg, respectively (table 4). These concentrations were more than twice the general (128 mg/kg) and TSMD-specific (150 mg/kg) PECs. Site SRF-19, located near the Short Creek confluence (fig. 3), had lead concentrations in the bulk and less than 63- μ m samples of 2,180 and 1,980 mg/kg, respectively (table 4). These concentrations were more than an order of magnitude larger than the general and TSMD-specific PECs.

Zinc concentrations in the bulk and less than 63- μ m samples exceeded the general PEC (459 mg/kg) for four sites—SRF-10 (located downstream from the Turkey Creek confluence), SRF-15, SRF-19, and SRF-27 (located downstream from Empire Lake) (fig. 4, table 4). Zinc concentrations in the bulk and less than 63- μ m samples approached the TSMD-specific PEC (2,083 mg/kg) for site SRF-15 and were more than twice the TSMD-specific PEC for site SRF-19 (table 4).

Contamination at depth was infrequent in the Spring River flood plain. Of the 34 cores collected along six transects (fig. 2A), lead concentrations larger than the general and TSMD-specific PECs were only measured in 5 (15 percent) of the cores (T1-2, T2-1, T4-2, T4-3, and T6-1). Zinc concentrations larger than the general PEC were only measured in 10 (29 percent) of the cores (T1-2, T2-1, T2-2, T4-1, T4-2, T4-3, T5-2, T5-3, T5-4, and T6-1). Zinc concentrations larger than the TSMD-specific PEC were only measured in three (9 percent) of the cores (T1-2, T2-1, and T6-1). With two exceptions, the contamination typically was confined to the upper 2 ft of the core and frequently was confined to the upper 6 in. One exception was core T2-1, located near the Center Creek confluence (figs. 1, 2A), in which zinc concentrations larger than the general PEC were measured to a depth of about 7 ft. In the upper 1.2 ft of this core, zinc concentrations were about two to six times larger than the TSMD-specific PEC. The other exception was core T6-1, located downstream from the Willow Creek and Spring Branch confluences (figs. 1, 2A), in which lead and zinc concentrations larger than the general or TSMD-specific PECs, or both, were measured to respective depths of 2.8 and 3.5 ft. The complete list of XRF results for all 34 cores is provided in table 1–7 at the back of this report.

Brush Creek

The Brush Creek basin does not include any lead- and zinc-mined areas (fig. 1). Surficial-soil and core samples collected at six sites (two transects, figs. 2A–2C) in the Brush Creek flood plain had lead and zinc concentrations (bulk and

less than 63 μ m) that were substantially less than the general PECs (figs. 3 and 4, table 5).

Cow Creek

The Cow Creek basin includes at least two lead- and zinc-mined areas (fig. 1). Surficial-soil and core samples collected from transect CC1 (three sites, figs. 2A and 2D), located along the main stem of Cow Creek, had lead and zinc concentrations (bulk and less than 63 μ m) that were substantially less than the general PECs (figs. 3 and 4, table 6). Surficial-soil and core samples collected from transect CC2 (two sites, figs. 2A and 2E), located along an unnamed tributary downstream from a mined area, had lead concentrations (bulk and less than 63 μ m) that were less than the general PEC. However, zinc concentrations (bulk and less than 63 μ m) in the surficial-soil samples collected from both sites along transect CC2 were greater than the general PEC. At site CC2-1, zinc concentrations for the bulk samples at the 6- and 12-in. depths were greater than the TSMD-specific PEC (figs. 3 and 4, table 6).

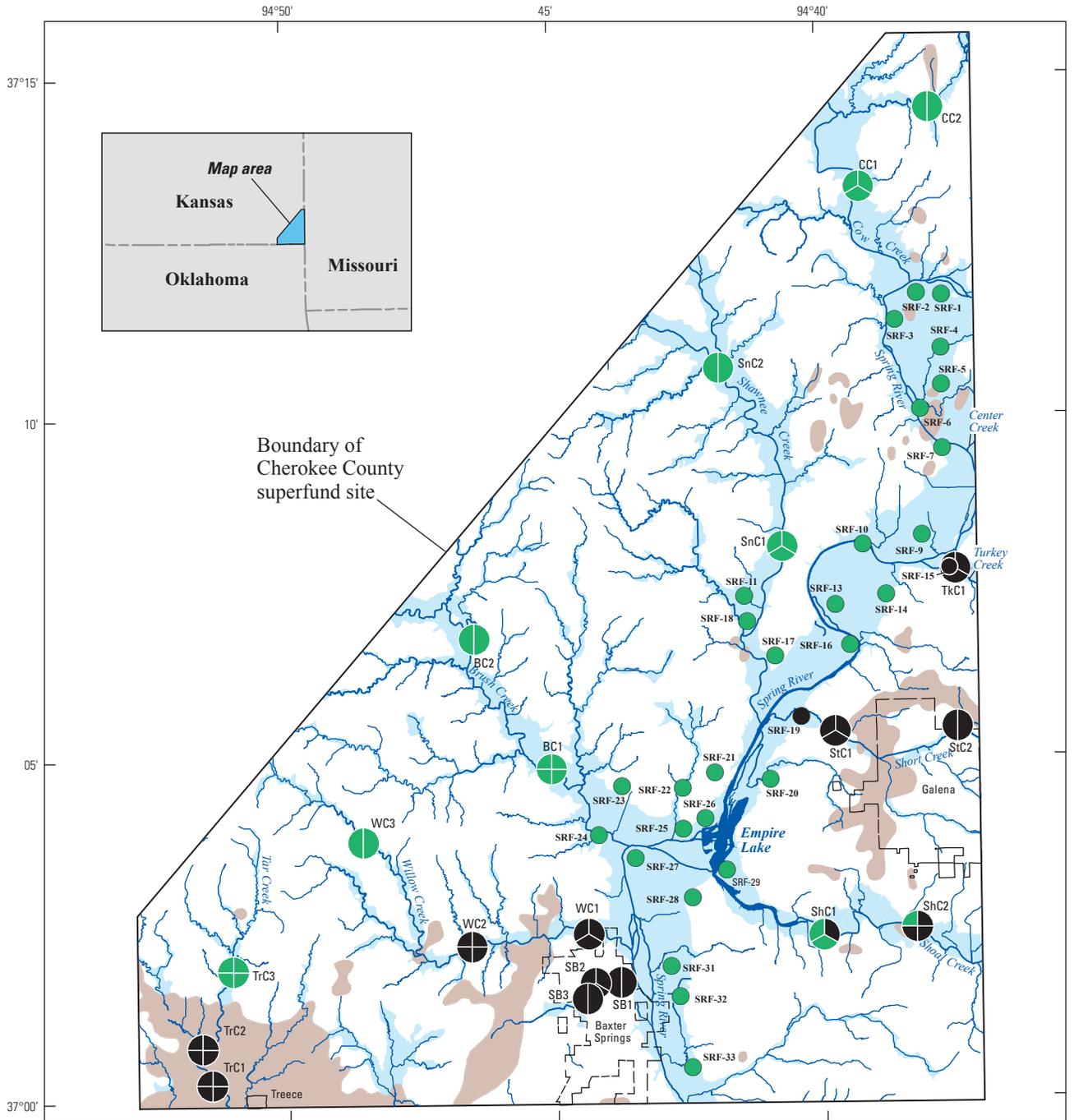
Shawnee Creek

The Shawnee Creek basin includes a few lead- and zinc-mined areas that primarily are located in the upland between Shawnee Creek and the Spring River (fig. 1). Surficial-soil and core samples collected at five sites (two transects, figs. 2A, 2F, and 2G) in the Shawnee Creek flood plain had lead and zinc concentrations (bulk and less than 63 μ m) that were substantially less than the general PECs (figs. 3 and 4, table 7).

Shoal Creek

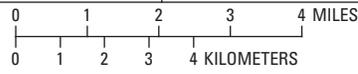
Multiple lead- and zinc-mined areas are located throughout the Shoal Creek basin (fig. 1). At downstream transect ShC1 (figs. 2A and 2H), surficial-soil concentrations greater than the general PECs were measured at one of three sites for lead (site ShC1-1, bulk sample only) and at two of three sites for zinc (sites ShC1-1 and ShC1-3, bulk samples for both sites and less than 63- μ m sample for one site) (figs. 3 and 4, table 8). The lead concentration also exceeded the TSMD-specific PEC. At the 6- and 12-in. depths, lead concentrations (bulk samples) were less than the general PEC at all three sites. Zinc concentrations (bulk samples) were greater than the general PEC at the 6- and 12-in. depths at the site located nearest the channel (site ShC1-1) (table 8).

At upstream transect ShC2 (figs. 2A and 2I), surficial-soil concentrations greater than the general PECs were typical for lead (three of four sites, bulk samples for all three sites and less than 63- μ m sample for one site) and zinc (all four sites, bulk samples for all four sites and less than 63- μ m



Base from U.S. Geological Survey digital data, 1987, 1:100,000
 Universal Transverse Mercator projection
 Zone 15
 Horizontal coordinate information is referenced to the North American
 Datum of 1983 (NAD 83)

Lead and zinc mined areas from Brichta, 1960
 Approximate flood-plain extent from Federal
 Emergency Management Agency (2008)



EXPLANATION

- Lead and zinc mined areas
- Approximate flood-plain extent
- U.S. Geological Survey surficial-soil sampling site in the Spring River flood plain and site identifier
- U.S. Geological Survey surficial-soil sampling and coring transect in tributary flood plain and transect identifier. Number of slices in the circle indicates how many sites are on the transect. See figures 2B-2U
- Lead concentration, in milligrams per kilogram**
- Less than 128
- 128-150
- Greater than 150

Figure 3. Lead concentrations in surficial-soil samples collected from the Spring River flood plain and tributary flood plains, Cherokee County, Kansas, 2009, 2011.

Table 4. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil samples collected from the Spring River flood plain, Cherokee County, Kansas, November 2009.

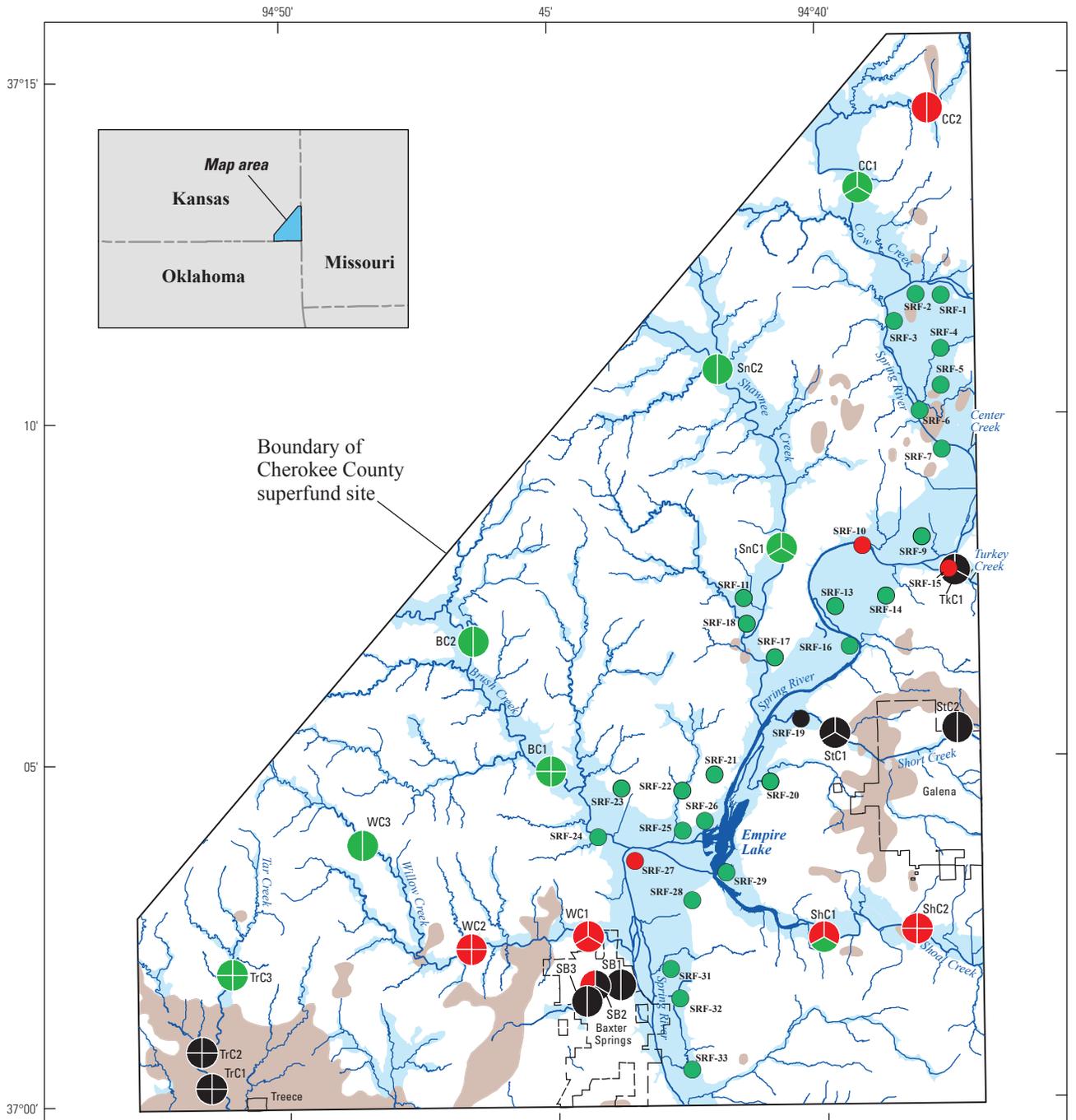
[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; <, less than; μm , micrometer; C, cropland; G, grassland]

Surficial-soil sampling site identifier (fig. 2A)	Land use ¹	Percentage of silt and clay in bulk sample	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample ²	<63- μm fraction ³	Bulk sample ²	<63- μm fraction ³
SRF-1	C	70.9	24	<14.0	56	46
SRF-2	C	94.4	20	<25.6	91	50
SRF-3	C	91.0	<19	<9.4	78	<13.2
SRF-4	C	90.2	16	<17.2	53	<37
SRF-5	C	87.2	14	<15.4	46	43
SRF-6	G	91.9	31	28	108	134
SRF-7	G	67.6	21	<17.5	186	152
SRF-9	C	82.9	29	<16.3	75	25
SRF-10	G	49.9	83	93	704	732
SRF-11	C	79.4	17	<16.7	38	38
SRF-13	C	83.9	30	<17.6	102	68
SRF-14	C	83.2	19	<17.1	60	50
SRF-15	G	93.3	310	314	2,010	2,060
SRF-16	C	83.3	43	<18.1	151	112
SRF-17	C	81.7	21	<18.0	55	46
SRF-18	C	70.3	18	<15.6	40	40
SRF-19	G	89.9	2,180	1,980	4,850	4,170
SRF-20	G	79.7	28	<17.1	58	30
SRF-21	G	77.9	17	<20.3	32	73
SRF-22	G	65.5	32	23	96	117
SRF-23	C	63.8	17	<16.0	22	<23.4
SRF-24	G	78.1	26	27	150	185
SRF-25	G	73.7	20	<15.2	39	<18.5
SRF-26	G	61.6	35	<11.1	96	<28
SRF-27	G	85.6	69	62	761	684
SRF-28	C	85.6	26	34	88	150
SRF-29	C	96.5	47	28	200	212
SRF-31	G	87.3	19	<17.1	81	91
SRF-32	C	96.6	20	<17.2	60	55
SRF-33	G	87.3	13	<19.1	73	58

¹Land use on the date the surficial-soil sample was collected. Sampling dates are provided in table 1-1 at the back of this report.

²For samples SRF-1, SRF-3, SRF-4, SRF-10, SRF-15, and SRF-19, the reported concentration estimated using x-ray fluorescence (XRF) was computed as the average of three XRF analyses that were done for each bulk sample.

³For samples SRF-3, SRF-4, SRF-10, SRF-15, SRF-16, SRF-17, SRF-18, SRF-19, SRF-24, and SRF-26, the reported concentration estimated using XRF was computed as the average of three XRF analyses that were done for each less than 63-micrometer sample.



Base from U.S. Geological Survey digital data, 1987, 1:100,000
 Universal Transverse Mercator projection
 Zone 15

Horizontal coordinate information is referenced to the North American
 Datum of 1983 (NAD 83)

0 1 2 3 4 MILES

0 1 2 3 4 KILOMETERS

Lead and zinc mined areas from Brichta, 1960
 Approximate flood-plain extent from Federal
 Emergency Management Agency (2008)

EXPLANATION

- Lead and zinc mined areas
- Approximate flood-plain extent
- U.S. Geological Survey surficial-soil sampling site in the Spring River flood plain and site identifier
- U.S. Geological Survey surficial-soil sampling and coring transect in tributary flood plain and transect identifier. Number of slices in the circle indicates how many sites are on the transect. See figures 2B–2U
- Zinc concentration, in milligrams per kilogram**
- Less than 459
- 459–2,083
- Greater than 2,083

Figure 4. Zinc concentrations in surficial-soil samples collected from the Spring River flood plain and tributary flood plains, Cherokee County, Kansas, 2009, 2011.

Table 5. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Brush Creek flood plain, Cherokee County, Kansas, April and May 2011.[mg/kg, milligrams per kilogram; <, less than; μm , micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A–2C)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63- μm fraction	Bulk sample	<63- μm fraction
Transect BC1 (downstream)						
BC1-1	47.6	0	41	27	68	90
	--	6	13	--	103	--
	--	12	16	--	101	--
BC1-2	62.5	0	50	17	90	80
	--	6	24	--	121	--
	--	12	26	--	148	--
BC1-3	80.8	0	64	32	146	177
	--	6	22	--	95	--
	--	12	21	--	51	--
BC1-4	87.6	0	62	22	203	125
	--	6	21	--	144	--
	--	12	19	--	77	--
Transect BC2 (upstream)						
BC2-1	79.6	0	55	24	133	127
	--	6	24	--	104	--
	--	12	10	--	63	--
BC2-2	81.3	0	66	16	200	116
	--	6	31	--	177	--
	--	12	20	--	50	--

samples for three sites) (figs. 3 and 4, table 8). Lead and zinc concentrations (bulk samples) greater than the general PECs were measured at the 6- and 12-in. depths at the site located nearest the channel (site ShC2-1). At the 6-in. depth for that site, the zinc concentration also exceeded the TSMD-specific PEC. For all samples collected along transect ShC2 with lead concentrations greater than the general PEC, the lead concentrations also exceeded the TSMD-specific PEC (table 8).

Short Creek

Short Creek drains an area that was extensively mined for lead and zinc (fig. 1). The landscape in the vicinity of Galena was so disturbed by mining activity that it came to be known as “Hell’s Half Acre” (Brosius and Sawin, 2001). All surficial-soil and core samples (bulk and less than 63 μm) collected at five sites (two transects, figs. 2A, 2J, and 2K) in the Short

Creek flood plain had lead and zinc concentrations that were substantially greater than both the general and TSMD-specific PECs (figs. 3 and 4, table 9). Mining-related contamination was most pronounced at the sampling sites located along downstream transect StC1 (figs. 2A and 2J). At these sites, lead and zinc concentrations ranged up to more than 30 and 6 times greater than the TSMD-specific PECs, respectively (table 9).

Spring Branch

An extensive lead- and zinc-mined area is located in the upstream part of the Spring Branch basin (fig. 1). Lead and zinc concentrations in the surficial-soil samples (bulk and less than 63 μm) collected at seven sites (three transects, figs. 2A, 2L, 2M, and 2N) typically were greater than both the general and TSMD-specific PECs (figs. 3 and 4, table 10). At depths ranging from 4 to 12 in., lead concentrations (bulk samples)

Table 6. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Cow Creek flood plain, Cherokee County, Kansas, March 2011.

[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; <, less than; μm , micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A, 2D, and 2E)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63- μm fraction	Bulk sample	<63- μm fraction
Transect CC1 (downstream)						
CC1-1	90.1	0	59	20	178	121
	--	4	26	--	203	--
	--	10	18	--	178	--
CC1-2	81.4	0	63	<9.4	165	76
	--	6	18	--	151	--
	--	12	19	--	130	--
CC1-3	77.6	0	55	14	158	83
	--	6	16	--	148	--
	--	12	22	--	127	--
Transect CC2 (upstream)						
CC2-1 ¹	94.9	0	96	40	1,353	1,050
	--	6	51	--	2,208	--
	--	12	40	--	9,042	--
CC2-2 ¹	91.7	0	89	48	1,477	1,145
	--	6	<8.0	--	114	--
	--	12	10	--	388	--

¹Sampling site located along an unnamed tributary of Cow Creek. The tributary basin includes a historical lead- and zinc-mined area (fig. 1).

typically exceeded the general PEC and frequently exceeded the TSMD-specific PEC. Zinc concentrations (bulk samples) at depths ranging from 4 to 12 in. typically exceeded the general PEC and occasionally exceeded the TSMD-specific PEC (table 10).

Tar Creek

Within Cherokee County, most of the downstream half of the Tar Creek basin was extensively mined for lead and zinc (fig. 1). Transects TrC1 and TrC2 were located within the extensively mined area whereas transect TrC3 was located upstream from the extensively mined area (fig. 2A). All surficial-soil and core samples collected along transects TrC1 and TrC2 (eight sites, figs. 2O and 2P) had lead and zinc concentrations (bulk and less than 63 μm) that were much larger than both the general and TSMD-specific PECs. For lead, concentrations ranged from about 2 to more than 50 times greater than the TSMD-specific PEC. For zinc,

concentrations ranged from 1.3 to 45 times greater than the TSMD-specific PEC (figs. 3 and 4, table 11). All surficial-soil and core samples collected along transect TrC3 (four sites, fig. 2Q) had lead and zinc concentrations (bulk and less than 63 μm) that were substantially less than the general PECs (figs. 3 and 4, table 11).

Turkey Creek

The Turkey Creek basin includes numerous lead- and zinc-mined areas (fig. 1). All surficial-soil samples collected along transect TkC1 (three sites, figs. 2A and 2R) had lead and zinc concentrations (bulk and less than 63 μm) that were larger than both the general and TSMD-specific PECs (figs. 3 and 4, table 12). At the 6- and 12-in. depth, lead and zinc concentrations (bulk samples) at sites TkC1-1 and TkC1-2 (located north of Turkey Creek, fig. 2R) were much greater than the general and TSMD-specific PECs. However, at site TkC1-3 (located south of Turkey Creek, fig. 2R), only the zinc

Table 7. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Shawnee Creek flood plain, Cherokee County, Kansas, March 2011.

[mg/kg, milligrams per kilogram; <, less than; μm, micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A, 2F, and 2G)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63-μm fraction	Bulk sample	<63-μm fraction
Transect SnC1 (downstream)						
SnC1-1	81.3	0	58	13	51	44
	--	6	20	--	45	--
	--	12	12	--	24	--
SnC1-2	68.2	0	56	31	99	80
	--	6	19	--	37	--
	--	12	12	--	<14.7	--
SnC1-3	89.2	0	64	35	165	129
	--	6	41	--	99	--
	--	12	<9.2	--	22	--
Transect SnC2 (upstream)						
SnC2-1	95.6	0	47	12	54	35
	--	6	<9.6	--	31	--
	--	12	<9.2	--	<13.7	--
SnC2-2	90.5	0	46	18	58	49
	--	6	12	--	44	--
	--	12	<9.6	--	20	--

concentration (bulk sample) at the 6-in. depth was greater than the general PEC (table 12).

Willow Creek

Lead- and zinc-mined areas are located in the downstream half of the Willow Creek basin (fig. 1). Transects WC1 and WC2 were located downstream from mined areas, whereas transect WC3 was located upstream from the mined areas (fig. 2A). Surficial-soil and core samples collected along transects WC1 and WC2 (seven sites, figs. 2A, 2S, and 2T) had lead concentrations (bulk and less than 63 μm) that typically were greater than both the general and TSMD-specific PECs. Zinc concentrations for these samples typically were greater than the general PEC but less than the TSMD-specific PEC. All surficial-soil and core samples collected along transect WC3 (two sites, fig. 2U) had lead and zinc concentrations (bulk and less than 63 μm) that were substantially less than the general PECs (figs. 3 and 4, table 13).

Variability of Lead and Zinc Concentrations in Relation to Mining Activity and Other Factors

In this section, the variability of lead and zinc concentrations in the Spring River flood plain and tributary flood plains was interpreted in relation to historical mining activity and other factors. Topics addressed include source effects, downstream effects, distance-from-channel effects, and particle-size effects.

Source Effects

Sources of sediment to the segment of the Spring River flood plain located within the Cherokee County superfund site include tributaries and the upstream Spring River. Lead and zinc concentrations in surficial-soil samples collected from the Spring River flood plain typically were less than the general

Table 8. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Shoal Creek flood plain, Cherokee County, Kansas, May 2011.

[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; <, less than; μm , micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A, 2H, and 2I)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63- μm fraction	Bulk sample	<63- μm fraction
Transect ShC1 (downstream)						
ShC1-1	94.3	0	177	104	1,269	857
	--	6	99	--	669	--
	--	12	73	--	530	--
ShC1-2	94.4	0	87	30	456	253
	--	6	35	--	263	--
	--	12	31	--	251	--
ShC1-3	95.3	0	106	41	521	219
	--	6	44	--	354	--
	--	12	33	--	301	--
Transect ShC2 (upstream)						
ShC2-1	88.6	0	281	162	2,007	1,255
	--	6	283	--	2,551	--
	--	12	231	--	1,857	--
ShC2-2	84.2	0	177	67	1,135	508
	--	5	23	--	339	--
ShC2-3	91.4	0	167	99	1,133	722
	--	6	30	--	405	--
	--	12	28	--	375	--
ShC2-4	86.5	0	92	40	519	293

PECs even though several tributaries (flood-plain soils and streambed sediment) were substantially contaminated with lead and zinc concentrations that frequently or typically exceeded the general PECs and often exceeded the TSMD-specific PECs (tables 4, 8–13; Pope, 2005). Several possible explanations, singly or in combination, may account for this condition. First, mining-contaminated sediment delivered by tributary inflows during periods of low to moderate Spring River flow may remain largely confined to the Spring River channel. Second, mining-contaminated sediment delivered by tributary inflows may be diluted when mixed with relatively uncontaminated sediment delivered by the upstream Spring River. Third, mining-contaminated sediment delivered by tributary inflows may be immediately transported downstream or, if deposited on the Spring

River flood plain, it may subsequently be remobilized and transported downstream.

A fourth possibility is that lead and zinc concentrations in Spring River flood-plain surficial-soil samples collected from cropland were diluted by plowing (that is, by mixing the contaminated surficial deposits with underlying “clean” soil). Within the Spring River flood plain, 16 sampling sites were located in cropland and 14 sampling sites were located in grassland (table 4). Lead concentrations in the bulk surficial-soil samples collected from cropland ranged from 14 to 47 mg/kg with a median of 20 mg/kg. In comparison, lead concentrations in the bulk samples collected from grassland ranged from 13 to 2,180 mg/kg with a median of 30 mg/kg (table 4, fig. 3). Zinc concentrations in the bulk samples collected from cropland ranged from 22 to 200 mg/kg with

Table 9. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Short Creek flood plain, Cherokee County, Kansas, March and April 2011.

[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; <, less than; μm, micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A, 2J, and 2K)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63-μm fraction	Bulk sample	<63-μm fraction
Transect StC1 (downstream)						
StC1-1	81.1	0	4,677	3,020	10,400	5,579
	--	6	2,303	--	12,800	--
	--	12	3,456	--	3,503	--
StC1-2	80.1	0	4,897	3,284	10,700	5,436
	--	6	1,759	--	8,077	--
	--	9	1,332	--	8,671	--
	--	12	253	--	3,516	--
StC1-3	83.4	0	3,711	2,586	12,700	8,212
	--	6	4,986	--	12,700	--
Transect StC2 (upstream)						
StC2-1	74.2	0	300	650	5,341	4,028
	--	6	256	--	4,935	--
StC2-2	78.9	0	439	284	5,697	4,597

a median of 60 mg/kg. In comparison, zinc concentrations in the bulk samples collected from grassland ranged from 32 to 4,850 mg/kg with a median of 102 mg/kg (table 4, fig. 4). These results substantiate the possibility of a cropland-related dilution effect associated with plowing. Such an effect will only be appreciable if the total thickness of contaminated sediment deposited is substantially less than the total depth of the plow layer.

Lead and zinc contamination in the tributary flood plains was related to the availability of sources; that is, the amount of historical lead and zinc mining activity in the basins. Typically, the tributary flood-plain surficial-soil sampling sites were located in woodland or grassland (table 1–1). Tributaries with little or no historical mining activity in their basins were Brush, Cow, and Shawnee Creeks (fig. 1). With one exception, lead and zinc concentrations in the surficial soils and subsurface (that is, 6- and 12-in. depths) of these tributary flood plains were substantially less than the general PECs (tables 3, 5, 6, and 7). The exception was transect CC2, which was located along an unnamed tributary of Cow Creek and immediately downstream from a historically mined area (figs. 2A and 2E). Along this transect, zinc concentrations greater than the general PEC were measured for the surficial soil at both sampling sites. At site CC2-1, zinc concentrations at depth exceeded the TSMD-specific PEC (table 6). In an

assessment of streambed sediment contamination within the Cherokee County superfund site, Pope (2005) measured lead and zinc concentrations (in the less than 63-μm fraction) for Brush, Cow, and Shawnee Creeks that typically were less than the general PECs.

The remaining six tributaries—Shoal Creek, Short Creek, Spring Branch, Tar Creek, Turkey Creek, and Willow Creek—have substantial historically mined areas in their basins (fig. 1). All six tributary flood plains had lead and zinc concentrations that frequently or typically exceeded the general PECs (tables 3, 8–13). Likewise, lead concentrations frequently or typically exceeded the TSMD-specific PEC. With the exception of Shoal and Willow Creeks, zinc concentrations typically exceeded the TSMD-specific PEC (tables 8–13). Similar results were reported for streambed-sediment concentrations (less than 63-μm fraction) in the six tributaries (Pope, 2005).

Along Tar and Willow Creeks, the longitudinal change in flood-plain contamination, in relation to the location of historically mined areas, was pronounced. For both basins, lead and zinc concentrations in samples collected along the transect located upstream from the historically mined areas (that is, transects TrC3 and WC3; fig. 2A) were substantially less than the general PECs. Conversely, lead and zinc concentrations in samples collected along the transects located

Table 10. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Spring Branch flood plain, Cherokee County, Kansas, March 2011.

[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; <, less than; μm , micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A and 2L–2M)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63- μm fraction	Bulk sample	<63- μm fraction
Transect SB1 (downstream)						
SB1-1	73.7	0	510	350	5,702	3,205
	--	4	497	--	5,708	--
	--	10	834	--	792	--
SB1-2	66.7	0	434	387	5,285	4,615
Transect SB2						
SB2-1	62.5	0	697	654	3,515	2,546
	--	4	928	--	2,699	--
	--	10	917	--	2,293	--
SB2-2	73.4	0	598	651	3,149	2,940
	--	6	148	--	697	--
	--	12	95	--	519	--
SB2-3	71.3	0	233	182	973	781
Transect SB3 (upstream)						
SB3-1	61.7	0	702	987	2,303	4,068
	--	6	469	--	171	--
	--	10	84	--	147	--
SB3-2	41.8	0	487	104	4,361	1,165

within or downstream from the historically mined areas (that is, transects TrC1, TrC2, WC1, and WC2; fig. 2A) typically exceeded the general PECs (tables 11 and 13). Contamination was most pronounced (of all the sites sampled for this study) for the two downstream transects on the Tar Creek flood plain, with lead and zinc concentrations that frequently far exceeded the TSMD-specific PECs (table 11). A similar longitudinal pattern in streambed-sediment contamination (less than 63- μm fraction) for these two streams was reported by Pope (2005).

Downstream Effects

Once introduced into the fluvial system, mining-contaminated sediment is affected by several processes including temporary deposition, long-term storage, remobilization, transport, hydraulic sorting, dilution by mixing with relatively uncontaminated sediment, chemical sorption and desorption, and biological uptake (Lewin and Macklin,

1987; Macklin, 1996; Miller, 1997; Luoma and Rainbow, 2008). Because mining-related trace elements are mostly (often more than 90 percent) transported in the particulate phase, fluvial geomorphic processes are important, if not dominant, in the redistribution of mining-contaminated sediment in the environment (Horowitz, 1991; Miller, 1997). With distance downstream from the source area, sediment concentrations of mining-related trace elements typically will decrease unless additional downstream sources contribute contaminated sediment (Axtmann and Luoma, 1991; Macklin, 1996; Luoma and Rainbow, 2008).

Within the Cherokee County superfund site, the Spring River receives inflows from several tributaries that drain mining-affected areas (fig. 1). Along its 22-mi length within the superfund site, Pope (2005) determined that lead and zinc concentrations in the bed sediment of the Spring River increased about 7 and 17 times, respectively. Surficial-soil concentrations of lead and zinc in the Spring River flood plain

Table 11. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Tar Creek flood plain, Cherokee County, Kansas, March and April 2011.

[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; <, less than; μm , micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A and 2O-2Q)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63- μm fraction	Bulk sample	<63- μm fraction
Transect TrC1 (downstream)						
TrC1-1	89.7	0	3,076	2,238	18,800	20,300
	--	6	4,774	--	35,300	--
	--	12	5,450	--	24,100	--
TrC1-2	91.7	0	5,363	4,050	25,500	23,100
	--	6	4,708	--	20,000	--
	--	12	5,737	--	24,000	--
TrC1-3	46.9	0	4,278	2,016	15,300	6,896
	--	6	3,773	--	14,900	--
	--	12	4,515	--	19,000	--
TrC1-4	59.8	0	5,069	7,837	14,700	22,000
	--	6	5,344	--	14,900	--
	--	12	2,324	--	4,937	--
Transect TrC2						
TrC2-1	93.1	0	524	313	3,594	2,720
	--	4	486	--	3,173	--
	--	10	496	--	4,071	--
TrC2-2	90.7	0	591	296	4,331	2,869
	--	4	626	--	3,522	--
	--	10	606	--	2,939	--
TrC2-3	90.2	0	466	337	4,069	3,086
	--	4	425	--	3,738	--
	--	10	3,544	--	51,300	--
TrC2-4	84.4	0	513	409	4,895	3,737
	--	4	519	--	3,768	--
	--	10	2,494	--	94,200	--
Transect TrC3 (upstream)						
TrC3-1	94.5	0	62	30	290	201
	--	6	53	--	290	--
	--	12	49	--	242	--

28 Occurrence and Variability of Mining-Related Lead and Zinc in the Spring River Flood Plain, Cherokee County, Kansas

Table 11. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Tar Creek flood plain, Cherokee County, Kansas, March and April 2011.—Continued

[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; <, less than; μm, micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A and 2O–2Q)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63-μm fraction	Bulk sample	<63-μm fraction
Transect TrC3 (upstream)—Continued						
TrC3-2	95.9	0	76	44	313	223
	--	6	53	--	245	--
	--	12	30	--	197	--
TrC3-3	94.6	0	79	46	336	234
	--	6	53	--	212	--
	--	12	39	--	176	--
TrC3-4	89.4	0	90	58	348	276
	--	6	55	--	220	--
	--	12	13	--	83	--

Table 12. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Turkey Creek flood plain, Cherokee County, Kansas, March 2011.

[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; <, less than; μm, micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A and 2R)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63-μm fraction	Bulk sample	<63-μm fraction
Transect TkC1						
TkC1-1	94.8	0	823	785	5,110	4,899
	--	6	923	--	6,722	--
	--	12	1,610	--	10,100	--
TkC1-2	77.3	0	825	677	5,458	4,165
	--	6	677	--	4,289	--
	--	12	1,216	--	8,826	--
TkC1-3	96.6	0	475	363	2,839	2,130
	--	6	92	--	670	--
	--	12	31	--	143	--

Table 13. Percentage of silt and clay and concentrations of lead and zinc determined by x-ray fluorescence for surficial-soil and core samples collected from the Willow Creek flood plain, Cherokee County, Kansas, April 2011.

[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; <, less than; μm , micrometer; --, not available]

Surficial-soil sampling and coring site identifier (figs. 2A, and 2S-2U)	Percentage of silt and clay in bulk sample	Sample depth, inches	Lead concentration, mg/kg		Zinc concentration, mg/kg	
			Bulk sample	<63- μm fraction	Bulk sample	<63- μm fraction
Transect WC1 (downstream)						
WC1-1	63.0	0	210	181	927	788
	--	6	239	--	1,053	--
	--	12	257	--	1,010	--
WC1-2	77.3	0	258	188	1,128	879
	--	6	274	--	1,064	--
	--	12	152	--	723	--
WC1-3	78.4	0	224	151	927	704
	--	6	140	--	906	--
Transect WC2						
WC2-1	76.4	0	261	174	1,511	1,290
	--	6	336	--	1,783	--
	--	12	305	--	1,565	--
WC2-2	82.4	0	277	178	947	658
	--	6	256	--	1,078	--
	--	12	220	--	1,117	--
WC2-3	71.4	0	264	143	1,112	545
	--	6	31	--	346	--
	--	12	475	--	1,736	--
WC2-4	86.1	0	290	370	1,235	1,592
	--	6	2,607	--	2,560	--
	--	12	493	--	1,858	--
Transect WC3 (upstream)						
WC3-1	96.1	0	68	52	184	271
	--	6	68	--	328	--
	--	12	30	--	132	--
WC3-2	87.9	0	91	23	289	157
	--	6	47	--	248	--
	--	12	42	--	122	--

were variable and did not indicate a pronounced upstream-to-downstream trend (figs. 3 and 4, table 4). The variability was caused, in part, by the complexity of factors that determine the distribution of mining-contaminated sediment on the flood plain.

A comparison of lead and zinc concentrations in the bottom sediment of two reservoirs located on the Spring River indicated less contamination with distance downstream from the mining-affected areas. Median lead and zinc concentrations in the bottom sediment of Empire Lake, Kansas (located within the superfund site and immediately downstream from several mining-affected areas within the TSMD) (fig. 1), were about 5 and 6 times larger than median concentrations in the bottom sediment of Grand Lake O' the Cherokees, Oklahoma (located at least 13 miles downstream from the last Spring River tributary that drains a substantial mining-affected area) (Juracek, 2006; Juracek and Becker, 2009). The Neosho River (fig. 1), with its larger flows and less-contaminated sediment, likely dilutes the load of contaminated sediment delivered to Grand Lake O' the Cherokees by the Spring River (Juracek and Becker, 2009).

A pronounced downstream decrease in flood-plain and bed-sediment lead and zinc concentrations typically was not indicated for the sections of the mining-affected tributaries located within the Cherokee County superfund site (tables 8–13; Pope, 2005). The explanation largely was related to the distribution of historically mined areas within each basin (fig. 1).

Distance-from-Channel Effects

The distribution of mining-contaminated sediment on flood plains is complex because it is determined by the interaction of several factors including the size and density of the contaminated particles, flood-plain width and topography, flood-plain characteristics (frequency, magnitude, duration), and fluvial geomorphic processes (Lewin and others, 1977; Brewer and Taylor, 1997; Lecce and Pavlowsky, 1997). The complexity is evidenced by previous studies in which mining-related flood-plain contamination with increasing distance from the channel increased, decreased, or indicated no trend (Bradley and

Cox, 1990; Macklin and others, 1994; Brewer and Taylor, 1997; Walling and others, 2003).

Mining-related contamination in surficial soils (bulk sample results) was variable in the Spring River flood plain and tributary flood plains with respect to increasing distance from the channel. For the Spring River flood plain, distance-from-channel effects were assessed using the cores (generally, the top 1–2 in.) collected along six transects (fig. 2A). Four to six cores were used for each transect. No consistent trend in lead and zinc concentrations with distance from the channel was evident for transect T1. For transect T2, lead and zinc concentrations initially decreased with distance from the channel then stabilized. For transect T3, lead concentrations were relatively stable with distance whereas zinc concentrations initially were variable then decreased. Lead and zinc concentrations along transect T4 increased then decreased. For transect T5, lead and zinc concentrations were variable with an overall decrease with distance. Along transect T6, lead concentrations decreased with distance whereas zinc concentrations decreased then increased. Overall, a tendency for the largest lead and zinc concentrations to be located near the channel was indicated (table 14, fig. 5).

Variability in lead and zinc concentrations with distance from the channel was indicated for the tributary flood plains. Only transects with at least two surficial-soil sampling sites located on the same side of the channel were used to assess changes in contamination with increasing distance from the channel. The availability of only two sampling sites on the

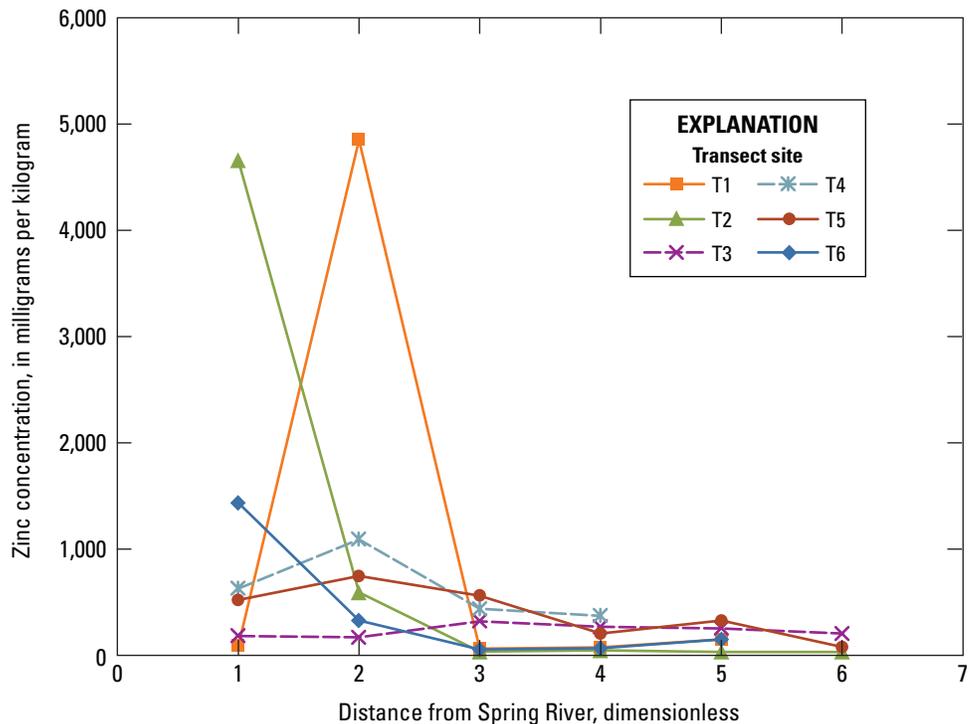


Figure 5. Variability of flood-plain zinc concentrations (surficial-soil bulk samples) with distance from the Spring River along transects T1 through T6. Location of transects shown in figure 2A.

Table 14. Lead and zinc concentrations (surficial-soil bulk samples) with distance from the Spring River for flood-plain coring sites located along transects T1 through T6. Location of transects shown in figure 2A.

[Shading indicates concentration greater than the general probable-effect concentration listed in table 3. mg/kg, milligrams per kilogram; N, nearest to channel; <, less than; F, farthest from channel]

Transect (fig. 2A)	Coring site	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Depth interval analyzed (inches)
T1	T1-1 (N)	27	90	0-2
	T1-2	260	4,850	0-2
	T1-3	26	66	0-1
	T1-4	<27	77	0-2
	T1-5 (F)	30	152	0-2
T2	T2-1 (N)	187	4,656	0-2
	T2-2	40	592	0-2
	T2-3	<20	36	0-2
	T2-4	27	48	0-1
	T2-5	23	34	0-1
	T2-6 (F)	21	34	0-2
T3	T3-1 (N)	<51	184	0-2
	T3-2	45	170	0-2
	T3-6	45	323	0-2
	T3-3	51	269	0-2
	T3-4	50	255	0-2
T3-5 (F)	38	205	0-2	
T4	T4-2 (N)	153	631	0-1
	T4-3	210	1,092	0-1
	T4-4	51	438	0-1
	T4-5 (F)	<57	374	0-1
T5	T5-2 (N)	64	521	0-1
	T5-3	70	747	0-1
	T5-4	67	563	0-1
	T5-5	49	206	0-1
	T5-6	58	329	0-1
	T5-7 (F)	25	80	0-1
T6	T6-1 (N)	116	1,435	0-1
	T6-2	70	329	0-2
	T6-3	22	56	0-1
	T6-4	31	67	0-1.5
	T6-5 (F)	<20	150	0-3

same side of the channel for multiple transects constrained the ability to determine if trends in lead and zinc concentrations with distance from the channel were present. Nevertheless, the available data demonstrated the spatial complexity of lead and zinc contamination on the tributary flood plains.

For Brush Creek, transects BC1 (both sides of channel, two sampling sites on each side) and BC2 (one side of channel, two sampling sites) were evaluated (figs. 2A–2C). In all three cases, lead and zinc concentrations were larger for the sampling site located farthest from the channel (table 5).

Transect CC1 (one side of channel, two sampling sites) was evaluated for Cow Creek. Lead and zinc concentrations were slightly smaller for the sampling site located farthest from the channel (figs. 2A and 2D, table 6).

For Shawnee Creek, transect SnC1 (one side of channel, two sampling sites) was evaluated. With distance from the channel, the lead concentration essentially was unchanged whereas the zinc concentration substantially decreased (figs. 2A and 2F, table 7).

Two transects were evaluated for Shoal Creek (fig. 2A). Along transect ShC1 (one side of channel, three sampling sites), lead and zinc concentrations with distance from the channel decreased then increased. However, along transect ShC2 (one side of channel, four sampling sites), lead and zinc concentrations decreased with distance from the channel (figs. 2A, 2H, and 2I, table 8).

For Short Creek, transects StC1 (one side of channel, three sampling sites) and StC2 (one side of channel, two sampling sites) were evaluated (figs. 2A, 2J, and 2K). With distance from the channel along transect StC1, lead concentration increased then decreased and zinc concentration decreased. Lead and zinc concentrations were larger for the sampling site located farthest from the channel for transect StC2 (table 9).

The transects evaluated for Spring Branch were SB1 (one side of channel, two sampling sites) and SB2 (one side of channel, three sampling sites) (figs. 2A, 2L, and 2M). Lead and zinc concentrations were larger for the sampling site located farthest from the channel for transect SB1. Along transect SB2, lead and zinc concentrations decreased with distance from the channel (table 10).

For Tar Creek, the transects evaluated were TrC1 (one side of channel, four sampling sites), TrC2 (both sides of channel, two sampling sites on each side), and TrC3 (one side of channel, four sampling sites) (figs. 2A, and 2O–2Q). Along transect TrC1, lead concentration was variable whereas zinc concentration increased then decreased with distance from the channel. For transect TrC2, lead and zinc concentrations for the sampling site located farthest from the channel, compared to the near-channel site, were larger on one side of the channel and smaller on the other side of the channel. For transect TrC3, lead and zinc concentrations increased with distance from the channel (table 11).

For Turkey Creek, transect TkC1 (one side of channel, two sampling sites) was evaluated (figs. 2A and 2R). Whereas the lead concentration was virtually the same for both

sampling sites, the zinc concentration was smaller for the site located farthest from the channel (table 12).

The transects evaluated for Willow Creek were WC1 (one side of channel, three sampling sites) and WC2 (both sides of channel, two sampling sites on each side) (figs. 2A, 2S, and 2T). With distance from the channel, lead and zinc concentrations increased then decreased for transect WC1. On both sides of the channel along transect WC2, the zinc concentration was larger for the sampling site located farthest from the channel. However, the lead concentration for the site located farthest from the channel was larger on one side and smaller on the other side (table 13).

Particle-Size Effects

In general, there is an inverse relation between particle size and trace element concentrations in sediment. That is, as particle size decreases, trace element concentrations increase, in part, because of the greater surface area available for elements to accumulate (Horowitz, 1991; Luoma and Rainbow, 2008). However, for mining-contaminated sediment, this general relation may not hold because coarse sediment (that is, particles larger than 63 μm) can have large concentrations of mining-related elements (Bradley, 1989; Moore and others, 1989).

For all surficial-soil sampling sites in the Spring River flood plain and tributary flood plains, XRF analyses were performed on the bulk sample and the less than 63- μm fraction to assess compositional differences related to particle size. Typically, substantial differences in lead and zinc concentration were measured for the bulk and less than 63- μm samples. For lead and zinc, concentrations in the less than 63- μm fraction were within ± 20 percent of the concentrations in the bulk sample for only 17 and 32 percent of the cases, respectively. Lead and zinc concentrations in the less than 63- μm fraction were smaller than the concentrations in the bulk sample for 89 and 80 percent of the cases, respectively (tables 4–13). One possible explanation to account, in part, for the divergent concentrations is analytical variability. A second possible explanation is differences in the chemical composition of the coarse particles (that is, larger than 63 μm) in comparison to the fine particles (that is, less than 63 μm). Specifically, for the surficial-soil samples analyzed by XRF in this study, the coarse particles possibly contained larger concentrations of lead and zinc compared to the fine particles.

Summary and Conclusions

A 4-year study by the U.S. Geological Survey, which was requested and funded by the U.S. Environmental Protection Agency, was begun in 2009 to investigate the occurrence and variability of mining-related lead and zinc in the Spring River flood plain and tributary flood plains in the Cherokee County, Kansas, superfund site. The study used a combination of

surficial-soil sampling and coring completed in 2009 through 2011. The results of this study are summarized below:

1. With few exceptions, surficial soils in the Spring River flood plain had lead and zinc concentrations that were less than the general probable-effect concentrations (PECs), which represent the concentrations above which adverse aquatic biological effects are likely to occur.
2. Lead and zinc concentrations larger than the general or TSMD-specific PECs, or both, were infrequent at depth in the Spring River flood plain. When present, such contamination typically was confined to the upper 2 feet of the core and frequently was confined to the upper 6 inches.
3. Tributaries with few or no lead- and zinc-mined areas in the basin—Brush Creek, Cow Creek, and Shawnee Creek—generally had flood-plain lead and zinc concentrations (surficial soil, 6- and 12-inch depth) that were substantially less than the general PECs.
4. Tributaries with extensive lead- and zinc-mined areas in the basin—Shoal Creek, Short Creek, Spring Branch, Tar Creek, Turkey Creek, and Willow Creek—had flood-plain lead concentrations (surficial soil, 6- and 12-inch depth) that frequently or typically exceeded the general and TSMD-specific PECs.
5. Tributaries with extensive lead- and zinc-mined areas in the basin—Shoal Creek, Short Creek, Spring Branch, Tar Creek, Turkey Creek, and Willow Creek—had flood-plain zinc concentrations (surficial soil, 6- and 12-inch depth) that frequently or typically exceeded the general PEC. With the exception of Shoal and Willow Creeks, zinc concentrations typically exceeded the TSMD-specific PEC.
6. The largest flood-plain lead and zinc concentrations (surficial soil, 6- and 12-inch depth) were measured for Short and Tar Creeks.
7. Lead and zinc concentrations in the surficial-soil samples from the Spring River flood plain were variable with distance downstream and with distance from the channel. Overall, a tendency for the largest lead and zinc concentrations to be located near the channel was indicated.
8. Lead and zinc concentrations in the surficial-soil samples from the tributary flood plains varied longitudinally in relation to sources of mining-contaminated sediment in the basins. The concentrations also varied with distance from the channel; however, no consistent spatial trend was evident.
9. For the surficial-soil samples collected from the Spring River flood plain and tributary flood plains, both the coarse (larger than 63 micrometers) and fine particles (less than 63 micrometers) contained substantial lead and zinc concentrations.

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Appendixes

Table 1–1. Latitude and longitude coordinates, and land use, for surficial-soil sampling sites in the Spring River flood plain and tributary flood plains in Cherokee County, Kansas, 2009, 2011.

Sampling site identifier (figs. 2A–2U)	Date sampled (month/day/year)	Latitude (decimal degrees)	Longitude (decimal degrees)	Land use ¹
Spring River				
SRF-1	11/12/09	37.19567	94.62797	Cropland.
SRF-2	11/12/09	37.19608	94.63589	Cropland.
SRF-3	11/12/09	37.18958	94.64267	Cropland.
SRF-4	11/12/09	37.18272	94.62847	Cropland.
SRF-5	11/12/09	37.17367	94.62850	Cropland.
SRF-6	11/13/09	37.16772	94.63506	Grassland.
SRF-7	11/13/09	37.15814	94.62844	Grassland.
SRF-9	11/13/09	37.13692	94.63506	Cropland.
SRF-10	11/13/09	37.13481	94.65361	Grassland.
SRF-11	11/17/09	37.12239	94.69069	Cropland.
SRF-13	11/17/09	37.12006	94.66225	Cropland.
SRF-14	11/17/09	37.12253	94.64644	Cropland.
SRF-15	11/17/09	37.12897	94.62683	Grassland.
SRF-16	11/17/09	37.11019	94.65789	Cropland.
SRF-17	11/17/09	37.10778	94.68119	Cropland.
SRF-18	11/17/09	37.11614	94.68992	Cropland.
SRF-19	11/17/09	37.09272	94.67336	Grassland.
SRF-20	11/17/09	37.07742	94.68325	Grassland.
SRF-21	11/18/09	37.07939	94.70044	Grassland.
SRF-22	11/18/09	37.07558	94.71056	Grassland.
SRF-23	11/18/09	37.07628	94.72953	Cropland.
SRF-24	11/18/09	37.06428	94.73683	Grassland.
SRF-25	11/23/09	37.06572	94.71061	Grassland.
SRF-26	11/23/09	37.06817	94.70367	Grassland.
SRF-27	11/23/09	37.05853	94.72561	Grassland.
SRF-28	11/23/09	37.04872	94.70792	Cropland.
SRF-29	11/23/09	37.05542	94.69722	Cropland.
SRF-31	11/23/09	37.03203	94.71469	Grassland.
SRF-32	11/24/09	37.02469	94.71200	Cropland.
SRF-33	11/24/09	37.00719	94.70869	Grassland.
Brush Creek				
BC1-1	04/14/11	37.08067	94.75128	Woodland.
BC1-2	05/04/11	37.08028	94.75083	Grassland.
BC1-3	05/04/11	37.08008	94.75061	Grassland.
BC1-4	05/04/11	37.08086	94.75144	Woodland.
BC2-1	05/04/11	37.11256	94.77489	Woodland.
BC2-2	05/04/11	37.11269	94.77506	Woodland.

Table 1–1. Latitude and longitude coordinates, and land use, for surficial-soil sampling sites in the Spring River flood plain and tributary flood plains in Cherokee County, Kansas, 2009, 2011.—Continued

Sampling site identifier (figs. 2A–2U)	Date sampled (month/day/year)	Latitude (decimal degrees)	Longitude (decimal degrees)	Land use ¹
Cow Creek				
CC1-1	03/16/11	37.22239	94.65353	Woodland.
CC1-2	03/16/11	37.22239	94.65222	Cropland.
CC1-3	03/16/11	37.22239	94.65122	Cropland.
CC2-1	03/16/11	37.24161	94.63156	Woodland.
CC2-2	03/16/11	37.24153	94.63147	Woodland.
Shawnee Creek				
SnC1-1	03/17/11	37.13450	94.67867	Cropland.
SnC1-2	03/17/11	37.13456	94.67833	Woodland.
SnC1-3	03/17/11	37.13464	94.67778	Woodland.
SnC2-1	03/16/11	37.17831	94.69786	Cropland.
SnC2-2	03/16/11	37.17831	94.69650	Cropland.
Shoal Creek				
ShC1-1	05/05/11	37.03939	94.66717	Woodland.
ShC1-2	05/05/11	37.03989	94.66706	Grassland.
ShC1-3	05/05/11	37.04017	94.66700	Grassland.
ShC2-1	05/05/11	37.04111	94.63814	Grassland.
ShC2-2	05/05/11	37.04094	94.63814	Grassland.
ShC2-3	05/05/11	37.04075	94.63811	Grassland.
ShC2-4	05/05/11	37.04031	94.63814	Grassland.
Short Creek				
StC1-1	03/15/11	37.08925	94.66289	Grassland.
StC1-2	03/15/11	37.08914	94.66294	Grassland.
StC1-3	03/15/11	37.08903	94.66297	Grassland.
StC2-1	04/13/11	37.09014	94.62481	Grassland.
StC2-2	04/13/11	37.09019	94.62481	Grassland.
Spring Branch				
SB1-1	03/30/11	37.02831	94.73042	Woodland.
SB1-2	03/30/11	37.02828	94.73042	Woodland.
SB2-1	03/30/11	37.02814	94.73839	Woodland.
SB2-2	03/30/11	37.02811	94.73833	Woodland.
SB2-3	03/30/11	37.02811	94.73831	Woodland.
SB3-1	03/31/11	37.02436	94.74094	Woodland.
SB3-2	03/31/11	37.02433	94.74067	Woodland.
Tar Creek				
TrC1-1	03/31/11	37.00406	94.85781	Grassland.
TrC1-2	03/31/11	37.00400	94.85786	Grassland.
TrC1-3	03/31/11	37.00394	94.85792	Grassland.
TrC1-4	03/31/11	37.00386	94.85808	Disturbed.
TrC2-1	04/01/11	37.01297	94.86067	Woodland.
TrC2-2	04/01/11	37.01289	94.86072	Woodland.
TrC2-3	04/01/11	37.01272	94.86086	Woodland.

Table 1–1. Latitude and longitude coordinates, and land use, for surficial-soil sampling sites in the Spring River flood plain and tributary flood plains in Cherokee County, Kansas, 2009, 2011.—Continued

Sampling site identifier (figs. 2A–2U)	Date sampled (month/day/year)	Latitude (decimal degrees)	Longitude (decimal degrees)	Land use¹
TrC2-4	04/01/11	37.01269	94.86089	Woodland.
TrC3-1	04/12/11	37.03181	94.85097	Grassland.
TrC3-2	04/12/11	37.03189	94.85106	Grassland.
TrC3-3	04/12/11	37.03203	94.85111	Grassland.
TrC3-4	04/12/11	37.03211	94.85122	Grassland.
Turkey Creek				
TkC1-1	03/15/11	37.12870	94.62492	Grassland.
TkC1-2	03/15/11	37.12858	94.62508	Grassland.
TkC1-3	03/15/11	37.12811	94.62586	Grassland.
Willow Creek				
WC1-1	04/13/11	37.04022	94.74033	Woodland.
WC1-2	04/13/11	37.04025	94.74033	Woodland.
WC1-3	04/13/11	37.04028	94.74031	Woodland.
WC2-1	04/13/11	37.03739	94.77664	Grassland.
WC2-2	04/13/11	37.03747	94.77661	Grassland.
WC2-3	04/13/11	37.03761	94.77656	Grassland.
WC2-4	04/13/11	37.03767	94.77656	Grassland.
WC3-1	04/14/11	37.06306	94.81008	Woodland.
WC3-2	04/14/11	37.06322	94.81003	Grassland.

¹Land use observed on the day the surficial-soil sample was collected.

Table 1–2. Latitude and longitude coordinates for coring sites in the Spring River flood plain in Cherokee County, Kansas, November 2009 and March 2010.

Coring site identifier (fig. 2A)	Date cored (month/day/year)	Latitude (decimal degrees)	Longitude (decimal degrees)
T1-1	11/04/09	37.18159	94.64084
T1-2	11/04/09	37.18149	94.63608
T1-3	11/03/09	37.18164	94.63330
T1-4	11/04/09	37.18167	94.63009
T1-5	11/04/09	37.18209	94.62711
T2-1	03/15/10	37.14627	94.62048
T2-2	03/15/10	37.14639	94.62400
T2-3	03/15/10	37.14481	94.62752
T2-4	03/15/10	37.14483	94.63155
T2-5	03/15/10	37.14483	94.63570
T2-6	03/15/10	37.14485	94.63972
T3-1	11/05/09	37.11937	94.66467
T3-2	11/06/09	37.11930	94.66115
T3-3	11/05/09	37.11909	94.65642
T3-4	11/05/09	37.11910	94.65400
T3-5	11/05/09	37.11906	94.65043
T3-6	11/06/09	37.11888	94.65869
T4-1	03/16/10	37.09111	94.68756
T4-2	03/16/10	37.09022	94.68355
T4-3	03/16/10	37.08937	94.67899
T4-4	03/16/10	37.08875	94.67538
T4-5	03/16/10	37.08853	94.67194
T5-1	03/17/10	37.05256	94.73207
T5-2	03/17/10	37.05334	94.72497
T5-3	03/17/10	37.05306	94.72222
T5-4	03/17/10	37.05311	94.71757
T5-5	03/17/10	37.05311	94.71254
T5-6	03/17/10	37.05270	94.70870
T5-7	03/17/10	37.05272	94.70523
T6-1	11/03/09	37.01228	94.71766
T6-2	11/03/09	37.01195	94.71477
T6-3	11/03/09	37.01210	94.71135
T6-4	11/02/09	37.01190	94.70998
T6-5	11/02/09	37.01184	94.70650

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Table 1-3. Percentage of silt and clay and constituent concentrations determined by combustion and spectroscopic methods for three surficial-soil samples (SRF-2, SRF-5, SRF-10) collected from the Spring River flood plain, Cherokee County, Kansas, November 2009.

[Location of sampling sites shown in figure 2.4. Values in parentheses are concentrations in the less than 63-micrometer fraction. mg/kg, milligrams per kilogram; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration		
	Sample SRF-2	Sample SRF-5	Sample SRF-10
Percentage of silt and clay in bulk sample	95	88	51
Nutrients			
Total nitrogen, mg/kg	1,500 (1,100)	1,300 (1,000)	1,200 (1,500)
Total phosphorus, mg/kg	620 (610)	520 (550)	500 (690)
Carbon			
Carbon (total organic), %	1.5 (1.4)	1.4 (1.2)	1.7 (2.1)
Carbon (total), %	1.5 (1.3)	1.4 (1.2)	1.6 (1.8)
Trace elements			
Aluminum, %	4.0 (4.2)	2.7 (3.1)	2.3 (3.9)
Antimony, mg/kg	0.6 (0.6)	0.6 (0.6)	0.4 (0.6)
Arsenic, mg/kg	5.4 (5.7)	5.0 (4.9)	6.3 (7.4)
Barium, mg/kg	490 (520)	380 (420)	270 (450)
Beryllium, mg/kg	1.4 (1.4)	0.9 (0.9)	1.0 (1.5)
Cadmium, mg/kg	0.8 (0.7)	0.3 (0.4)	5.7 (7.4)
Chromium, mg/kg	44 (46)	39 (39)	37 (54)
Cobalt, mg/kg	9 (9)	7 (8)	11 (15)
Copper, mg/kg	13 (14)	11 (12)	10 (17)
Iron, %	1.5 (1.6)	1.2 (1.3)	1.6 (2.1)
Lead, mg/kg	28 (25)	30 (26)	91 (140)
Lithium, mg/kg	25 (26)	19 (21)	17 (26)
Manganese, mg/kg	1,100 (940)	500 (520)	650 (930)
Molybdenum, mg/kg	<1 (<1)	<1 (<1)	<1 (<1)
Nickel, mg/kg	17 (16)	8 (9)	14 (19)
Selenium, mg/kg	0.3 (0.3)	0.4 (0.4)	0.3 (0.5)
Silver, mg/kg	<0.5 (<0.5)	<0.5 (<0.5)	<0.5 (0.6)
Strontium, mg/kg	62 (65)	50 (53)	40 (62)
Sulfur, %	0.019 (0.019)	0.019 (0.020)	0.046 (0.058)
Thallium, mg/kg	<50 (<50)	<50 (<50)	<50 (<50)
Tin, mg/kg	2 (2)	<1 (<1)	1 (2)
Titanium, %	0.47 (0.49)	0.42 (0.40)	0.25 (0.45)
Uranium, mg/kg	<50 (<50)	<50 (<50)	<50 (<50)
Vanadium, mg/kg	59 (59)	49 (49)	42 (63)
Zinc, mg/kg	110 (110)	60 (67)	940 (1,200)

Table 1-4. Results of x-ray fluorescence analysis of standard reference samples and comparison to most probable values.

[Shading indicates values not within ± 10 percent of the most probable value. mg/kg, milligrams per kilogram; MPV, most probable value; --, not determined or not applicable; <, less than; LOD, limit of detection. Reference samples from Fisher Scientific]

Sample code		Cadmium		Lead		Zinc	
		Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV
RCRA	MPV	500	--	500	--	--	--
Results obtained during analyses of Spring River flood-plain samples							
		536	7.2	488	-2.4	36	--
		539	7.8	548	9.6	--	--
		545	9.0	485	-3.0	<34.1	--
		518	3.6	482	-3.6	47	--
		525	5.0	515	3.0	61	--
		535	7.0	508	1.6	55	--
		511	2.2	481	-3.8	64	--
		489	-2.2	503	0.6	51	--
		525	5.0	482	-3.6	<33.8	--
		548	9.6	449	-10.2	47	--
		517	3.4	522	4.4	34	--
		482	-3.6	494	-1.2	42	--
		512	2.4	514	2.8	38	--
		527	5.4	477	-4.6	85	--
		516	3.2	513	2.6	50	--
		527	5.4	522	4.4	48	--
		542	8.4	525	5.0	49	--
		509	1.8	506	1.2	55	--
		529	5.8	505	1.0	41	--
		526	5.2	435	-13.0	54	--
		544	8.8	508	1.6	69	--
		531	6.2	519	3.8	63	--
		525	5.0	515	3.0	61	--
		535	7.0	508	1.6	55	--
		511	2.2	481	-3.8	64	--
		503	0.6	486	-2.8	51	--
		531	6.2	540	8.0	98	--
		529	5.8	467	-6.6	54	--
		527	5.4	456	-8.8	54	--
		530	6.0	568	13.6	56	--
		532	6.4	452	-9.6	48	--
		483	-3.4	449	-10.2	<35.0	--
		521	4.2	463	-7.4	44	--
		528	5.6	538	7.6	60	--
		530	6.0	532	6.4	50	--
		505	1.0	514	2.8	56	--

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Table 1-4. Results of x-ray fluorescence analysis of standard reference samples and comparison to most probable values.—Continued

[Shading indicates values not within ± 10 percent of the most probable value. mg/kg, milligrams per kilogram; MPV, most probable value; --, not determined or not applicable; <, less than; LOD, limit of detection. Reference samples from Fisher Scientific]

Sample code	Cadmium		Lead		Zinc	
	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV
Results obtained during analyses of Spring River flood-plain samples—Continued						
525		5.0	502	0.4	51	--
513		2.6	506	1.2	43	--
512		2.4	488	-2.4	34	--
540		8.0	524	4.8	37	--
578		15.6	505	1.0	68	--
610		22.0	506	1.2	77	--
541		8.2	441	-11.8	74	--
606		21.2	510	2.0	64	--
617		23.4	489	-2.2	84	--
598		19.6	538	7.6	68	--
520		4.0	444	-11.2	65	--
Results obtained during analyses of tributary flood-plain samples						
552		10.4	566	13.2	53	--
542		8.4	532	6.4	47	--
517		3.4	519	3.8	43	--
561		12.2	500	0	46	--
536		7.2	538	7.6	61	--
541		8.2	497	-0.6	46	--
545		9.0	499	-0.2	42	--
535		7.0	501	0.2	50	--
532		6.4	520	4.0	45	--
518		3.6	532	6.4	59	--
509		1.8	517	3.4	49	--
529		5.8	507	1.4	57	--
544		8.8	483	-3.4	47	--
544		8.8	473	-5.4	47	--
524		4.8	461	-7.8	44	--
516		3.2	431	-13.8	49	--
542		8.4	478	-4.4	58	--
545		9.0	445	-11.0	23	--
531		6.2	478	-4.4	36	--
551		10.2	465	-7.0	44	--
493		-1.4	465	-7.0	42	--
523		4.6	459	-8.2	30	--
541		8.2	474	-5.2	49	--
543		8.6	415	-17.0	43	--
514		2.8	439	-12.2	40	--

Table 1-4. Results of x-ray fluorescence analysis of standard reference samples and comparison to most probable values.—Continued

[Shading indicates values not within ± 10 percent of the most probable value. mg/kg, milligrams per kilogram; MPV, most probable value; --, not determined or not applicable; <, less than; LOD, limit of detection. Reference samples from Fisher Scientific]

Sample code		Cadmium		Lead		Zinc	
		Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV
Results obtained during analyses of tributary flood-plain samples—Continued							
		524	4.8	429	-14.2	36	--
		545	9.0	452	-9.6	40	--
		522	4.4	460	-8.0	44	--
		528	5.6	478	-4.4	45	--
		547	9.4	478	-4.4	48	--
		543	8.6	461	-7.8	53	--
		522	4.4	497	-0.6	58	--
		507	1.4	455	-9.0	47	--
		529	5.8	431	-13.8	35	--
		539	7.8	467	-6.6	49	--
		525	5.0	482	-3.6	45	--
GBW	MPV	28.2	--	2,700	--	3,800	--
Results obtained during analyses of Spring River flood-plain samples							
		46	63.1	2,641	-2.2	3,511	-7.6
		41	45.4	2,642	-2.1	3,706	-2.5
		43	52.5	2,626	-2.7	3,638	-4.3
		45	59.6	2,462	-8.8	3,233	-14.9
		40	41.8	2,593	-4.0	3,687	-3.0
		48	70.2	2,700	0	3,684	-3.1
		37	31.2	2,641	-2.2	3,779	-0.6
		35	24.1	2,723	0.9	3,911	2.9
		45	59.6	2,326	-13.9	3,243	-14.7
		40	41.8	2,697	-0.1	3,574	-5.9
		41	45.4	2,635	-2.4	3,672	-3.4
		43	52.5	2,710	0.4	3,716	-2.2
		52	84.4	2,735	1.3	3,810	0.3
		46	63.1	2,647	-2.0	3,755	-1.2
		46	63.1	2,563	-5.1	3,578	-5.8
		40	41.8	2,769	2.6	3,777	-0.6
		38	34.8	2,653	-1.7	3,843	1.1
		37	31.2	2,690	-0.4	3,751	-1.3
		50	77.3	2,671	-1.1	3,583	-5.7
		43	52.5	2,626	-2.7	3,638	-4.3
		45	59.6	2,462	-8.8	3,233	-14.9
		53	87.9	2,693	-0.3	3,889	2.3
		37	31.2	2,617	-3.1	3,683	-3.1
		43	52.5	2,706	0.2	3,757	-1.1

Table 1-4. Results of x-ray fluorescence analysis of standard reference samples and comparison to most probable values.—Continued

[Shading indicates values not within ± 10 percent of the most probable value. mg/kg, milligrams per kilogram; MPV, most probable value; --, not determined or not applicable; <, less than; LOD, limit of detection. Reference samples from Fisher Scientific]

Sample code	Cadmium		Lead		Zinc	
	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV
Results obtained during analyses of Spring River flood-plain samples—Continued						
43		52.5	2,682	-0.7	3,700	-2.6
30		6.4	2,743	1.6	3,923	3.2
36		27.7	2,753	2.0	3,891	2.4
37		31.2	2,261	-16.3	3,229	-15.0
46		63.1	2,861	6.0	3,853	1.4
37		31.2	2,767	2.5	3,770	-0.8
--		--	2,759	2.2	3,826	0.7
41		45.4	2,682	-0.7	3,676	-3.3
38		34.8	2,760	2.2	3,677	-3.2
48		70.2	2,660	-1.5	3,885	2.2
38		34.8	2,534	-6.1	3,670	-3.4
48		70.2	2,762	2.3	3,799	0
38		34.8	2,647	-2.0	3,827	0.7
46		63.1	2,567	-4.9	3,765	-0.9
40		41.8	2,659	-1.5	3,759	-1.1
45		59.6	2,610	-3.3	3,670	-3.4
35		24.1	2,659	-1.5	3,641	-4.2
41		45.4	2,706	0.2	3,502	-7.8
47		66.7	2,672	-1.0	3,580	-5.8
Results obtained during analyses of tributary flood-plain samples						
25		-11.3	2,588	-4.1	3,358	-11.6
20		-29.1	2,574	-4.7	3,351	-11.8
21		-25.5	2,602	-3.6	3,405	-10.4
19		-32.6	2,549	-5.6	3,379	-11.1
26		-7.8	2,579	-4.5	3,390	-10.8
20		-29.1	2,574	-4.7	3,353	-11.8
17		-39.7	2,625	-2.8	3,409	-10.3
19		-32.6	2,610	-3.3	3,430	-9.7
26		-7.8	2,593	-4.0	3,319	-12.7
20		-29.1	2,535	-6.1	3,437	-9.6
21		-25.5	2,618	-3.0	3,413	-10.2
19		-32.6	2,664	-1.3	3,378	-11.1
25		-11.3	2,564	-5.0	3,392	-10.7
34		20.6	2,534	-6.1	3,331	-12.3
23		-18.4	2,484	-8.0	3,368	-11.4
22		-22.0	2,550	-5.6	3,446	-9.3
21		-25.5	2,533	-6.2	3,329	-12.4

Table 1-4. Results of x-ray fluorescence analysis of standard reference samples and comparison to most probable values.—Continued

[Shading indicates values not within ± 10 percent of the most probable value. mg/kg, milligrams per kilogram; MPV, most probable value; --, not determined or not applicable; <, less than; LOD, limit of detection. Reference samples from Fisher Scientific]

Sample code	Cadmium		Lead		Zinc		
	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV	
Results obtained during analyses of tributary flood-plain samples—Continued							
	23	-18.4	2,491	-7.7	3,395	-10.7	
	19	-32.6	2,520	-6.7	3,400	-10.5	
	20	-29.1	2,571	-4.8	3,419	-10.0	
	22	-22.0	2,477	-8.3	3,319	-12.7	
	18	-36.2	2,541	-5.9	3,334	-12.3	
	<17.1	--	2,532	-6.2	3,327	-12.4	
	<16.9	--	2,559	-5.2	3,426	-9.8	
	27	-4.3	2,545	-5.7	3,380	-11.1	
	20	-29.1	2,490	-7.8	3,315	-12.8	
	31	9.9	2,577	-4.6	3,388	-10.8	
	27	-4.3	2,640	-2.2	3,348	-11.9	
	25	-11.3	2,556	-5.3	3,338	-12.2	
	20	-29.1	2,505	-7.2	3,387	-10.9	
	28	-0.7	2,520	-6.7	3,362	-11.5	
	27	-4.3	2,556	-5.3	3,404	-10.4	
	23	-18.4	2,555	-5.4	3,374	-11.2	
	22	-22.0	2,478	-8.2	3,330	-12.4	
	22	-22.0	2,587	-4.2	3,437	-9.6	
	28	-0.7	2,504	-7.3	3,322	-12.6	
NCS	MPV	1.12	--	27	--	46	--
Results obtained during analyses of Spring River flood-plain samples							
	10	793	18	-33.3	24	-47.8	
	<LOD	--	28	3.7	27	-41.3	
	<12.9	--	<14.8	--	48	4.3	
	<12.5	--	19.9	-26.3	28	-39.1	
	<16.8	--	<16.8	--	35	-23.9	
	<17.7	--	<17.8	--	42	-8.7	
	<17.6	--	<16.9	--	30	-34.8	
	<16.4	--	19	-29.6	46	0	
	<17.4	--	<18.1	--	28	-39.1	
Results obtained during analyses of tributary flood-plain samples							
	<14.0	--	105	289	26	-43.5	
	<14.1	--	55	104	25	-45.7	
	<13.5	--	53	96.3	30	-34.8	
	<13.3	--	59	119	28	-39.1	
	<13.8	--	58	115	25	-45.7	
	<13.7	--	60	122	20	-56.5	

Table 1-4. Results of x-ray fluorescence analysis of standard reference samples and comparison to most probable values.—Continued

[Shading indicates values not within ± 10 percent of the most probable value. mg/kg, milligrams per kilogram; MPV, most probable value; --, not determined or not applicable; <, less than; LOD, limit of detection. Reference samples from Fisher Scientific]

Sample code	Cadmium		Lead		Zinc	
	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV	Concentration (mg/kg)	Percent difference from MPV
Results obtained during analyses of tributary flood-plain samples—Continued						
<13.9	--		53	96.3	28	-39.1
<13.6	--		51	88.9	30	-34.8
<14.0	--		53	96.3	26	-43.5
<14.2	--		53	96.3	30	-34.8
<13.8	--		51	88.9	19	-58.7
<13.6	--		53	96.3	28	-39.1
<13.8	--		27	0	23	-50.0
<14.1	--		22	-18.5	33	-28.3
<14.1	--		20	-25.9	29	-37.0
<14.0	--		20	-25.9	19	-58.7
<13.6	--		20	-25.9	22	-52.2
<14.1	--		17	-37.0	21	-54.3
<13.6	--		18	-33.3	23	-50.0
<13.9	--		18	-33.3	24	-47.8
<14.0	--		20	-25.9	23	-50.0
<13.8	--		26	-3.7	29	-37.0
<14.1	--		21	-22.2	25	-45.7
<14.0	--		25	-7.4	26	-43.5
<13.9	--		15	-44.4	28	-39.1
<13.9	--		17	-37.0	33	-28.3
<14.0	--		15	-44.4	21	-54.3
<14.2	--		21	-22.2	24	-47.8
<14.2	--		23	-14.8	23	-50.0
<14.2	--		13	-51.9	30	-34.8
<14.0	--		22	-18.5	24	-47.8
<14.1	--		24	-11.1	24	-47.8
<14.5	--		17	-37.0	31	-32.6
<14.0	--		14	-48.1	31	-32.6
<14.1	--		19	-29.6	21	-54.3
<13.7	--		17	-37.0	15	-67.4

Table 1-5. Percentage of silt and clay and constituent concentrations determined by combustion and spectroscopic methods for six surficial-soil samples (BC2-1, SB2-2, SnC2-1, StC1-2, TrC1-3, WC2-1) collected from tributary flood plains, Cherokee County, Kansas, March, April, and May 2011.

[Location of sampling sites shown in figure 2.4. Values in parentheses are concentrations in the less than 63-micrometer fraction. mg/kg, milligrams per kilogram; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration		
	Sample BC2-1	Sample SB2-2	Sample SnC2-1
Percentage of silt and clay in bulk sample	54	57	90
Nutrients			
Total nitrogen, mg/kg	1,900 (2,500)	7,500 (6,900)	1,400 (1,100)
Total phosphorus, mg/kg	580 (790)	1,100 (1,100)	400 (430)
Carbon			
Carbon (total organic), %	2.3 (2.8)	10 (9)	1.4 (1.1)
Carbon (total), %	2.2 (2.6)	9.5 (8.2)	2.4 (1.1)
Trace elements			
Aluminum, %	3.1 (4.8)	2.7 (3.1)	3.8 (4.2)
Antimony, mg/kg	0.6 (0.7)	1.5 (1.8)	0.7 (0.7)
Arsenic, mg/kg	5.6 (7.6)	12 (13)	6.9 (7.0)
Barium, mg/kg	300 (460)	300 (360)	390 (430)
Beryllium, mg/kg	1.2 (1.6)	1.2 (1.4)	1.3 (1.4)
Cadmium, mg/kg	0.5 (0.9)	24 (22)	0.1 (0.2)
Chromium, mg/kg	45 (61)	55 (56)	53 (58)
Cobalt, mg/kg	11 (16)	14 (13)	14 (13)
Copper, mg/kg	11 (15)	47 (50)	11 (12)
Iron, %	1.9 (2.7)	3.1 (3.2)	2.2 (2.3)
Lead, mg/kg	24 (36)	670 (740)	28 (35)
Lithium, mg/kg	27 (39)	22 (27)	31 (34)
Manganese, mg/kg	520 (710)	710 (730)	660 (600)
Molybdenum, mg/kg	<1 (1)	1 (1)	<1 (1)
Nickel, mg/kg	18 (23)	29 (29)	17 (18)
Selenium, mg/kg	0.4 (0.5)	0.9 (0.9)	0.4 (0.4)
Silver, mg/kg	<0.5 (<0.5)	<0.5 (0.5)	<0.5 (<0.5)
Strontium, mg/kg	64 (86)	57 (64)	64 (70)
Sulfur, %	0.03 (0.04)	0.18 (0.17)	0.02 (0.02)
Thallium, mg/kg	<50 (<50)	<50 (<50)	<50 (<50)
Tin, mg/kg	1 (2)	10 (11)	2 (2)
Titanium, %	0.36 (0.50)	0.26 (0.33)	0.47 (0.54)
Uranium, mg/kg	<50 (<50)	<50 (<50)	<50 (<50)
Vanadium, mg/kg	54 (77)	55 (62)	66 (71)
Zinc, mg/kg	170 (250)	3,400 (3,500)	75 (97)

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Table 1-5. Percentage of silt and clay and constituent concentrations determined by combustion and spectroscopic methods for six surficial-soil samples (BC2-1, SB2-2, SnC2-1, StC1-2, TrC1-3, WC2-1) collected from tributary flood plains, Cherokee County, Kansas, March, April, and May 2011.—Continued

[Location of sampling sites shown in figure 2.4. Values in parentheses are concentrations in the less than 63-micrometer fraction. mg/kg, milligrams per kilogram; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration		
	Sample StC1-2	Sample TrC1-3	Sample WC2-1
Percentage of silt and clay in bulk sample	68	43	62
Nutrients			
Total nitrogen, mg/kg	4,000 (3,300)	1,500 (1,900)	2,300 (2,200)
Total phosphorus, mg/kg	2,900 (3,200)	960 (800)	670 (770)
Carbon			
Carbon (total organic), %	5.6 (4.0)	2.0 (2.7)	3.0 (2.5)
Carbon (total), %	5.3 (3.9)	2.8 (3.3)	3.1 (2.5)
Trace elements			
Aluminum, %	2.9 (3.4)	2.6 (2.5)	4.1 (5.3)
Antimony, mg/kg	10 (12)	2.3 (1.8)	0.7 (0.8)
Arsenic, mg/kg	17 (19)	18 (13)	7.5 (8.6)
Barium, mg/kg	380 (450)	180 (170)	360 (480)
Beryllium, mg/kg	2.4 (2.1)	2.0 (1.7)	1.4 (1.8)
Cadmium, mg/kg	80 (78)	100 (93)	9.9 (8.9)
Chromium, mg/kg	55 (62)	74 (63)	53 (67)
Cobalt, mg/kg	23 (21)	18 (14)	14 (16)
Copper, mg/kg	330 (320)	300 (250)	23 (26)
Iron, %	2.1 (2.2)	2.7 (2.0)	2.4 (2.8)
Lead, mg/kg	5,600 (6,100)	8,300 (8,000)	260 (280)
Lithium, mg/kg	22 (24)	46 (32)	40 (50)
Manganese, mg/kg	1,000 (980)	1,000 (700)	750 (870)
Molybdenum, mg/kg	3 (3)	3 (2)	1 (1)
Nickel, mg/kg	33 (32)	46 (41)	25 (30)
Selenium, mg/kg	2.2 (2.3)	2.9 (2.4)	0.7(0.7)
Silver, mg/kg	2.4 (2.4)	0.5 (<0.5)	<0.5 (<0.5)
Strontium, mg/kg	59 (67)	49 (38)	110 (110)
Sulfur, %	0.21 (0.20)	0.75 (0.53)	0.10 (0.07)
Thallium, mg/kg	<50 (<50)	<50 (<50)	<50 (<50)
Tin, mg/kg	270 (370)	3 (2)	2 (2)
Titanium, %	0.27 (0.36)	0.21 (0.21)	0.38 (0.50)
Uranium, mg/kg	<50 (<50)	<50 (<50)	<50 (<50)
Vanadium, mg/kg	57 (65)	73 (64)	67 (85)
Zinc, mg/kg	11,000 (11,000)	26,000 (26,000)	1,700 (1,600)

Table 1-6. Cadmium concentrations determined by x-ray fluorescence for surficial-soil samples collected from the Spring River flood plain and tributary flood plains, Cherokee County, Kansas, 2009, 2011.[mg/kg, milligrams per kilogram; μm , micrometer; <, less than]

Surficial-soil sampling site identifier (figs. 2A-2U)	Cadmium concentration, mg/kg		Surficial-soil sampling site identifier (figs. 2A-2U)	Cadmium concentration, mg/kg	
	Bulk sample	<63- μm fraction		Bulk sample	<63- μm fraction
Spring River			Brush Creek		
SRF-1	<12.3	<13.8	BC1-1	<13.1	<12.3
SRF-2	<11.3	<21.8	BC1-2	<12.7	<12.3
SRF-3	<11.3	<7.4	BC1-3	<12.8	<11.9
SRF-4	<11.2	<13.0	BC1-4	<12.6	<11.7
SRF-5	<11.2	<8.6	BC2-1	<12.9	<12.3
SRF-6	<11.2	<11.9	BC2-2	<12.4	<13.1
SRF-7	<11.4	<14.2	Cow Creek		
SRF-9	<11.4	<12.0	CC1-1	<12.7	<11.6
SRF-10	<12.0	<14.6	CC1-2	<13.1	<11.9
SRF-11	<11.1	<17.4	CC1-3	<13.0	<12.7
SRF-13	<10.3	<10.0	CC2-1	<13.1	<12.1
SRF-14	<10.9	<10.0	CC2-2	<13.2	<11.6
SRF-15	20	<18.9	Shawnee Creek		
SRF-16	<11.3	<14.4	SnC1-1	<13.3	<11.6
SRF-17	<10.7	<12.2	SnC1-2	<12.7	<11.2
SRF-18	<11.1	<10.5	SnC1-3	<12.8	<11.8
SRF-19	31	22	SnC2-1	<12.9	<11.8
SRF-20	<11.0	<10.1	SnC2-2	<13.1	<11.3
SRF-21	<10.6	<16.8	Shoal Creek		
SRF-22	<11.1	<11.4	ShC1-1	<12.8	<12.5
SRF-23	<11.2	<11.4	ShC1-2	<12.8	<12.6
SRF-24	<10.8	<10.4	ShC1-3	<12.5	<11.7
SRF-25	<10.4	<10.3	ShC2-1	<13.9	<12.5
SRF-26	<11.5	<6.3	ShC2-2	<13.4	<10.8
SRF-27	<11.6	<11.8	ShC2-3	<12.6	<12.6
SRF-28	<11.4	<17.1	ShC2-4	<12.5	<10.5
SRF-29	<11.4	<14.5	Short Creek		
SRF-31	<10.9	<15.1	StC1-1	55	<14.1
SRF-32	<11.4	<14.0	StC1-2	48	28
SRF-33	<11.2	<16.4	StC1-3	77	19
			StC2-1	30	<16.0
			StC2-2	27	<13.5

Table 1–6. Cadmium concentrations determined by x-ray fluorescence for surficial-soil samples collected from the Spring River flood plain and tributary flood plains, Cherokee County, Kansas, 2009, 2011.—Continued[mg/kg, milligrams per kilogram; μm , micrometer; <, less than]

Surficial-soil sampling site identifier (figs. 2A–2U)	Cadmium concentration, mg/kg		Surficial-soil sampling site identifier (figs. 2A–2U)	Cadmium concentration, mg/kg	
	Bulk sample	<63- μm fraction		Bulk sample	<63- μm fraction
Spring Branch			Tar Creek—Continued		
SB1-1	36	<18.1	TrC3-3	<12.7	<11.4
SB1-2	38	<14.3	TrC3-4	<12.4	<12.0
SB2-1	<13.9	<14.2	Turkey Creek		
SB2-2	<13.1	<13.3	TkC1-1	19	<13.6
SB2-3	<12.8	<11.2	TkC1-2	18	<13.3
SB3-1	<13.8	<13.1	TkC1-3	<13.7	<13.5
SB3-2	32	<14.2	Willow Creek		
Tar Creek			WC1-1	<13.6	<11.7
TrC1-1	67	<14.4	WC1-2	<13.0	<13.8
TrC1-2	70	<14.9	WC1-3	<12.8	<13.3
TrC1-3	54	<9.4	WC2-1	<13.2	<13.0
TrC1-4	69	54	WC2-2	<13.4	<11.2
TrC2-1	16	<13.6	WC2-3	<13.1	<8.8
TrC2-2	20	<13.5	WC2-4	<12.9	<12.6
TrC2-3	<13.4	<13.6	WC3-1	<12.2	<12.0
TrC2-4	<13.1	<13.2	WC3-2	<12.0	<12.1
TrC3-1	<12.0	<11.7			
TrC3-2	<12.3	<12.2			

Table 1-7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T1-1				Coring site T1-1—Continued			
0' 2"	28	33	79	11' 10"	25	25	39
0' 2"	20	29	86	12' 2"	40	<20.5	63
0' 2"	21	18	104	12' 6"	28	19	64
0' 6"	21	<15.3	39	12' 10"	<14.5	<16.2	37
0' 6"	<13.7	16	37	13' 2"	31	<16.8	<28.1
0' 6"	17	17	<23.3	13' 2"	25	<15.7	42
0' 10"	25	<14.7	<25.0	13' 2"	31	26	34
1' 2"	16	19	<24.0	13' 6"	25	<14.4	52
1' 6"	19	26	32	13' 10"	34	25	46
1' 10"	25	<18.8	<30.1	14' 2"	22	28	34
2' 2"	20	<13.7	56	14' 6"	28	<15.9	41
2' 6"	21	<17.2	<27.5	14' 10"	18	<13.3	<21.9
2' 10"	26	<16.6	34	15' 2"	21	<14.1	32
3' 2"	18	19	38	15' 6"	22	<18.6	<28.4
3' 6"	19	<16.1	34	15' 10"	45	<16.8	<36.8
3' 10"	21	<16.2	35	Coring site T1-2			
4' 2"	22	22	32	0' 2"	56	275	4,158
4' 6"	20	<15.4	<27.9	0' 2"	62	257	4,692
4' 10"	<16.1	24	<31.4	0' 2"	75	248	5,701
5' 2"	25	<17.6	43	0' 6"	45	146	1,871
5' 6"	20	105	35	0' 10"	48	127	2,793
5' 10"	37	<18.6	41	1' 2"	35	377	2,148
6' 2"	20	18	<24.2	1' 6"	52	1,226	1,302
6' 6"	21	<14.5	34	1' 10"	73	179	4,984
6' 10"	23	18	<28.6	2' 2"	20	55	408
7' 2"	20	<12.2	39	2' 6"	21	39	224
7' 2"	23	18	41	2' 10"	27	21	99
7' 2"	26	<14.9	35	3' 2"	25	<23.2	<44.4
7' 6"	35	<17.2	<27.6	3' 6"	30	<18.0	82
7' 10"	16	19	<26.3	3' 10"	26	40	71
8' 2"	38	<13.1	<27.4	4' 2"	<14.2	<12.9	38
8' 6"	20	23	<25.9	4' 6"	22	<15.3	44
8' 10"	21	19	<24.0	4' 10"	17	16	45
9' 2"	31	<13.6	<26.4	5' 2"	25	<13.2	44
9' 6"	29	17	45	5' 2"	25	<14.2	<28.3
9' 10"	19	<13.2	35	5' 2"	19	<17.3	35
10' 2"	24	<14.5	<25.2	5' 6"	25	<14.6	41
10' 6"	27	21	46	5' 10"	26	<18.6	45
11' 2"	30	<14.5	39	6' 2"	23	<14.7	42
11' 6"	24	29	64	6' 6"	17	<16.6	<26.9

Table 1–7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T1-2—Continued				Coring site T1-3—Continued			
6' 10"	30	<15.5	46	2' 6"	24	20	<27.3
7' 2"	<14.9	24	74	2' 9"	27	39	34
7' 6"	15	<15.9	52	3' 3"	24	22	38
7' 10"	27	30	68	3' 6"	22	<15.5	41
8' 2"	20	40	67	3' 9"	24	<16.8	51
8' 6"	35	29	60	4' 2"	<17.6	42	<37.4
8' 10"	17	35	62	4' 6"	--	--	--
9' 2"	18	26	62	4' 10"	--	--	--
9' 6"	16	22	71	5' 3"	40	34	<40.1
9' 10"	29	20	87	5' 6"	26	21	48
10' 2"	19	26	81	5' 9"	46	<20.1	38
10' 6"	23	20	59	6' 2"	29	<16.5	31
10' 10"	18	18	68	6' 6"	44	<20.2	<38.9
11' 2"	23	<15.3	103	6' 10"	32	<15.6	52
11' 6"	--	--	--	7' 2"	27	26	68
11' 10"	--	--	--	7' 6"	31	18	56
12' 2"	20	<17.6	<29.5	7' 10"	31	45	<43.6
12' 6"	22	20	64	8' 2"	32	26	<36.5
12' 10"	23	23	71	8' 6"	40	<14.9	<24.5
13' 2"	29	18	66	8' 10"	31	26	<30.0
13' 6"	29	<16.6	86	9' 2"	56	24	46
13' 6"	20	31	59	9' 6"	--	--	--
13' 6"	19	24	63	9' 10"	--	--	--
13' 10"	28	<13.8	52	10' 3"	48	<23.0	79
14' 2"	28	<16.8	47	10' 3"	50	<21.2	72
14' 6"	31	<19.0	<37.2	10' 3"	48	<21.7	90
14' 10"	64	<22.2	<54.3	10' 6"	36	<20.0	<36.0
15' 2"	30	<26.6	<56.0	10' 9"	40	<30.0	<66.7
15' 6"	38	31.1	<68.3	11' 2"	46	<18.8	<43.7
15' 10"	53	<23.7	<46.3	11' 6"	28	<28.3	<60.8
Coring site T1-3				11' 10"	19	<20.1	<44.4
0' 1"	21	28	63	12' 2"	41	<12.7	<24.5
0' 1"	18	28	74	12' 6"	30	28	49
0' 1"	29	22	61	12' 6"	39	20	<36.3
0' 6"	27	32	90	12' 6"	33	<18.0	69
0' 11"	30	41	93	12' 10"	34	22	54
1' 3"	23	22	100	13' 2"	<25.2	<37.5	<73.6
1' 6"	24	35	51	13' 6"	51	<38.0	<69.0
1' 9"	22	<15.9	47	13' 10"	63	<35.7	<78.1
2' 3"	18	23	55	14' 2"	34	<41.8	<77.9

Table 1-7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T1-3—Continued				Coring site T1-4—Continued			
14' 6"	45	<40.9	<63.6	10' 1"	34	<15.7	43
14' 10"	40	<24.5	<49.6	10' 6"	26	<19.6	<34.1
15' 2"	44	<14.6	82	10' 10"	<15.4	<14.9	45
15' 6"	44	<16.3	<34.2	11' 2"	<15.1	30	<32.8
15' 10"	36	<20.4	<42.7	11' 6"	24	43	45
Coring site T1-4				11' 10"	30	<16.4	<25.8
0' 2"	24	27	76	12' 2"	15	<12.3	<21.5
0' 2"	17	<16.4	79	12' 6"	27	17	25
0' 2"	18	<16.8	77	12' 10"	28	<15.2	41
0' 5"	23	32	60	13' 2"	15	<13.8	<25.9
0' 10"	25	<17.5	61	13' 6"	18	21	<42.3
1' 2"	20	<16.5	37	13' 6"	<16.6	<21.3	<41.0
1' 6"	29	<17.0	43	13' 6"	18	25	<39.5
1' 10"	<14.3	22	<24.2	13' 10"	<15.8	<17.0	<35.7
2' 2"	<14.9	<16.0	<21.0	14' 2"	19	<16.3	40
2' 6"	19	19	<23.4	14' 4"	23	<18.2	33
2' 10"	20	23	<23.5	14' 7"	16	<15.4	42
3' 2"	34	<16.2	<23.3	Coring site T1-5			
3' 6"	23	<16.6	28	0' 2"	22	30	139
3' 10"	17	<16.6	30	0' 2"	<13.6	23	142
4' 2"	21	<16.0	32	0' 2"	20	37	176
4' 6"	16	<16.7	28	0' 6"	20	43	157
4' 10"	17	33	40	0' 10"	16	<15.7	72
5' 2"	15	<17.4	45	1' 2"	22	21	88
5' 6"	14	<13.4	50	1' 6"	42	58	212
5' 10"	24	<18.0	37	1' 10"	17	35	151
6' 2"	32	<17.9	38	2' 2"	19	46	106
6' 6"	22	17	<27.2	2' 6"	26	<17.2	37
6' 6"	29	<17.5	<26.7	2' 10"	15	17	44
6' 6"	26	<15.5	<26.4	3' 2"	19	22	<26.0
6' 10"	16	24	31	3' 6"	16	<17.6	<27.3
7' 2"	17	<13.5	51	3' 10"	24	<19.0	<30.7
7' 6"	17	18	43	4' 2"	18	<15.6	<24.4
7' 10"	15	21	43	4' 2"	<14.2	20	<26.0
8' 2"	28	<15.5	36	4' 2"	21	<15.3	<24.5
8' 6"	18	19	40	4' 6"	24	25	30
8' 10"	23	20	<24.3	4' 10"	27	19	<25.2
9' 2"	20	<15.1	46	5' 2"	21	26	<25.8
9' 6"	26	23	46	5' 6"	21	24	26
9' 10"	18	25	34	5' 10"	18	22	51

Table 1–7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T1-5—Continued				Coring site T2-1—Continued			
6' 2"	<15.4	28	<30.5	2' 1"	26	22	822
6' 6"	34	21	<29.1	2' 5"	19	<15.5	705
6' 10"	29	<14.9	39	2' 9"	10	<16.5	62
7' 2"	27	<15.2	29	3' 1"	19	<17.5	605
7' 6"	24	<19.8	49	3' 5"	21	<15.8	343
7' 10"	23	16	<22.4	3' 9"	24	<14.4	321
8' 2"	22	17	26	4' 1"	26	25	595
8' 6"	27	<14.6	<24.5	4' 5"	<14.8	<16.6	491
8' 10"	27	<13.0	<20.2	4' 9"	15	<16.6	462
9' 2"	29	18	<23.0	5' 1"	21	<13.6	439
9' 6"	30	<18.2	55	5' 5"	23	<17.8	409
9' 10"	37	<17.0	<28.3	5' 9"	18	<15.2	454
10' 2"	28	17	<26.5	6' 1"	34	<16.8	413
10' 6"	36	<16.1	39	6' 5"	17	<12.6	470
10' 10"	38	17	<24.2	6' 10"	<13.9	<12.9	465
11' 2"	19	<16.0	<23.3	7' 1"	<19.1	<13.2	502
11' 6"	28	<17.9	<25.9	7' 6"	30	<12.4	415
11' 10"	18	<18	24	7' 10"	29	16	342
12' 2"	23	<14.6	<23.2	Coring site T2-2			
12' 6"	37	<26.3	52	0' 2"	37	52	634
12' 10"	32	20	37	0' 2"	27	27	549
12' 10"	32	26	37	0' 6"	19	28	323
12' 10"	28	23	33	0' 10"	27	49	375
13' 2"	34	27	<51.2	1' 1"	18	30	72
13' 6"	<17.3	<20.1	<36.1	1' 5"	21	<15.9	65
13' 10"	38	<22.3	<41.2	1' 10"	30	<19.3	56
14' 2"	44	<20.0	45	2' 1"	25	<16.3	47
14' 6"	35	43	<63.6	2' 5"	28	21	<31.6
14' 10"	26	<19.4	61	2' 10"	22	24	<30.7
15' 2"	45	<18.3	<46.1	3' 1"	27	25	42
15' 6"	16	<19.1	<33.6	3' 5"	24	28	52
15' 10"	<15.9	<14.6	42	3' 9"	25	31	38
Coring site T2-1				4' 1"	<16.4	<16.7	<32.3
0' 2"	54	172	5,201	4' 1"	23	28	<31.8
0' 2"	54	202	4,110	4' 5"	25	<15.2	<24.2
0' 6"	53	75	5,912	4' 8"	29	<15.5	43
0' 10"	215	644	9,728	5' 1"	39	<13.1	70
1' 2"	134	810	11,500	5' 5"	20	<16.3	<23.9
1' 5"	25	19	1,495	5' 8"	17	<13.4	43
1' 9"	24	23	864	6' 1"	41	22	61

Table 1-7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T2-2—Continued				Coring site T2-4—Continued			
6' 5"	34	31	62	2' 1"	26	<15.0	<26.7
6' 9"	26	<16.9	47	2' 5"	24	<13.5	<20.4
7' 2"	18	<16.4	40	2' 10"	19	18	<24.9
7' 5"	28	16	59	3' 1"	<13.8	<14.4	<19.9
7' 10"	14	<13.2	72	3' 5"	22	<13.6	<20.7
Coring site T2-3				3' 11"	23	<14.4	<26.5
0' 2"	20	<20.0	38	4' 1"	21	22	<29.2
0' 2"	17	<18.7	34	4' 5"	32	28	<31.6
0' 5"	20	21	44	4' 10"	<14.1	20	<27.6
0' 10"	16	25	60	5' 1"	<14.5	<14.7	29
1' 1"	17	32	87	5' 5"	18	<15.9	<28.3
1' 5"	21	31	84	5' 10"	23	20	<24.5
1' 10"	23	45	<14.5	6' 1"	31	22	<25.4
2' 1"	16	21	<25.9	6' 5"	20	<14.6	<23.3
2' 5"	17	22	32	6' 10"	31	<16.0	<23.9
2' 10"	<14.1	<15.1	28	7' 1"	34	19	<23.0
3' 1"	21	30	33	7' 5"	30	29	32
3' 5"	19	<13.7	36	7' 5"	33	24	<30.3
3' 9"	21	<16.1	36	7' 10"	33	<18.2	<33.7
4' 1"	32	<18.6	<28.8	Coring site T2-5			
4' 5"	16	28	<24.9	0' 1"	19	25	34
4' 9"	20	20	41	0' 1"	<13.8	21	33
5' 1"	20	16	35	0' 5"	<13.4	18	33
5' 5"	22	<18.2	37	0' 11"	22	<17.9	45
5' 10"	22	17	39	1' 1"	33	20	36
6' 1"	22	22	36	1' 5"	22	<13.9	41
6' 5"	19	23	<28.1	1' 9"	<14.0	<16.0	39
6' 10"	<15.3	23	<30.5	2' 1"	20	21	33
7' 1"	29	<16.4	50	2' 5"	<13.9	16	29
7' 1"	28	26	42	2' 10"	18	18	<23.5
7' 5"	22	23	48	3' 1"	20	<16.0	38
7' 10"	21	20	59	3' 5"	15	23	32
Coring site T2-4				3' 10"	16	18	<22.0
0' 1"	16	25	53	4' 1"	23	21	34
0' 1"	20	28	42	4' 5"	22	<14.6	29
0' 5"	20	19	41	4' 10"	32	<16.7	43
0' 10"	18	24	40	5' 1"	<12.1	<11.9	<18.6
1' 1"	29	20	53	5' 5"	22	18	40
1' 5"	23	<14.0	34	5' 10"	17	<12.3	33
1' 10"	<14.6	<16.5	<26.0	6' 1"	21	<16.8	<27.7

Table 1–7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T2-5—Continued				Coring site T3-1—Continued			
6' 5"	21	<14.5	28	1' 6"	19	24	44
6' 5"	19	<13.0	<23.8	1' 10"	35	19	<22.2
6' 10"	<14.9	27	<28.4	2' 2"	26	<16.4	<24.0
7' 1"	23	19	37	2' 6"	<13.9	<15.6	<24.0
7' 5"	28	<14.2	47	2' 10"	32	22	<25.0
7' 10"	17	<17.1	<25.3	3' 2"	31	72	46
Coring site T2-6				3' 6"	28	19	31
0' 2"	<13.3	25	37	3' 10"	18	20	50
0' 2"	17	17	30	4' 2"	22	<13.2	41
0' 6"	22	20	48	4' 6"	17	19	53
0' 11"	12	21	13	4' 10"	24	<15.2	28
1' 1"	25	26	<24.1	5' 2"	36	18	39
1' 6"	24	<15.6	32	5' 6"	24	15	<24.9
1' 9"	21	20	33	5' 10"	31	<16.8	<26.9
2' 1"	<14.0	21	37	6' 2"	21	<15.7	33
2' 5"	16	31	35	6' 2"	26	<13.9	34
2' 9"	17	17	<22.9	6' 2"	15	<15.2	<26.8
3' 1"	15	25	<25.4	6' 6"	19	<15.3	<24.3
3' 5"	20	<16.9	<29.5	6' 10"	29	<16.6	<27.3
3' 9"	27	<17.6	<27.8	7' 2"	<14.3	<15.3	42
4' 1"	<14.7	23	<26.0	7' 6"	30	<21.5	<41.3
4' 5"	17	25	<26.9	7' 10"	17	<12.8	48
4' 9"	20	29	<24.0	8' 2"	22	20	31
5' 1"	27	24	33	8' 6"	<14.6	<15.6	48
5' 5"	17	56	<29.7	8' 10"	22	28	59
5' 9"	<15.5	<19.0	<30.8	9' 2"	14	<14.9	49
5' 9"	23	28	42	9' 6"	17	46	79
6' 1"	20	<14.0	<26.6	9' 10"	17	20	<26.6
6' 5"	37	<17.5	<29.3	10' 2"	<15.1	20	66
6' 9"	20	62	<33.1	10' 6"	21	31	66
7' 1"	24	26	<33.6	10' 10"	19	20	32
7' 5"	31	<17.0	40	11' 2"	24	27	47
7' 9"	29	28	<44.1	11' 6"	29	32	60
Coring site T3-1				11' 10"	<13.0	<14.9	35
0' 2"	28	50	177	12' 2"	27	25	36
0' 2"	28	<24.9	186	12' 6"	27	<19.8	<36.1
0' 2"	<18.2	51	188	12' 10"	31	<15.5	30
0' 6"	20	51	118	13' 2"	22	<17.5	69
0' 10"	27	29	161	13' 2"	24	20	54
1' 2"	<14.1	<16.0	101	13' 2"	20	<15.8	44

Table 1-7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T3-1—Continued				Coring site T3-2—Continued			
13' 6"	21	<16.2	61	9' 2"	<14.5	<16.5	49
13' 10"	29	43	37	9' 6"	21	<14.4	32
14' 2"	17	25	66	9' 10"	37	<20.0	<33.7
14' 6"	25	<19.0	70	10' 2"	46	<15.4	44
14' 10"	25	30	74	10' 6"	28	<16.7	45
15' 2"	27	<18.3	54	10' 10"	24	26	53
15' 6"	42	<26.4	<59.6	Coring site T3-3			
15' 10"	30	<17.5	39	0' 2"	19	48	281
Coring site T3-2				0' 2"	23	50	260
0' 2"	24	34	221	0' 2"	19	54	267
0' 2"	<19.6	62	138	0' 6"	--	--	--
0' 2"	<19.4	39	152	0' 10"	--	--	--
0' 6"	23	47	195	1' 2"	24	<16.0	28
0' 10"	20	36	188	1' 6"	22	37	<27.6
1' 2"	26	<15.4	29	1' 10"	18	<16.7	30
1' 6"	32	<15.6	36	2' 2"	28	<16.2	<25.0
1' 10"	25	<13.9	<26.7	2' 6"	37	21	<27.4
2' 2"	25	<16.4	<23.0	2' 10"	16	<13.9	<22.9
2' 6"	24	<15.6	<23.1	3' 2"	27	27	32
2' 10"	<14.3	25	26	3' 6"	23	<14.6	<22.9
3' 2"	17	<14.8	<22.9	3' 10"	26	<13.4	28
3' 6"	22	20	31	4' 2"	25	18	<20.7
3' 10"	20	<16.9	39	4' 6"	17	<13.0	<21.8
4' 2"	19	23	28	4' 10"	23	<14.1	<21.7
4' 6"	20	<15.0	29	5' 2"	<14.6	19	30
4' 10"	27	<16.0	45	5' 6"	26	21	33
5' 2"	28	<16.4	34	5' 10"	25	18	35
5' 2"	15	<16.5	35	6' 2"	30	25	<25.0
5' 2"	21	<17.4	40	6' 6"	25	21	33
5' 6"	23	17	38	6' 6"	<14.5	<16.7	<27.5
5' 10"	26	<16.3	<26.0	6' 6"	20	<14.7	28
6' 2"	24	<15.6	59	6' 10"	<14.8	<17.0	<25.2
6' 6"	26	19	49	7' 2"	22	<14.3	27
6' 10"	16	<15.5	60	7' 6"	31	26	<31.2
7' 2"	25	19	60	7' 10"	16	<12.1	<22.0
7' 6"	17	17	52	8' 2"	22	<11.3	<23.8
7' 10"	21	20	43	8' 6"	<14.9	26	<24.0
8' 2"	18	<17.6	57	8' 10"	18	<14.7	23.2
8' 6"	27	30	57	9' 2"	19	<15.9	<20.5
8' 10"	19	<14.9	73	9' 6"	25	18	28

Table 1–7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T3-3—Continued				Coring site T3-4—Continued			
9' 10"	26	<15.1	37	10' 6"	<18.0	<18.0	<34.8
10' 2"	30	<7.8	<26.2	10' 10"	27	<21.9	<36.2
10' 6"	42	<17.4	35	11' 2"	25	<16.4	<29.3
10' 10"	41	28	52	11' 6"	36	<17.7	49
Coring site T3-4				11' 10"	39	<16.2	39
0' 2"	19	55	249	12' 2"	22	20	39
0' 2"	16	44	266	12' 6"	32	<20.6	148
0' 2"	15	52	249	12' 10"	45	<19.5	<40.7
0' 6"	22	36	168	13' 2"	33	<19.8	54
0' 10"	19	<15.5	<27.8	13' 6"	<14.5	<15.5	<28.5
1' 2"	20	23	38	13' 10"	20	<13.8	<23.4
1' 6"	26	19	<26.9	14' 2"	20	<17.8	<34.9
1' 10"	<14.1	20	38	14' 2"	20	<17.0	<34.9
2' 2"	18	28	<24.2	14' 2"	26	<15.8	<29.9
2' 6"	<14.7	<14.8	39	14' 6"	<15.1	32	56
2' 10"	15	17	<24.1	14' 10"	18	<15.7	<28.5
3' 2"	20	<14.1	<21.5	15' 2"	25	<8.1	63
3' 6"	19	19	<24.3	15' 6"	25	<20.6	<43.0
3' 10"	17	<13.8	<21.8	15' 10"	49	<15.9	51
4' 2"	29	22	<24.3	Coring site T3-5			
4' 6"	17	<15.2	27	0' 2"	32	45	212
4' 10"	17	<12.7	25	0' 2"	23	26	183
5' 2"	19	<15.3	<23.4	0' 2"	24	44	221
5' 2"	26	<15.3	<22.9	0' 6"	24	22	261
5' 2"	21	<14.4	36	0' 10"	26	<15.0	<26.3
5' 6"	28	<14.2	33	1' 2"	17	<15.0	<27.4
5' 10"	23	<15.2	<26.1	1' 6"	22	<17.6	<28.2
6' 2"	17	24	<26.0	1' 10"	22	<19.0	<29.9
6' 6"	40	21	<19.5	2' 2"	21	25	<27.5
6' 10"	24	21	<21.7	2' 6"	29	<15.4	44
7' 2"	20	19	<23.2	2' 10"	24	21	35
7' 6"	20	<15.7	<24.2	3' 2"	17	16	34
7' 10"	14	<15.2	27	3' 6"	<37.7	<15.9	28
8' 2"	21	22	<20.5	3' 10"	21	<14.9	32
8' 6"	43	<17.4	<30.1	4' 2"	19	<14.9	<24.2
8' 10"	25	<19.7	50	4' 6"	23	<15.4	<22.3
9' 2"	30	<13.3	<28.2	4' 10"	18	<14.3	<23.4
9' 6"	33	<18.0	<29.9	5' 2"	28	20	<26.0
9' 10"	39	<16.3	39	5' 2"	16	<12.1	35
10' 2"	40	21	42	5' 2"	20	<14.4	37

Table 1-7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T3-5—Continued				Coring site T3-6—Continued			
5' 2"	27	<15.8	<18.8	6' 2"	39	27	54
5' 6"	<15.0	<14.9	<23.8	6' 6"	33	<28.5	<49.9
6' 2"	25	23	38	6' 10"	35	<17.3	<31.1
6' 6"	21	28	<33.7	7' 4"	37	<21.5	<35.3
6' 10"	23	<15.8	<33.5	7' 8"	57	<14.5	<48.9
7' 2"	23	28	78	8' 2"	44	<18.2	<33.5
7' 6"	35	<23.9	<38.6	8' 6"	53	<15.4	<29.3
7' 10"	32	<15.5	<31.0	8' 10"	22	<15.4	<30.3
8' 2"	35	<22.6	<50.8	Coring site T4-1			
8' 6"	32	<14.0	<28.1	0' 1"	21	54	529
8' 10"	36	<25.4	<47.6	0' 1"	21	61	538
9' 2"	19	<17.1	44	0' 4"	29	63	694
9' 6"	25	<20.1	55	0' 8"	25	56	465
9' 10"	34	<19.0	51	1' 1"	22	34	541
10' 2"	32	<18.8	<34.7	1' 4"	<14.1	25	94
10' 6"	28	18	50	1' 7"	24	18	<29.3
10' 10"	18	<14.9	61	2' 1"	22	<15.4	50
11' 2"	29	44	113	2' 4"	23	<14.2	27
11' 6"	39	<24.8	77	2' 7"	19	<14.8	33
11' 10"	62	<36.3	106	3' 1"	23	18	48
Coring site T3-6				3' 4"	26	19	38
0' 2"	33	48	325	3' 7"	16	<16.8	46
0' 2"	29	45	317	4' 1"	20	<16.1	33
0' 2"	22	43	328	4' 5"	18	<16.6	<27.7
0' 6"	28	49	325	4' 5"	15	<13.8	36
0' 10"	19	28	166	4' 9"	15	<17.2	44
1' 2"	28	<18.3	<31.7	4' 9"	15	<17.2	44
1' 6"	43	<23.9	<39.7	5' 1"	20	<16.6	<27.8
1' 10"	42	<25.1	<34.6	5' 5"	30	<16.8	30
2' 2"	42	31	<37.1	5' 10"	26	<16.7	30
2' 6"	26	24	<37.7	6' 1"	19	<12.8	<22.6
2' 10"	28	<17.7	93	6' 6"	15	25	<23.7
3' 6"	28	<13.1	<20.7	6' 10"	16	24	26
4' 4"	34	27	47	7' 1"	20	<14.7	<23.5
4' 8"	50	<16.8	<29.2	7' 5"	21	31	<25.3
5' 2"	29	<26.0	62	7' 10"	30	<16.4	37
5' 6"	41	<20.0	<32.9	Coring site T4-2			
5' 10"	32	28	<36.8	0' 1"	30	136	626
6' 2"	46	<21.1	55	0' 1"	16	169	635
6' 2"	40	<20.7	<40.1	0' 5"	15	157	522
				0' 11"	16	36	276

Table 1–7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T4-2—Continued				Coring site T4-3—Continued			
1' 1"	21	38	159	5' 1"	<12.5	35	125
1' 5"	19	20	64	5' 5"	<12.7	36	137
1' 10"	18	25	75	5' 10"	<13.1	61	115
2' 1"	19	25	75	6' 1"	<13.8	59	144
2' 5"	19	<14.7	47	6' 5"	<12.5	75	99
2' 10"	19	<15.6	77	6' 10"	<12.5	35	99
3' 1"	17	19	42	7' 1"	13	42	117
3' 5"	23	<15.6	49	7' 5"	<12.2	34	59
3' 10"	24	20	32	7' 10"	<12.2	29	67
4' 1"	<14.6	32	46	Coring site T4-4			
4' 5"	<14.1	17	35	0' 1"	<12.5	51	461
4' 5"	<14.2	<13.9	38	0' 1"	<12.2	51	414
4' 9"	26	<16.9	60	0' 4"	<12.7	57	399
5' 1"	25	<16.1	56	0' 8"	<12.4	52	283
5' 5"	30	22	44	1' 1"	<12.5	40	228
5' 10"	19	22	35	1' 5"	15	21	118
6' 1"	19	<16.2	39	1' 9"	14	24	64
6' 5"	17	<16.1	40	2' 1"	9	38	69
6' 10"	17	<15.8	58	2' 4"	19	18	66
7' 1"	28	23	50	2' 8"	<13.1	32	88
7' 5"	<12.5	17	31	3' 1"	21	<14.3	65
7' 10"	20	<13.1	40	3' 5"	<13.9	33	77
Coring site T4-3				3' 8"	<17.6	28	51
0' 1"	23	169	760	4' 1"	28	90	69
0' 1"	24	251	1,423	4' 5"	27	28	70
0' 4"	14	97	495	4' 10"	<15.0	36	50
0' 9"	17	22	97	5' 1"	24	81	111
1' 1"	<13.2	45	87	5' 5"	<14.4	42	75
1' 4"	20	35	85	5' 10"	33	79	107
1' 8"	<13.0	39	90	6' 1"	21	73	114
2' 1"	14	48	88	6' 5"	<14.4	89	158
2' 4"	<12.1	57	107	6' 9"	<14.3	115	145
2' 8"	<12.2	88	103	7' 1"	21	94	217
3' 1"	<12.1	38	91	7' 5"	16	65	129
3' 4"	<12.5	53	88	7' 10"	28	73	126
3' 8"	<12.3	62	72	Coring site T4-5 (rocky and cherty, difficult to analyze)			
4' 1"	13	89	107	0' 1"	<14.2	57	381
4' 1"	<12.9	88	112	0' 1"	<14.0	<17.1	366
4' 5"	<12.3	60	102	0' 5"	<13.5	39	219
4' 10"	13	39	111	0' 10"	35	29	29

Table 1-7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T4-5 (rocky and cherty, difficult to analyze)—Continued				Coring site T5-2—Continued			
1' 1"	<13.8	24	35	1' 8"	30	28	83
1' 7"	20	147	45	2' 1"	29	21	82
3' 10"	20	82	73	2' 4"	27	21	72
4' 5"	<14.1	80	96	3' 1"	30	25	50
5' 4"	16	95	95	3' 4"	22	19	57
7' 3"	<15.2	116	116	3' 7"	27	34	88
Coring site T5-1				4' 1"	18	24	45
0' 1"	<12.9	<12.6	24	4' 5"	19	17	93
0' 1"	<11.9	15	36	4' 9"	24	30	102
0' 5"	13	<12.8	<19.8	5' 1"	31	<16.2	81
0' 10"	<12.0	<12.0	<18.5	5' 1"	22	<14.8	79
1' 1"	16	<12.1	<19.5	5' 5"	24	33	70
1' 5"	17	<10.5	<20.6	5' 9"	15	24	122
1' 9"	15	<13.4	27	6' 1"	37	20	108
2' 1"	<12.7	<12.5	<22.7	6' 5"	20	18	88
2' 5"	14	<12.5	<19.1	6' 8"	23	34	90
2' 10"	<12.9	<10.9	<21.1	7' 1"	26	27	123
3' 1"	13	<12.4	<18.5	7' 5"	<13.1	25	117
3' 5"	16	16	<23.2	7' 9"	15	72	156
3' 10"	14	<14.3	<23.2	Coring site T5-3			
4' 1"	14	17	26	0' 1"	25	40	537
4' 5"	<12.7	18	<20.9	0' 1"	15	99	957
4' 10"	<12.8	<12.3	<20.8	0' 4"	<14.0	106	723
4' 10"	<12.9	<11.4	<22.3	1' 1"	23	23	131
5' 1"	<15.4	<15.4	<24.3	1' 4"	23	38	126
5' 5"	48	<19.5	<28.4	2' 1"	24	23	110
5' 10"	<16.2	<20.1	<30.8	2' 4"	<14.5	<16.4	86
6' 1"	<13.3	<12.5	<25.4	3' 1"	16	23	43
6' 5"	30	19	<32.8	3' 4"	30	20	31
6' 10"	21	<19.3	<40.4	4' 1"	21	<16.7	42
7' 1"	19	23	<29.3	4' 6"	<13.6	17	52
7' 5"	40	32	<36.1	4' 10"	<14.2	<15.0	71
7' 10"	23	<18.8	<34.3	5' 1"	16	28	61
Coring site T5-2				5' 6"	<14.1	<16.0	73
0' 1"	36	72	513	5' 10"	18	<15.3	84
0' 1"	24	55	528	6' 1"	32	43	94
0' 4"	22	66	426	6' 1"	22	26	68
0' 7"	22	62	356	6' 6"	15	19	63
1' 1"	<13.9	49	197	6' 11"	15	22	106
1' 4"	27	32	142	7' 1"	18	25	71

Table 1–7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T5-3—Continued				Coring site T5-5—Continued			
7' 6"	18	18	68	7' 4"	23	23	106
7' 10"	24	26	88	7' 8"	40	<20.6	106
Coring site T5-4				Coring site T5-6			
0' 1"	23	74	538	0' 1"	21	67	312
0' 1"	19	59	587	0' 1"	<13.3	48	345
0' 6"	15	54	296	0' 5"	18	<17.8	72
0' 10"	25	47	185	0' 8"	26	<14.7	32
1' 1"	<13.6	<14.3	98	1' 1"	18	30	<24.4
1' 5"	16	23	81	1' 5"	24	34	<23.2
1' 9"	29	<16.5	88	1' 9"	32	24	<22.2
2' 1"	19	<16.0	55	2' 1"	26	19	<27.9
2' 5"	18	27	51	2' 5"	21	29	39
2' 9"	23	23	52	2' 8"	17	23	43
3' 1"	24	<15.8	73	3' 1"	31	<12.7	46
3' 6"	25	18	74	3' 5"	19	21	44
3' 6"	28	<15.1	86	3' 9"	27	24	<32.9
4' 2"	34	20	78	4' 4"	25	<14.9	63
4' 8"	67	65	157	4' 7"	25	44	83
Coring site T5-5				4' 11"	21	33	76
0' 1"	28	50	199	5' 1"	<15.5	31	104
0' 1"	29	47	212	5' 6"	23	22	112
0' 5"	15	41	230	5' 11"	28	20	75
0' 9"	17	<17.1	125	6' 1"	38	28	75
1' 1"	<14.4	33	103	6' 6"	22	24	79
1' 5"	37	42	66	6' 11"	21	20	63
1' 9"	20	27	61	7' 1"	25	<17.9	<27.9
2' 1"	27	28	55	7' 1"	36	<15.2	34
2' 5"	15	30	42	7' 5"	28	<15.9	39
2' 9"	<15.6	<18.1	57	7' 10"	23	<14.6	54
3' 1"	29	<16.2	35	Coring site T5-7			
3' 5"	22	21	48	0' 1"	<13.9	18	78
4' 2"	32	27	81	0' 1"	<14.1	32	82
4' 8"	22	21	70	0' 5"	<13.1	23	60
5' 2"	37	18	81	0' 10"	21	<16.4	<26.9
5' 5"	30	<24.1	66	1' 1"	23	27	<27.6
5' 5"	28	<24.4	65	1' 5"	<14.4	19	45
6' 1"	42	31	62	1' 11"	19	<15.1	34
6' 4"	35	<19.2	104	2' 1"	15	16	<26.4
6' 9"	<19.6	26	112	2' 1"	14	<14.4	35
7' 1"	23	28	88	2' 5"	14	<12.8	32

Table 1-7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T5-7—Continued				Coring site T6-1—Continued			
2' 10"	24	21	<26.5	6' 4"	19	23	127
3' 1"	<16.0	33	54	6' 8"	<14.0	20	139
3' 5"	16	20	48	7' 1"	16	28	149
3' 10"	20	28	36	7' 4"	24	17	126
4' 1"	31	<18.1	71	7' 8"	17	113	20
4' 5"	24	<14.4	58	8' 1"	20	<15.5	101
4' 10"	26	21	45	8' 5"	20	30	87
5' 1"	<14.6	25	44	8' 9"	28	23	96
5' 5"	17	62	40	9' 1"	<13.9	<13.3	91
5' 10"	26	13	69	9' 4"	<13.4	24	61
6' 1"	19	<15.8	52	9' 7"	14	24	61
6' 5"	17	29	41	10' 1"	22	21	109
6' 9"	25	22	46	10' 5"	25	21	76
7' 1"	25	45	<28.4	10' 9"	31	30	125
7' 5"	23	<13.0	<24.5	11' 1"	20	29	119
7' 10"	28	<14.9	41	11' 5"	25	<17.4	119
Coring site T6-1				11' 9"	38	25	149
0' 1"	41	117	1,411	12' 1"	27	27	103
0' 1"	32	113	1,378	12' 6"	24	25	98
0' 1"	37	117	1,517	12' 10"	15	22	96
0' 4"	58	141	1,654	13' 1"	19	<20.7	132
0' 8"	45	213	1,475	13' 1"	22	43	116
1' 2"	42	212	1,503	13' 1"	22	<20.1	112
1' 5"	36	212	1,868	13' 6"	23	33	150
1' 9"	46	167	1,651	13' 10"	18	19	105
2' 1"	47	757	3,086	14' 1"	15	20	84
2' 1"	45	774	3,033	14' 6"	23	27	62
2' 1"	45	731	2,989	14' 10"	22	27	53
2' 4"	44	166	1,599	15' 1"	<14.0	24	69
2' 8"	40	129	1,478	15' 3"	22	35	79
3' 1"	24	91	1,345	15' 8"	29	<16.5	96
3' 5"	27	30	622	Coring site T6-2			
3' 8"	25	27	429	0' 2"	24	59	361
4' 1"	27	27	252	0' 2"	32	74	353
4' 4"	24	33	172	0' 2"	27	76	274
4' 8"	15	17	179	0' 5"	27	32	172
5' 1"	21	<15.7	139	1' 1"	20	43	224
5' 5"	24	26	177	1' 5"	26	31	101
5' 9"	17	25	179	2' 2"	22	29	72
6' 1"	16	<15.9	184	2' 5"	<22.6	<37.4	87

Table 1–7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T6-2—Continued				Coring site T6-3—Continued			
3' 1"	32	23	62	4' 10.5"	25	21	36
3' 5"	20	<18.4	46	5' 1.5"	35	22	36
4' 1"	25	39	43	5' 6"	17	18	61
4' 6"	20	22	49	5' 11"	16	23	69
4' 11"	<15.7	24	39	6' 1"	<14.0	35	59
5' 1"	37	<20.0	40	6' 1"	<14.9	21	52
5' 6"	29	<15.7	37	6' 1"	<14.2	<14.9	69
5' 10"	22	<14.2	47	6' 5"	<13.9	49	66
6' 1"	37	22	<39.2	6' 10"	18	40	69
6' 6"	27	<15.9	<33.4	7' 1"	26	27	40
6' 10"	34	20	45	7' 5.5"	15	20	41
7' 2"	28	33	68	7' 10"	16	29	58
7' 6"	53	24	96	8' 2"	28	44	62
7' 11"	42	<16.4	46	8' 6"	25	<17.1	55
7' 11"	32	<15.3	<25.9	8' 11"	26	19	68
7' 11"	37	<12.9	35	9' 2"	<15.4	38	45
8' 1"	44	<23.7	54	9' 6"	19	<13.9	40
8' 5"	95	<21.2	<43.2	9' 11"	24	<15.1	58
8' 8"	26	<15.0	<32.6	Coring site T6-3 (duplicate)			
9' 1"	28	<15.6	47	0' 1"	<12.5	21	52
9' 5"	44	<17.6	146	0' 1"	<12.0	23	54
9' 8"	32	<16.2	<33.5	0' 1"	<12.4	23	63
10' 1"	32	<15.1	<27.9	0' 6"	<13.7	20	27
Coring site T6-3				0' 10.5"	<25.8	<37.5	<66.0
0' 1"	<13.3	24	56	1' 1.5"	32	18	<27.8
0' 1"	15	29	75	1' 6"	30	24	41
0' 1"	<12.9	24	53	1' 9"	28	21	<33.0
0' 6"	<14.1	25	40	2' 1.5"	17	<15.7	54
0' 10"	24	<15.7	33	2' 5"	10	<17.1	22
1' 1.5"	17	<16.2	<29.5	2' 9"	17	<14.3	35
1' 6"	18	<18.4	40	3' 1.5"	18	<16.2	47
1' 8.5"	23	<15.4	52	3' 5"	29	25	44
2' 1.5"	<14.0	20	39	3' 10"	26	31	40
2' 6"	27	20	69	4' 1.5"	29	32	47
2' 10"	<13.9	21	43	4' 6"	<14.0	31	47
3' 2"	20	25	27	4' 11"	31	49	44
3' 6"	16	24	44	5' 1.5"	23	23	58
3' 10"	<14.2	22	58	5' 5.5"	<13.9	47	34
4' 1.5"	19	16	49	5' 11"	14	<13.2	51
4' 6"	<14.6	25	63	6' 1.5"	<13.8	46	43

Table 1-7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T6-3 (duplicate)—Continued				Coring site T6-4—Continued			
6' 5.5"	22	21	72	1' 4.5"	<16.2	<15.6	<29.9
6' 5.5"	21	<14.5	71	1' 7.5"	25	<15.2	29
6' 5.5"	23	16	44	2' 1"	23	<17.2	34
6' 10"	<14.0	34	95	2' 4"	17	22	55
7' 1.5"	28	27	45	2' 7"	<14.4	<17.5	<26.5
7' 6"	20	<15.5	53	3' 4"	20	<15.2	37
7' 10.5"	29	48	59	3' 8"	37	<18.9	<34.4
8' 1.5"	22	60	58	4' 1.5"	<15.1	44	<30.7
8' 6"	23	<17.1	57	4' 6"	28	<16	54
8' 11"	22	23	47	4' 10.5"	21	21	<22.9
9' 1.5"	50	24	36	5' 1"	25	<16.3	33
9' 5.5"	36	17	59	5' 4"	19	19	29
9' 11"	<15.3	<19.1	41	5' 11"	22	<13.1	28
10' 1.5"	<13.5	20	63	6' 1"	22	18	30
10' 5.5"	15	24	65	6' 5.5"	35	32	49
10' 11"	18	<11.8	61	6' 10.5"	22	21	47
11' 1.5"	<14.3	27	66	7' 1"	25	20	47
11' 5.5"	21	22	57	7' 5"	19	20	56
11' 5.5"	15	<14.2	52	7' 9"	20	<18.9	<33.1
11' 5.5"	<13.9	27	58	8' 2"	26	<16.8	56
11' 10.5"	<22.4	<19.5	84	8' 6"	23	<16	51
12' 1.5"	21	27	44	8' 10"	27	<17.2	37
12' 5.5"	25	37	82	9' 1.5"	27	21	59
12' 10"	19	<16.8	77	9' 7"	38	<17.7	59
13' 2"	<14.2	18	79	9' 10"	30	19	38
13' 6"	22	<16.5	39	9' 10.5"	32	<15.1	<36.8
13' 10"	26	18	49	10' 2.5"	<16.7	<17.9	58
14' 2"	21	34	73	10' 5.5"	21	31	82
14' 6"	25	<15.2	64	10' 10"	23	27	44
14' 10"	16	26	59	11' 1.5"	22	29	77
15' 2"	<14.6	22	60	11' 5.5"	34	27	<39.8
15' 7"	31	<12.1	<34.3	11' 10"	17	26	<34.4
15' 10"	32	17	60	12' 2"	38	<18.8	79
Coring site T6-4				12' 6"	32	<18.5	62
0' 1.5"	<13.9	29	64	12' 11"	26	<20.5	50
0' 1.5"	17	28	59	13' 1.5"	35	<57	57
0' 1.5"	14	37	77	13' 6"	22	21	46
0' 5"	<14.4	32	58	13' 11"	19	16	54
0' 8.5"	16	25	37	14' 1.5"	20	24	95
1' 2"	22	<15	41	14' 1.5"	<19.4	<12.2	<37.2

Table 1-7. Constituent concentrations determined by x-ray fluorescence for cores collected from the Spring River flood plain, Cherokee County, Kansas, 2009, 2010.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)	Core depth interval (in feet and inches)	Cadmium concentration (mg/kg)	Lead concentration (mg/kg)	Zinc concentration (mg/kg)
Coring site T6-4—Continued				Coring site T6-5—Continued			
14' 1.5"	20	32	85	3' 4"	<16.4	22	31
14' 7"	27	32	52	3' 4"	22	<16	<29.5
14' 11"	36	24	49	3' 8"	28	21	<30.1
15' 2"	37	24	43	4' 2"	17	<15.3	39
15' 6"	41	23	50	4' 7"	17	17	29
15' 11"	35	<14.6	<34.8	4' 10"	25	20	<27.6
Coring site T6-5				5' 2"	15	28	<27.9
0' 3"	<11.9	20	149	5' 6"	23	<15.1	42
0' 3"	<11.9	19	153	5' 11"	<13.6	30	45
0' 3"	<11.9	<13	148	6' 2"	23	20	39
1' 1–1.4"	37	<22.6	<37.9	6' 6"	23	22	47
1' 1.4–1.8"	40	53	<36.3	6' 10"	25	<13.2	31
1' 3–7"	<14.0	14	40	7' 2"	21	22	<27.3
2' 4"	30	39	30	7' 6"	45	<17.4	<33.2
2' 8"	25	<19.2	49	7' 10"	34	35	89

Table 1–8. Cadmium concentrations determined by x-ray fluorescence for cores collected from tributary flood plains, Cherokee County, Kansas, 2011.

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Coring site identifier (figs. 2A–2U)	Sample depth, inches	Cadmium concentration, mg/kg	Coring site identifier (figs. 2A–2U)	Sample depth, inches	Cadmium concentration, mg/kg
Brush Creek			Shoal Creek		
BC1-1	6	<12.6	ShC1-1	6	<12.8
	12	<12.7		12	<12.9
BC1-2	6	<12.7	ShC1-2	6	<12.2
	12	<12.7		12	<12.7
BC1-3	6	<12.8	ShC1-3	6	<13.0
	12	<13.3		12	<12.8
BC1-4	6	<12.6			
	12	<13.0	ShC2-1	6	<13.5
				12	<13.5
BC2-1	6	<12.3	ShC2-2	5	<12.7
	12	<12.3	ShC2-3	6	<12.5
BC2-2	6	<12.4		12	<12.7
	12	<12.8	ShC2-4	--	--
Cow Creek			Short Creek		
CC1-1	4	<12.7	StC1-1	6	78
	10	<12.5		12	<14.2
CC1-2	6	<13.0	StC1-2	6	<14.3
	12	<12.7		9	34
CC1-3	6	<12.8		12	<14.1
	12	<12.7	StC1-3	6	66
CC2-1	6	<13.3	StC2-1	6	17
	12	52	StC2-2	--	--
CC2-2	6	<12.3	Spring Branch		
	12	<13.0	SB1-1	4	32
Shawnee Creek				10	<14.7
SnC1-1	6	<12.5	SB1-2	--	--
	12	<13.0			
SnC1-2	6	<13.0	SB2-1	4	<14.9
	12	<13.1		10	<13.9
SnC1-3	6	<13.0	SB2-2	6	<13.8
	12	<13.2		12	<13.2
			SB2-3	--	--
SnC2-1	6	<13.2			
	12	<13.0	SB3-1	6	<12.9
SnC2-2	6	<12.9		10	<13.0
	12	<12.7	SB3-2	--	--

Table 1–8. Cadmium concentrations determined by x-ray fluorescence for cores collected from tributary flood plains, Cherokee County, Kansas, 2011.—Continued

[mg/kg, milligrams per kilogram; <, less than; --, not available]

Coring site identifier (figs. 2A–2U)	Sample depth, inches	Cadmium concentration, mg/kg	Coring site identifier (figs. 2A–2U)	Sample depth, inches	Cadmium concentration, mg/kg
Tar Creek			Turkey Creek		
TrC1-1	6	89	TkC1-1	6	21
	12	84		12	53
TrC1-2	6	66	TkC1-2	6	19
	12	110		12	35
TrC1-3	6	53	TkC1-3	6	<12.7
	12	60		12	<12.4
TrC1-4	6	54	Willow Creek		
	12	<14.0	WC1-1	6	<12.8
TrC2-1	4	<13.2		12	<13.4
	10	16	WC1-2	6	<13.3
TrC2-2	4	<13.6		12	<13.7
	10	<13.5	WC1-3	6	<13.5
TrC2-3	4	<13.9	WC2-1	6	<13.5
	10	129		12	<13.8
TrC2-4	4	<14.5	WC2-2	6	<13.3
	10	214		12	<13.5
TrC3-1	6	<12.7	WC2-3	6	<14.0
	12	<12.9		12	<13.3
TrC3-2	6	<12.5	WC2-4	6	<13.2
	12	<12.8		12	<12.8
TrC3-3	6	<12.9	WC3-1	6	<12.6
	12	<12.8		12	<12.6
TrC3-4	6	<12.5	WC3-2	6	<12.6
	12	<12.8		12	<12.4

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Back Cover. Top—Collection of a soil core near Cow Creek, Cherokee County, Kansas (photograph by Kyle Juracek, U.S. Geological Survey). Bottom—Collection of a surficial-soil sample near Empire Lake, Cherokee County, Kansas (photograph by Kyle Juracek, U.S. Geological Survey).

