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Streamflow, Water Quality, and Metal Loads from Chat Leachate and Mine Outflow into Tar Creek, Ottawa County, Oklahoma, 2005

Scientific Investigations Report 2007-5115

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

Cover: Photograph showing seepage from chat piles entering Tar Creek. Photograph taken by Mark Becker, U.S. Geological Survey.

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound per day (lb/day)	2000	metric ton per day

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to North American Datum of 1983 (NAD 83) and North American Datum of 1927 (NAD 27).

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

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

Streamflow, Water Quality, and Metal Loads from Chat Leachate and Mine Outflow into Tar Creek, Ottawa County, Oklahoma, 2005

By Caleb C. Cope, Mark F. Becker, William J. Andrews, and Kelli DeHay

Abstract

Picher mining district is an abandoned lead and zinc mining area located in Ottawa County, northeastern Oklahoma. During the first half of the 20th century, the area was a primary producer of lead and zinc in the United States. Large accumulations of mine tailings, locally referred to as chat, produce leachate containing cadmium, iron, lead, and zinc that enter drainages within the mining area. Metals also seep to local ground water and streams from unplugged shafts, vent holes, seeps, and abandoned mine dewatering wells. Streamflow measurements were made and water-quality samples were collected and analyzed from two locations in Picher mining district from August 16 to August 29 following a rain event beginning on August 14, 2005, to determine likely concentrations and loads of metals from tailings and mine outflows in the part of Picher mining district near Tar Creek.

Locations selected for sampling included a tailings pile with an adjacent mill pond, referred to as the Western location, and a segment of Tar Creek from above the confluence with Lytle Creek to below Douthat bridge, referred to as Tar Creek Study Segment. Measured streamflow was less than 0.01 cubic foot per second at the Western location, with streamflow only being measurable at that site on August 16, 2005. Measured streamflows ranged from <0.01 to 2.62 cubic feet per second at Tar Creek Study Segment.

One water-quality sample was collected from runoff at the Western location. Total metals concentrations in that sample were 95.3 micrograms per liter cadmium, 182 micrograms per liter iron, 170 micrograms per liter lead, 1,760 micrograms per liter zinc. Total mean metals concentrations in 29 water-quality samples collected from Tar Creek Study Segment from August 16–29, 2005, were 21.8 micrograms per liter cadmium, 7,924 micrograms per liter iron, 7.68 micrograms per liter lead, and 14,548 micrograms per liter zinc.

No metals loading values were calculated for the Western location. Metals loading to Tar Creek Study Segment were calculated based on instantaneous streamflow and metals concentrations. Total metals loading to Tar Creek from chat leachate ranged from 0.062 to 0.212 pound per day of cadmium, <0.001 to 0.814 pound per day of iron, 0.003 to 0.036 pound per day of lead, and 10.6 to 47.9 pounds per day of zinc.

Metals loading to Tar Creek Study Segment from chat leachate and mine outflow was determined by subtracting values at appropriate upstream and downstream stations. Four sources of calculated metal loads are from Tar Creek and Lytle Creek entering the study segment, from chat pile leachate, and from old Lytle Creek mine outflow. Less than 1 percent of total and dissolved iron loading came from chat leachate, while about 99 percent of total iron loading came from mine outflow. Total and dissolved lead loading percentages from chat leachate were greater than total and dissolved lead loading percentages from mine outflow. About 19 percent of total zinc loading came from chat leachate, about 29 percent of total zinc loading came from mine outflow, and about 52 percent of total zinc loading came from Lytle Creek.

Introduction

Picher mining district, located in northeastern Ottawa County, Oklahoma (fig. 1), is part of Tri-State mining district, a 1,188-square-mile area in southwest Missouri, southeast Kansas, and northeast Oklahoma that was the most productive site of mining for sulfide ores of lead and zinc in the U.S. from the late 1830s to the 1970s, producing about 1.7 million tons of lead and 8.8 million tons of zinc (Gibson, 1972; Gibson, 1982; State of Oklahoma, 2000; and Robertson, 2006). Picher mining district, included in the initial National Priority list of Superfund sites as the Tar Creek Superfund site by the U.S. Environmental Protection Agency in 1983, is plagued by some of the most severe or widespread environmental degradation of any of the tens of thousands of abandoned mining sites in the U.S. (Ferderer, 1996; State of Oklahoma, 2000; and Robertson, 2006).

When mining stopped about 1979, as much as 165–300 million tons of mine tailings, some of which had been reprocessed one or more times to recover metals, remained in Picher mining district (State of Oklahoma, 2000). U.S. Army Corps of Engineers estimated in 2000 that 60 million cubic yards or 75 million tons of mine tailings remained in the

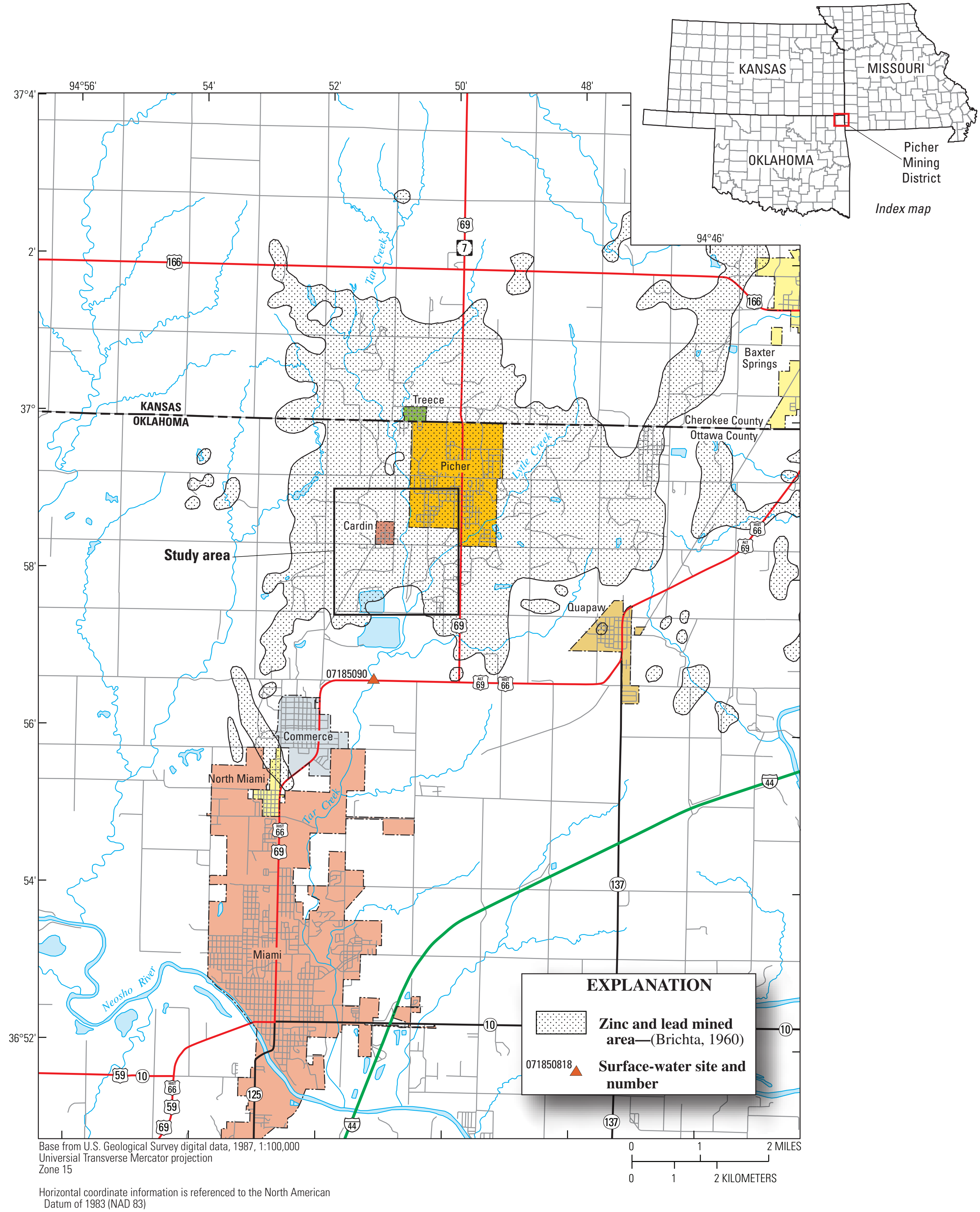

Figure 1a. Location of study area in Ottawa County, Oklahoma.

Base from U.S. Geological Survey digital data, 1987, 1:100,000
Albers Conic Equal-Area projection
Horizontal coordinate information is referenced to the North American
Datum of 1983 (NAD 83)

Aerial photo from Oklahoma Conservation Commission

0 500 1,000 1,500 2,000 FEET
0 150 300 450 600 METERS

EXPLANATION

Approximate boundary of chat pile

071850818 **Surface-water site and number**

Shallow monitoring well—Transect 1

Shallow monitoring well—Transect 2

Figure 1b. Location of sampling sites and wells in Tar Creek Study Segment, Ottawa County, Oklahoma.

A.

B.

C.

Figure 2. Photographs of : (A) tailings or "chat" pile near Picher, Oklahoma; (B) iron-hydroxide-stained water along ditch draining to Tar Creek near Douthat, Oklahoma; and (C) fine-tailings in settling pond near Douthat, Oklahoma. (Photographs by Robert W. Nairn, University of Oklahoma.)

district (State of Oklahoma, 2000). Large accumulations of gravel- to sand-sized mine tailings, locally referred to as chat, are present throughout the mining area (fig. 2). Ponds of silt- and clay-sized by-products of the gravity separation process, referred to as mill pond wastes, are located near many of the chat piles. Chat and mill pond wastes contain metals associated with lead and zinc sulfide ores. Leachate from chat and mill pond wastes discharges to streams draining the mining area. Mining in the district occurred at depths below the water table, necessitating continuous pumping of ground water to prevent flooding of the workings. As mining ceased in the 1970s, those pumps were turned off, the mine workings filled with ground water, and seeps of water with large concentrations of metals started to flow at the land surface and drain to local streams in late 1979 (State of Oklahoma, 2002). Outflow of water from the mine workings occurs from several locations in the mining area, including unplugged mine shafts, vent holes, seeps, and abandoned mine dewatering wells. Metals from mine outflows can comprise a substantial contribution to the total metal loading of streams. Information about the amount of metal loading from chat and mill pond waste and mine outflow is needed to evaluate the fate and transport of metals in the mining district.

Picher mining district was placed on the National Priorities List in September 1983, as part of the Tar Creek Superfund Site, making the district a subject of evaluation and reclamation activities conducted under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), otherwise known as "Superfund," which is administered by U.S. Environmental Protection Agency (EPA) and delegated state environmental agencies, such as Oklahoma Department of Environmental Quality (ODEQ). CERCLA establishes procedures under law for cleanup of hazardous waste sites and reimbursement for such cleanup by collection from responsible parties or a trust fund. An Administrative Order on Consent was entered into in 1983 between EPA, U.S. Department of Interior, and two former mining operators to investigate the mine and mill residues remaining at the site. EPA divides parts of a superfund site into Operable Units, which may refer to geographical parts of a site or specific site problems to be remediated. The investigation of mine and mill residues is designated by EPA Region 6 as Operable Unit 4 (Oklahoma Department of Environmental Quality, 2004).

U.S. Geological Survey (USGS), in cooperation with EPA, began a study in 2005 to characterize flow, collect water-quality data, and calculate loads of selected metals entering Tar Creek. Data collected for this report can be used to better understand the nature of metal loading to surface water systems adjacent to mine tailings and mine outflows.

Purpose and Scope

The purpose of this report is to characterize streamflow, water-quality, and metals loads discharged to Tar Creek from chat leachate and mine outflow at two locations in Picher mining district in August 2005. Locations selected for surface-water sampling were: (1) drainage from an individual chat pile with an adjacent mill pond, referred to as the Western location, and (2) a segment of Tar Creek from above the confluence with Lytle Creek to below Douthat bridge, referred to as Tar Creek Study Segment location (figs. 1 and 3). The Western location contained one surface-water sampling site; whereas, Tar Creek Study Segment contained four surface-water sampling sites (fig. 1 and table 1). Sites were sampled over a 14-day period following a rainfall event until streamflow returned to pre-event status. One streamflow measurement was made and a water-quality sample was collected at the Western location. Seven streamflow measurements were made and seven water-quality samples were collected at each of the four sites in Tar Creek Study Segment.

Metal loading data are presented from two surface-water locations, one of which receives substantial water from an upstream mine outflow into Tar Creek. Instantaneous loads for total and dissolved cadmium, iron, lead, and zinc are calculated for samples collected. Results of this investigation will be used by EPA staff to estimate metal loading from chat leachate for the Remedial Investigation and Feasibility Study (RI/FS) for Operable Unit 4 of Tar Creek Superfund Site.

Description of Study Area

Picher mining district is located in northeastern Ottawa County (fig. 1) (McKnight and Fischer, 1970). Located upon flat prairie land between the Spring and Neosho Rivers near the Kansas/Oklahoma state line, the former mining communities of Picher, Commerce, Cardin, and Quapaw are included in the district (fig. 1).

Lytle Creek is the main tributary to Tar Creek (figs. 1 and 3). Originally Lytle Creek flowed into an open mine collapse before entering Tar Creek just above the Douthat bridge (fig. 3). Oklahoma Water Resources Board and EPA diverted the flow of Lytle Creek away from the mine collapse in the mid-1980s in an attempt to reduce recharge of metals-contaminated runoff water to the Boone aquifer (Keheley and Pritchard, 2000). Although the main channel of Lytle Creek has been diverted away from the collapse, a substantial amount of mine outflow enters Tar Creek through the old Lytle Creek channel. Base flow in Tar and Lytle Creeks throughout Picher mining district to the Douthat bridge is mostly maintained by discharges from chat pile leachate and mill ponds. Substantial volumes of mine outflow enter Tar Creek downstream from Douthat bridge to U.S. Highway 69.

Chat is deposited extensively throughout the Picher mining district. Chat is unconsolidated and highly permeable. Rainfall readily infiltrates chat and slowly seeps from the larger chat piles. Shale of the Krebs Group of Middle Pennsylvanian age underlies most of the land surface in the Picher mining district (McKnight and Fischer, 1970), creating a confining unit on top of which leachate from chat and millponds will tend to seep laterally to local streams. Rainfall reacts with the soluble minerals and mobilizes metals associated with residual ore minerals in the chat.

Table 1. Station name, station number, and location of sampling sites in the Picher mining district, Ottawa County, Oklahoma.

[dms, degrees minutes seconds; NAD 83, North American Datum of 1983; NAD 27, North American Datum of 1927]

Station name	Station number	Latitude (dms)	Longitude (dms)	Datum
Tar Creek near Cardin, Okla.	071850825	365746	945047	NAD 83
Lytle Creek near Cardin, Okla.	071850870	365744	945046	NAD 83
Tar Creek above Douthat Bridge, near Cardin, Okla.	071850875	365731	945042	NAD 83
Tar Creek near Picher, Okla.	07185088	365729	945044	NAD 27
Tar Creek Tributary at Western location	071850818	365839	945108	NAD 83

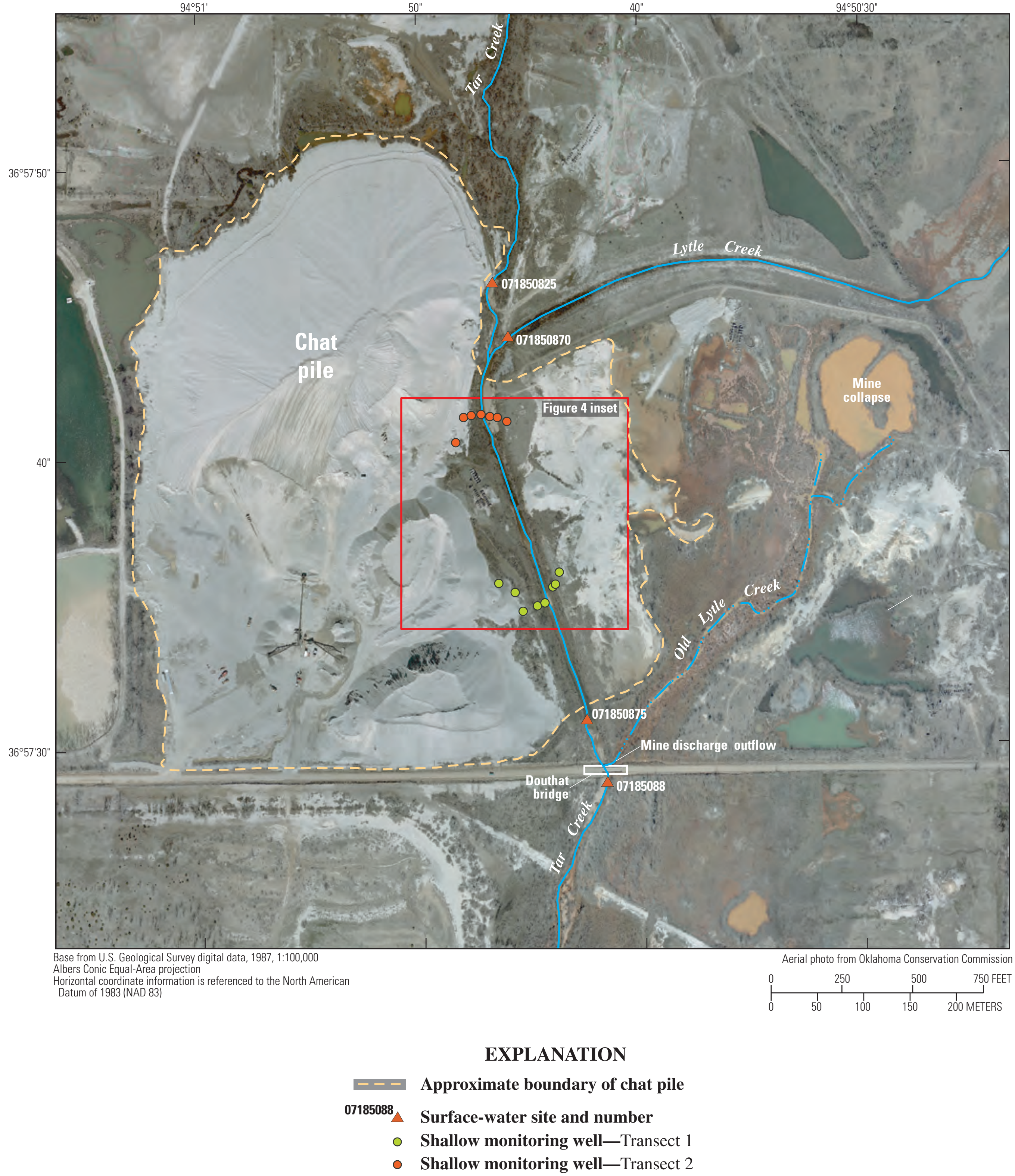

Figure 3. Location of sites in Tar Creek Study Segment, Ottawa County, Oklahoma.

Acknowledgments

Authors would like to thank all those who assisted in the collection of data for this report. Thanks to Sam Beets of the Bureau of Indian Affairs for access to the Western location. Gratitude is extended to Daniel Yeatts, Jerrod Smith, and Lyn Osburn, USGS, for their help in the review of the report, and to Tim Raines for technical support.

Methods

Ground-water levels were monitored in the chat over a two-week period following a rain event on August 14 and 15, 2005. Streamflow measurements and water-quality samples also were conducted and collected from Tar Creek and Lytle Creek during that two-week period. Metal loading values in pounds per day (lb/day) were calculated for cadmium, iron, lead, and zinc based on those streamflow measurements and water-quality data.

Location of Sampling Sites

Two locations were selected for surface-water sampling: Western location (Township 29N–Range 23E–Section 19) west of the town of Cardin, Oklahoma, and Tar Creek Study Segment (Township 29N–Range 23E–Sections 29 and 32) (fig. 1). The Western location contains one sampling site (071850818) (fig. 1 and table 1) located at a discharge point where a berm around a mill pond was breached and incised by previous runoff. Field reconnaissance indicated most of the runoff from the Western location flowed through that breach.

Tar Creek Study Segment is a reach of Tar Creek that passes through chat piles from above the confluence with Lytle Creek to Douthat bridge. Tar Creek Study Segment contains four sampling sites (071850825, 071850870, 071850875, and 07185088) (fig. 3 table 1). A substantial amount of mine outflow enters Tar Creek just above Douthat bridge from the old Lytle Creek channel (fig. 3). Samples collected at Tar Creek near Picher, Okla. (site 07185088) contain both leachate from chat piles and mine outflow.

Water-Level Monitoring

Shallow monitor wells were installed along two transects in the chat at Tar Creek Study Segment (figs. 1, 4, 5, and table 2). Fifteen wells were driven to a depth of up to 3 feet (ft) into chat. Ground-water levels were measured prior to surface-water sampling and during each day of surface-water sampling (table 3), using an electric tape marked in increments of 0.01 ft (fig. 5).

Two wells near the chat pile (TCW 1.3 and TCW 2.2) were instrumented with pressure transducers and data loggers to continuously record ground-water levels in chat and to monitor response of ground-water levels in chat to precipitation. Ground-water levels were assumed to have returned to pre-event levels, seepage of chat leachate to Tar Creek returned to pre-event rates.

Streamflow Measurements and Water-Quality Sampling

Streamflow measurements were made coincident with collection of water-quality samples. Streamflow measurements were made using acoustic Doppler profiler (ACDP) and conventional current meters in accordance with protocols described in Rantz and others (1982).

Water-quality samples were collected according to protocols described in USGS Techniques of Water-Resources Investigations (Wilde and Radtke, 1998 and 1999). Water properties were measured in the field in conjunction with each water-quality sample and streamflow measurement. Properties analyzed were: specific conductance, pH, temperature, turbidity, dissolved oxygen, oxidation-reduction potential, and alkalinity.

Water-quality samples were placed in a churn splitter and homogenized for field processing. Samples to be analyzed for major ions and total metals were collected directly from the churn splitter. Samples to be analyzed for dissolved metals were passed through a 0.45-micrometer pore size capsule filter. Samples to be analyzed for metals were preserved with nitric acid. Water samples were analyzed by USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado, for physical properties and for concentrations of dissolved major ions (calcium, magnesium, sodium, potassium, and sulfate), total metals (cadmium, iron, lead, and zinc) and dissolved metals (cadmium, iron, lead, and zinc). Major ion and metals concentrations were determined at NWQL by the inductively coupled plasma (ICP) method (Faires, 1993). Suspended sediment concentrations were analyzed by USGS sediment laboratory in Rolla, Missouri.

Metals Loads Calculation

Metals loading estimates in pound per day (lb/day) were calculated by the following equation:

Load (lb/day) = streamflow (ft^3/s) * metal concentration (mg/L) * 5.393 (lb*sec*L)/(day*ft^3*mg)

where lb/day = pound per day

ft^3/s = cubic foot per second,

mg/L = milligram per liter, and

L = liter

Metals in water in Tar Creek Study Segment were assumed to have originated from four sources: (1) Tar Creek above the study segment, (2) Lytle Creek, (3) leachate from adjacent chat pile, and (4) mine outflow from old Lytle Creek directly above Douthat bridge (fig. 3).

Estimated metals loading values entering the study segment from upper Tar Creek and Lytle Creek were calculated

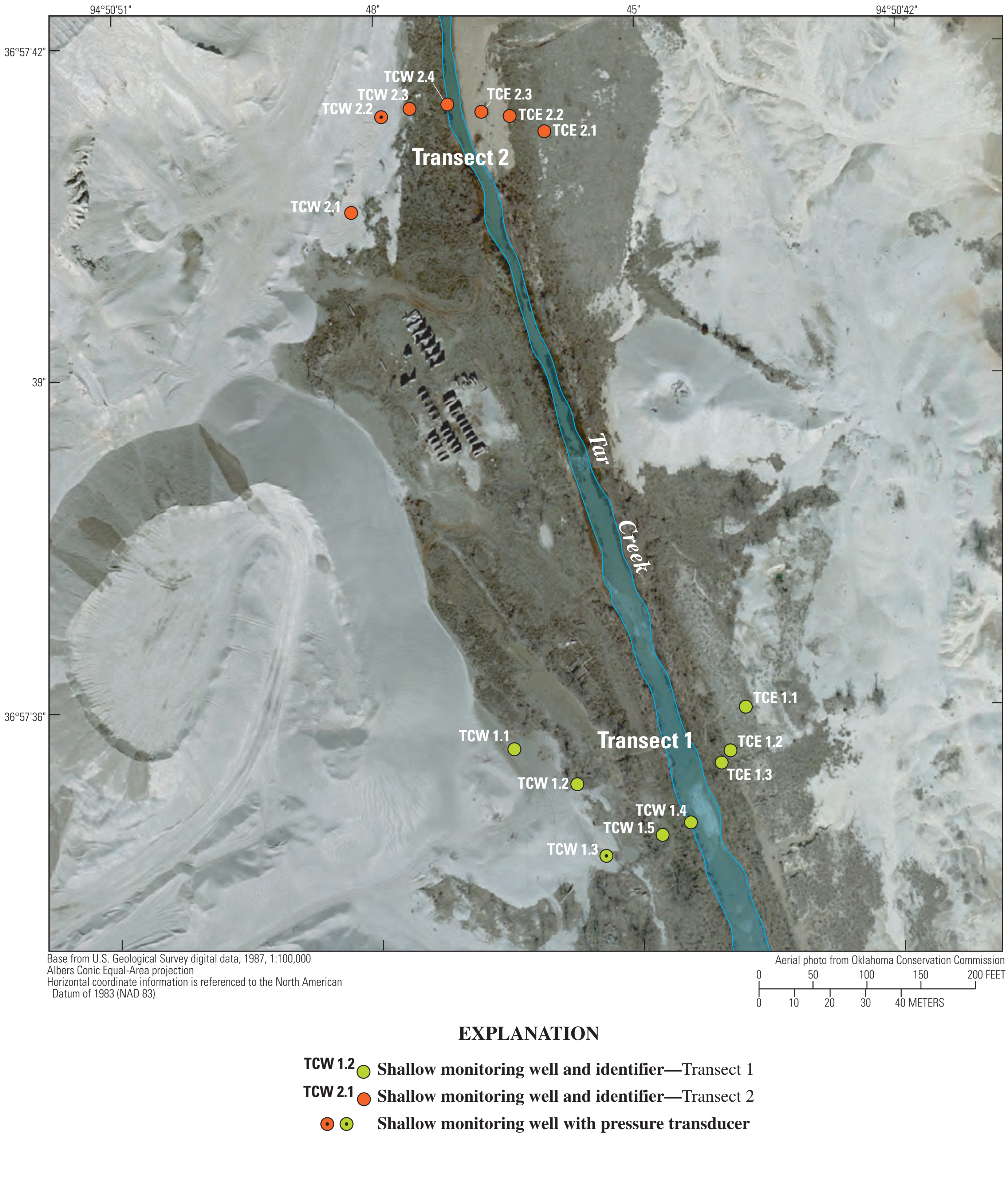

Figure 4. Location of transects 1 and 2 in the Tar Creek Study Segment, Ottawa County, Oklahoma.

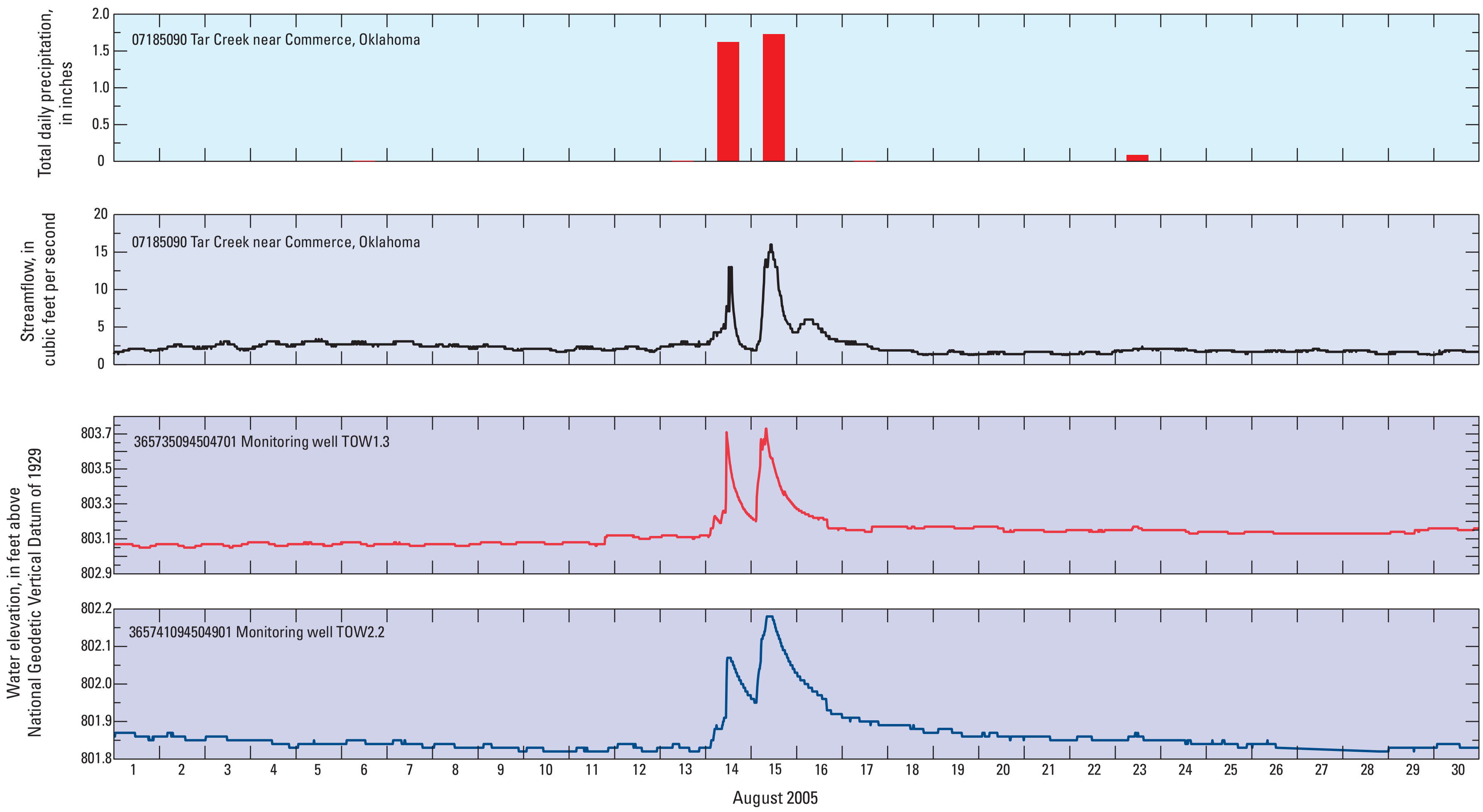

Figure 5. Precipitation, stream discharge, stream-water levels, and water elevations in the chat pile prior to and during the sampling period, August 16–29, 2005.

Table 2. Name and location of water-level monitoring wells in chat along Tar Creek in the Picher mining district, Ottawa County, Oklahoma.

[*, recorder wells; dec, decimal degrees]

Well name	Latitude (dec)	Longitude (dec)
TCE 1.1	36.94392	94.78561
TCE 1.2	36.95989	94.84555
TCE 1.3	36.95986	94.84558
TCE 2.1	36.96145	94.84612
TCE 2.2	36.96149	94.84623
TCE 2.3	36.96150	94.84632
TCW 1.1	36.95990	94.84624
TCW 1.2	36.95981	94.84604
TCW 1.3*	36.95963	94.84595
TCW 1.4	36.95971	94.84568
TCW 1.5	36.95968	94.84577
TCW 2.1	36.96125	94.84674
TCW 2.2*	36.96149	94.84664
TCW 2.3	36.96153	94.84698
TCW 2.4	36.96156	94.84646

using water-quality samples and streamflow measurements at sites 071850825 and 071850870, respectively (fig. 3).

Estimated metals loading to Tar Creek Study Segment from chat leachate was determined by subtracting loads from sites upstream from chat pile (Tar Creek site 071850825 and Lytle Creek site 071850870) from Tar Creek site 071850875 downstream from the chat pile (fig. 3). Estimated metals loading to Tar Creek Study Segment from mine outflow from old Lytle Creek above Douthat Bridge also was determined by subtracting loads in Tar Creek directly above the confluence with old Lytle Creek (site 071850875) from loads in Tar Creek directly below the confluence with old Lytle Creek (site 07185088) (fig. 3).

Total cumulative loading estimates from chat leachate and mine outflow were calculated for the period beginning August 16 and ending August 30. Instantaneous loading values in pounds per day were interpolated throughout the 14-day period. Loading values calculated for samples and streamflow measurements collected August 16, 18, 20, 22, 24, and 29 were doubled to estimate cumulative loading values for August 17, 19, 21, 23, 25, and 30, when samples were not collected. Instantaneous loading value for August 26 was tripled to estimate cumulative loading on August 26–28.

Quality Assurance/Quality Control

An equipment blank for major ions and metals was collected for sampling equipment using metals-grade blank water prior to data collection (table 4). One sample of laboratory deionized water used for decontamination from all sources was sent for analysis of major ions and metals. In addition, a field blank and a duplicate sample were collected and analyzed for major ions and metals (table 4) (Wilde and Radtke, 1999).

Streamflow, Water Quality, and Metal Loads from Chat Leachate and Mine Outflow

All streamflow measurements and water-quality samples were collected following a rain event beginning on August 14, 2005. A total of about 3.3 inches of rainfall was recorded at USGS gaging station Tar Creek near Commerce (07185090) (fig. 1) on August 14–15 (fig. 5). Streamflow responded rapidly to rainfall over the study area and slowly declined to pre-event conditions (fig. 5 and table 5). Rainfall readily infiltrated the unconsolidated chat and subsequently released leachate to Tar Creek. Streamflows generally declined over time following rainfall and ranged from less than 0.01 to 2.62 ft^3/s (table 5). Water-level elevations measured in wells installed

Table 3. Water levels measured during August 2005 in water-level monitoring wells, in the Picher mining district, Ottawa County, Oklahoma.

[feet above National Geodetic Vertical Datum of 1929; *, wells with pressure transducers; ND, no data]

Well number	Identifier number	Land surface datum or water-level elevation	Measurement date 8/11/2005	Measurement date 8/16/2005	Measurement date 8/17/2005	Measurement date 8/18/2005	Measurement date 8/20/2005	Measurement date 8/22/2005	Measurement date 8/24/2005	Measurement date 8/26/2005	Measurement date 8/29/2005
Transect 1											
TCW 1.1	365736094504601	806.35	803.85	803.99	803.96	803.93	803.97	803.99	803.96	803.91	803.93
TCW 1.2	365735094504601	806.32	803.33	803.46	803.44	803.43	803.42	803.42	803.41	803.39	803.4
TCW 1.3*	365735094504502	805.53	803.11	803.16	803.17	803.16	803.14	803.15	803.15	803.13	803.15
TCW 1.5	365735094504501	801.55	799.16	799.2	799.23	799.26	799.25	799.24	799.24	799.24	799.23
TCW 1.4	365735094504402	797.76	792.93	793.06	793.04	793.03	793.03	793.04	793.04	793.02	793.05
TCE 1.3	365735094504401	798.46	794.85	ND	794.9	794.81	794.71	794.78	794.78	794.75	794.77
TCE 1.2	365736094504401	801.54	796.88	798.23	797.92	797.74	797.35	797.35	797.35	797.27	797.15
TCE 1.1	365638094470801	803.89	dry	799.82	799.62	799.52	799.36	799.39	799.36	799.27	799.14
Transect 2											
TCW 2.1	365740094504801	805.99	801.78	801.87	801.83	801.81	801.79	801.78	801.77	801.75	801.76
TCW 2.2*	365741094504801	805.33	801.81	801.93	801.9	801.89	801.87	801.85	801.85	801.84	801.83
TCW 2.3	365741094504901	800.75	798.81	798.8	798.83	798.78	798.78	798.78	798.77	798.75	798.74
TCW 2.4	365741094504702	796.24	793.49	793.52	793.54	793.48	793.45	793.48	793.49	793.5	793.45
TCE 2.3	365741094504701	797.79	793.38	793.57	793.48	793.45	793.42	793.41	793.41	793.39	793.4
TCE 2.2	365741094504602	800.57	dry	797.47	797.37	797.28	797.05	796.97	796.86	796.76	dry
TCE 2.1	365741094504601	805.39	dry	dry	dry	dry	dry	dry	dry	dry	dry

Table 4. Quality assurance/quality control data for samples collected from stations on Tar Creek, Lytle Creek, and the Western location, Picher mining district, Ottawa County, Oklahoma.

[µS/cm, microsiemen per centimeter; deg C, degree Celsius; mg/L, milligram per liter; µg/L, microgram per liter; <. less than; –, not analyzed; E, estimated]

Sample type	Station number	Date	Time	Specific conductance, water unfiltered lab, (µS/cm 25 deg C)	Calcium water, filtered, (mg/L)	Magnesium, water, filtered, (mg/L)	Sodium, water, filtered, (mg/L)	Potassium, water, filtered, (mg/L)	Sulfate water, filtered, (mg/L)	Chloride, water, filtered, (mg/L)	Cadmium water, filtered, (µg/L)	Cadmium water, unfiltered (µg/L)	Iron, water, filtered, (µg/L)
Equipment blank	07185088	9/07/2005	1500	4	<0.02	<0.008	<0.20	<0.16	<0.18	<0.20	<0.04	<0.04	<6
Lab DI sample	07185088	9/16/2005	1520	3	–	–	–	–	–	–	–	<0.04	–
Field blank	071850870	8/22/2005	1236	<3	<0.02	<0.008	<0.20	<0.16	<0.18	<0.20	<0.04	<0.04	<6
Duplicate	07185088	8/20/2005	0836	2,250	560	48.4	19	2.46	1,410	8.73	25	25.2	32,100

Sample type	Station number	Date	Time	Iron, water, unfiltered recoverable, (µg/L)	Lead water, filtered, (µg/L)	Lead, water, unfiltered recoverable, (µg/L)	Zinc, water, filtered, (µg/L)	Zinc, water, unfiltered recoverable, (µg/L)
Field blank	071850870	8/22/2005	1236	<6	<0.08	<0.06	0.7	E1.6
Equipment blank	07185088	9/07/2005	1500	<6	<0.08	<0.06	<0.6	<2
Lab DI sample	07185088	9/16/2005	1520	<6	–	<0.06	–	<2
Duplicate	07185088	8/20/2005	0836	32,200	0.1	7	11,400	11,100

Table 5. Streamflow and water-quality data from stations on Tar Creek, Lytle Creek, and the Western location, Picher mining district, Ottawa County, Oklahoma.

[ft^3/s, cubic foot per second; unfiltered is total concentration and filtered is dissolved concentration for all constituents; µS/cm, microsiemen per centimeter; <, less than; LED, light emitting diode; FNU, formazin nephelometric unit; mg/L, milligram per liter; mV, millivolt; E, estimated; µg/L, microgram per liter; mm, millimeter]

Station name	Date	Time	Streamflow, (ft^3/s)	Specific conductance, water unfiltered lab (µS/cm 25 degrees Celsius)	Specific conductance water unfiltered field (µS/cm 25 degrees Celsius)	pH, water, unfiltered field (standard Units)	Temperature, water (degrees Celsius)	Turbidity, infrared LED light, detection angle 90 degrees (FNU)	Dissolved oxygen (mg/L)	Oxidation reduction potential, (mV)	Alkalinity, water filtered incremental titration field (mg/L as $CaCO_3$)
071850825	8/16/2005	1350	0.06	919	947	7.2	25.3	–	7.2	-38	138
	8/18/2005	1115	0.09	909	935	7.1	25	2.2	5.3	-32	140
	8/20/2005	1130	0.04	935	944	7.1	25.6	2.5	5.3	-77	142
	8/22/2005	1325	0.03	960	956	7	25	1.8	6.3	-122	151
	8/24/2005	1310	0.02	936	957	7.1	25.3	2.1	7.8	-8	152
	8/26/2005	1145	0.02	932	958	7.1	25.9	2.5	11.3	-79	160
	8/29/2005	1229	0.02	934	956	7	25.2	1.9	9.8	-115	165
071850870	8/16/2005	1415	1.58	1,780	1,820	6.7	29.6	–	7.8	-17	58
	8/18/2005	1200	0.13	1,760	1,790	6.9	31.1	4	8.3	-49	76
	8/20/2005	1030	0.04	1,820	1,830	7.1	29.1	1.5	7.8	-40	100
	8/22/2005	1235	0.01	1,790	1,830	7.1	27.5	4.6	9	-8	118
	8/24/2005	1215	0.02	1,780	1,820	7.2	32.5	1.7	9.8	-31	113
	8/26/2005	1115	<0.01	1,850	1,890	7.2	30.3	5	11.4	-50	139
	8/29/2005	1200	<0.01	1,980	2,000	6.9	28.6	1	11.4	-93	E146
071850875	8/16/2005	1125	1.62	1,850	1,880	6.9	26.6	3.1	8.5	17	72
	8/18/2005	0950	0.52	1,860	1,880	7	25.7	1.7	7.9	-25	105
	8/20/2005	0905	0.28	1,970	2,000	6.8	25.7	5.4	7.7	-63	101
	8/22/2005	1115	0.28	2,050	2,000	7.1	26.4	2.9	10.1	-12	100
	8/24/2005	1050	0.28	2,030	2,060	7	27.2	1.6	10.8	5	99
	8/26/2005	0955	0.19	2,110	2,150	7	26.9	2	11.1	-32	102
	8/29/2005	1050	0.2	2,170	2,200	7.1	26.4	2.2	13	-79	101
07185088	8/16/2005	1050	2.62	1,990	2,030	6.3	23.4	4.8	7.1	18	82
	8/18/2005	0813	1.3	2,120	2,200	6.2	21.8	7.6	6.8	-21	103
	8/20/2005	0835	0.87	2,240	2,270	6	19.6	7.6	7.7	-23	127
	8/22/2005	1045	0.94	2,230	2,310	6	19.4	7.4	10.1	-52	114
	8/24/2005	1030	0.86	2,240	2,340	6	18.8	7.8	13.5	-43	126
	8/26/2005	0930	0.78	2,280	2,380	6	18.9	5.9	18.8	-27	131
	8/29/2005	1025	0.69	2,310	2,390	5.9	18.2	6.4	16.5	-65	134
071850818	8/16/2005	1200	<0.01	2,040	2,070	7.1	30.5	–	8.4	–	69

Table 5. Streamflow and water-quality data from stations on Tar Creek, Lytle Creek, and the Western location, Picher mining district, Ottawa County, Oklahoma.—Continued

[ft³/s, cubic foot per second; unfiltered is total concentration and filtered is dissolved concentration for all constituents; µS/cm, microsiemen per centimeter; <, less than; LED, light emitting diode; FNU, formazin nephelometric unit; mg/L, milligram per liter; mV, millivolt; E, estimated; µg/L, microgram per liter; mm, millimeter]

Station name	Date	Time	Calcium water, filtered (mg/L)	Magnesium, water, filtered (mg/L)	Sodium, water, filtered (mg/L)	Potassium, water, filtered (mg/L)	Bicarbonate, water filtered incremental titration field, (mg/L)	Sulfate, water, filtered (mg/L)	Chloride, water, filtered (mg/L)	Cadmium, water, filtered (µg/L)	Cadmium, water, unfiltered (µg/L)
071850825	8/16/2005	1350	169	17.4	13	2.34	E166	335	14.4	7.09	7.68
	8/18/2005	1115	191	20.6	16.7	3.07	170	330	15.5	4.27	5.04
	8/20/2005	1130	181	17.6	14.2	2.52	–	343	14.9	3.32	4.28
	8/22/2005	1325	190	18.5	13.7	2.5	183	349	13.8	3	3.78
	8/24/2005	1310	172	18.5	13.2	2.54	185	344	13	2.91	4.27
	8/26/2005	1145	184	19.7	13.3	2.59	194	341	12.6	2.24	3.1
	8/29/2005	1229	190	20.2	13.7	2.51	200	339	12.4	1.83	2.72
071850870	8/16/2005	1415	345	38.8	19.5	8.46	E71	1,020	15.3	7.9	8.55
	8/18/2005	1200	357	37.7	21.6	7.01	93	986	16.6	2.09	2.07
	8/20/2005	1030	405	45.3	25.3	6.31	121	1010	17.5	1.26	1.13
	8/22/2005	1235	408	45.2	25.6	5.98	143	994	17.6	1.09	1.13
	8/24/2005	1215	372	45.6	26.1	5.55	136	969	17.1	0.7	0.83
	8/26/2005	1115	397	50	26.7	5.54	169	1,000	18.1	1.26	1.36
	8/29/2005	1200	442	52.4	29.1	5.05	E178	1,090	20.1	2.3	3.61
071850875	8/16/2005	1125	361	44	16.8	7.28	87	1,070	12.3	35	32.9
	8/18/2005	0950	382	52.2	15.8	4.08	128	1,070	10.8	48.8	43.8
	8/20/2005	0905	447	61.1	13.8	2.59	122	1,180	7.7	61.3	58
	8/22/2005	1115	463	63.6	12.9	2.33	121	1,220	6.63	59.7	58
	8/24/2005	1050	438	65.5	12.8	2.16	120	1,210	6.75	59.7	58.5
	8/26/2005	0955	442	70	11.8	1.99	123	1,270	6.17	60.2	60.8
	8/29/2005	1050	467	73.4	11.3	1.77	122	1,330	5.54	58.4	62
07185088	8/16/2005	1050	439	44.6	18.1	5.68	100	1,180	11.3	28.4	27.7
	8/18/2005	0813	482	48.1	18.9	3.28	125	1,310	10.1	27.7	25.4
	8/20/2005	0835	558	48.6	19	2.51	155	1,410	8.77	25.2	25
	8/22/2005	1045	528	50.5	19.2	2.56	139	1,400	8.5	25.5	24.8
	8/24/2005	1030	525	50.5	19	2.45	154	1,420	8.56	24.2	24.2
	8/26/2005	0930	542	51.4	18.2	2.35	160	1,420	8.52	23.9	24.2
	8/29/2005	1025	557	49.7	18.9	2.39	163	1,450	8.7	17	18.2
071850818	8/16/2005	1200	554	16.2	2.35	1.24	83	1,260	<1.00	103	95.3

Table 5. Streamflow and water-quality data from stations on Tar Creek, Lytle Creek, and the Western location, Picher mining district, Ottawa County, Oklahoma.—Continued

[ft³/s, cubic foot per second; unfiltered is total concentration and filtered is dissolved concentration for all constituents; µS/cm, microsiemen per centimeter; <, less than; LED, light emitting diode; FNU, formazin nephelometric unit; mg/L, milligram per liter; mV, millivolt; E, estimated; µg/L, microgram per liter; mm, millimeter]

Station name	Date	Time	Iron, water, filtered (µg/L)	Iron, water, unfiltered recover-able (µg/L)	Lead, water, filtered (µg/L)	Lead, water, unfiltered recover-able (µg/L)	Zinc, water, filtered (µg/L)	Zinc, water, unfiltered recover-able (µg/L)	Suspended sedi-ment, sieve diameter percent (<.063mm)	Sus-pended Sedi-ment, concen-tration (mg/L)
071850825	8/16/2005	1350	51	586	0.81	10.2	4,160	4,280	60	4
	8/18/2005	1115	11	509	0.21	6.5	3,330	3,510	50	3
	8/20/2005	1130	86	645	0.21	8.5	3,210	3,140	67	3
	8/22/2005	1325	116	676	0.34	10.4	3,050	3,120	83	5
	8/24/2005	1310	86	821	0.23	26.7	2,800	3,420	60	12
	8/26/2005	1145	145	727	0.16	8	2,700	2,750	50	6
	8/29/2005	1229	102	662	0.14	10.2	2,370	2,430	93	4
071850870	8/16/2005	1415	300	1,100	0.61	10.3	59,900	59,900	70	17
	8/18/2005	1200	762	1,560	E0.04	0.8	17,300	17,700	75	12
	8/20/2005	1030	<6	441	0.14	0.5	4,530	4,430	54	4
	8/22/2005	1235	E3	689	0.1	1.8	3,080	3,100	75	9
	8/24/2005	1215	8	458	E0.07	1.6	1,620	1,670	57	6
	8/26/2005	1115	8	170	0.25	0.8	2,360	2,260	71	4
	8/29/2005	1200	E6	3,690	0.23	17.4	3,580	4,380	59	94
071850875	8/16/2005	1125	49	626	1.88	14.5	61,700	59,800	60	32
	8/18/2005	0950	40	350	0.64	3.9	23,700	22,100	31	10
	8/20/2005	0905	92	656	0.89	11.1	22,000	19,800	29	22
	8/22/2005	1115	75	638	0.82	13.8	20,400	18,300	39	13
	8/24/2005	1050	43	596	0.62	10.2	17,800	19,300	44	16
	8/26/2005	0955	68	578	1.2	8.2	19,200	19,600	60	25
	8/29/2005	1050	73	401	0.64	3.7	19,800	19,700	47	27
07185088	8/16/2005	1050	11,400	12,300	0.57	10.7	43,400	46,600	88	47
	8/18/2005	0813	24,600	26,200	0.17	4.3	14,800	13,900	97	63
	8/20/2005	0835	32,200	33,200	0.15	7	11,500	10,900	96	76
	8/22/2005	1045	31,200	30,200	0.17	3.8	10,400	11,600	98	67
	8/24/2005	1030	32,100	32,200	0.14	3.9	10,100	10,900	96	77
	8/26/2005	0930	33,600	33,200	0.23	3.1	10,300	9,830	95	76
	8/29/2005	1025	37,500	38,000	0.16	3.2	9,070	8,950	99	72
071850818	8/16/2005	1200	47	182	117	170	1,730	1,760	26	5

in the chat (table 3 and fig. 5) show general rise and decline as water moves through chat to the streams. Water-level elevations also show that gradient of flow is from chat to the streams (table 3).

Streamflow

Only one streamflow measurement was collected August 16 from runoff at the Western location (site 071850818) (table 5). Measured streamflow on August 16 was less than 0.01 ft^3/s, with streamflows after that date diminishing to levels too small to be measured.

Seven streamflow measurements were made at each site in Tar Creek Study Segment during sampling (table 5). Streamflow measurements were made on August 16, 18, 20, 22, 24, 26, and 29. No streamflow measurements were made in Tar Creek Study Segment after August 29 as streamflow values and water levels had returned to pre-rain event levels. Measured streamflow within Tar Creek Study Segment ranged from less than 0.01 to 2.62 ft^3/s.

Water Quality

One water-quality sample was collected August 16 from runoff at the Western location (site 071850818) (table 5). Seven water-quality samples were collected at each of the four sites in Tar Creek Study Segment (table 5). Samples were collected on August 16, 18, 20, 22, 24, 26, and 29. No water-quality samples were collected in Tar Creek Study Segment after August 29 as streamflow values and water levels had returned to pre-rain event levels.

Field measurements collected at the Western location (site 071850818) were as follows: Specific conductance 2,070 microsiemens per centimeter at 25° Celsius (µS/cm), pH 7.1 standard units, temperature 30.5 ° Celsius, dissolved oxygen 8.4 mg/L, and alkalinity 69 mg/L (table 5). No turbidity or oxidation-reduction potential readings were collected at this site due to equipment malfunction.

Field measurements of specific conductance at Tar Creek Study Segment ranged from 935 to 2,390 µS/cm with a mean of 1,750 µS/cm (table 5). The pH ranged from 5.9 to 7.2 standard units, with a mean of 6.8 standard units. Temperature ranged from 18.2 to 32.5 ° Celsius with a mean of 25.4° Celsius. Alkalinity ranged from 58 to 165 mg/L with a mean of 118 mg/L. Turbidity ranged from 1 to 7.8 formazin nephelometric units, (fnu), with a mean of 3.3 fnu. Dissolved oxygen ranged from 5.3 to 18.8 mg/L with a mean of 9.6 mg/L. Oxidation-reduction potential ranged from -122 to 18 millivolts (mV) with a mean of -41 mV.

Metals, with the exception of iron, at the Western location generally were predominate in the dissolved phase (table 5). Total cadmium concentration of the sample collected at the Western location (site 071850818) was 95.3 micrograms per liter (µg/L) and dissolved cadmium concentration was 103 µg/L. A dissolved cadmium concentration greater than the total cadmium concentration can be the result of the analytical or sampling process. Total iron concentration was 182 µg/L, while dissolved iron concentration was 47 µg/L. Total and dissolved lead concentrations were 170 and 117 µg/L, respectively. Total zinc concentration was 1,760 µg/L and dissolved zinc concentration was 1,730 µg/L.

Cadmium and zinc at Tar Creek Study Segment generally were predominate in the dissolved phase, while total iron and lead generally were predominate (table 5). Total cadmium concentrations of samples collected from Tar Creek Study Segment ranged from 0.83 to 62 µg/L with a mean of 21.18 µg/L (table 5). Total iron concentrations ranged from 170 to 38,000 µg/L with a mean of 7,924 µg/L. Total lead concentrations ranged from 0.50 to 26.7 µg/L with a mean of 7.68 µg/L. Total zinc concentrations ranged from 1,670 to 59,900 µg/L with a mean of 14,548 µg/L.

Metal Loads from Chat Leachate and Mine Outflow

No loading values were calculated for the Western location (site 071850818). The low streamflow value (<0.01 ft^3/s) indicates that during the sampling period metal load contributions would have been negligible.

Instantaneous loads, in pounds per day, were calculated for cadmium, iron, lead, and zinc at each of the four sampling sites in Tar Creek Study Segment (table 6). Instantaneous loads generally decreased following the first day of sampling.

Total cadmium loading values from Tar Creek near Cardin, Okla. (site 071850825) ranged from <0.001 to 0.002 lb/day. Total iron loading values ranged from 0.071 to 0.247 lb/day with a mean of 0.132 lb/day. Total lead loading values ranged from <0.001 to 0.003 lb/day. Total zinc loading values ranged from 0.262 to 1.70 lb/day with a mean of 0.743 lb/day (table 6).

Total cadmium loading values from Lytle Creek near Cardin, Okla. (site 071850870) ranged from <0.001 to 0.073 lb/day. Total iron loading values ranged from <0.001 to 9.37 lb/day. Total lead loading values ranged from <0.001 to 0.088 lb/day. Total zinc loading values ranged from E0.047 to 510 lb/day (table 6).

Total cadmium loading values from Tar Creek above Douthat Bridge (site 071850875) ranged from 0.062 to 0.287 lb/day with a mean of 0.115 lb/day. Total iron loading values ranged from 0.432 to 5.47 lb/day with a mean of 1.48 lb/day. Total lead loading values ranged from 0.004 to 0.127 lb/day with a mean of 0.029 lb/day. Total zinc loading values ranged from 20.1 to 522 lb/day with a mean of 102 lb/day (table 6).

Total cadmium loading values from Tar Creek near Picher, Okla. (site 07185088) ranged from 0.068 to 0.391 lb/day with a mean of 0.156 lb/day. Total iron loading values ranged from 140 to 184 lb/day with a mean of 157 lb/day. Total lead loading values ranged from 0.012 to 0.151 lb/day with a mean of 0.039 lb/day. Total zinc loading

Table 6. Calculated total and dissolved instantaneous metal loads from Tar Creek Study Segment in Ottawa County, Oklahoma.

[lb/day, pound per day; <, less than; all values smaller than 0.001 are presented as <0.001; and actual values are used in summary statistics; –, value not calculated; E, estimated load due to estimated discharge]

Date sampled	Total			
	Station number 071850825 Tar Creek near Cardin, Okla. (lb/day)	Station number 071850870 Lytle Creek near Cardin, Okla. (lb/day)	Station number 071850875 Tar Creek above Douthat Bridge near Cardin, Okla. (lb/day)	Station number 07185088 Tar Creek near Picher, Okla. (lb/day)
		Cadmium		
8/16/2005	0.002	0.073	0.287	0.391
8/18/2005	0.002	0.001	0.123	0.178
8/20/2005	<0.001	<0.001	0.088	0.117
8/22/2005	<0.001	<0.001	0.088	0.126
8/24/2005	<0.001	<0.001	0.088	0.112
8/26/2005	<0.001	<0.001	0.062	0.102
8/29/2005	<0.001	<0.001	0.067	0.068
max	**0.002**	**0.073**	**0.287**	**0.391**
min	**<0.001**	**<0.001**	**0.062**	**0.068**
mean	**–**	**–**	**0.115**	**0.156**
		Iron		
8/16/2005	0.190	9.37	5.47	174
8/18/2005	0.247	1.09	0.982	184
8/20/2005	0.139	0.10	0.990	156
8/22/2005	0.109	0.04	0.963	153
8/24/2005	0.088	0.05	0.900	149
8/26/2005	0.078	<0.001	0.592	140
8/29/2005	0.071	<0.001	0.432	141
max	**0.247**	**9.37**	**5.47**	**184**
min	**0.071**	**<0.001**	**0.432**	**140**
mean	**0.132**	**1.52**	**1.48**	**157**
		Lead		
8/16/2005	0.003	0.088	0.127	0.151
8/18/2005	0.003	<0.001	0.011	0.030
8/20/2005	0.002	<0.001	0.017	0.033
8/22/2005	0.002	<0.001	0.021	0.019
8/24/2005	0.003	<0.001	0.015	0.018
8/26/2005	<0.001	<0.001	0.008	0.013
8/29/2005	<0.001	<0.001	0.004	0.012
max	**0.003**	**0.088**	**0.127**	**0.151**
min	**<0.001**	**<0.001**	**0.004**	**0.012**
mean	**–**	**–**	**0.029**	**0.039**
		Zinc		
8/16/2005	1.38	510	522	658
8/18/2005	1.70	12.4	62.0	97.4
8/20/2005	0.677	0.956	30	51.1
8/22/2005	0.505	0.167	27.6	58.8
8/24/2005	0.369	0.180	29.1	50.6
8/26/2005	0.297	E0.049	20.1	41.4
8/29/2005	0.262	E0.047	21.2	33.3
max	**1.70**	**510**	**522**	**658**
min	**0.262**	**E0.047**	**20.1**	**33.3**
mean	**0.743**	**73.0**	**102**	**142**

Table 6. Calculated total and dissolved instantaneous metal loads from Tar Creek Study Segment in Ottawa County, Oklahoma.—Continued

[lb/day, pound per day; <, less than; all values smaller than 0.001 are presented as <0.001; and actual values are used in summary statistics; –, value not calculated; E, estimated load due to estimated discharge]

Date sampled	Dissolved			
	Station number 071850825 Tar Creek near Cardin, Okla. (lb/day)	Station number 071850870 Lytle Creek near Cardin, Okla. (lb/day)	Station number 071850875 Tar Creek above Douthat Bridge near Cardin, Okla. (lb/day)	Station number 07185088 Tar Creek near Picher, Okla. (lb/day)
		Cadmium		
8/16/2005	0.002	0.067	0.306	0.401
8/18/2005	0.002	0.001	0.137	0.194
8/20/2005	<0.001	<0.001	0.092	0.118
8/22/2005	<0.001	<0.001	0.090	0.129
8/24/2005	<0.001	<0.001	0.090	0.112
8/26/2005	<0.001	<0.001	0.062	0.100
8/29/2005	<0.001	<0.001	0.063	0.063
max	**0.002**	**0.067**	**0.306**	**0.401**
min	**<0.001**	**<0.001**	**0.062**	**0.063**
mean	**–**	**–**	**0.120**	**0.160**
		Iron		
8/16/2005	0.016	2.56	0.428	161
8/18/2005	0.005	0.534	0.112	172
8/20/2005	0.018	<0.001	0.139	151
8/22/2005	0.019	<0.001	0.113	158
8/24/2005	0.009	<0.001	0.065	149
8/26/2005	0.016	<0.001	0.070	141
8/29/2005	0.011	<0.001	0.079	140
max	**0.019**	**2.56**	**0.428**	**172**
min	**0.005**	**<0.001**	**0.065**	**140**
mean	**0.014**	**–**	**0.144**	**153**
		Lead		
8/16/2005	<0.001	0.005	0.016	0.008
8/18/2005	<0.001	<0.001	0.002	0.001
8/20/2005	<0.001	<0.001	0.001	<0.001
8/22/2005	<0.001	<0.001	0.001	<0.001
8/24/2005	<0.001	<0.001	<0.001	<0.001
8/26/2005	<0.001	<0.001	0.001	<0.001
8/29/2005	<0.001	<0.001	<0.001	<0.001
max	**<0.001**	**0.005**	**0.016**	**0.008**
min	**<0.001**	**<0.001**	**<0.001**	**<0.001**
mean	**–**	**–**	**–**	**–**
		Zinc		
8/16/2005	1.35	510	539	613
8/18/2005	1.62	12.1	66.5	104
8/20/2005	0.692	0.977	33.2	54.0
8/22/2005	0.493	0.175	30.8	52.7
8/24/2005	0.302	0.131	26.9	46.8
8/26/2005	0.291	E0.051	19.7	43.3
8/29/2005	0.256	E0.039	21.4	33.8
max	**1.62**	**510**	**539**	**613**
min	**0.256**	**E0.039**	**19.7**	**33.8**
mean	**0.714**	**74.9**	**105**	**135**

values ranged from 33.3 to 658 lb/day with a mean of 142 lb/day (table 6).

Metals loading to Tar Creek Study Segment from chat leachate were estimated by subtracting loads upstream of the chat pile from loads downstream of the chat pile (fig. 3 and table 7). Total cadmium loading from chat leachate ranged from 0.062 to 0.212 lb/day with a mean of 0.104 lb/day. Total iron loading from chat leachate ranged from <0.001 to 0.814 lb/day. Total lead loading from chat leachate ranged from 0.003 to 0.036 lb/day with a mean of 0.014 lb/day. Total zinc loading from chat leachate ranged from 10.6 to 47.9 lb/day with a mean of 26.2 lb/day (table 7).

Metals loading to Tar Creek Study Segment from mine outflow were estimated by subtracting loads above the confluence with old Lytle Creek from loads below the confluence with old Lytle Creek (fig. 3 and table 7). Total cadmium loading from mine outflow ranged from 0.001 to 0.104 lb/day with a mean of 0.042 lb/day. Total iron loading from mine outflow ranged from 139 to 183 lb/day with a mean of 155 lb/day. Total lead loading from mine outflow ranged from <0.001 to 0.024 lb/day. Total zinc loading from mine outflow ranged from 12.1 to 136 lb/day with a mean of 39.8 lb/day (table 7).

Total metal loads for Tar Creek Study Segment were estimated for the period beginning August 16 and ending August 30 and the percentage from each source calculated (table 8). Four sources of calculated metal loads are from Tar Creek and Lytle Creek entering the study segment, from chat pile leachate, and from mine outflow from old Lytle Creek. About 68 percent of total and dissolved cadmium was from chat leachate and about 26 percent was from mine outflow. About 99 percent of total and dissolved iron loading was from mine outflow. About 51 percent of total lead loading was from chat leachate, about 21 percent from mine drainage, and about 24 percent from Lytle Creek, while about 77 percent of dissolved lead loading was from chat leachate and about 23 percent from Lytle Creek. About 19 percent of total zinc loading was from chat leachate, about 29 percent from mine outflow, and about 52 percent from Lytle Creek (table 8).

An estimate of the metals loading from chat within Tar Creek watershed, which includes Lytle Creek, can be made from loads measured at Tar Creek above Douthat Bridge (071850875). This estimate would be limited to conditions of the study, but would provide an estimated range of daily loading. Prior to chat leachate sampling there was no measurable velocity in Tar Creek at the Kansas/Oklahoma state line. Streamflow measured at Lytle Creek approximately 200 yards south of the state line was less than 0.01 ft^3/s. Therefore, all base flow is presumed to come from chat leachate from state line to the sampling site at Tar Creek. Estimated base flow loading from chat leachate into Tar Creek Study Segment from state line to Tar Creek above Douthat Bridge (071850875) contained substantial amounts of zinc. Estimated median total zinc load was 29.1 lb/day. Iron was next highest metal load with estimated median total iron load of 0.970 lb/day (table 9).

Summary

Picher mining district is an abandoned lead and zinc mining area located in Ottawa County, northeastern Oklahoma. During the first half of the 20th century, the area was a primary producer of lead and zinc in the United States. These minerals were found in the sulfide minerals of Mississippian-age Boone Formation. Ore production in Picher mining district was active from about 1900 until the mid-1970s. Production reached a peak by 1925 with 387,000 tons of recoverable zinc and 101,000 tons of recoverable lead being produced. The mines maintained moderate production levels until the 1950s when yields began to decline.

Large accumulations of gravel- to sand-sized mine tailings, locally referred to as chat, are present throughout the mining area. Ponds of silt- and clay-sized byproducts of the gravity separation process, referred to as mill pond wastes, are generally located adjacent to chat piles. Chat and mill pond wastes contain trace amounts of metals associated with lead and zinc sulfide ores. Leachate from chat and mill pond wastes discharges to drainage areas within the mining area. Mine outflow occurs from several locations in the mining area, from unplugged mine shafts, vent holes, seeps, and abandoned mine dewatering wells. Metals from mine outflow can be a substantial contribution to total metal loading to streams. Information about the amount of metal loading from chat and mine outflow is needed. U.S. Geological Survey in cooperation with Environment Protection Agency, began a study in 2005 to collect water-quality data, characterize flow, and calculate loads of selected metals entering Tar Creek.

Two locations were selected for surface-water sampling: Western location, (29N–23E–19), west of the town of Cardin, and Tar Creek Study Segment, (29N–23E–29 and 32). The Western location contains one sampling site, (071850818). This site is located at a discharge point where a berm around a mill pond has been breached and incised by previous runoff.

Tar Creek Study Segment is a reach of Tar Creek that passes through chat piles from above the confluence with Lytle Creek to Douthat bridge. Tar Creek Study Segment contains four sampling sites, (071850825, 071850870, 071850875, and 07185088). A substantial amount of mine outflow enters Tar Creek just above Douthat bridge from the old Lytle Creek channel. Samples collected at Tar Creek near Picher, Okla., (07185088), represent both leachate from chat piles and mine outflow.

Streamflow measurements and water-quality samples were collected following a rain event August 2005. Samples were analyzed for water properties, dissolved major ions (calcium, magnesium, sodium, potassium, and sulfate), total metals (cadmium, iron, lead, and zinc), and dissolved metals (cadmium, iron, lead, and zinc). Suspended sediment also was analyzed.

Water properties analyzed were: specific conductance, pH, temperature, turbidity, dissolved oxygen, oxidation-reduction potential, and alkalinity.

Table 7. Calculated total and dissolved metal loads from chat leachate and mine outflow to Tar Creek in the Picher mining district in Ottawa County Oklahoma.

[lb/day, pound per day; <, less than]

Date sampled	Total		Dissolved	
	Leachate load (lb/day)	Mine outflow load (lb/day)	Leachate load (lb/day)	Mine outflow load (lb/day)
		Cadmium		
8/16/2005	0.212	0.104	0.237	0.095
8/18/2005	0.120	0.055	0.134	0.057
8/20/2005	0.088	0.029	0.092	0.026
8/22/2005	0.088	0.038	0.090	0.039
8/24/2005	0.088	0.024	0.090	0.022
8/26/2005	0.062	0.040	0.062	0.038
8/29/2005	0.067	0.001	0.063	0
max	**0.212**	**0.104**	**0.237**	**0.095**
min	**0.002**	**0.001**	**0.062**	**0**
mean	**0.104**	**0.042**	**0.110**	**0.040**
		Iron		
8/16/2005	<0.001	168	<.001	160
8/18/2005	<0.001	183	<.001	172
8/20/2005	0.751	155	0.121	151
8/22/2005	0.814	152	0.094	158
8/24/2005	0.762	148	0.056	149
8/26/2005	0.514	139	0.054	141
8/29/2005	0.361	140	0.068	140
max	**0.814**	**183**	**0.121**	**172**
min	**<0.001**	**139**	**<0.001**	**140**
mean	**0.457**	**155**	**–**	**153**
		Lead		
8/16/2005	0.036	0.024	0.011	<.001
8/18/2005	0.008	0.019	0.002	<.001
8/20/2005	0.015	0.016	0.001	<.001
8/22/2005	0.019	<0.001	0.001	<.001
8/24/2005	0.012	0.003	<.001	<.001
8/26/2005	0.008	0.005	0.001	<.001
8/29/2005	0.003	0.008	<.001	<.001
max	**0.036**	**0.024**	**0.011**	**<.001**
min	**0.003**	**<0.001**	**<.001**	**<.001**
mean	**0.014**	**–**	**–**	**<.001**
		Zinc		
8/16/2005	10.6	136	27.6	74.0
8/18/2005	47.9	35.4	52.8	37.5
8/20/2005	28.4	21.1	31.5	20.8
8/22/2005	26.9	31.2	30.1	21.9
8/24/2005	28.6	21.5	26.4	19.9
8/26/2005	19.8	21.3	19.4	23.6
8/29/2005	20.9	12.1	21.1	12.4
max	**47.9**	**136**	**52.8**	**74.0**
min	**10.6**	**12.1**	**19.4**	**12.4**
mean	**26.2**	**39.8**	**29.9**	**30**

Table 8. Total estimated metal load for the 14-day sampling period and percentage from source for the Tar Creek Study Segment, Ottawa County, Oklahoma.

[%, percent; percentages do not add up to 100 due to rounding]

	Total	Dissolved
Cadmium		
Total load (14 days)	2.2	2.3
% from source		
Chat leachate	66.0	68.5
Mine outflow load	27.2	0.5.4
Upper Tar Creek load	0.3	0.3
Lytle Creek load	6.4	5.8
Iron		
Total load (14 days)	2,339	2,290
% from source		
Chat leachate	0.3	0.04
Mine outflow load	98.7	99.7
Upper Tar Creek load	0.08	0.01
Lytle Creek load	0.9	0.2
Lead		
Total load (14 days)	0.73	0.04
% from source		
Chat leachate	50.9	76.7
Mine outflow load	21.3	–
Upper Tar Creek load	3.6	–
Lytle Creek load	24.2	23.2
Zinc		
Total load (14 days)	2,022	1,938
% from source		
Chat leachate	19.1	22.6
Mine outflow lead	28.6	22.9
Upper Tar Creek load	0.5	0.5
Lytle Creek load	51.8	54.0

Table 9. Summary statistics of metal loads and streamflow from Tar Creek above Douthat Bridge, near Cardin, Oklahoma (071850875) sampled from August 16, 2005, to August 29, 2005, in the Picher mining district, Ottawa County, Oklahoma.

[ft^3/s, cubic foot per second; lb/day, pound per day]

Summary statistics	Streamflow (ft^3/s)	Total cadmium (lb/day)	Dissolved cadmium (lb/day)	Total iron (lb/day)	Dissolved iron (lb/day)	Total lead (lb/day)	Dissolved lead (lb/day)	Total zinc (lb/day)	Dissolved zinc (lb/day)
Maximum	1.62	0.287	0.306	5.47	0.428	0.127	0.016	522	539
Minimum	0.188	0.062	0.062	0.432	0.065	0.004	—	20.1	19.7
Mean	0.480	0.114	0.120	1.48	0.143	0.029	—	102	105
Median	0.278	0.088	0.09	0.963	0.112	0.015	—	29.1	30.8

One streamflow measurement was collected on August 16 from runoff at the Western location, (site 071850818). Estimated streamflow at site 071850818 on August 16 was <0.01 cubic foot per second (ft^3/s). Following August 16 flow diminished to levels that could no longer be measured.

Seven streamflow measurements were made at each site in Tar Creek Study Segment. Streamflow measurements were made on August 16, 18, 20, 22, 24, 26, and 29. Measured streamflows within Tar Creek Study Segment ranged from <0.01 to 2.62 ft^3/s. No streamflow measurements were made in Tar Creek Study Segment after August 29 as water levels and streamflow values had returned to pre-event levels.

Metals, with the exception of iron, at the Western location generally were predominate in the dissolved phase. Total cadmium concentration of the sample collected at the Western location, (site 071850818) was 95.3 micrograms per liter (µg/L), dissolved cadmium concentration was 103 µg/L. Total iron concentration was 182 µg/L, while dissolved iron concentration was 47 µg/L. Total and dissolved lead concentrations were 170 and 117 µg/L, respectively. Total zinc concentration was 1,760 µg/L and dissolved zinc concentration was 1,730 µg/L.

Cadmium and zinc at Tar Creek Study Segment generally were predominate in the dissolved phase, while total iron and lead generally were predominate. Total cadmium concentrations of samples collected from Tar Creek Study Segment ranged from 0.83 to 62 µg/L with a mean of 21.18 µg/L. Total iron concentrations ranged from 170 µg/L to 38,000 µg/L with a mean of 7,924 µg/L. Total lead concentrations ranged from 0.50 µg/L to 26.7 µg/L with a mean of 7.68 µg/L. Total zinc concentrations ranged from 1,670 to 59,900 µg/L with a mean of 14,548 µg/L.

No loading values were calculated for the Western location, (site 071850818). Low streamflow value, (<0.01 ft^3/s), indicates that during the sampling period metal load contributions would have been negligible.

Metals loading to Tar Creek Study Segment were calculated based on instantaneous streamflow and metals concentrations. Total cadmium loading to Tar Creek from chat leachate ranged from 0.062 to 0.212 pound per day (lb/day) with a mean of 0.104 lb/day. Total iron loading to Tar Creek from chat leachate ranged from <0.001 to 0.814 lb/day. Total lead loading to Tar Creek from chat leachate ranged from 0.003 to 0.036 lb/day with a mean of 0.014 lb/day. Total zinc loading to Tar Creek from chat leachate ranged from 10.6 to 47.9 lb/day with a mean of 26.2 lb/day.

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