



Prepared in cooperation with the Prairie Band Potawatomi Nation

Water Quality on the Prairie Band Potawatomi Reservation, Northeastern Kansas, June 1996 Through August 2006

Scientific Investigations Report 2007–5201

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

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By Heather C. Ross Schmidt, Heidi E. Mehl, and Larry M. Pope

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**U.S. Department of the Interior
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Conversion Factors, Abbreviations, and Datums

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m ²)
square mile (mi ²)	2.590	square kilometer (km ²)
Flow rate		
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
Weight		
milligram per day (mg/d)	0.0000353	ounce per day (oz/d)
ton (short)	0.9072	megagram (Mg)

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

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32.$$

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

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) / 1.8.$$

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

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).

Water-Quality Abbreviations

col/100 mL	colonies per 100 milliliters of water
<i>E. coli</i>	<i>Escherichia coli</i>
FNU	formazin nephelometric unit
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter at 25 degrees Celsius
meq/L	milliequivalents per liter
mg/L	milligrams per liter
mV	millivolts
NTRU	nephelometric turbidity ratio unit

Acronyms

ANC	acid neutralizing capacity
CaCO ₃	calcium carbonate
COD	chemical oxygen demand
DWA	Drinking-Water Advisory
ELISA	enzyme-linked immunosorbent assay
GC/MS	gas chromatography/mass spectrometry
HCO ₃	bicarbonate
KDHE	Kansas Department of Health and Environment
MCL	Maximum Contaminant Level
NWQL	National Water-Quality Laboratory
OGRL	Organic Geochemistry Research Laboratory
PVC	polyvinyl chloride
RPD	relative percentage difference
SDWR	Secondary Drinking-Water Regulation
SSC	suspended-sediment concentration
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound
YSI	Yellow Springs Instruments, Yellow Springs, Ohio

Water Quality on the Prairie Band Potawatomi Reservation, Northeastern Kansas, June 1996 through August 2006

By Heather C. Ross Schmidt, Heidi E. Mehl, and Larry M. Pope

Abstract

This report describes surface- and ground-water-quality data collected on the Prairie Band Potawatomi Reservation in northeastern Kansas from November 2003 through August 2006 (hereinafter referred to as the “current study period”). Data from this study period are compared to results from June 1996 through August 2003, which are published in previous reports as part of a multiyear cooperative study with the Prairie Band Potawatomi Nation. Surface and ground water are valuable resources to the Prairie Band Potawatomi Nation as tribal members currently (2007) use area streams to fulfill subsistence hunting and fishing needs and because ground water potentially could support expanding commercial enterprise and development.

Surface-water-quality samples collected from November 2003 through August 2006 were analyzed for physical properties, dissolved solids, major ions, nutrients, trace elements, pesticides, fecal-indicator bacteria, suspended-sediment concentration, and total suspended solids. Ground-water samples were analyzed for physical properties, dissolved solids, major ions, nutrients, trace elements, pesticides, and fecal-indicator bacteria. Chemical oxygen demand and volatile organic compounds were analyzed in all three samples from one monitoring well located near a construction and demolition landfill on the reservation, and in one sample from another well in the Soldier Creek drainage basin.

Previous reports published as a part of this ongoing study identified total phosphorus, triazine herbicides, and fecal coliform bacteria as exceeding their respective water-quality criteria in surface water on the reservation. Previous ground-water assessments identified occasional sample concentrations of dissolved solids, sodium, sulfate, boron, iron, and manganese as exceeding their respective water-quality criteria.

Fifty-six percent of the 55 surface-water samples collected during the current study period and analyzed for total phosphorus exceeded the goal of 0.1 mg/L (milligram per liter) established by the U.S. Environmental Protection Agency (USEPA) to limit cultural eutrophication in flowing water. Concentrations of dissolved solids frequently exceeded

the USEPA Secondary Drinking-Water Regulation (SDWR) of 500 mg/L in samples from two sites. Concentrations of sodium exceeded the Drinking-Water Advisory of 20 mg/L set by USEPA in almost 50 percent of the surface-water samples. All four samples analyzed for atrazine concentrations showed some concentration of the pesticide, but none exceeded the Maximum Contaminant Level (MCL) established for drinking water by USEPA of 3.0 µg/L (micrograms per liter) as an annual average. A triazine herbicide screen was used on 55 surface-water samples, and triazine compounds were frequently detected. Triazine herbicides and their degradates are listed on the USEPA Contaminant Candidate List. In 41 percent of surface-water samples, densities of *Escherichia coli* (*E. coli*) bacteria exceeded the primary contact, single-sample maximum in public-access bodies of water (1,198 colonies per 100 milliliters of water for samples collected between April 1 and October 31) set by the Kansas Department of Health and Environment (KDHE).

Nitrite plus nitrate concentrations in all three water samples from 1 of 10 monitoring wells exceeded the MCL of 10 mg/L established by USEPA for drinking water. Arsenic concentrations in all three samples from one well exceeded the proposed MCL of 10 µg/L established by USEPA for drinking water. Boron also exceeded the drinking-water advisory in three samples from one well, and iron concentrations were higher than the SDWR in water from four wells. There was some detection of pesticides in ground-water samples from three of the wells, and one detection of the volatile organic compound diethyl ether in one well. Concentrations of dissolved solids exceeded the SDWR in 20 percent of ground-water samples collected during the current study period, and concentrations of sulfate and chloride exceeded their respective SDWR in 10 percent of the ground-water samples. Concentrations exceeded the Drinking-Water Advisory Level set by USEPA for sodium in 50 percent of the ground-water samples.

Results from the current study period remained similar to results from previous study periods. The median triazine herbicide concentration (triazine screen by ELISA) for the current study period decreased slightly compared to past study

periods. In the event that ground water on the reservation is to be used as a drinking-water source, additional treatment may be necessary to remove excess dissolved solids, sulfate, sodium, and chloride.

Introduction

Water quality is important to the Prairie Band Potawatomi Nation. Three of the four creeks draining the reservation (Soldier, Little Soldier, and South Cedar Creeks) in northeastern Kansas provide fishing and hunting resources for tribal members (fig. 1). Ground water is used as a domestic water supply within the reservation boundaries, and the potential of developing a stable ground-water supply is important as the tribe expands commercial enterprise and development. Establishing a baseline for ground-water quality on the reservation will help identify any potential treatment concerns for this prospective water source (Trombley, 2001). Presently, all drinking water on the reservation is purchased from Rural Water District #3 in Jackson County (Sharon Bosse, Prairie Band Potawatomi Nation Department of Planning and Environmental Protection, oral commun., 2007).

Nonpoint sources such as runoff from agricultural lands and point-source seepage from septic systems or sewage lagoons servicing a rural population are considered to be the primary sources of potential water-quality problems on the reservation (Trombley, 2001). Three documented wastewater facilities (including a sewage-treatment lagoon) are operated by the tribe on the reservation (fig. 1) and are potential sources of point-source wastewater discharge (Sharon Bosse, Prairie Band Potawatomi Nation Department of Planning and Environmental Protection, oral commun., 2006).

Under the Federal Clean Water Act of 1972, an Indian tribe is sovereign for the purposes of delegating the authority to regulate water within reservation boundaries. The Prairie Band Potawatomi Nation, in cooperation with the U.S. Geological Survey (USGS), began a water-quality monitoring program in 1996 with the purpose of establishing water-quality standards for the reservation. The program began as a surface-water assessment focused on nutrients, pesticides, bacteria, and total suspended solids and now includes major ions, dissolved solids, trace elements, and suspended-sediment analysis of surface-water samples as well as the addition of a ground-water-quality monitoring component using dedicated ground-water monitoring wells.

Purpose and Scope

The purpose of this report is to describe surface- and ground-water quality on the Prairie Band Potawatomi Reservation from November 2003 through August 2006 (hereinafter referred to as the “current study period”) and to compare results from this study period to results from June 1996 through August 2003, which are published in previous reports

as part of this ongoing study. Surface-water samples were collected approximately every 3 months from November 2003 through August 2006, and ground-water samples were collected annually in July 2004, July 2005, and August 2006 to describe the distribution of inorganic and organic constituents and bacteria in water on the reservation.

This report is the fourth in a series of reports resulting from the ongoing cooperative study with the Prairie Band Potawatomi Nation. Previous reports describe the surface-water quality on the reservation from June 1996 through November 1998 (Trombley, 1999), the surface- and ground-water quality on the reservation from February 1999 through February 2001 (Trombley, 2001), and the surface- and ground-water quality on the reservation from May 2001 through August 2003 (Schmidt, 2004).

Principal Results from Previous Study Periods

Total phosphorus and triazine herbicide concentrations, and fecal coliform bacteria densities in surface water were identified as exceeding water-quality criteria established by the U.S. Environmental Protection Agency (USEPA) and the Kansas Department of Health and Environment (KDHE) during the June 1996 through November 1998 study period (Trombley, 1999). The same constituents in surface water exceeded water-quality criteria established by USEPA and KDHE during the study period February 1999 through February 2001 (Trombley, 2001). Dissolved solids, sodium, sulfate, boron, iron, and manganese concentrations occasionally exceeded their respective water-quality criteria established by USEPA for drinking water during the February 1999 through February 2001 ground-water assessment and were related to large mineral concentrations resulting from dissolution of the surrounding sedimentary rocks (Trombley, 2001).

During the study period May 2001 through August 2003, 40 percent of surface-water samples exceeded the water-quality goal of 0.10 mg/L established by USEPA for total phosphorus. Triazine herbicides, specifically atrazine, were detected frequently in surface-water samples but did not exceed the USEPA Maximum Contaminant Level (MCL) of 3.0 µg/L for atrazine as an annual average (Schmidt, 2004). Fecal-indicator bacteria were detected in the majority of surface-water samples and exceeded water-quality criteria in 45 samples (12 of 65 exceeded USEPA recommended criterion for *E. coli*; 33 of 36 exceeded USEPA recommended criterion for enterococci). Dissolved-solids concentrations in some surface-water samples exceeded water-quality criteria established by USEPA and were greatest in water samples from Big Elm Creek, at a site located downstream from a sewage-treatment lagoon. Dissolved-solids concentrations exceeded USEPA Secondary Drinking-Water Regulations (SDWRs) in 20 percent of ground-water samples (Schmidt, 2004). Sodium, sulfate, nitrite plus nitrate, and boron concentrations in ground-water samples occasionally exceeded their respective water-quality criteria for drinking water as established by

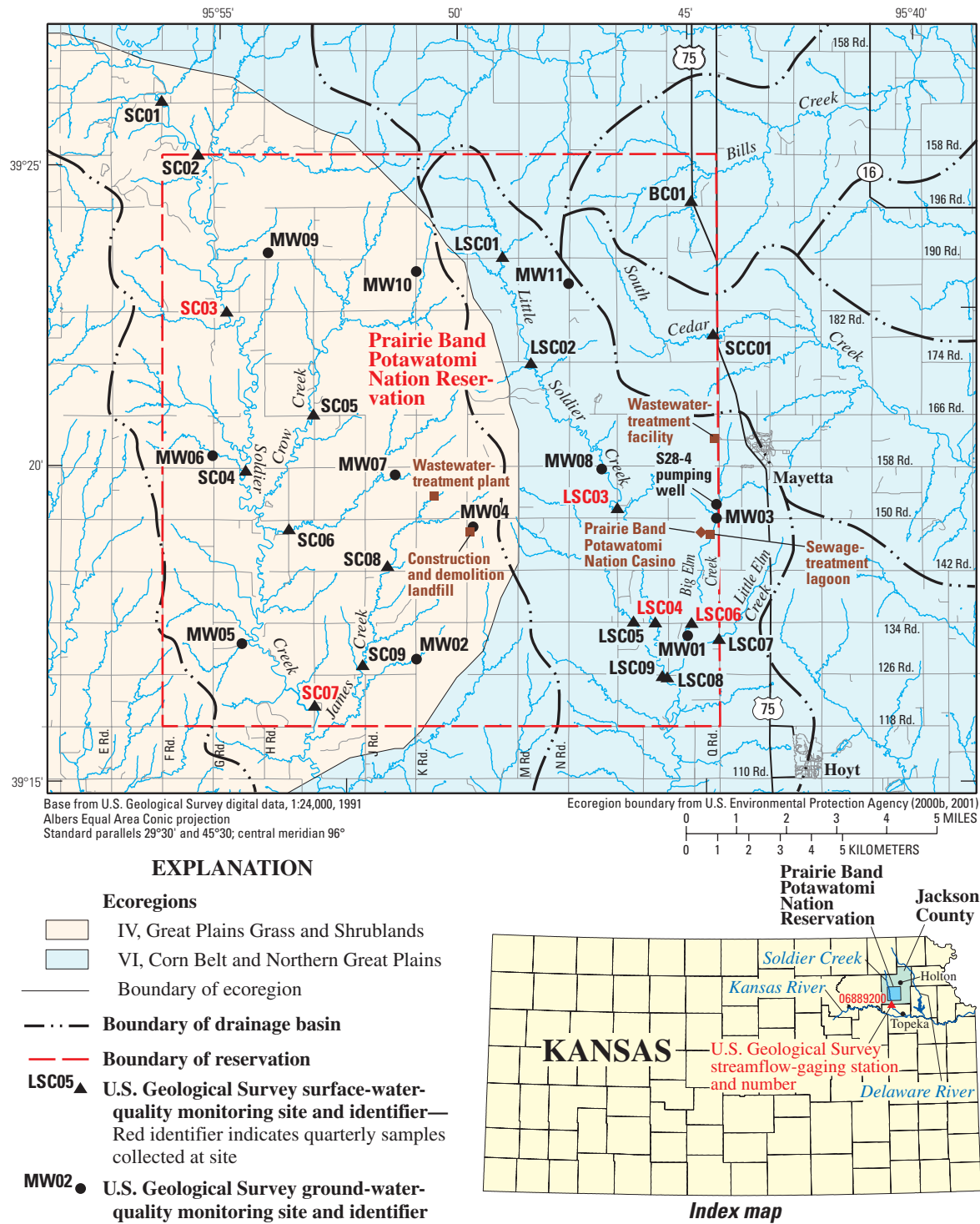


Figure 1. Ecoregions and location of water-quality monitoring sites on and near Prairie Band Potawatomi Reservation, northeastern Kansas.

USEPA. Arsenic concentrations in two ground-water samples exceeded the MCL for arsenic; the largest arsenic concentration also corresponded to the largest iron concentration. Arsenic was detected in other ground-water samples as well but in concentrations that were substantially less than the MCL. Three volatile organic compounds (VOCs) were detected in one ground-water sample; these were carbon disulfide, ethyl methyl ketone, and tetrahydrofuran. The presence of these compounds may be explained by a nearby construction and demolition landfill (fig. 1; Schmidt, 2004).

Description of Study Area

The Prairie Band Potawatomi Reservation is located approximately 20 mi north of the city of Topeka in northeastern Kansas and encompasses approximately 121 mi² of Jackson County (fig. 1). Primary land uses in the two major drainage basins (Soldier and Little Soldier Creek Basins), which comprise about 86 percent of the reservation, are cropland (26 and 27 percent, respectively) and pastureland (68 and 64 percent, respectively) (Kansas Applied Remote Sensing Program, 1993). Cropland is mostly along the streams, and pastureland is in upland areas (table 1, fig. 2).

The Prairie Band Potawatomi Reservation is located within the Kansas Drift Plains section of the Central Lowland Province of the Interior Plains (Fenneman, 1938; Fenneman and Johnson, 1946; Schoewe, 1949). The topography of the Kansas Drift Plains reflects a gently undulating, glacial-drift-dominated, erosional surface. The broad, smooth, well-rounded, interstream areas are remnants of the uneroded original basal till deposited by the last retreating glacial ice sheet. Glacial deposits of boulder till, sand and gravel, silt, and clay lie beneath the erosional surface. A preglacial bedrock valley, buried by glacial deposits, lies along the course of Soldier Creek within the reservation (Dreeszen and Burchett, 1971).

Geologically, the Prairie Band Potawatomi Reservation lies within the stable interior of the North American Continent. Since Precambrian time (about 600 million years ago), most of this part of the continent has undergone gentle upwarp and downwarp of the Earth's crust over large areas. Structurally, this part of the continent is characterized by broad basins and arches, with subtle folding of sedimentary rocks and few major fault zones (Jorgensen and others, 1993). Uppermost bedrock within the reservation consists mostly of limestone and shale of Permian and Pennsylvanian age (about 245 to 320 million years ago) (Walters, 1953). Unconsolidated glacial and stream (alluvial) deposits overlie the erosional surface of sedimentary rocks (fig. 3). The composition of these unconsolidated deposits varies vertically and horizontally and ranges from fine-grained sediment consisting of till, silt, and clay to coarse-grained sediment consisting of sand, gravel, pebbles, cobbles, and boulders (Trombley and others, 1996). The unconsolidated glacial and alluvial deposits are the primary source of ground water on the reservation. Well yields from

Table 1. Drainage area and land-use percentages in Soldier and Little Soldier Creek Basins within the Prairie Band Potawatomi Reservation, northeastern Kansas, 1993.

[Land-use data from Kansas Applied Remote Sensing Program, 1993]

	Soldier Creek Basin	Little Soldier Creek Basin
Drainage area (acres)	43,720	23,090
Land-use classes	Land use (percent)	
Cropland	25.6	27.0
Pastureland	68.5	63.7
Woodland	5.7	8.9
Water	.15	.33
Other	.05	.07

these deposits are largely variable and are generally less than 300 gal/min (Trombley and others, 1996).

The average monthly precipitation received on the Prairie Band Potawatomi Reservation over a 30-year period (1971 through 2000) and the monthly divergence from the average during the current study period (September 2003–August 2006) is shown in figure 4. During the current study period, the amount of precipitation received on the reservation was below the monthly average for 23 out of 36 months (fig. 4). The basin experienced precipitation significantly above average (3 in. or more above the monthly average) in June and October 2005, and August 2006. Precipitation data for the reservation are estimated from data collected near Holton, Kansas (fig. 1) by the High Plains Regional Climate Center (long-term average monthly precipitation) and the National Climatic Data Center (monthly precipitation for September 2003–August 2006). Precipitation data are available on the Web at <http://www.hprcc.unl.edu/> and <http://cdo.ncdc.noaa.gov>, respectively.

The average monthly streamflow in Soldier Creek near Delia (station 06889200, fig. 1) over a 30-year period (1971 through 2000) and the monthly divergence from the average during the current study period (September 2003–August 2006) is shown in figure 5. Streamflow was below average at this Soldier Creek site for most of the current study period (32 out of 36 months). Streamflow was markedly higher than the 30-year average in June and October 2005 (275 and 786 ft³/s, respectively). Low streamflow during the current study period probably affected some water-quality constituents such as suspended-sediment concentration, total suspended solids, and bacteria densities. Streamflow data for the Soldier Creek near Delia gaging station are available on the Web at <http://waterdata.usgs.gov/nwis>.

Months with above-average precipitation amounts generally increased streamflow in Soldier Creek, at least relative to preceding months. However, large precipitation months did not necessarily produce large mean monthly streamflow, relative

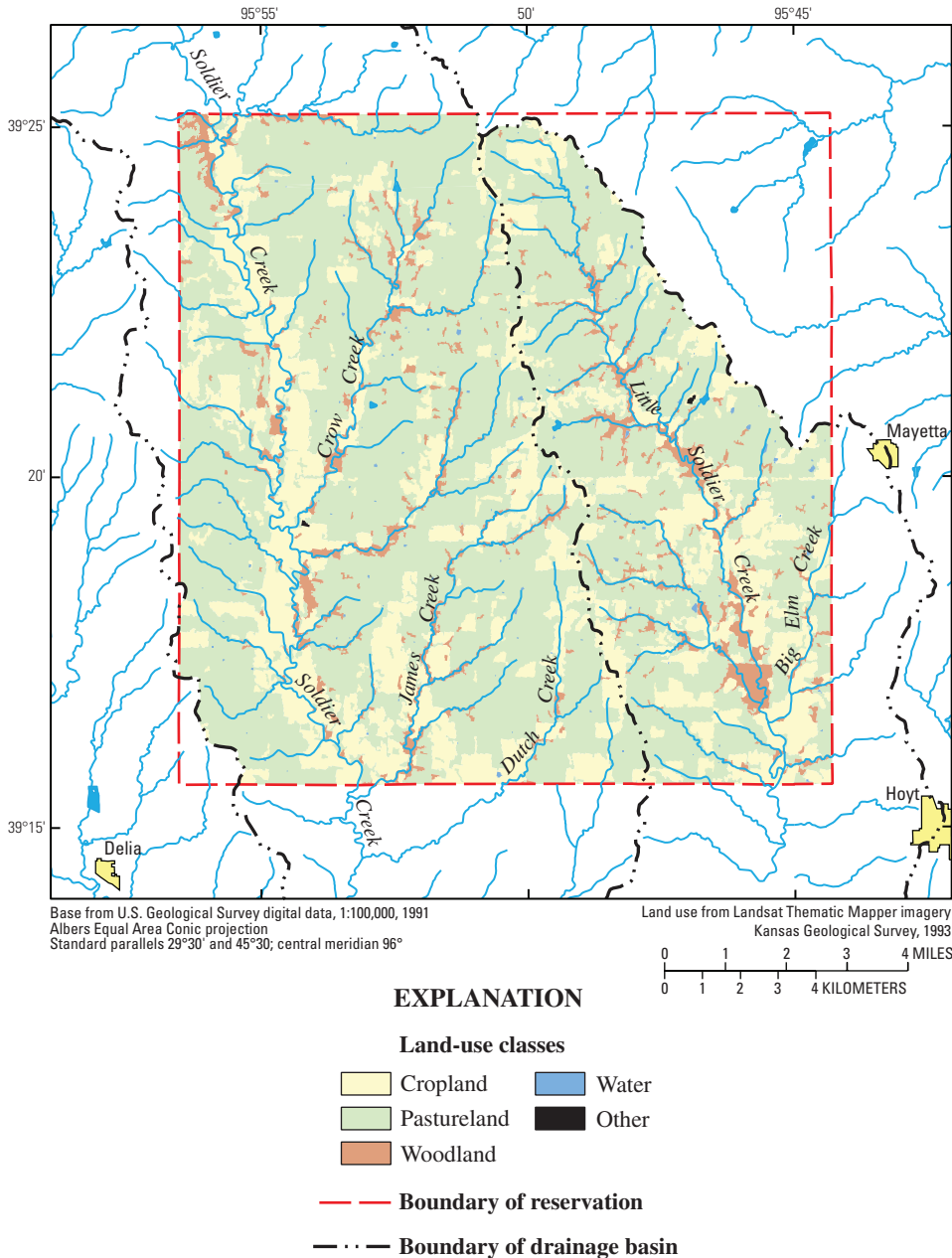


Figure 2. Land use in Soldier and Little Soldier Creek Basins within Prairie Band Potawatomi Reservation, 1993.

to the 30-year average. For example, in August 2006, the total precipitation was 9.32 in. for the month but was split between 11 days. The largest daily total was 2.83 in. on August 26th. Antecedent dry conditions for the four preceding months produced extreme low flow at the site for the first 2 weeks in August. These conditions resulted in an average streamflow for the month that was less than the 30-year average. Similar conditions contributed to lower-than-average streamflow despite above-average precipitation in August 2005.

Methods of Sample Collection and Analysis

Sample Collection

Water samples were collected from surface- and ground-water sites on and near the reservation to assess the quality of the Prairie Band Potawatomi Nation’s water resources. Analyses were performed to identify potential contaminants and treatment concerns. This section describes the sampling sites, methods used to collect samples, analyses performed on the water-quality samples, and quality-assurance and quality-control measures.

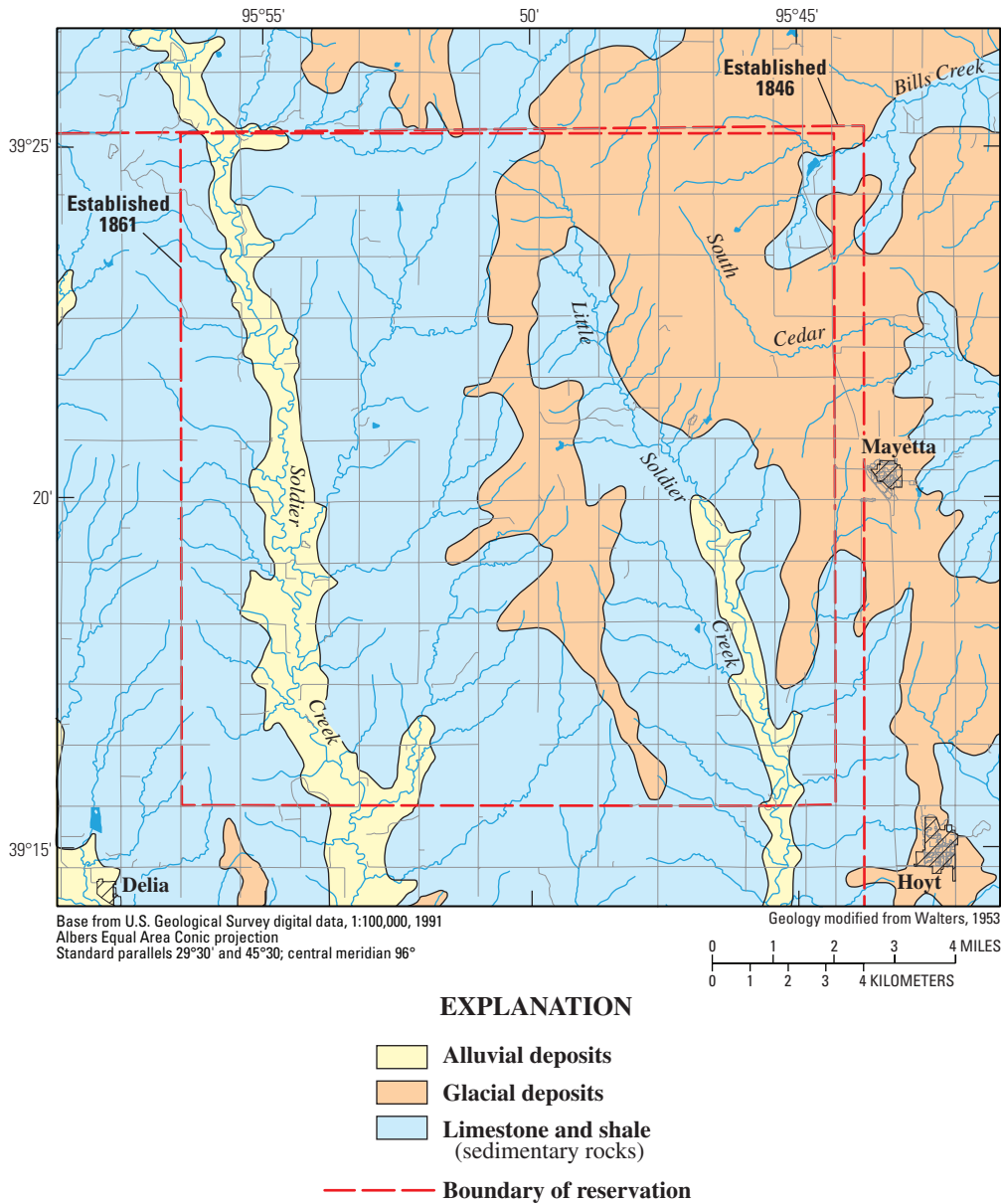


Figure 3. Generalized geology underlying Prairie Band Potawatomi Reservation.

Surface Water

A network of 20 monitoring sites (referred to herein as “synoptic sites”) was established in 1996 to evaluate the spatial and temporal variability of water quality on and near the reservation (fig. 1, table 2). Eighteen of the 20 sites were located within the two major drainage basins on the reservation, Soldier Creek and Little Soldier Creek, which eventually drain into the Kansas River at Topeka (fig. 1). Surface-water-quality sampling sites were spatially distributed across the reservation, representing surface water flowing into and out of the reservation, as well as surface water downstream from potential sources of contamination. Two sites (BC01 and SCC01) were located on streams that flow eastward into the Delaware River. All 20 sites were sampled at least annually

from 1996 to 2001 as part of previous study periods (results from these previous study periods are published in Trombley 1999, 2001; Schmidt, 2004). Six synoptic sampling events were conducted from 1996–2001. The last synoptic sampling event was conducted in June 2001 (Schmidt, 2004). Synoptic sampling is the collection of samples from many locations during a short period of time, typically a few hours.

Since November 1996, a subset of 5 of the 20 surface-water-quality monitoring sites have been sampled approximately quarterly (referred to herein as “quarterly sites”) (fig. 1). Two sites are located on Soldier Creek (sites SC03 and SC07), two are located on Little Soldier Creek (sites LSC03 and LSC04), and one is located on Big Elm Creek (site LSC06) (fig. 1) downstream from a sewage-treatment lagoon in operation on the reservation (Sharon Bosse, Prairie

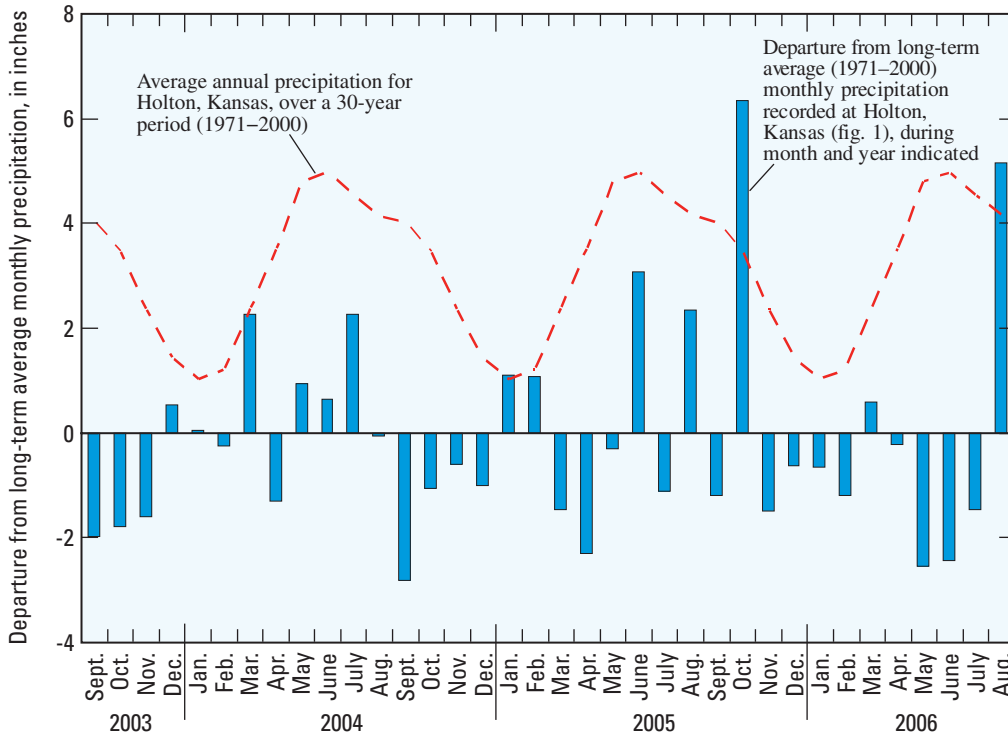


Figure 4. Average monthly precipitation at Holton, Kansas, and departure from average during current study period, September 2003 through August 2006.

Band Potawatomi Nation Department of Planning and Environmental Protection, oral commun., 2006) and approximately 1 mi upstream from its confluence with Little Soldier Creek.

Fifty-five surface-water samples were collected from November 2003 through August 2006. These samples were analyzed for physical properties, dissolved solids, major ions, nutrients, trace elements, pesticides, fecal-indicator bacteria, suspended sediment, and total suspended solids (table 3). Streamflow was measured concurrently with each surface-water-quality sample. Surface-water sampling and streamflow measurement techniques are described in Wilde and others (1999).

Ground Water

Ground-water samples were collected from 11 wells installed in August 2002 and July 2003 and dedicated solely for water-quality-monitoring purposes (fig. 1, table 2). A previous ground-water assessment on the reservation used water collected from domestic and pumping wells (Trombley, 2001). For the current study period, a total of 10 ground-water monitoring wells within the reservation were sampled in July 2004, July 2005, and August 2006. Monitoring well MW05 had been sampled during a previous study period (2003) but was omitted for the current study period because of low water production. Monitoring wells were located to provide a spatial assessment of the ground-water quality across the reservation. The monitoring wells, installed by a private contractor through the Prairie Band Potawatomi Nation, consist of 2-in. polyvinyl chloride (PVC) pipe and are completed at various depths in the local water-bearing formation (table 2) (Gregory Wold,

Prairie Band Potawatomi Nation, Department of Planning and Environmental Protection, oral commun., 2004). Water in these wells is derived from alluvial and glacial deposits of Pleistocene age as well as carbonate deposits of Pennsylvanian age (Walters, 1953).

Ground-water-quality samples were analyzed for physical properties, dissolved solids, major ions, nutrients, trace elements, pesticides, and fecal-indicator bacteria (table 3). Additional analyses for chemical oxygen demand (COD) and volatile organic compounds (VOCs) were completed on all three annual samples from monitoring well MW04 and one annual sample collected from well MW07 in July 2004. Ground-water-quality samples were collected and processed in a mobile water-quality laboratory following ground-water-sampling protocols described in detail in Gibs and Wilde (1999). Each well was purged of at least three well volumes before samples were collected. Well purging was necessary to assure that water samples were representative of aquifer conditions. During the purging period, physical properties of the water (specific conductance, pH, water temperature, dissolved oxygen, oxidation-reduction potential, and turbidity) were observed and recorded every 5 minutes. Water-quality samples were collected after the three-volume purge was complete and physical properties stabilized (Gibs and Wilde, 1999).

After onsite processing, all water-quality samples were chilled to a temperature of 4°C during transport to the USGS laboratory in Lawrence, Kansas. Samples then were processed, preserved, and shipped according to the desired analysis to the USGS National Water-Quality Laboratory (NWQL), Lakewood, Colorado; the Organic Geochemistry Research

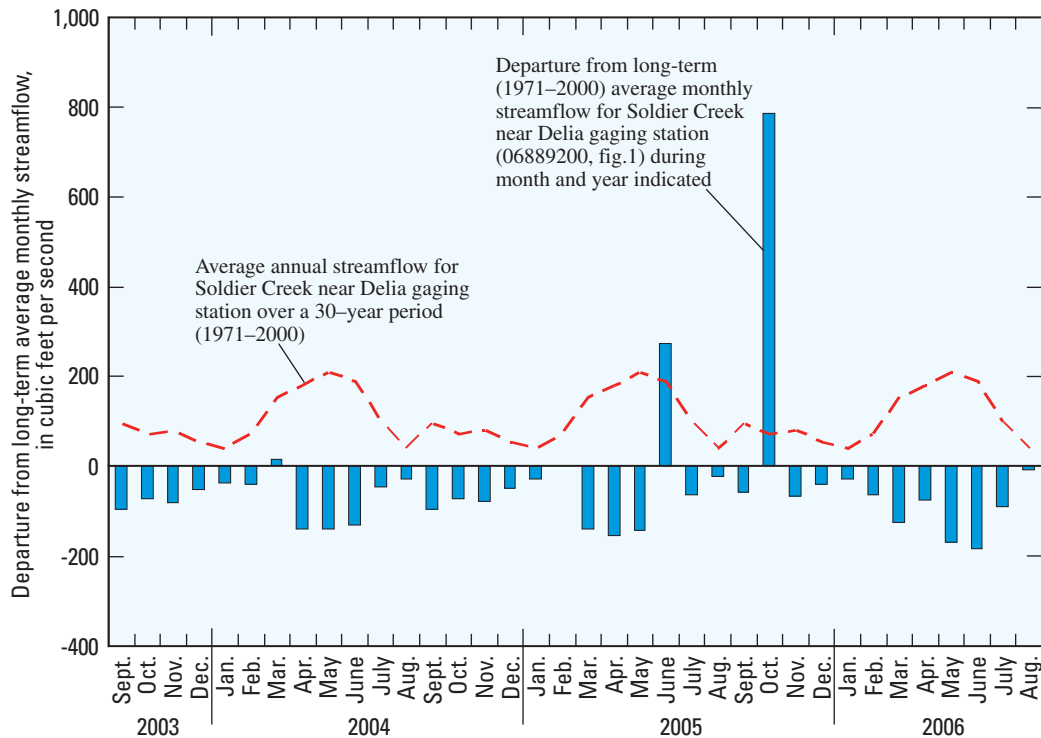


Figure 5. Average monthly streamflow at Soldier Creek near Delia streamflow-gaging station and departure from average during current study period, September 2003 through August 2006.

Laboratory (OGRL), Lawrence, Kansas; and the USGS Sediment Laboratory, Iowa City, Iowa.

Sample Analysis

Water-quality samples were analyzed at NWQL for physical properties, major ions, nutrients, trace elements, COD, and VOCs using methods described in Fishman and Friedman (1989), Zaugg and others (1995), Connor and others (1998), and Jones and Garbarino (1999). Dissolved pesticides, including herbicides and insecticides, were analyzed at OGRL using two different methods. Enzyme-linked immunosorbent assay (ELISA) was used for all surface-water samples to screen for triazine herbicides using procedures described in Thurman and others (1990). Selected surface-water and all ground-water samples were analyzed using gas chromatography/mass spectrometry (GC/MS) for concentrations of selected pesticides using methods described in Kish and others (2000). Suspended-sediment concentrations in surface-water samples were determined at the USGS Sediment Laboratory in Iowa City, Iowa, using methods described in Guy (1977).

Fecal coliform, *Escherichia coli* (*E. coli*), fecal streptococcus, and enterococci indicator bacteria in water samples were processed onsite by USGS or tribal personnel. Bacteria samples were returned to the USGS laboratory in Lawrence, Kansas, to complete incubation and subsequent enumeration of bacteria colonies in each water sample. All bacteria (samples) were processed within 6 hours of collection using

membrane-filtration methods presented in Myers and Wilde (2003). Fecal coliform bacteria were cultured using the mFC method (American Public Health Association and others, 1992), *E. coli* bacteria were cultured using a modified mTec agar (U.S. Environmental Protection Agency, 2002a), and enterococci bacteria were cultured using the mEI method EPA 1600 (U.S. Environmental Protection Agency, 2000a).

Constituents that were detected at concentrations less than minimum laboratory reporting levels and that could be identified are reported as estimated. Estimated concentrations are noted with a remark code of “E” preceding the value in the data tables and should be used with the knowledge that there are increased uncertainties associated with these data (Childress and others, 1999). The remark code “E” also is used in the reporting of bacterial data where calculations to determine concentrations were based on nonideal counts of colonies. Ideal counts are ranges of colony counts that are defined for the individual bacteria types. The maximum limit of the range is established because overcrowding of the colonies inhibits the full growth of individual colonies causing atypical growth and increased errors in counting colonies. The lower limit of the ideal range is set as a number below which statistical validity becomes questionable (Britton and Greeson, 1989).

Quality Assurance and Quality Control

Field blank and replicate samples were collected and analyzed to identify variability in the collection and processing

Table 2. Surface- and ground-water-quality monitoring sites on Prairie Band Potawatomi Reservation, northeastern Kansas.

[--, not determined; *, asterisk indicates quarterly samples collected at site]

Stream basin and site grouping	Monitoring-site identifier (fig. 1)	U.S. Geological Survey site identification number	Local number (township, range, and section) ¹	Site name	Years sampled	Approximate well depth (feet)	Approximate depth of screened interval (feet)	Age of water-bearing formation
Surface-water monitoring sites								
Bills Creek Basin	BC01	392425095445100	7S 15E 28CDD	Bills Creek, U.S. Highway 75 near Holton	2001	--	--	--
Little Soldier Creek Basin	LSC01	3922328095490300	7S 14E 35DCDC	Little Soldier Creek, 190 Road near Mayetta		--	--	--
	LSC02	392143095482700	8S 14E 12CCDD	Little Soldier Creek, 174 Road near Mayetta		--	--	--
	LSC03*	391915095463100	8S 15E 29CCBC	Little Soldier Creek, O Road near Mayetta	1996–2006	--	--	--
	LSC04*	391720095454200	9S 15E 08ABAA	Little Soldier Creek, 134 Road near Mayetta	1996–2006	--	--	--
	LSC05	391721095460900	9S 15E 05CDCD	Little Soldier Creek tributary, 134 Road near Hoyt	1996–2001	--	--	--
Soldier Creek Basin	LSC06*	391720095445400	9S 15E 04CDDD	Big Elm Creek, 134 Road near Hoyt	1996–2006	--	--	--
	LSC07	391704095441700	9S 15E 10BCBB	Little Elm Creek, Q Road near Hoyt	1996–2001	--	--	--
	LSC08	391629095452400	9S 15E 09CCCC	Big Elm Creek, P Road near Hoyt	1996–2001	--	--	--
	LSC09	391628095452800	9S 15E 17AAAA	Little Soldier Creek, 126 Road near Hoyt	1996–2001	--	--	--
	SC01	392603095563000	7S 13E 23BBBB	Soldier Creek, 214 Road near Circleville	1996–2001	--	--	--
	SC02	392512095552800	7S 13E 23DDDD	Soldier Creek tributary, G Road near Circleville	1996–2001	--	--	--
	SC03*	06889180	8S 13E 12BABB	Soldier Creek near Saint Clere	1996–2006	--	--	--
	SC04	391956095544000	8S 13E 25ABAB	Soldier Creek, 158 Road near Saint Clere		--	--	--

Table 2. Surface- and ground-water-quality monitoring sites on Prairie Band Potawatomi Reservation, northeastern Kansas.—Continued

[--, not determined; *, asterisk indicates quarterly samples collected at site]

Stream basin and site grouping	Monitoring-site identifier (fig. 1)	U.S. Geological Survey site identification number	Local number (township, range, and section) ¹	Site name	Years sampled	Approximate well depth (feet)	Approximate depth of screened interval (feet)	Age of water-bearing formation
Surface-water monitoring sites—Continued								
Soldier Creek Basin	SC05	392049095531300	8S 14E 18DDDD	Crow Creek, 166 Road near Saint Clere		--	--	--
	SC06	391852095534500	8S 14E 31BADD	South Branch Soldier Creek, H.5 Road near Saint Clere	1996–2001	--	--	--
	SC07*	391557095531100	9S 14E 17CBBC	Soldier Creek, I Road near Delia	1996–2006	--	--	--
	SC08	391813095513200	8S 14E 33CDDD	James Creek, 142 Road near Delia	1996–2001	--	--	--
	SC09	391630095520800	9S 14E 08DDDD	James Creek, 126 Road near Delia	1996–2001	--	--	--
South Cedar Creek Basin	SCC01	392212095441800	8S 15E 09ADDA	South Cedar Creek, U.S. Highway 75 near Mayetta		--	--	--
Ground-water monitoring sites								
Little Soldier Creek Basin	MW01	391707095445901	09S 15E 09BADCO1	Monitoring well #1	2003–2006	33.5	--	Pleistocene
Soldier Creek Basin	MW02	391644095505601	09S 14E 10CBCCO1	Monitoring well #2	2003–2006	26.0	9–25	Pennsylvanian
Little Soldier Creek Basin	MW03	391907095441901	08S 15E 28DDDDO1	Monitoring well #3	2003–2006	96.5	73–93	Pleistocene
Soldier Creek Basin	MW04	391850095483801	08S 14E 36BCBD01	Monitoring well #4	2003–2006	40.0	10–30	Pleistocene
Do.	MW05	391700095544601	09S 13E 12ACCAO1	Monitoring well #5	2003	22.8	10–20	Pleistocene
Do.	MW06	392010095552301	08S 13E 24CBCCO1	Monitoring well #6	2003–2006	40.1	20–40	Pennsylvanian
Do.	MW07	391948095512201	08S 14E 28ABCAO1	Monitoring well #7	2003–2006	28.6	16–26	Pennsylvanian
Little Soldier Creek Basin	MW08	391955095465301	08S 15E 30ABABO1	Monitoring well #8	2003–2006	37.2	15–35	Pleistocene
Soldier Creek Basin	MW09	392325095542101	08S 13E 01AAABO1	Monitoring well #9	2003–2006	73.7	20–70	Pennsylvanian
Do.	MW10	392315095505801	08S 14E 04AADDO1	Monitoring well #10	2003–2006	41.1	10–40	Pennsylvanian
Little Soldier Creek Basin	MW11	392310095473501	08S 14E 01ADAD01	Monitoring well #11	2003–2006	63.0	15–60	Pleistocene

¹Local numbers are assigned according to a modification of the Bureau of Land Management's system of land subdivision. In this system, the first set of digits in the number refers to the township north (N) or south (S) of the Kansas-Nebraska State line; the second set refers to the range east (E) or west (W) of the sixth principal meridian; and the third set refers to the section in which the site is located. The terminal letters refer to the 160-acre, 40-acre, 10-acre, and 2.5-acre tracts within the section. The letters A, B, C, D are assigned in a counterclockwise direction beginning in the northeast quadrant. For example, the local number 7S 14E 35DCDC indicates a site located in the southwest quarter of the southeast quarter of the southwest quarter of the southeast quarter of sec. 35, T.7 S., R.14 E.

Table 3. Constituents analyzed as part of water-quality assessment on Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.

[Unless otherwise noted, constituents were analyzed in both surface- and ground-water samples; ELISA, enzyme-linked immunosorbent assay]

Physical properties (various units)	
Specific conductance	Hardness
pH	Oxidation-reduction potential (Eh)
Water temperature	Acid neutralizing capacity as CaCO ₃ , field, total ¹
Turbidity	Acid neutralizing capacity as CaCO ₃ , laboratory, total
Oxygen, dissolved	Alkalinity as CaCO ₃ , dissolved ²
Dissolved solids (milligrams per liter)	
Major ions (milligrams per liter)	
Calcium, dissolved	Fluoride, dissolved
Magnesium, dissolved	Silica, dissolved
Sodium, dissolved	Sulfate, dissolved
Potassium, dissolved	Bicarbonate as HCO ₃ , dissolved
Chloride, dissolved	
Nutrients (milligrams per liter)	
Nitrogen, ammonia, dissolved	Nitrogen, nitrite plus nitrate, dissolved
Nitrogen, ammonia plus organic nitrogen, dissolved	Phosphorus, dissolved
Nitrogen, ammonia plus organic nitrogen, total	Phosphorus, total
Nitrogen, nitrite, dissolved	Phosphorus, orthophosphate, dissolved
Trace elements (micrograms per liter)	
Arsenic, dissolved	Iron, dissolved
Selenium, dissolved	Boron, dissolved
Triazine pesticides or metabolites (micrograms per liter)	
Triazine screen (ELISA), dissolved	Flufenacet, dissolved
2-Chloro-4-isopropylamino-6-amino-s-triazine, dissolved	Metolachlor, dissolved
2-Chloro-6-ethylamino-4-amino-s-triazine, dissolved	Pendimethalin, dissolved
Acetochlor, dissolved	Prometon, dissolved
Alachlor, dissolved	Prometryn, dissolved
Ametryn, dissolved	Propachlor, dissolved
Atrazine, dissolved	Propazine, dissolved
Cyanazine amide, dissolved	Simazine, dissolved
Cyanazine, dissolved	Terbutryn, dissolved
Dimethenamid, dissolved	
Other pesticides (micrograms per liter)	
2,6-Diethylaniline, dissolved	Disulfoton, dissolved
2-Hydroxy-4-isopropylamino-6-amino-s-triazine, dissolved	Diuron, dissolved
2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine, dissolved	EPTC, dissolved
2-Hydroxy-6-ethylamino-4-amino-s-triazine, dissolved	Ethoprop, dissolved
alpha-HCH, dissolved	Fluometuron, dissolved
Azinphos-methyl, dissolved	Fonofos, dissolved

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Table 3. Constituents analyzed as part of water-quality assessment on Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[Unless otherwise noted, constituents were analyzed in both surface- and ground-water samples; ELISA, enzyme-linked immunosorbent assay]

Other pesticides (micrograms per liter)—Continued	
Benfluralin, dissolved	Lindane, dissolved
Bromacil, dissolved	Linuron, dissolved
Butylate, dissolved	Malathion, dissolved
Carbaryl, dissolved	Methyl parathion, dissolved
Carbofuran, dissolved	Molinate, dissolved
Chlorodiamino-s-triazine, dissolved	Napropamide, dissolved
Chlorodiamino-s-triazine, dissolved	p,p'-DDE, dissolved
Chlorpyrifos, dissolved	Parathion, dissolved
cis-Permethrin, dissolved,	Pebulate, dissolved
Cyanazine acid, dissolved	Phorate, dissolved
DCPA, dissolved	Pronamide, dissolved
Deethylcyanazine acid, dissolved	Propanil, dissolved
Deethylcyanazine amide, dissolved	Propargite, dissolved
Deethylcyanazine, dissolved	Tebuthiuron, dissolved
Demethylfluometuron, dissolved	Terbacil, dissolved
Diazinon, dissolved	Terbufos, dissolved
Dieldrin, dissolved	Thiobencarb, dissolved
Hydroxysimazine, dissolved	Triallate, dissolved
	Trifluralin, dissolved
Chemical oxygen demand (milligrams per liter) ²	
Volatile organic compounds (micrograms per liter) ²	
Acetone, total	Ethylbenzene, total
Acrylonitrile, total	Ethyl methacrylate, total
Benzene, total	Ethyl methyl ketone, total
Bromobenzene, total	2-Ethyltoluene, total
Bromochloromethane, total	Hexachlorobutadiene, total
Bromodichloromethane, total	Hexachloroethane, total
Bromoethene, total	Iodomethane, total
Bromomethane, total	Isobutyl methyl ketone, total
n- Butylbenzene, total	Isopropylbenzene, total
sec-Butylbenzene, total	4- Isopropyltoluene, total
tert-Butylbenzene, total	Methacrylonitrile, total
tert-Butyl ethyl ether, total	Methyl acrylate, total
n-Butyl methyl ketone, total	Methyl methacrylate, total
Carbon disulfide, total	Methyl tert-butyl ether, total

Table 3. Constituents analyzed as part of water-quality assessment on Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[Unless otherwise noted, constituents were analyzed in both surface- and ground-water samples; ELISA, enzyme-linked immunosorbent assay]

Volatile organic compounds (micrograms per liter) ² —Continued	
Chlorobenzene, total	Methyl tert-pentyl ether, total
Chloroethane, total	Naphtalene, total
Chloromethane, total	n-Propylbenzene, total
3-Chloropropene, total	Styrene, total
2-Chlorotoluene, total	Tetrachloroethane, total
4-Chlorotoluene, total	1,1,1,2-Tetrachloroethane, total
Dibromochloromethane, total	Tetrachloromethane, total
1,2-Dibromoethane, total	Tetrahydrofuran, total
Dibromomethane, total	1,2,3,4-Tetramethylbenzene, total
1,2,-Dibromo-3-chloropropane, total	1,2,3,5-Tetramethylbenzene, total
1,2-Dichlorobenzene, total	Tribromomethane, total
1,3-Dichlorobenzene, total	1,2,3-Trichlorobenzene, total
1,4-Dichlorobenzene, total	1,2,4-Trichlorobenzene, total
Dichlorodifluoromethane, total	Trichloroethene, total
1,1-Dichloroethane, total	1,1,1-Trichloroethane, total
1,2-Dichloroethane, total	1,1,2-Trichloroethane, total
cis-1,2-Dichloroethane, total	Trichlorofluoromethane, total
trans-1,2-Dichloroethane, total	Trichloromethane, total
Dichloromethane, total	1,2,3-Trichloropropane, total
1,2-Dichloropropane, total	1,1,2,2-Trichloro-1,2,2-trifluoroethane, total
1,3-Dichloropropane, total	1,2,3-Trimethylbenzene, total
2,2-Dichloropropane, total	1,2,4-Trimethylbenzene, total
1,1-Dichloropropene, total	1,3,5-Trimethylbenzene, total
cis-1,3-Dichloropropene, total	Toluene, total
trans-1,3-Dichloropropene, total	Vinyl chloride, total
trans-1,4-Dichloro-2-butene, total	m-Xylene plus p-xylene, total
Diethyl ether, total	o-Xylene, total
Diisopropyl ether, total	
Fecal indicator bacteria (colonies per 100 milliliters)	
Fecal coliform bacteria	Fecal streptococcus bacteria
<i>Escherichia coli</i> bacteria	Enterococci bacteria
Sediment (milligrams per liter) ¹	
Suspended-sediment concentration	Total suspended solids

¹Sampled in surface water only.

²Sampled in ground water only.

of water-quality data. Water-quality samples were collected and processed in the field; therefore, field blank samples were collected throughout the study. Field blank samples were collected by passing blank water through the same sampling equipment as the environmental samples and processing the blank sample in the same manner as an environmental sample would be processed. The inorganic and organic blank water used are quality assured by the USGS National Field Supply Services Unit (Denver, Colorado). Quality-assurance data are on file with the USGS office in Lawrence, Kansas, and are available upon request.

The purpose of a field blank sample is to determine the concentrations of the analytes of interest that could be present in the environment in which the samples are collected and processed (Wilde and others, 1999). Field blanks incorporate contamination from all potential sources, including environmental contamination, sample equipment, and laboratory analysis. For the current study period (November 2003 through August 2006) reported herein, one ground-water field blank was collected and analyzed in July 2004 for major ions, nutrients, and selected trace elements. Analytical results of this sample detected small concentrations of calcium (0.02 mg/L), boron (12 µg/L), and iron (estimated at 5 µg/L). All other analyzed constituents were less than reporting levels. These concentrations are small relative to environmental sample results; therefore, equipment and procedures used in collection of ground-water samples for the study period described in this report are environmentally insignificant sources of sample contamination. The field blank sample was not analyzed for pesticides in the 2004 sample; however, a blank sample collected in 2000, during the previous reporting period, was analyzed for pesticides and had no detection of the pesticides listed in table 3. Results from the previous study period, May 2001 through August 2003, indicated similar analytical results in field blank samples relative to the major ions, nutrients, and selected trace elements (Schmidt, 2004).

Replicate samples are a set of samples collected close in time and space. Replicate samples are collected to provide information on the variability introduced from collection, processing, shipping, and laboratory handling and analysis of the sample (Wilde and others, 1999). The current study period used concurrent replicate samples, meaning that two or more samples were collected consecutively from the same place using the same methods and analyzed identically.

The target goal for variability among analyses of replicate samples was a relative percentage difference (RPD) of ± 20 percent except when constituent concentrations were at or near analytical detection limits. RPD was calculated as the difference in replicate analyses divided by the mean and expressed as a percentage.

Thirteen surface-water and three ground-water replicate samples were collected and analyzed during the current study period described in this report. In the analyses of these 16 replicate-sample pairs, only three physical property analyses exceeded the ± 20 percent RPD quality-assurance goal; the largest was a turbidity pair with an RPD of

29 percent collected from well MW09 on August 17, 2006. All replicate analyses for major ions were within the established quality-assurance goal except for replicate surface-water samples collected on May 19, 2004, from site LSC03 (fig. 1). This replicate-sample pair had RPDs for dissolved fluoride, silica, and sulfate, as well as dissolved solids and total suspended solids that exceeded the ± 20 percent RPD goal. These excesses ranged from 24 percent (dissolved solids and total suspended solids) to 33 percent (chloride). The results for this one replicate-sample pair from site LSC03 were examined, but no apparent reason for the relative inconsistent RPDs could be determined.

Nutrient and trace element constituents had replicate-sample RPDs within the ± 20 percent quality-assurance goal except for two instances of dissolved ammonia plus organic nitrogen (23 and 26 percent, respectively) and one instance of dissolved iron (48 percent). Bacteria analyses showed the largest variability between replicate samples of all constituent groups. Among the four bacterial groups or species listed in table 3, a total of 27 paired-replicate analyses of surface-water samples were performed. RPDs for these paired analyses ranged from 0 to 39 percent with 10 (37 percent of the replicates) exceeding the ± 20 -percent quality-assurance goal. This relatively large variability probably is a combination of factors that may include (1) nonrandom distribution of bacteria in surface water and samples of surface water, (2) nonrandom distribution in sample bottles, (3) interferences with colony development during the incubation period (turbidity, nontarget bacteria, water/chemical matrix), and (4) analyst inconsistency in distinguishing and counting target bacteria. However, with the possible exception of bacterial results and the sample of major ions from site LSC03 on May 19, 2004, variability in sample collection and analysis was within acceptable limits.

During the current reporting period, replicate analysis samples for pesticides listed in table 3 were not collected. However, during previous reporting periods (1996–2003), five surface-water replicate samples were collected and analyzed for pesticides. Most of the pesticides listed in table 3 had concentrations less than laboratory reporting levels. Replicate analyses of surface-water samples with concentrations of pesticides greater than laboratory reporting levels generally did not exceed the ± 20 -percent quality-assurance goal, with the exception of one paired analyses of metolachlor and simazine. RPDs for these paired analyses were 23 and 21 percent, respectively. For sampling sites or wells with replicate analyses, analytical results of these paired samples were averaged prior to assessment, presentation, and discussion in this report.

Water Quality on the Prairie Band Potawatomi Reservation

Surface-water-quality samples collected during November 2003 through August 2006 were analyzed for physical properties, dissolved solids, major ions, nutrients, trace

elements, pesticides, fecal-indicator bacteria, suspended-sediment concentration, and total suspended solids. Ground-water samples were analyzed for physical properties, dissolved solids, major ions, nutrients, trace elements, pesticides, and fecal-indicator bacteria. COD and VOCs were analyzed in selected ground-water samples. This section describes the constituents analyzed and the results obtained from sample analysis.

Physical Properties

Physical properties of water include specific conductance, pH, water temperature, turbidity, dissolved oxygen, hardness, oxidation-reduction potential, and acid neutralizing capacity or alkalinity (table 3). Physical properties of surface water were measured onsite with a multiparameter water-quality instrument that determined specific conductance, pH, water temperature, turbidity (YSI 6136 sensor, Yellow Springs Instruments, Yellow Springs, Ohio), and dissolved oxygen. Specific conductance, pH, water temperature, and dissolved oxygen also were measured in ground water with a multiparameter water-quality instrument. Ground-water turbidity was measured with a portable benchtop turbidimeter (HACH 2100AN, Hach Company, Loveland, Colorado). Specific conductance, pH, and turbidity also were measured in all water samples submitted to NWQL. The acid neutralizing capacity of surface-water samples and the alkalinity of ground-water samples were determined onsite through digital titration techniques (HACH digital titrator, Hach Company, Loveland, Colorado), and the acid neutralizing capacity for each sample also was determined in the laboratory.

The health of aquatic life in a stream may be affected by pH, water temperature, dissolved oxygen, and turbidity. Fish and macroinvertebrate species, which some fish depend on as a food source, can be sensitive to changes in pH, dissolved oxygen, and turbidity. The physical properties of a water sample also can provide information about the major ion chemistry of a sample. For example, dissolved major ions (calcium, sodium, chloride, and sulfate) have a tendency to increase specific conductance values (Hem, 1992), which can have implications for drinking-water treatment.

Specific conductance is a measure of the capacity of a sample of water to conduct an electrical current and is associated with the concentration of ionized substances in the water. Therefore, the specific conductance becomes greater as the amount of ionized substances in the water increases (Hem, 1992). The reporting units for specific conductance in this report are microsiemens per centimeter at 25°C ($\mu\text{S}/\text{cm}$).

Onsite specific conductance measurements made at the five quarterly surface-water sites ranged from 172 to 1,170 $\mu\text{S}/\text{cm}$ (table 4). The smallest specific conductance measurement of 172 $\mu\text{S}/\text{cm}$ was recorded at site LSC04 on May 11, 2005, when streamflow was from runoff conditions (189 ft^3/s). The largest specific conductance measurement, 1,170 $\mu\text{S}/\text{cm}$, was recorded at site LSC06 on November 19,

2003, when streamflow was 0.02 ft^3/s . This site is downstream from a discharging sewage-treatment lagoon. Specific conductance measurements may be larger in streams affected by wastewater discharge (Pope and Putnam, 1997).

Specific conductance measurements made onsite in ground water ranged from 460 to 3,030 $\mu\text{S}/\text{cm}$ (table 5). The median onsite specific conductance measurement in ground water was 692 $\mu\text{S}/\text{cm}$. The largest specific conductance was detected in monitoring well MW03, which is the deepest well sampled during the current study period (table 2). Monitoring well MW03 is located next to a pumping well (S28-4, fig. 1) that was sampled during the 1999–2001 study period when water sampled on September 22 and 24, 2000, had onsite specific conductance values of 2,650 and 2,560 $\mu\text{S}/\text{cm}$, respectively (table 7 in Trombley, 2001). These large specific conductance measurements also correspond to the largest concentrations of dissolved solids. The reason for these large values currently (2007) is not known.

The pH of water is a measure of the activity of the hydrogen ion and indicates the degree of acidity or alkalinity of a solution. A pH of less than 7.0 standard units is considered acidic, and a pH greater than 7.0 standard units is considered alkaline. Generally, the pH of natural stream water ranges from 6.0 to 8.5 standard units (Hem, 1992). In water, extremes on the pH scale can stress aquatic organisms in addition to having effects on surface- or ground-water chemistry because water with a smaller pH can have an increased capacity for erosion (Hem, 1992).

The median onsite pH in all surface-water determinations was 8.0 standard units and ranged from 6.8 to 8.3 standard units (table 4). This range is within KDHE freshwater aquatic-life criterion of 6.5 to 8.5 standard units (Kansas Department of Health and Environment, 2001). Onsite pH measurements of ground-water samples from the Prairie Band Potawatomi Reservation ranged from 6.6 to 7.6 standard units, with a median of 7.0 standard units (table 5) and were within the USEPA primary drinking-water criterion (6.5–8.5 standard units) (U.S. Environmental Protection Agency, 2006).

The specific conductance of water, pH, density, solubility of dissolved constituents, rate of chemical reactions, and biological activity in water are all temperature dependent. Water temperature in streams on the reservation ranged from 0.1 to 27.2°C, with a median temperature of 13.0°C, and varied seasonally (table 4). Water temperature in ground water ranged from 13.2 to 17.0°C, with a median temperature of 14.0°C (table 5). The highest ground-water temperature was recorded in well MW11 on July 26, 2004. An open, hand-dug well, with a water-surface depth of about 10 ft below land surface, is located 10 ft from well MW11, and the warmer air temperatures may heat the water in the open well and possibly account for the higher water temperatures in well MW11. The other two samples collected from well MW11 in July 2005 and August 2006 were closer to the median value of the samples collected from all wells.

Turbidity refers to the murkiness of water and is caused by particles or “suspended matter.” Turbidity is measured by

Table 4. Streamflow measurements and results of analysis of physical properties in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.

[ft³/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; YSI, Yellow Springs Instruments Incorporated, Yellow Springs, Ohio; Hach 2100 AN, HACH Company, Loveland, Colorado; FNU, formazin nephelometric units; NTU, nephelometric turbidity ratio units; NTU, nephelometric turbidity unit; mg/L, milligrams per liter; mg/L as CaCO₃, milligrams per liter as calcium carbonate; --, not determined or not applicable; E, estimated; <, less than; >, greater than]

Monitoring site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Streamflow (ft ³ /s)	Specific conductance, onsite (μS/cm)	Specific conductance, laboratory (μS/cm)	pH, onsite (standard units)	pH, laboratory (standard units)	Air temperature (°C)	Water temperature (°C)	Turbidity, onsite (FNU)	Turbidity, laboratory (2100AN (NTRU))	Dissolved oxygen (mg/L)	Total calculated hardness (mg/L as CaCO ₃)	Acid neutralizing capacity, onsite (mg/L as CaCO ₃)	Acid neutralizing capacity, total, laboratory (mg/L as CaCO ₃)
Water-quality criteria															
		--	--	--	--	6.5–8.5	--	--	--	2 6.4, 5.0 NTU	--	3 4.0–5.5	--	--	--
Little Soldier Creek Basin															
LSC03	Little Soldier Creek, O Road near Mayetta	11/19/03	0	--	--	--	--	--	--	--	--	--	--	--	--
		02/25/04	.04	394	419	7.4	7.7	4.0	1.6	20	45	11.5	200	150	150
		05/19/04	41.0	319	339	8.0	7.7	25.5	18.5	100	130	8.3	170	--	150
		08/25/04	3.9	290	303	8.0	7.7	27.0	21.8	110	120	7.6	140	--	130
		12/08/04	.04	667	699	7.8	E7.7	--	3.6	13	15	--	290	--	260
		02/10/05	2.6	499	626	7.9	7.8	-2.0	.6	16	13	11.3	250	--	230
		06/01/05	.66	585	660	7.9	8.1	21.0	18.1	10	9.5	8.0	350	280	310
		08/16/05	.01	719	735	7.5	7.8	24.5	19.2	4.8	10	5.0	360	340	160
		11/09/05	.59	757	778	8.0	7.4	13.0	10.5	2.2	<2.0	9.8	400	360	260
		02/22/06	.55	868	892	4 --	8.0	--	.7	.90	<2.0	14.6	450	400	340
		06/06/06	.26	569	542	7.4	8.1	30.0	26.2	8.1	9.5	9.4	260	260	270
		08/02/06	0	--	--	--	--	--	--	--	--	--	--	--	--
LSC04	Little Soldier Creek, 134 Road near Mayetta	11/19/03	0	--	--	--	--	--	--	--	--	--	--	--	--
		02/25/04	.12	336	361	7.4	7.7	0	1.0	20	23	13.0	170	120	130
		05/19/04	73.0	268	274	8.0	E7.2	24.5	18.1	280	250	8.5	130	--	130
		08/25/04	6.7	243	247	8.0	7.8	25.0	21.8	210	210	7.6	120	--	120
		12/08/04	.07	485	519	8.1	8.0	0	1.9	11	8.0	11.0	230	--	230

Table 4. Streamflow measurements and results of analysis of physical properties in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[ft³/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; YSI, Yellow Springs Instruments Incorporated, Yellow Springs, Ohio; Hach 2100 AN, HACH Company, Loveland, Colorado; FNU, formazin nephelometric units; NTRU, nephelometric turbidity ratio units; NTU, nephelometric turbidity unit; mg/L, milligrams per liter; mg/L as CaCO₃, milligrams per liter as calcium carbonate; --, not determined or not applicable; E, estimated; <, less than; >, greater than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Stream-flow (ft ³ /s)	Specific conductance, onsite (μS/cm)	Specific conductance, laboratory (μS/cm)	pH, onsite (standard units)	pH, laboratory (standard units)	Air temperature (°C)	Water temperature (°C)	Turbidity, onsite, YSI 6136 (FNU)	Turbidity, laboratory, Hach 2100AN (NTRU)	Dissolved oxygen (mg/L)	Total calculated hardness (mg/L as CaCO ₃)	Acid neutralizing capacity, onsite (mg/L as CaCO ₃)	Acid neutralizing capacity, laboratory (mg/L as CaCO ₃)
Little Soldier Creek Basin—Continued															
LSC04	Little Soldier Creek, 134 Road near Mayetta	02/10/05	3.8	487	505	8.0	7.7	--	0.1	21	19	11.4	250	--	220
		05/11/05	189	172	154	8.0	7.3	--	17.4	>1,500	3,600	7.8	61	--	82
		08/16/05	.03	456	482	8.0	7.7	23.5	19.5	7.7	10	7.5	230	210	190
		11/09/05	.86	730	758	7.8	7.8	11.0	10.7	4.6	4.6	8.5	380	370	280
		02/22/06	.48	794	851	4--	7.8	.8	.3	2.3	<2.0	14.6	420	382	312
		06/06/06	.28	585	585	7.3	8.0	25.6	20.8	26	29	6.5	280	290	280
		08/02/06	0	--	--	--	--	--	--	--	--	--	--	--	--
LSC06	Big Elm Creek, 134 Road near Hoyt	11/19/03	.02	1,170	1,200	7.8	7.9	-1.0	4.9	.90	3.2	8.9	300	220	220
		02/25/04	.21	1,095	1,140	6.8	8.2	-1.0	.3	7.7	11	13.1	300	200	190
		05/19/04	26.0	278	282	7.9	7.4	21.0	17.9	280	280	8.5	110	--	100
		08/25/04	1.8	433	450	8.0	E7.6	26.0	22.1	23	24	7.6	150	--	130
		12/08/04	.30	786	850	8.1	8.0	-2.5	2.2	5.1	4.8	12.4	250	--	210
		02/10/05	.99	842	872	7.7	E7.6	--	.1	8.5	7.8	11.1	310	--	230
		06/01/05	.49	768	816	7.8	8.2	19.0	17.1	.80	20	8.4	320	230	250
		08/16/05	.10	848	875	7.6	8.1	23.0	19.1	.20	3.2	7.6	270	210	220
		11/09/05	.21	814	844	8.0	7.7	9.0	9.2	<.10	2.7	10.5	380	320	220
		02/22/06	.32	1,120	1,160	4--	7.8	--	.1	4.6	3.0	11.8	370	280	280

Table 4. Streamflow measurements and results of analysis of physical properties in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[ft³/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; YSI, Yellow Springs Instruments Incorporated, Yellow Springs, Ohio; Hach 2100 AN, HACH Company, Loveland, Colorado; FNU, formazin nephelometric units; NTU, nephelometric turbidity ratio units; NTU, nephelometric turbidity unit; mg/L, milligrams per liter; mg/L as CaCO₃, milligrams per liter as calcium carbonate; --, not determined or not applicable; E, estimated; <, less than; >, greater than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Stream-flow (ft ³ /s)	Specific conductance, onsite (μS/cm)	Specific conductance, laboratory (μS/cm)	pH, onsite (standard units)	pH, laboratory (standard units)	Air temperature (°C)	Water temperature (°C)	Turbidity, onsite, YSI 6136 (FNU)	Turbidity, laboratory, Hach 2100AN (NTRU)	Dissolved oxygen (mg/L)	Total calculated hardness (mg/L as CaCO ₃)	Acid neutralizing capacity, onsite (mg/L as CaCO ₃)	Acid neutralizing capacity, laboratory (mg/L as CaCO ₃)
Little Soldier Creek Basin—Continued															
LSC06	Big Elm Creek, 134 Road near Hoyt	06/06/06 08/02/06	0.42 0	742 --	700 --	7.4 --	8.2 --	24.0 --	20.1 --	2.4 --	3.2 --	8.0 --	250 --	230 --	220 --
Soldier Creek Basin															
SC03	Soldier Creek near Saint Clere	11/19/03 02/25/04 05/19/04 08/25/04 12/08/04	1.0 10.0 84.0 7.1 3.3	848 496 447 585 827	871 529 477 658 883	8.1 7.5 8.0 8.0 8.2	8.0 7.8 7.7 8.0 8.1	12.0 6.5 27.5 28.0 --	6.8 1.9 20.4 24.7 2.9	3.6 2.9 120 49 7.9	4.2 31 150 48 6.6	10.0 -- 7.8 7.3 12.9	460 260 230 320 430	270 170 -- -- --	100 170 200 200 220
		02/10/05 06/01/05 08/16/05 11/09/05 02/22/06	9.6 6.7 1.6 4.8 3.9	621 692 654 762 830	635 713 687 786 863	8.3 8.0 7.9 8.1 4--	8.0 8.1 7.9 7.9 7.8	5.0 25.0 -- 15.0 8.0	.6 20.3 22.8 11.2 1.5	11 33 11 3.1 2.7	9.9 33 15 4.0 <2.0	13.7 9.1 10.5 13.5 15.6	320 360 350 400 430	-- 230 230 290 280	240 190 190 200 250
		06/06/06 08/02/06	4.0 .23	768 627	794 628	7.7 4--	8.2 8.1	28.0 32.1	23.0 26.8	23 28	24 34	8.1 5.1	380 280	280 240	270 240
SC07	Soldier Creek, I Road near Delia	11/19/03 02/25/04 05/19/04	1.8 15.0 173	723 433 347	746 452 370	8.2 7.7 8.0	7.9 7.9 7.8	14.0 8.5 --	8.1 3.1 20.5	3.8 38 260	5.4 54 290	10.2 13.0 7.7	350 210 180	280 140 --	150 150 170

Table 4. Streamflow measurements and results of analysis of physical properties in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[ft³/s, cubic feet per second; μ S/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; YSI, Yellow Springs Instruments Incorporated, Yellow Springs, Ohio; Hach 2100 AN, HACH Company, Loveland, Colorado; FNU, formazin nephelometric units; NTRU, nephelometric turbidity ratio units; NTU, nephelometric turbidity unit; mg/L, milligrams per liter; mg/L as CaCO₃, milligrams per liter as calcium carbonate; --, not determined or not applicable; E, estimated; <, less than; >, greater than]

Monitoring site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Streamflow (ft ³ /s)	Specific conductance, onsite (μ S/cm)	Specific conductance, laboratory (μ S/cm)	pH, onsite (standard units)	pH, laboratory (standard units)	Air temperature (°C)	Water temperature (°C)	Turbidity, onsite, YSI 6136 (FNU)	Turbidity, laboratory, Hach 2100AN (NTRU)	Dissolved oxygen (mg/L)	Total calculated hardness (mg/L as CaCO ₃)	Acid neutralizing capacity, onsite (mg/L as CaCO ₃)	Acid neutralizing capacity, laboratory (mg/L as CaCO ₃)
Soldier Creek Basin—Continued															
SC07	Soldier Creek, I Road near Delia	08/25/04	23.0	376	426	8.1	8.0	32.5	24.7	68	69	7.3	200	--	160
		12/08/04	5.0	712	743	8.3	8.1	11.0	4.7	13	9.5	12.8	360	--	260
		02/10/05	23.0	599	623	8.2	8.0	2.0	0.9	29	28	12.3	310	--	230
		06/01/05	10.0	612	683	8.2	8.2	--	22.7	38	38	9.8	330	250	240
		08/16/05	3.9	578	599	8.2	7.9	28.5	22.3	23	28	9.0	280	200	210
		11/09/05	13.0	728	750	8.3	7.9	13.1	12.7	7.1	6.5	14.3	360	320	260
		02/22/06	6.7	806	819	4 --	7.9	11.4	3.7	3.3	2.1	18.4	410	450	270
		06/06/06	7.4	676	701	7.9	8.4	30.0	27.1	44	49	8.8	320	270	260
		08/02/06	.26	520	522	4 --	8.1	31.0	27.2	29	37	5.8	220	200	210

¹ Water-quality criteria established by the Kansas Department of Health and Environment (2001) for protection of aquatic life.

² Water-quality criteria established by U.S. Environmental Protection Agency (2001; 2006) for the protection of surface water in ecoregion IV and finished drinking water, respectively.

³ Water-quality criteria established by U.S. Environmental Protection Agency (1986) in support of freshwater aquatic life for warm-water species.

⁴ Value was determined to be erroneous due to equipment malfunction and was deleted from this data set.

Table 5. Results of analysis of physical properties in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.

[$\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; $^{\circ}\text{C}$, degrees Celsius; NTRU, nephelometric turbidity ratio units; NTU, nephelometric turbidity unit; mg/L , milligrams per liter; mg/L as CaCO_3 , milligrams per liter as calcium carbonate; mV, millivolts; --, not determined or not applicable; \leq , less than or equal to; $<$, less than; E, estimated]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Specific conductance, onsite ($\mu\text{S}/\text{cm}$)	Specific conductance, laboratory ($\mu\text{S}/\text{cm}$)	pH, onsite (standard units)	pH, laboratory (standard units)	Air temperature ($^{\circ}\text{C}$)	Water temperature ($^{\circ}\text{C}$)	Turbidity, onsite, Hach 2100P turbidity meter (NTRU)	Turbidity, laboratory, Hach 2100AN (NTRU)	Dissolved oxygen (mg/L)	Total calculated hardness, water, (mg/L as CaCO_3)	Oxidation-reduction potential (mV relative to a standard hydrogen electrode)	Alkalinity, water, filtered, incremental titration, onsite, (mg/L as CaCO_3)	Acid neutralizing capacity, total, laboratory, (mg/L as CaCO_3)
≤ 5 NTU															
6.5–8.5															
MW01	Monitoring well #1	7/28/2004 7/11/2005 8/16/2006	699 658 655	674 618 652	7.2 7.2 7.1	7.2 7.3 7.4	26.5 30.0 32.5	13.7 13.5 13.7	0.36 .54 2.3	8.0 12 8.0	0.11 .14 .10	330 320 280	110 110 110	280 260 270	210 150 270
MW02	Monitoring well #2	7/27/2004 7/11/2005 8/15/2006	476 460 509	470 428 511	6.8 6.9 6.8	6.9 7.0 7.2	-- 34.0 33.5	15.1 14.3 14.6	1.1 .22 5.5	<2.0 <2.0 3.6	.13 .19 .72	230 240 240	250 250 250	220 240 250	160 140 250
MW03	Monitoring well #3	7/26/2004 7/12/2005 8/15/2006	2,940 2,770 3,030	2,880 2,740 3,020	6.9 7.1 7.0	7.0 7.0 7.2	36.0 31.0 29.5	14.5 14.2 14.4	1.8 .52 .99	41 35 41	.14 .13 .94	1,100 1,100 1,100	110 30 110	320 330 300	220 190 310
MW04	Monitoring well #4	7/29/2004 7/14/2005 8/16/2006	677 646 661	654 630 653	7.2 6.6 7.6	7.6 7.4 7.6	-- 32.0 27.5	13.6 14.0 13.6	860 320 --	490 220 26	8.3 8.1 9.5	250 250 230	E430 510 450	300 300 310	330 280 320
MW06	Monitoring well #6	7/29/2004 7/13/2005 8/14/2006	767 753 771	756 711 768	7.1 7.1 6.9	7.1 7.1 7.1	23.5 29.0 24.0	14.1 14.2 14.4	.99 .45 1.4	44 42 62	.15 .17 1.7	400 390 390	100 130 110	390 370 390	240 280 380
MW07	Monitoring well #7	7/27/2004 7/13/2005 8/15/2006	585 564 574	575 534 576	7.1 7.2 7.0	7.3 7.3 7.5	-- -- 30.5	13.4 13.5 14.0	3.1 3.1 2.4	8.0 <2.0 <2.0	0.17 .29 1.3	310 310 300	210 220 200	310 290 300	200 220 310

¹ Primary drinking-water criteria

Table 5. Results of analysis of physical properties in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.—Continued

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Specific conductance, onsite ($\mu\text{S}/\text{cm}$)	Specific conductance, laboratory ($\mu\text{S}/\text{cm}$)	pH, onsite (standard units)	pH, laboratory (standard units)	Air temperature ($^{\circ}\text{C}$)	Water temperature ($^{\circ}\text{C}$)	Turbidity, onsite, Hach 2100P turbidity meter (NTRU)	Turbidity, laboratory, Hach 2100AN (NTRU)	Dissolved oxygen (mg/L)	Total calculated hardness, water (mg/L as CaCO_3)	Oxidation-reduction potential (mV relative to a standard hydrogen electrode)	Alkalinity, water, filtered, incremental titration, onsite (mg/L as CaCO_3)	Acid neutralizing capacity, total, laboratory (mg/L as CaCO_3)
MW08	Monitoring well #8	7/27/2004	836	827	6.9	7.1	28.0	13.5	.83	<2.0	.68	430	230	380	220
		7/12/2005	858	810	6.9	7.0	31.0	13.4	1.9	<2.0	1.0	470	260	380	190
		8/14/2006	856	880	6.8	7.1	25.0	13.7	2.6	<2.0	1.2	450	230	400	410
MW09	Monitoring well #9	7/29/2004	493	533	7.4	7.4	--	14.8	4.5	3.1	11.2	300	320	280	160
		7/14/2005	530	496	7.4	7.5	29.5	14.8	3.9	<2.0	8.1	290	460	270	150
		8/17/2006	541	546	7.3	7.7	30.5	13.9	>1,000	170	9.8	280	390	280	270
MW10	Monitoring well #10	7/28/2004	683	677	7.1	7.3	28.0	15.0	7.2	4.0	5.7	370	350	300	170
		7/14/2005	665	670	7.2	7.2	29.0	14.8	5.1	9.7	4.0	360	470	290	180
		8/16/2006	685	683	7.0	7.3	33.5	15.6	6.6	2.4	4.6	330	400	300	310
MW11	Monitoring well #11	7/26/2004	813	773	7.0	7.5	--	17.0	E190	220	1.7	400	270	320	300
		7/14/2005	799	754	6.7	7.4	32.5	13.4	92	71	3.5	370	480	320	260
		8/18/2006	795	817	7.0	7.3	--	13.2	220	240	2.0	390	260	360	380

¹Primary drinking-water criteria established by the U.S. Environmental Protection Agency (2006).

[$\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; $^{\circ}\text{C}$, degrees Celsius; NTRU, nephelometric turbidity ratio units; NTU, nephelometric turbidity unit; mg/L, milligrams per liter; mg/L as CaCO_3 , milligrams per liter as calcium carbonate; mV, millivolts; --, not determined or not applicable; \leq , less than or equal to; <, less than; E, estimated]

quantifying the amount of light scattered by particles in the water. In this report, turbidity is described using three different units of measurement—formazin nephelometric units (FNU), nephelometric turbidity units (NTUs), and nephelometric turbidity ratio units (NTRUs). These three turbidity units are not comparable and should be differentiated (Ziegler, 2002). Some suspended matter that causes turbidity in water is known to be harmful and includes lead, bacteria, viruses, and protozoan cysts such as *Giardia* and *Cryptosporidium*. Turbidity also can interfere with the disinfection of drinking water (Anderson, 2005).

The water-quality criteria for turbidity in finished drinking water established by USEPA state that at no time can turbidity in finished drinking water exceed 5 NTU, and filtration systems must ensure that turbidity in finished drinking water does not exceed 1 NTU in at least 95 percent of daily turbidity samples (U.S. Environmental Protection Agency, 2006). USEPA also has established water-quality criteria for onsite turbidity in streams and rivers according to ecoregions. An ecoregion is defined as an area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables (U.S. Environmental Protection Agency, 2001). The Prairie Band Potawatomi Reservation is located just north of the convergence of three of USEPA's defined Level III ecoregions. These are ecoregion IV, Great Plains Grass and Shrublands; ecoregion VI, Corn Belt and Northern Great Plains; and ecoregion IX, Southeastern Temperate Forested Plains and Hills (U.S. Environmental Protection Agency, 2000 b,c; 2001). Ecoregions IV and VI converge within reservation boundaries (fig. 1). Each ecoregion is assigned a unique turbidity criterion; the largest turbidity criterion on the reservation is assigned to ecoregion IV and is 6.4 NTU (U.S. Environmental Protection Agency, 2001). Turbidity was measured onsite with a YSI 6136 turbidity sensor (Yellow Springs Instruments Incorporated, Yellow Springs, Ohio).

Onsite turbidity measurements in the streams ranged from less than 0.10 to greater than 1,500 FNU (table 4). The largest onsite turbidity was measured in Little Soldier Creek at 134 Road near Mayetta (site LSC04) on May 11, 2005. This sample was collected during runoff when streamflow was 189 ft³/s, the largest streamflow measured during sample collection (1996–2006) since a sample collected at 3,050 ft³/s from site SC03 on June 22, 1999 (Trombley, 2001). Turbidity was not measured during the 1999 sampling period. The median turbidity concentration for all sites was 13 FNU, and 70 percent of turbidity measurements exceeded the water-quality criterion of 6.4 NTU for ecoregion IV. Turbidity samples also were collected and analyzed by NWQL using a HACH 2100 AN in differential mode (HACH Company, Loveland, Colorado). These measurements ranged from less than 2 to 3,600 NTRU (table 4). The largest laboratory turbidity for a surface-water sample also was collected at site LSC04 on May 11, 2005. The difference between the two values demonstrates the limits of the onsite sensors to record high turbidity values. The maximum detection limit for a YSI 6136 is

1,500 NTU, but the turbidity for this sample was much larger and would have been underestimated if not for the laboratory sample.

Onsite turbidity measurements in ground water were made using a HACH 2100 P turbidimeter (HACH Company, Loveland, Colorado). Turbidity also was measured in the laboratory by a HACH 2100 AN turbidimeter. Onsite turbidity concentrations in ground-water samples ranged from 0.22 to greater than 1,000 NTRU. The largest onsite turbidity was measured in a sample from well MW09 collected on August 17, 2006 (table 5). However, the corresponding laboratory value is much less (170 NTRU). Larger turbidity values occurred in water from wells that had slow recovery rates during pumping and were difficult to sample with the submersible pump. Water sampled from wells MW04 and MW11 also had large turbidity values.

The concentration of dissolved oxygen in surface water is related to atmospheric reaeration, photosynthetic activity of aquatic plants, temperature, and salinity of the water (Radtke and others, 1998). Dissolved oxygen contributes to chemical reactions in water and in the survival of aquatic organisms. USEPA has established a freshwater aquatic-life support standard of not less than 5.0 mg/L and a mean of 6.5 mg/L for cold water (defined as water containing one or more species of the family Salmonidae or other cold-water species), and a minimum of 4.0 mg/L and a mean of 5.5 mg/L for warm water (level set to protect early-life stages of warm-water fish species as sensitive as channel catfish and other life stages of species such as the largemouth bass) (U.S. Environmental Protection Agency, 1986). Surface water on the reservation is considered to be warm water.

Dissolved oxygen concentrations in ground water are one indicator of the oxidation-reduction (redox) environment of the aquifer in the vicinity of the monitoring well. Oxygen is supplied to ground water through recharge and by movement of air through the unsaturated zone above the water table. As the oxygen moves through the system it reacts with oxidizable material. Measurable amounts of dissolved oxygen in ground water may persist for long distances if little reactive material is available along the flow path (Hem, 1992).

Onsite dissolved oxygen measurements in surface water collected during the current study period ranged from 5.0 to 18.4 mg/L (table 4), which are above the minimum water-quality criterion (4.0 mg/L for warm-water aquatic life). The median dissolved oxygen concentration for surface water was 9.4 mg/L. Dissolved oxygen concentrations in ground water ranged from 0.10 to 11.2, with a median concentration of 1.2 mg/L. The largest dissolved oxygen concentrations in ground water were detected in monitoring wells MW04 and MW09 (table 5). About one-half of the wells showed consistently anoxic (oxygen-depleted) conditions, which may affect certain activities such as the rate of biodegradation of VOCs.

Hardness is a characteristic of water that causes an increase in soap consumption in water used for cleaning. The presence of calcium as well as magnesium (discussed in the section on "Major Ions") contributes to the "hardness"

of water. Hard water is typical in regions largely dominated by carbonate rocks (limestone and shale) at the land surface and causes increased expense in water treatment as well as sometimes requiring further treatment by consumers in the form of water softeners. The hardness of water is computed by multiplying the sum of milliequivalents per liter (meq/L) of calcium and magnesium by 50. The resulting hardness value is expressed as “hardness as calcium carbonate (CaCO_3)” (Hem, 1992). Milligrams-per-liter values may be converted to milliequivalents per liter by multiplying the milligrams per liter by the reciprocals of the combined weights of the appropriate ions (Hem, 1992). Water with total calculated hardness concentrations of 0 to 60 mg/L is considered “soft,” from 61 to 120 mg/L it is considered “moderately hard,” from 121 to 180 mg/L it is considered “hard,” and greater than 180 mg/L, “very hard” (Hem, 1992).

Total calculated hardness in surface-water samples ranged from 61 to 460 mg/L as CaCO_3 (table 4), with a median concentration of 300 mg/L. Total calculated hardness in ground-water samples ranged from 230 to 1,100 mg/L as CaCO_3 (table 5), with a median concentration of 330 mg/L. All ground-water sampled during the current study period (November 2003–August 2006) would be classified as “very hard,” and may require further treatment with water softeners before it is used as a domestic supply.

The oxidation-reduction (redox) potential (Eh) is a numerical index of the intensity of oxidizing or reducing conditions within a system (Hem, 1992). Eh was measured as a part of the ground-water-quality sampling to determine the redox conditions of the ground-water environment in the vicinity of the well. The redox potential of a system is important because the amount of oxygen in an environmental system is one of the factors affecting the chemical precipitation and dissolution of rocks and minerals. Some water-quality constituents such as arsenic, iron, and selenium are sensitive to the redox environment, and any change to the redox potential in an environment potentially could cause these constituents to dissolve into solution from surrounding aquifer material or to precipitate out of solution. Both situations eventually could affect the permeability of the aquifer in addition to releasing potentially harmful constituents such as arsenic. Positive potentials indicate that the system is relatively oxidizing, and negative potentials indicate that it is relatively reducing (Hem, 1992).

Eh measurements in samples from the monitoring wells ranged from 30 to 510 millivolts (mV) relative to a standard hydrogen electrode, with a median value of 250 mV (table 5). The smallest redox potential was measured in a sample from monitoring well MW03 collected on July 12, 2005, and the largest potential was measured in a sample from monitoring well MW04 collected on July 14, 2005.

The acid neutralizing capacity (ANC) or alkalinity of a solution is defined as the capacity of solutes it contains to react with and neutralize acid (Hem, 1992). The properties of alkalinity evaluate the potential of the solution for some kinds of water-rock interaction or interaction with other material the

water may contact (Hem, 1992). ANC is determined by titration of an unfiltered sample, whereas alkalinity is determined by titration of a filtered water sample.

The range of laboratory measurements of ANC in surface-water samples collected as a part of the current study period was 82 to 340 mg/L as CaCO_3 , with a median concentration of 220 mg/L as CaCO_3 (table 4). Laboratory ANC measurements for ground-water samples ranged from 140 to 410 mg/L as CaCO_3 , with a median concentration of 250 mg/L as CaCO_3 (table 5).

Dissolved Solids

Dissolved solids in natural water consist primarily of the cations calcium, magnesium, sodium, and potassium and the anions bicarbonate, sulfate, and chloride. Dissolved solids in surface water are a result of natural dissolution of rocks and minerals or of discharges from municipal or industrial sources (Hem, 1992). Dissolved-solids concentrations are used extensively as an evaluation of water quality. Freshwater has dissolved-solids concentrations less than 1,000 mg/L, whereas slightly saline water ranges from 1,000 to 3,000 mg/L (Hem, 1992). According to USEPA, excess dissolved solids and major ions are objectionable in drinking water because of unpalatable mineral tastes and higher costs because of corrosion or the necessity for additional treatment (U.S. Environmental Protection Agency, 1986). Consequently, USEPA established a Secondary Drinking-Water Regulation (SDWR) for dissolved solids of 500 mg/L (U.S. Environmental Protection Agency, 2006).

Dissolved-solids concentrations in surface-water samples collected for this study ranged from 120 to 696 mg/L, with the largest concentration occurring in a sample from site LSC06 (table 6, fig. 6A). The median concentration for dissolved solids in surface water was 400 mg/L. Twelve of the 55 surface-water samples (22 percent) collected during the current study period exceeded the USEPA SDWR of 500 mg/L for dissolved solids. Eight of 11 samples from site LSC06 exceeded 500 mg/L. Site LSC06 is located downstream from a discharging sewage-treatment lagoon, and larger concentrations of dissolved solids generally are found downstream from treated sewage when compared to upstream concentrations (Pope and Putnam, 1997). The remaining four samples exceeding 500 mg/L were from site SC03 and may reflect more mineralized water during low-flow conditions.

The range of dissolved-solids concentrations in ground-water samples was 186 to 2,360 mg/L. The largest concentration occurred in a sample from well MW03 collected on August 15, 2006. This concentration was approximately 5.7 times larger than the median concentration of 412 mg/L for all the ground-water samples (table 7, fig. 6B), and corresponds to large concentrations of major ions found in this sample. Currently (2007), the exact reason for the unusually large concentration of dissolved solids in water from well MW03 is unknown. Twenty percent of all ground-water samples had

Table 6. Results of analysis of dissolved solids and major ions in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	[mg/L, milligrams per liter; mg/L as HCO ₃ , milligrams per liter as calcium carbonate; mg/L as CaCO ₃ , milligrams per liter as calcium carbonate; SDWR, Secondary Drinking-Water Regulation; DWA, Drinking-Water Advisory; --, not determined or not applicable]										
			Dissolved solids (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Bicarbonate, total, onsite (mg/L as HCO ₃)	Carbonate, total, onsite (mg/L as CaCO ₃)	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)
Water-quality criteria ¹			500 (SDWR)	--	--	20 (DWA)	--	--	250 (SDWR)	250 (SDWR)	2.0 (SDWR)	--	
Little Soldier Creek Basin													
LSC03	Little Soldier Creek, O Road near Mayetta	11/19/03	--	--	--	--	--	--	--	--	--	--	
		02/25/04	263	57	13	10	4.7	180	0	44	8.2	0.3	
		05/19/04	209	48	11	7.9	4.1	--	--	18	3.0	.3	
		08/25/04	182	42	8.9	7.2	4.2	--	--	18	3.2	.3	
		12/08/04	424	83	20	23	3.5	--	--	58	28	.3	
		02/10/05	325	72	18	13	3.6	--	--	38	7.6	.2	
		06/01/05	401	96	26	19	3.4	350	0	40	12	.4	
		08/16/05	442	100	24	20	3.1	420	0	41	20	.3	
		11/09/05	470	120	26	18	4.7	440	0	48	11	.3	
		02/22/06	399	130	31	22	2.2	490	0	64	13	.3	
		06/06/06	347	76	18	15	3.0	320	0	32	8.5	.3	
		08/02/06	--	--	--	--	--	--	--	--	--	--	
LSC04	Little Soldier Creek, 134 Road near Mayetta	11/19/03	--	--	--	--	--	--	--	--	--	--	
		02/25/04	226	48	11	7.7	4.6	150	0	35	6.6	.3	
		05/19/04	192	39	7.8	6.8	4.4	--	--	18	3.3	.2	
		08/25/04	165	36	7.0	6.2	4.0	--	--	16	3.1	.3	
		12/08/04	314	69	14	15	3.6	--	--	34	12	.3	
		02/10/05	318	70	17	14	3.7	--	--	39	8.9	.2	
		05/11/05	120	18	4.0	6.2	3.7	--	--	14	3.1	.4	
		08/16/05	278	66	16	14	3.1	260	0	25	8.1	.3	
		11/09/05	454	110	24	19	4.6	460	0	45	12	.3	
		02/22/06	386	120	30	24	2.5	470	0	63	15	.3	

Table 6. Results of analysis of dissolved solids and major ions in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[mg/L, milligrams per liter; mg/L as HCO₃, milligrams per liter as bicarbonate; mg/L as CaCO₃, milligrams per liter as calcium carbonate; SDWR, Secondary Drinking-Water Regulation; DWA, Drinking-Water Advisory; --, not determined or not applicable]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Dissolved solids (mg/L)	Calcium dissolved (mg/L)	Magnesium dissolved (mg/L)	Sodium dissolved (mg/L)	Potassium dissolved (mg/L)	Bicarbonate, total, onsite (mg/L as HCO ₃)	Carbonate, total, onsite (mg/L as CaCO ₃)	Sulfate dissolved (mg/L)	Chloride dissolved (mg/L)	Fluoride dissolved (mg/L)	Silica dissolved (mg/L)
Little Soldier Creek Basin—Continued													
LSC03	Little Soldier Creek, O Road near Mayetta	06/06/06 08/02/06	360 --	81 --	18 --	15 --	3.1 --	350 --	0 --	30 --	7.8 --	0.3 --	11 --
LSC06	Big Elm Creek, 134 Road near Hoyt	11/19/03 02/25/04 05/19/04 08/25/04 12/08/04	696 668 195 278 495	89 89 33 47 72	19 18 6.0 8.8 16	140 100 15 33 65	8.5 9.4 4.8 5.4 6.9	270 250 -- -- --	0 0 -- -- --	83 94 19 39 71	200 170 17 41 98	.3 .4 .2 .3 .4	15 12 12 9.2 9.5
		02/10/05 06/01/05 08/16/05 11/09/05 02/22/06	517 509 523 543 681	92 92 82 110 110	19 22 17 24 24	60 57 79 33 91	5.4 6.0 7.0 4.8 6.7	-- 280 260 390 340	-- 0 0 0 0	74 91 70 100 120	94 66 100 31 120	.3 .4 .4 .3 .4	11 12 15 20 13
		06/06/06 08/02/06	603 --	75 --	16 --	50 --	4.8 --	280 --	0 --	90 --	62 --	.4 --	14 --
Soldier Creek Basin													
SC03	Soldier Creek near Saint Clere	11/19/03 02/25/04 05/19/04 08/25/04 12/08/04	538 331 302 427 563	140 76 68 94 120	31 16 15 22 27	24 12 13 16 20	3.6 4.7 4.4 3.1 2.4	330 200 -- -- --	0 0 -- -- --	170 71 45 120 190	24 12 8.2 14 22	.3 .3 .3 .3 .3	11 9.8 10 10 9.9
		02/10/05 06/01/05 08/16/05 11/09/05	401 450 448 512	93 100 96 120	21 23 26 26	19 21 20 18	2.7 3.6 3.2 3.8	-- 280 280 250	-- 0 0 0	90 110 120 120	15 17 18 16	.3 .3 .3 .3	7.7 9.1 11 8.2

Table 6. Results of analysis of dissolved solids and major ions in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[mg/L, milligrams per liter; mg/L as HCO₃, milligrams per liter as bicarbonate; mg/L as CaCO₃, milligrams per liter as calcium carbonate; SDWR, Secondary Drinking-Water Regulation; DWA, Drinking-Water Advisory; --, not determined or not applicable]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Dissolved solids (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Bicarbonate, total, onsite (mg/L as HCO ₃)	Carbonate, total, onsite (mg/L as CaCO ₃)	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)
Soldier Creek Basin—Continued													
SC03	Soldier Creek near Saint Clere	02/22/06	497	120	29	23	2.3	340	0	150	20	0.3	9.4
		06/06/06	512	110	26	22	3.3	340	0	130	19	.3	13
		08/02/06	396	80	20	21	4.1	290	0	71	20	.4	14
SC07	Soldier Creek, I Road near Delia	11/19/03	437	96	27	28	4.4	340	0	81	30	.3	10
		02/25/04	290	62	14	12	5.1	170	0	55	12	.3	9.2
		05/19/04	223	54	11	9.4	4.3	--	--	27	5.1	.3	9.6
		08/25/04	260	57	14	13	3.9	--	--	38	8.3	.3	9.2
		12/08/04	474	100	25	22	2.5	--	--	120	23	.3	8.1
		02/10/05	396	89	21	17	3.1	--	--	89	14	.3	7.8
		06/01/05	399	90	25	25	3.6	310	0	78	22	.3	8.1
		08/16/05	372	74	22	26	3.1	240	0	67	30	.3	7.3
		11/09/05	439	100	26	22	3.3	390	0	67	20	.3	9.1
		02/22/06	451	110	31	29	2.0	550	0	110	28	.3	3.1
		06/06/06	424	86	24	24	2.9	330	0	80	24	.3	10
		08/02/06	318	60	17	21	4.3	250	0	38	21	.4	13

¹Water-quality criteria established by the U.S. Environmental Protection Agency (2006).

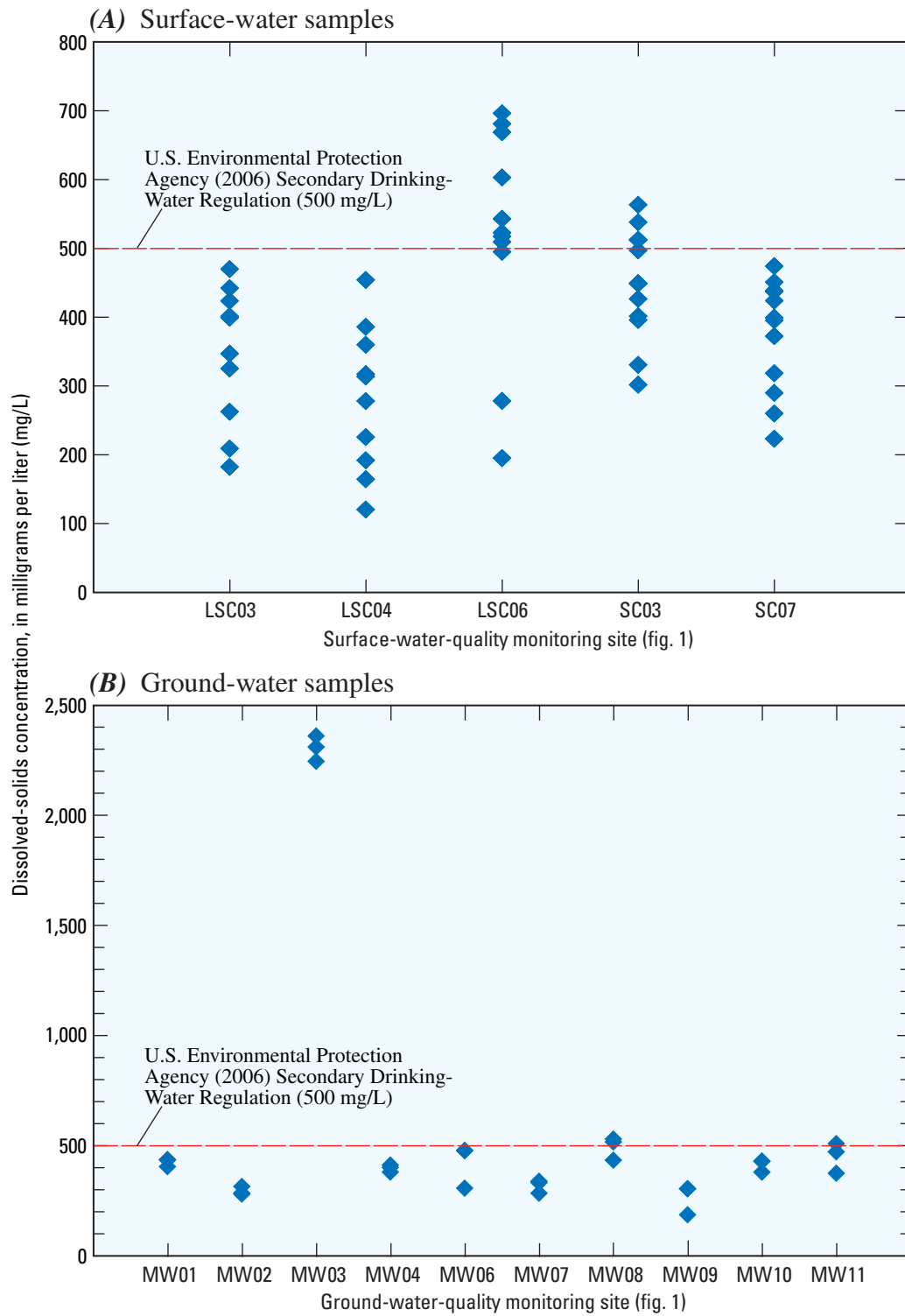


Figure 6. Concentrations of dissolved solids in (A) surface- and (B) ground-water-quality samples, November 2003 through August 2006.

Table 7. Results of analysis of dissolved solids and major ions in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.

[mg/L, milligrams per liter; mg/L as HCO₃, milligrams per liter as bicarbonate; mg/L as CaCO₃, milligrams per liter as calcium carbonate; SDWR, Secondary Drinking-Water Regulation; DWA, Drinking-Water Advisory; --, not determined or not applicable; <, less than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Dissolved solids (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Bicarbonate, total, onsite (mg/L as HCO ₃)	Carbonate, total, onsite (mg/L as CaCO ₃)	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)
MW01	Monitoring well #1	7/28/2004	405	100	19	29	1.6	340	0	87	14	0.3	26
		7/11/2005	437	95	19	28	1.6	310	0	82	12	.3	27
		8/16/2006	435	86	17	27	1.3	330	0	82	10	.3	26
MW02	Monitoring well #2	7/27/2004	280	71	13	14	.58	270	0	29	3.2	.4	18
		7/11/2005	285	72	14	13	.45	300	0	28	2.4	.4	19
		8/15/2006	315	71	14	14	.54	300	0	28	3.2	.4	19
MW03	Monitoring well #3	7/26/2004	2,240	270	100	270	8.3	390	0	940	290	.3	32
		7/12/2005	2,310	260	100	260	8.8	400	0	970	290	.3	32
		8/15/2006	2,360	280	110	300	8.7	370	0	1,000	300	.3	31
MW04	Monitoring well #4	7/29/2004	380	68	20	51	.89	370	0	32	7.2	.4	22
		7/14/2005	401	68	18	53	.81	340	0	24	6.2	.5	22
		8/16/2006	412	63	18	52	.85	380	0	25	6.5	.4	22
MW06	Monitoring well #6	7/29/2004	307	110	32	17	.99	480	0	50	4.6	.4	17
		7/13/2005	476	110	32	18	.94	450	0	50	4.7	.5	18
		8/14/2006	478	100	31	18	.92	470	0	49	4.3	.5	18
MW07	Monitoring well #7	7/27/2004	284	85	24	10	.84	380	0	17	2.9	.4	12
		7/13/2005	338	82	25	8.8	.87	350	0	17	2.7	.4	12
		8/15/2006	332	79	24	8.4	.81	360	0	16	2.3	.4	12
MW08	Monitoring well #8	7/27/2004	434	130	29	24	.82	460	0	47	25	.4	16
		7/12/2005	530	140	30	22	.81	470	0	53	23	.4	16
		8/14/2006	517	130	30	23	.82	490	0	48	23	.4	16
MW09	Monitoring well #9	7/29/2004	186	88	19	2.6	.57	340	0	9.5	1.5	.4	10
		7/14/2005	304	85	20	2.9	.60	320	0	9.6	<.2	.5	11
		8/17/2006	305	83	19	2.8	.65	340	0	9.2	1.5	.4	11
MW10	Monitoring well #10	7/28/2004	380	110	24	17	1.0	370	0	68	3.0	.3	17
		7/14/2005	430	100	24	17	.68	350	0	66	2.8	.3	17
		8/16/2006	429	94	24	16	.73	370	0	62	2.9	.3	17
MW11	Monitoring well #11	7/26/2004	375	99	36	20	1.9	390	0	19	16	.9	31
		7/14/2005	472	93	33	25	1.3	390	0	18	13	.8	32
		8/18/2006	509	98	36	21	2.1	440	0	32	14	.9	32

¹Water-quality criteria established by the U.S. Environmental Protection Agency (2006).

dissolved-solids concentrations equal to or greater than the SDWR of 500 mg/L (table 7, fig. 6B). Dissolved solids were identified as exceeding the SDWR by Trombley (2001) and continue to exceed the SDWR in the current ground-water assessment in three of the monitoring wells (MW03, MW08, and MW11). Treatment to remove the dissolved solids may be needed before ground-water resources on the reservation are used as a source for public drinking-water supply.

Major Ions

Major ions in natural water typically are a result of the dissolution of rocks and minerals but also can occur in discharge from municipal or industrial sources (Hem, 1992). The major ions analyzed for the current study period included calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, and silica. SDWRs have been established by USEPA for sulfate (250 mg/L), chloride (250 mg/L), and fluoride (2.0 mg/L) concentrations in finished drinking water, and a Drinking-Water Advisory (DWA) has been established by USEPA for sodium concentrations (20 mg/L) in finished drinking water (U.S. Environmental Protection Agency, 2006). Results of analyses for major ions in surface- and ground-water samples are reported in tables 6 and 7, respectively.

Calcium is a major constituent of carbonate rocks such as limestone and dolomite, and it dissolves readily in water; therefore, the calcium concentration in water from areas with carbonate rocks and associated deposits tends to be larger than in other areas (Hem, 1992). Carbonate rocks dominate the surface and near-surface geology in Kansas including the Prairie Band Potawatomi Reservation (fig. 3). Large concentrations of calcium are objectionable in domestic water supplies because they contribute to the hardness of the water and tend to cause encrustations on cooking utensils, pipes, and in water heaters.

Calcium concentrations in surface-water samples ranged from 18 to 140 mg/L, with a median concentration of 86 mg/L (table 6). In ground-water samples, calcium concentrations ranged from 63 to 280 mg/L, with a median concentration of 95 mg/L (table 7).

Magnesium is a common alkaline-earth metal and is essential for plant and animal nutrition (Hem, 1992). The principal sources for magnesium on the reservation are carbonate rocks. Magnesium also contributes to the total hardness of water and may cause encrustation and increase soap or detergent consumption in water used for cleaning.

Magnesium concentrations in the surface-water samples collected for this study ranged from 4.0 to 31 mg/L, with a median concentration of 20 mg/L (table 6). Concentrations in ground-water samples ranged from 13 to 110 mg/L, with a median concentration of 25 mg/L (table 7).

Sodium is the most abundant member of the alkali-metal group of elements in the Earth and, once dissolved, tends to remain in solution. Natural sources of sodium include the weathering of plagioclase feldspar and the dissolution of

sodium salts from sedimentary rocks (Hem, 1992). Human-related sources include road salt, seepage from septic systems, and a by-product of water treatment (it is discharged by water softeners and reverse-osmosis units) (U.S. Environmental Protection Agency, 2003). Sodium in drinking water may impart a salty taste and could be harmful to persons suffering from heart, kidney, and circulatory diseases and women with toxemias of pregnancy (U.S. Environmental Protection Agency, 2003). Therefore, USEPA has established a DWA of 20 mg/L in finished drinking water for people who are on restricted sodium diets (500 mg/d) and a taste threshold of 30 to 60 mg/L in finished drinking water (U.S. Environmental Protection Agency, 2006).

Sodium concentrations in surface-water samples ranged from 6.2 to 140 mg/L, with a median concentration of 20 mg/L (table 6). The largest sodium concentrations were detected in samples from site LSC06. Six of 11 samples from this site equaled or exceeded the maximum taste threshold of 60 mg/L. The relatively large sodium concentrations in water at site LSC06 may be the result of discharge from an upstream sewage-treatment lagoon. Although sodium concentrations exceeded the USEPA DWA of 20 mg/L in almost 50 percent of surface-water samples, the concentrations at each of the other four sites generally were about 20 mg/L or less and never exceeded 30 mg/L (fig. 7A).

Sodium concentrations in ground-water samples ranged from 2.6 to 300 mg/L (table 7). The largest concentration was detected in a water sample from well MW03 (fig. 7B) and was 15 times larger than the median sodium concentration of 20 mg/L from all samples collected from ground-water monitoring wells. Sodium concentrations exceeded the USEPA DWA in 15 ground-water samples from wells MW01, MW03, MW04, MW08, and MW11 (a total of 50 percent of ground-water samples).

Potassium is an essential element for both plants and animals. Maintenance of optimal soil fertility depends on a supply of available potassium. Potassium is present in plant material and is lost from agricultural soil by crop harvesting and by leaching and runoff acting on organic residues. Although potassium is an abundant element and its common salts are highly soluble, it seldom occurs in large concentrations in natural water (Hem, 1992).

Concentrations of potassium in surface-water samples collected during the current study period ranged from 2.0 to 9.4 mg/L, with a median concentration of 3.8 mg/L (table 6). The largest concentration of 9.4 mg/L occurred in a water sample from site LSC06. Potassium concentrations from site LSC06 generally were larger than results from the other surface-water sites. This site had a median concentration of 6.0 mg/L, compared with a median of about 3.5 mg/L in samples from the other four sites.

Potassium concentrations in ground-water samples ranged from 0.45 to 8.8 mg/L, with a median concentration of 0.89 mg/L. The largest concentration in ground water was detected in water from monitoring well MW03 (table 7).

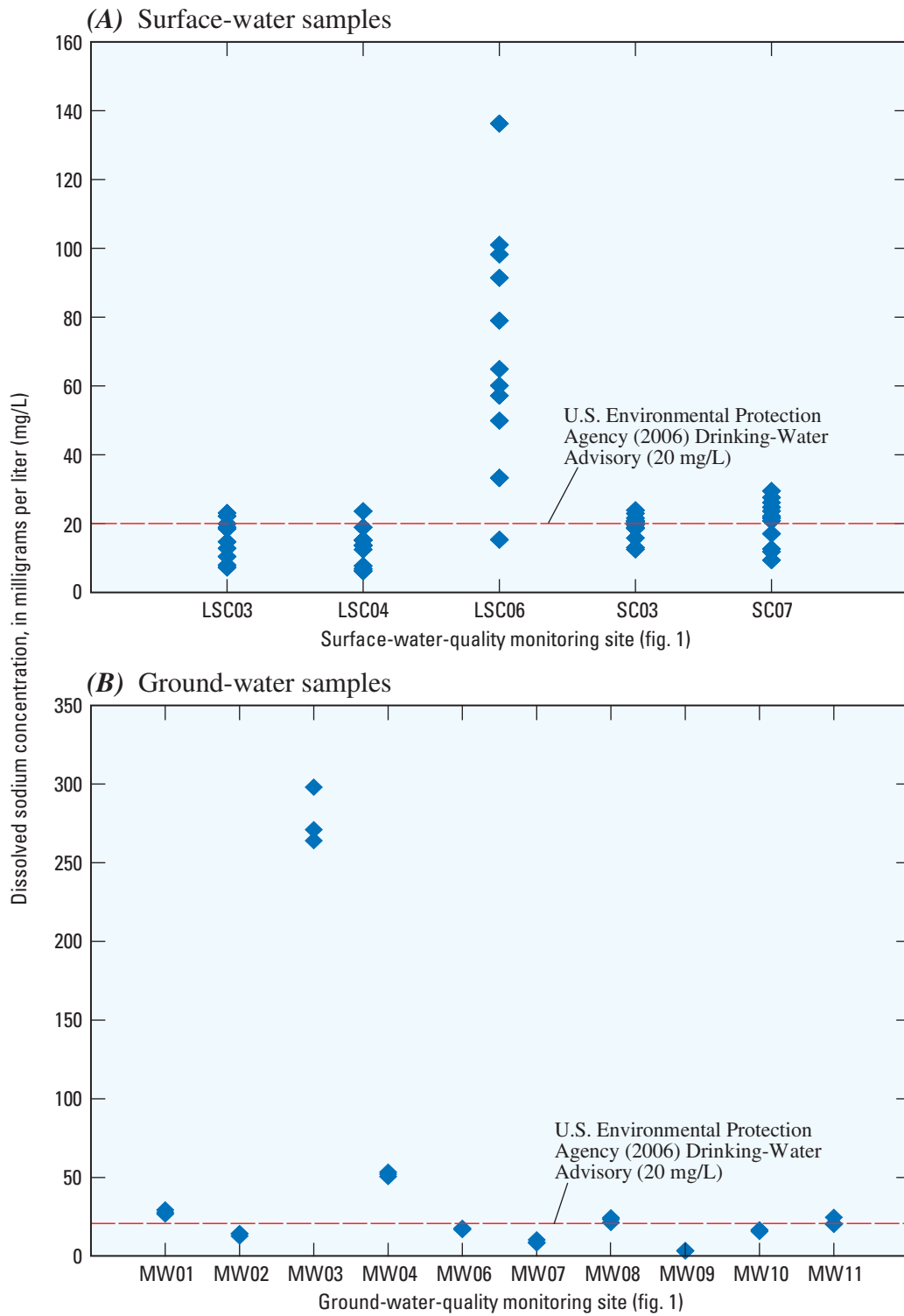


Figure 7. Concentrations of dissolved sodium in (A) surface- and (B) ground-water-quality samples, November 2003 through August 2006.

In surface water, bicarbonate concentrations generally are less than 200 mg/L, but larger concentrations in ground water are not uncommon (Hem, 1992). The primary source for bicarbonate on the Prairie Band Potawatomi Reservation is the dissolution of carbonate rocks and deposits.

Bicarbonate concentrations in surface-water samples ranged from 150 to 550 mg/L, with a median concentration of 315 mg/L (table 6). The largest concentration of bicarbonate occurred in water sampled from site SC07 on February 22, 2006.

Bicarbonate concentrations in ground-water samples ranged from 270 to 490 mg/L, with a median concentration of 370 mg/L (table 7). The largest bicarbonate concentrations in ground water were detected in samples from wells MW06 and MW08.

Natural sources of sulfate in water include the weathering of sulfur-bearing minerals, such as pyrite and gypsum, volcanic discharges to the atmosphere, and biologic and biochemical processes (Hem, 1992). Human-related sources include industrial discharges to both streams and the atmosphere and the combustion of fossil fuels, such as coal and gasoline. USEPA established a SDWR of 250 mg/L in drinking water to avoid laxative effects that can result from excessive sulfate concentrations in drinking water (U.S. Environmental Protection Agency, 2006).

Sulfate concentrations in surface-water samples ranged from 14 to 190 mg/L, with a median concentration of 67 mg/L. Sulfate concentrations were less than the SDWR of 250 mg/L (table 6, fig. 8A).

Sulfate concentrations in ground-water samples ranged from 9.2 to 1,000 mg/L, with a median concentration of 32 mg/L (table 7, fig. 8B). Sulfate concentrations exceeded the SDWR in 10 percent of ground-water samples. The largest sulfate concentration was detected in water from well MW03 and was approximately 31 times the median concentration from all ground-water samples and four times the SDWR of 250 mg/L. The large sulfate concentration in water from well MW03 corresponds to large specific conductance values and large concentrations of other dissolved ions in the water from this well. Treatment to remove excess dissolved ion concentrations would be needed in the event this water should become a drinking-water source.

Chloride is present in all natural water but generally is found in small concentrations in surface water (Hem, 1992). The probable natural source of chloride on the reservation is dissolution of halite from sedimentary rocks. The discharge of human, agricultural, animal, or industrial wastes also may add substantial quantities of chloride to surface and ground water. Chloride can impart a salty taste to drinking water and may accelerate the corrosion of metals used in water-supply systems. On the basis of taste, USEPA established a SDWR of 250 mg/L in finished drinking water (U.S. Environmental Protection Agency, 2006). KDHE established an aquatic-life criterion of 352 mg/L for chronic exposure to chloride (Kansas Department of Health and Environment, 2001).

Chloride concentrations in surface-water samples collected during the current study period ranged from 3.0 to 200 mg/L and were less than the SDWR (table 6, fig. 9A). The median concentration of chloride in the surface-water samples was 17 mg/L. The concentrations of chloride from site LSC06 were substantially larger than from the other four sites, but these concentrations were still less than the SDWR. Relatively large chloride concentrations at this site probably are attributable to its location downstream from a discharging sewage-treatment lagoon.

Chloride concentrations in ground-water samples ranged from less than 0.2 to 300 mg/L, with a median concentration of 6.4 mg/L (table 7, fig. 9B). Chloride concentrations exceeded the SDWR in 10 percent of ground-water samples. The largest chloride concentration was detected in water from well MW03, and all samples from this well exceeded the SDWR.

Nutrients

Nitrogen and phosphorus are essential for the growth and reproduction of plants (Hem, 1992). Rooted aquatic plants and algae require dissolved forms of nitrogen and phosphorus as nutrients. Compounds of nitrogen, such as nitrite, nitrate, and ammonia, are the basic building blocks for protein synthesis, and phosphorus serves as an energy source in cellular chemical reactions. However, large inputs of nitrogen and phosphorus compounds to bodies of water can cause excessive algal growth (Hem, 1992). This may result in taste-and-odor problems in drinking water, reduce the aesthetic and recreational value of water, and stress aquatic organisms due to decreased dissolved oxygen concentrations during decomposition. Therefore, it is desirable to prevent or mitigate the introduction of excessive nutrient concentrations into surface water used as public supply or where sensitive aquatic organisms may be present (Trombley, 1999, 2001).

Major sources of nutrients in and around the reservation include agricultural activities such as the application of fertilizers to enhance crop production and the pasturing and confined feeding of livestock. Common fertilizers used include, among others, anhydrous ammonia, ammonium nitrate, urea, and mono- and diammonium phosphates. The amount of fertilizer sold in Kansas has increased substantially during the last four decades. In 1950, about 180,000 tons of fertilizer were sold in Kansas, whereas by 2003 sales increased to more than 1,100,000 tons during a 6-month period (January through June 2003) (Kansas Department of Agriculture, 2004). It is likely that this statewide upward trend in fertilizer use also occurred on and near the reservation. Additionally, farm livestock such as cattle and buffalo can produce considerable amounts of nitrogenous waste (urine and manure) that can concentrate in areas where large numbers of animals are pastured or confined. Decomposition of large amounts of fertilizers and manure can release nutrients to surface runoff

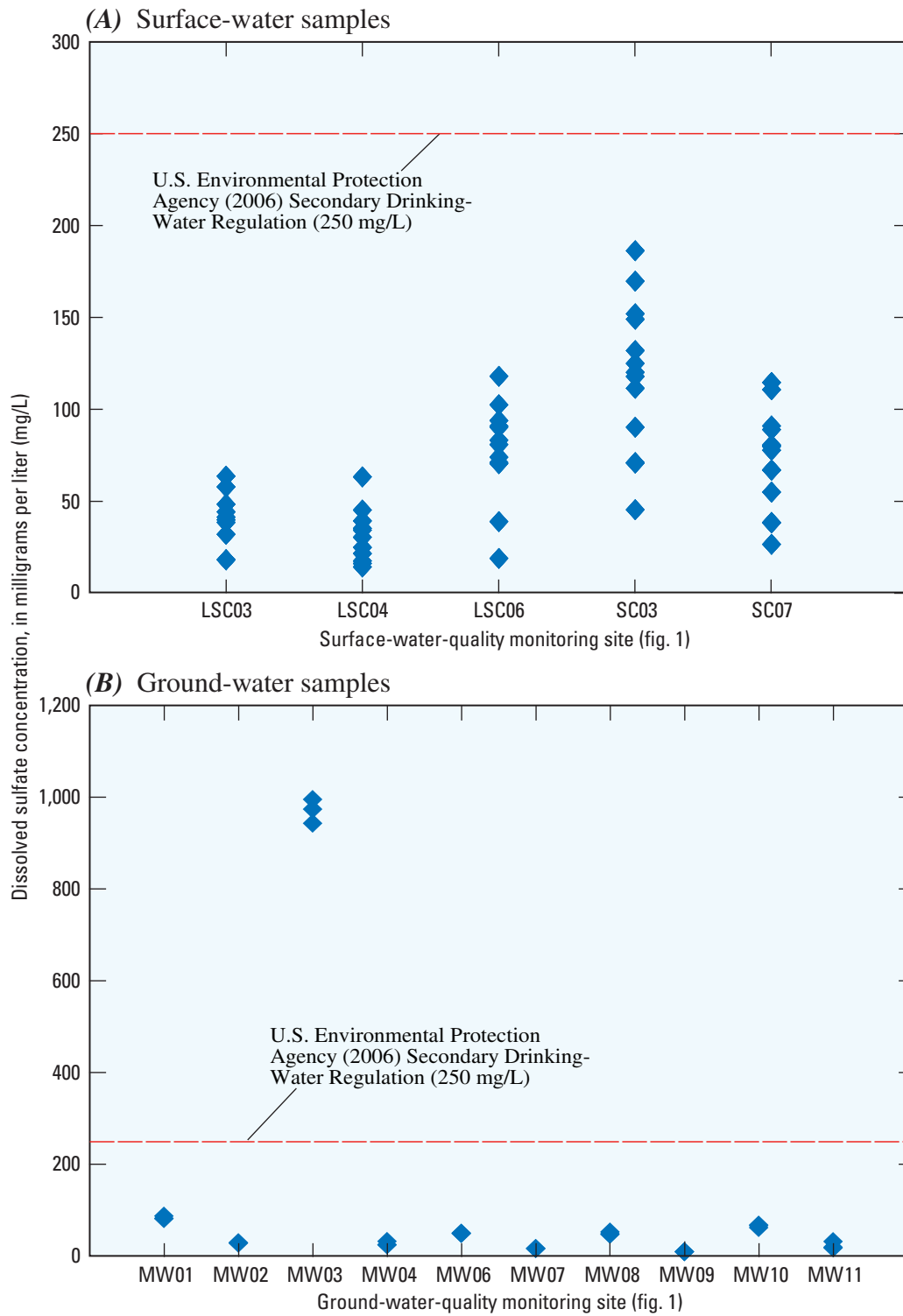


Figure 8. Concentrations of dissolved sulfate in (A) surface- and (B) ground-water-quality samples, November 2003 through August 2006.

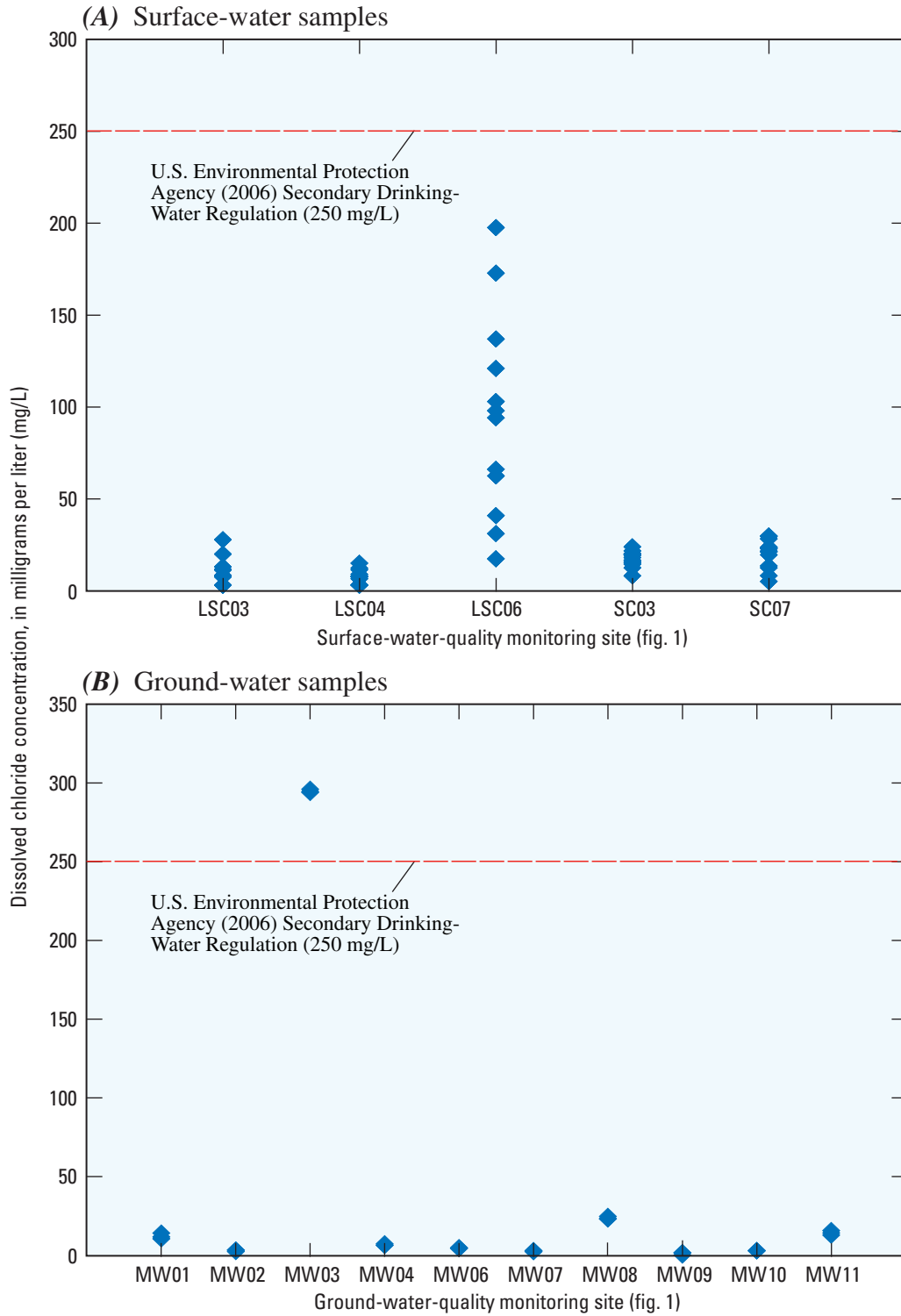


Figure 9. Concentrations of dissolved chloride in (A) surface- and (B) ground-water-quality samples, November 2003 through August 2006.

or to shallow ground water with the potential for discharge to nearby streams (Trombley, 1999, 2001).

Another potential source of nutrients on the reservation is bacterial decomposition of plant and animal protein and seepage from septic systems or sewage lagoons. Nutrients, particularly nitrate and ammonia, also may be components of precipitation (Christensen and Pope, 1997); however, because of dominant agricultural land use in the area, precipitation probably is a relatively minor contributor of nutrients to surface water and ground water on the reservation.

Nitrate is formed by complete oxidation of ammonium ions by microorganisms found in soil, water, sewage, and the digestive tract (U.S. Environmental Protection Agency, 1986). In most oxygenated surface water, nitrate is by far the dominant nitrogen ion due to rapid oxidation of nitrite. Nitrate nitrogen is the form of nitrogen most easily used by most rooted green plants and algae. Nitrate generally occurs in uncontaminated surface water, with a worldwide mean concentration of 0.30 mg/L (Reid and Wood, 1976). Larger nitrate nitrogen concentrations may stimulate growth of rooted plants or accelerate algal production to an extent that may result in taste-or-odor problems in finished drinking water. Because most aquatic organisms can tolerate nitrite plus nitrate concentrations far in excess of what normally might be found even in contaminated surface water, no water-quality criteria have been established for protection of aquatic life. However, USEPA has established recommended criteria on the basis of aggregate Level III nutrient ecoregions as well as sub-ecoregions; the recommended criteria for aggregate ecoregion VI are 0.633 mg/L for nitrite plus nitrate and 1.22 mg/L for total nitrogen in surface water (U.S. Environmental Protection Agency, 2000b). A MCL in drinking water of 10 mg/L nitrate as nitrogen was established by USEPA because of possible toxic effects to infants and is applicable to any supply that may be used for drinking water (U.S. Environmental Protection Agency, 2006).

Nitrite plus nitrate concentrations ranged from an estimated 0.03 to 3.0 mg/L in the surface-water samples collected from the reservation (table 8, fig. 10A). The median surface-water concentration was 0.18 mg/L. Nitrite plus nitrate concentrations exceeded the USEPA recommended criterion for ecoregion VI (0.633 mg/L) in 25 percent of surface-water samples. There was some annual variability in nitrite plus nitrate concentrations, with the largest concentrations detected in winter and spring samples and the smallest concentrations in summer and fall. Total nitrogen also was compared to the recommended criterion for aggregate ecoregion VI and exceeded the recommendation (1.22 mg/L) in 25 percent of surface-water samples. Total nitrogen for each site is calculated as the sum of the corresponding ammonia plus organic nitrogen and nitrite plus nitrate concentrations.

Nitrite plus nitrate concentrations in ground-water samples ranged from less than 0.06 to 15 mg/L (table 9, fig. 10B), with a median concentration of 0.34 mg/L. The largest concentration was in water from well MW11; the well had similarly large concentrations in all three rounds of testing. The

nitrite plus nitrate concentrations in water from well MW11 exceeded the USEPA MCL. The well is located adjacent to an open hand-dug well that could provide a conduit for contaminants into the ground water in that localized area. Primary land use near the well is pastureland and cropland, and agricultural activities in the area could contribute to elevated nitrite plus nitrate concentrations in water from this well.

Ammonia toxicity is dependent on the pH and temperature of the water; as the pH and temperature increase, the chronic exposure criterion for ammonia decreases (U.S. Environmental Protection Agency, 1999). Acute toxicity of ammonia in fish causes increased respiration, oxygen uptake, and heart rate; reduction in hatching success and growth and morphologic development; and injuries to gills, liver, and kidneys. At larger concentrations, fish may experience convulsions, coma, and death. Small ammonia concentrations can cause reduction in hatching success, reduction in growth rate or morphological development, and pathologic changes in tissues of the gills, livers, and kidneys (U.S. Environmental Protection Agency, 1986). The pH in surface water on the reservation ranged from 6.8 to 8.3 standard units, and the water temperature ranged from 0.1 to 27.2°C (table 4). For these pH and water temperature conditions, the range of the chronic ammonia criteria for streams that have fish early-life stages present is 0.7 to 6.7 mg/L (U.S. Environmental Protection Agency, 1999). The most likely sources of ammonia on the reservation probably are related to agricultural land use or wastewater.

Dissolved ammonia concentrations in surface-water samples ranged from less than 0.01 to 1.8 mg/L, with a median concentration of less than 0.04 mg/L (table 8). The largest concentration of 1.8 mg/L occurred on February 25, 2004, in a water sample from site LSC06, which is located downstream from a discharging sewage-treatment lagoon. This ammonia concentration was substantially larger than other samples from that site as well as all the other surface-water sites. The chronic exposure criterion for this sample (pH of 6.8 and temperature of 0.3°C) is 6.3 mg/L (U.S. Environmental Protection Agency, 1999).

Ammonia concentrations in ground-water samples ranged from an estimated 0.01 to 1.8 mg/L, with a median concentration of less than 0.04 mg/L (table 9). None of these concentrations exceeded USEPA (1999) chronic exposure criteria for early-life stages of fish, which are not directly applicable to ground water; however, in cases where ground water provides the base flow to streams on the reservation, these criteria could be relevant.

Total phosphorus includes all forms of phosphorus (Hem, 1992). Excessive concentrations of phosphorus in water may contribute to eutrophication of water bodies. Eutrophication (nutrient enrichment) is characterized by excessive nutrient concentrations, decreased dissolved oxygen concentrations, and dense growths of algae (Reid and Wood, 1976). Domestic, municipal, and industrial sewage effluents are substantial sources of phosphorus in surface water because phosphorus is essential in metabolism and is present in human and animal

Table 8. Results of analysis of nutrients in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.

[mg/L as N, milligrams per year as nitrogen; mg/L, milligrams per liter as phosphorus; MCL, Maximum Contaminant Level; --, not determined or not applicable; <, less than; E, estimated]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Ammonia plus organic nitrogen, dissolved (mg/L as N)	Ammonia plus organic nitrogen, total (mg/L as N)	Phosphorus, dissolved (mg/L)	Phosphorus, total (mg/L)	Ortho-phosphate, dissolved (mg/L as P)
Water-quality criteria										
			--	¹ 10 (MCL)	--	--	--	--	² 0.10 (aquatic-life goal)	--
Little Soldier Creek Basin										
LSC03	Little Soldier Creek, O Road near Mayetta	11/19/03	--	--	--	--	--	--	--	--
		02/25/04	0.04	1.9	<0.04	0.53	0.82	0.09	0.17	0.07
		05/19/04	.02	.62	E.04	.63	1.1	.05	.22	.04
		08/25/04	.01	.27	<.04	.45	1.0	.07	.22	.06
		12/08/04	<.008	.06	E.02	.26	.42	.05	.08	.04
		02/10/05	.01	.86	<.04	.49	.60	.05	.08	.05
		06/01/05	<.008	.14	E.02	.54	.40	E.02	.07	E.01
		08/16/05	.02	.76	.05	.29	.40	E.02	.04	<.018
		11/09/05	<.008	.13	<.04	.30	.30	.12	.14	.11
		02/22/06	<.008	E.06	<.04	.21	.18	E.02	E.03	.02
		06/06/06	.01	.28	.04	.36	.45	E.03	.06	.04
		08/02/06	--	--	--	--	--	--	--	--
LSC04	Little Soldier Creek, 134 Road near Mayetta	11/19/03	--	--	--	--	--	--	--	--
		02/25/04	.03	1.9	.07	.56	.74	.11	.16	.09
		05/19/04	.02	.68	.05	.69	1.8	.08	.43	.06
		08/25/04	.01	.40	<.04	.44	1.1	.08	.29	.06
		12/08/04	<.008	E.03	<.04	.27	.33	E.03	.05	.03
		02/10/05	E.006	.80	E.02	.50	.66	.06	.09	.05
		05/11/05	.03	3.0	.34	1.2	12	.12	3.5	.10
		08/16/05	E.007	.17	<.04	.26	.34	E.03	.04	<.018
		11/09/05	<.008	.07	<.04	.35	.36	.08	.11	.07
		02/22/06	<.008	.08	<.04	.24	.22	<.04	E.02	<.018

Table 8. Results of analysis of nutrients in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[mg/L as N, milligrams per year as nitrogen; mg/L, milligrams per liter as phosphorus; MCL, Maximum Contaminant Level; --, not determined or not applicable; <, less than; E, estimated]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Ammonia plus organic nitrogen, dissolved (mg/L as N)	Ammonia organic nitrogen, total (mg/L as N)	Phos-phorus, dissolved (mg/L)	Phos-phorus, total (mg/L)	Ortho-phosphate, dissolved (mg/L as P)
Little Soldier Creek Basin—Continued										
LSC04	Little Soldier Creek, 134 Road near Mayetta	06/06/06 08/02/06	0.02 --	0.38 --	0.07 --	0.40 --	0.60 --	E0.04 --	0.10 --	0.04 --
LSC06	Big Elm Creek, 134 Road near Hoyt	11/19/03 02/25/04 05/19/04 08/25/04 12/08/04	<.008 .01 .01 <.008 E.004	<.06 .48 .31 .13 .42	<.04 1.8 E.02 E.02 E.02	.64 2.6 .77 .48 .48	.85 3.8 2.0 .77 .55	.50 .72 .20 .20 .55	.54 .91 .68 .26 .58	.45 .63 .18 .18 .54
		02/10/05 06/01/05 08/16/05 11/09/05 02/22/06	.01 E.005 E.004 <.008 .03	.93 .09 .17 <.06 1.5	.12 <.04 E.02 <.04 .04	.61 .46 .42 .31 .61	.68 .49 .47 .23 .85	.29 .15 .18 .20 .30	.32 .17 .20 .21 .38	.26 .14 .16 .19 .28
		06/06/06 08/02/06	.01 --	.25 --	.02 --	.39 --	.40 --	.10 --	.13 --	.10 --
Soldier Creek Basin										
SC03	Soldier Creek near Saint Clere	11/19/03 02/25/04 05/19/04 08/25/04 12/08/04	<.008 .05 .02 E.004 <.008	<.06 2.5 .71 .16 E.05	<.04 .24 .07 <.04 E.03	.20 .86 .53 .21 .14	.27 1.2 1.2 .58 .28	E.03 .17 .08 .04 E.02	.05 .25 .28 .13 E.03	.03 .14 .70 .03 E.02
		02/10/05 06/01/05 08/16/05	<.008 <.008 <.008	.19 <.06 <.06	<.04 <.04 <.04	.24 .26 .32	.36 .67 .47	E.02 E.02 E.02	E.04 .10 .07	E.02 <.018 <.018

Table 8. Results of analysis of nutrients in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[mg/L as N, milligrams per year as nitrogen; mg/L as P, milligrams per liter as phosphorus; MCL, Maximum Contaminant Level; —, not determined or not applicable; <, less than; E, estimated]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Ammonia plus organic nitrogen, dissolved (mg/L as N)	Ammonia plus organic nitrogen, total (mg/L as N)	Phosphorus, dissolved (mg/L)	Phosphorus, total (mg/L)	Orthophosphate, dissolved (mg/L as P)
Soldier Creek Basin—Continued										
SC03	Soldier Creek near Saint Clere	11/09/05	<.008	E.04	<.04	0.25	0.36	E.02	0.05	E.01
		02/22/06	<.008	E.04	<.04	.23	.21	<.04	E.02	<.018
		06/06/06	<.002	<.06	E.01	.30	.81	<.04	.13	.01
		08/02/06	.002	E.03	.02	.42	.90	.07	.19	.06
SC07	Soldier Creek, I Road near Delia	11/19/03	<.008	<.06	<.04	.36	.42	.06	.08	.05
		02/25/04	.05	2.7	.27	.95	1.3	.19	.28	.14
		05/19/04	.02	.90	.05	.57	1.7	.11	.48	.09
		08/25/04	.01	.47	<.04	.54	.79	.10	.19	.08
		12/08/04	<.008	.06	E.02	.18	.31	.07	.09	.06
		02/10/05	E.005	.41	<.04	.34	.51	.05	.09	.04
		06/01/05	<.008	<.06	<.04	.32	.62	E.02	.12	E.01
		08/16/05	E.004	.15	<.04	.29	.42	.04	.08	.03
		11/09/05	<.008	.15	<.04	.29	.36	.04	.08	.03
		02/22/06	E.005	.18	<.04	.23	.27	<.04	E.02	<.018
		06/06/06	<.002	<.06	<.01	.32	.98	E.03	.17	.02
		08/02/06	.03	.29	.13	.64	.95	.10	.18	.10

¹U.S. Environmental Protection Agency (2006).

² U.S. Environmental Protection Agency (1986).

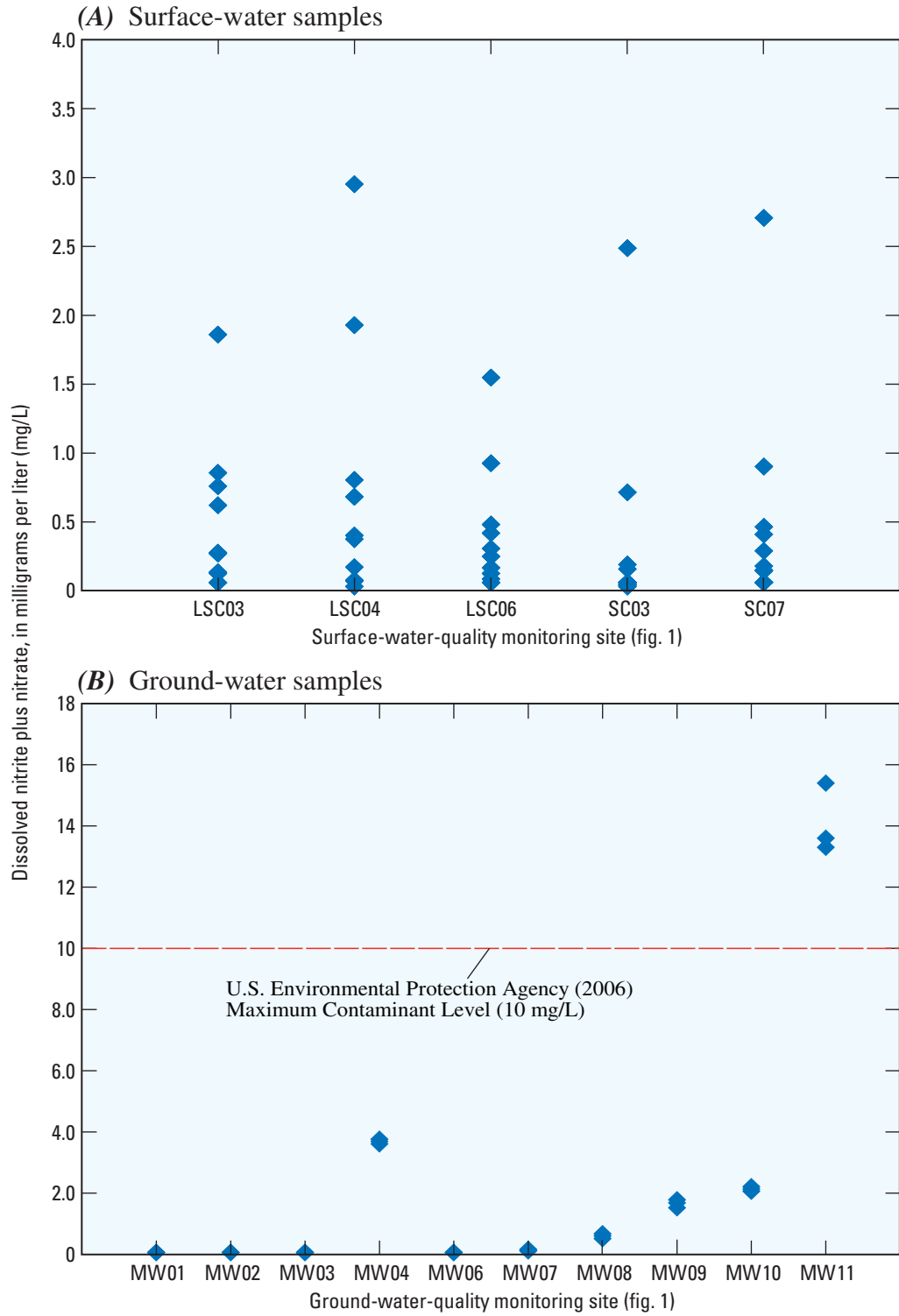


Figure 10. Concentrations of dissolved nitrite plus nitrate in (A) surface- and (B) ground-water-quality samples, November 2003 through August 2006.

Table 9. Results of analysis of nutrients in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.

[mg/L as N, milligrams per liter as nitrogen; mg/L, milligrams per liter as phosphorus; MCL, Maximum Contaminant Level; --, not determined or not applicable; <, less than; E, estimated]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Ammonia plus organic nitrogen, dissolved (mg/L as N)	Ammonia plus organic nitrogen, total (mg/L as N)	Phos-phorus, dissolved (mg/L)	Phos-phorus, total (mg/L)	Orthophosphate, dissolved (mg/L as P)
Water-quality criterion										
			--	¹ 10	--	--	--	--	--	--
										(MCL)
MW01	Monitoring well #1	7/28/2004	<.008	<.06	0.08	E0.08	0.11	<.04	0.05	0.03
		7/11/2005	<.008	<.06	.07	.11	.20	E.03	.09	.05
		8/16/2006	<.002	<.06	.07	.30	.48	.06	.05	.06
MW02	Monitoring well #2	7/27/2004	<.008	<.06	<.04	<.10	<.10	E.03	E.04	.03
		7/11/2005	<.008	<.06	<.04	E.08	E.06	E.02	E.04	.03
		8/15/2006	<.002	<.06	.03	.15	.35	.04	.04	.04
MW03	Monitoring well #3	7/26/2004	<.008	<.06	1.8	1.8	1.9	<.04	.11	.02
		7/12/2005	<.008	<.06	1.8	2.0	1.9	.06	.08	.05
		8/15/2006	<.002	<.06	1.8	1.9	2.0	.12	.07	.08
MW04	Monitoring well #4	7/29/2004	<.008	3.6	<.04	<.10	.80	E.03	.62	.02
		7/14/2005	<.008	3.7	<.04	.11	.52	<.04	.30	<.018
		8/16/2006	<.002	3.8	.01	.15	.20	<.04	.05	.02
MW06	Monitoring well #6	7/29/2004	<.008	<.06	.17	.16	.27	.15	.16	.10
		7/13/2005	E.006	<.06	.16	.13	.18	.12	.15	.08
		8/14/2006	E.002	<.06	.27	.31	.31	.20	.21	.19
MW07	Monitoring well #7	7/27/2004	<.008	.12	<.04	<.10	<.10	E.02	E.03	E.02
		7/13/2005	<.008	.16	<.04	<.10	<.10	E.02	E.03	E.02
		8/15/2006	E.001	.11	E.01	E.09	.11	E.03	E.03	.02

Table 9. Results of analysis of nutrients in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.—Continued

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Ammonia plus organic nitrogen, dissolved (mg/L as N)	Ammonia plus organic nitrogen, total (mg/L as N)	Phos-phorus, dissolved (mg/L)	Phos-phorus, total (mg/L)	Orthophosphate, dissolved (mg/L as P)
MW08	Monitoring well #8	7/27/2004	<.008	0.67	0.05	E0.10	E0.09	0.05	0.07	0.05
		7/12/2005	<.008	.60	E.02	.12	.10	.05	.07	.05
		8/14/2006	.003	.51	.04	E.08	.10	.04	.05	.06
MW09	Monitoring well #9	7/29/2004	<.008	1.7	<.04	<.10	.11	<.04	<.04	<.018
		7/14/2005	<.008	1.5	<.04	<.10	E.06	<.04	<.04	<.018
		8/17/2006	<.002	1.8	E.01	.12	.23	<.04	.23	.01
MW10	Monitoring well #10	7/28/2004	<.008	2.2	<.04	<.10	<.10	<.04	<.04	E.01
		7/14/2005	<.008	2.1	<.04	<.10	E.08	<.04	E.02	<.018
		8/16/2006	<.002	2.1	E.01	E.08	E.08	<.04	<.04	.01
MW11	Monitoring well #11	7/26/2004	<.008	15	<.04	E.05	.33	.06	.29	.06
		7/14/2005	<.008	13	<.04	.32	.49	E.02	.14	E.02
		8/18/2006	.007	14	E.01	.12	.39	.07	.28	.08

¹ U.S. Environmental Protection Agency (2006).

[mg/L as N, milligrams per liter as nitrogen; mg/L, milligrams per liter as phosphorus; MCL, Maximum Contaminant Level; --, not determined or not applicable; <, less than; E, estimated]

metabolic waste. Potential sources for large concentrations of phosphorus in streams on the Prairie Band Potawatomi Reservation include human or animal waste and fertilizers applied to agricultural lands.

USEPA established a goal for total phosphorus concentration of 0.10 mg/L to limit cultural eutrophication of flowing water (U.S. Environmental Protection Agency, 1986). Larger concentrations also may interfere with coagulation in water-treatment plants. USEPA also has recommended water-quality criteria for total phosphorus on the basis of aggregate nutrient ecoregions. A total phosphorus criterion of 0.076 mg/L has been established by USEPA for ecoregion VI (U.S. Environmental Protection Agency, 2000b). However, previous reports compared stream concentrations of total phosphorus to the recommended goal of 0.10 mg/L (Trombley, 1999, 2001; Schmidt, 2004). Therefore, this criterion also will be used for total phosphorus evaluation in this report. Total phosphorus was identified as exceeding water-quality criteria on the reservation in three previous reports published as part of this cooperative study (Trombley, 1999, 2001; Schmidt, 2004).

Concentrations of total phosphorus in surface-water samples ranged from an estimated 0.02 to 3.5 mg/L, with a median concentration of 0.13 mg/L (table 8, fig. 11). All 11 samples from site LSC06 exceeded the water-quality goal of 0.10 mg/L; however, the largest concentration of 3.5 mg/L occurred in a sample from site LSC04 on May 11, 2005, during runoff conditions (streamflow of 189 ft³/s, table 4). Concentrations of other nutrients also were large in the May 11, 2005, sample from site LSC04. Overall, 56 percent

of the 55 surface-water samples that were analyzed for total phosphorus exceeded the goal of 0.10 mg/L to prevent cultural eutrophication (U.S. Environmental Protection Agency, 1986).

Total phosphorus concentrations in ground-water samples ranged from an estimated 0.02 to 0.62 mg/L, with a median concentration of 0.07 mg/L (table 9). Although the cultural eutrophication goal does not apply to ground water, it should be noted for comparison purposes that 33 percent of ground-water samples exceeded the 0.10-mg/L goal.

Trace Elements

Trace elements are found in small quantities (less than 1 percent) in or adsorbed to mineral surfaces (Bates and Jackson, 1980). Trace elements generally are found in the environment at relatively small concentrations (less than 1.0 mg/L), but some are vital for human and plant health. Concentrations of trace elements in surface and ground water can be increased as a result of human activities such as mining and industrial activities. Water samples for this study were analyzed for the trace elements arsenic, boron, iron, and selenium; all of which have applicable water-quality criteria.

Arsenic is a trace element that occurs naturally in the environment, but the presence of arsenic in water also can be a result of mining activity or application of pesticides. Arsenic also can occur in water as a result of an arsenic-bearing formation dissolving naturally over time (Haack and Rachol, 2000). Large concentrations of arsenic have shown to be detrimental to human health (Hem, 1992). In 2001, USEPA revised the

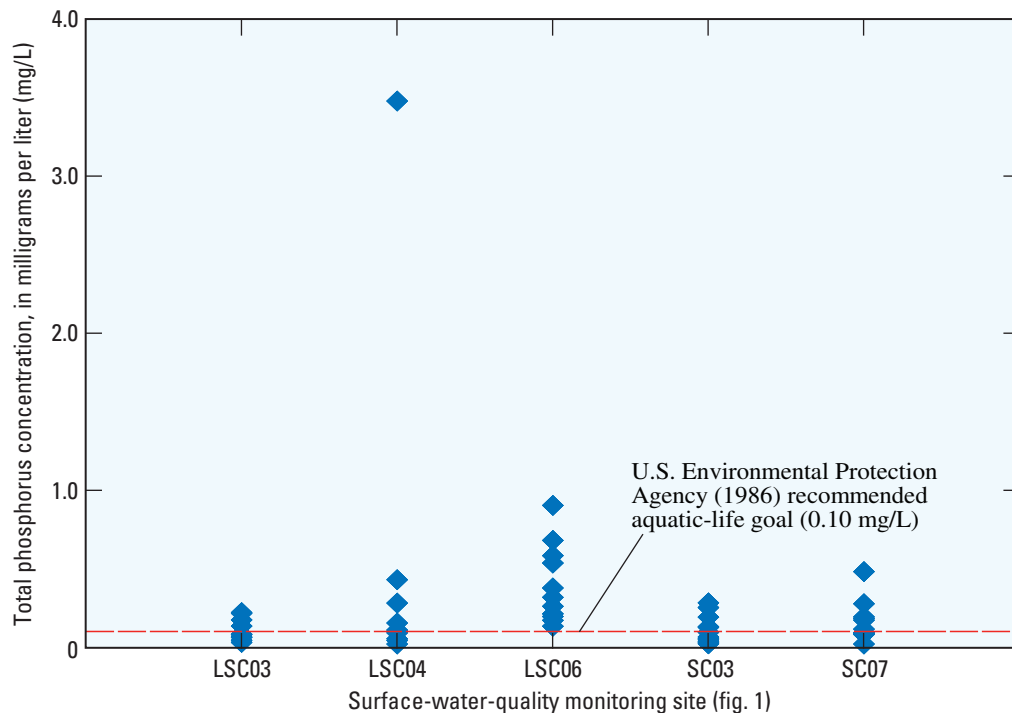


Figure 11. Concentrations of total phosphorus in surface-water-quality samples, November 2003 through August 2006.

drinking-water MCL for arsenic from 50 to 10 µg/L, which became effective in 2006 (U.S. Environmental Protection Agency, 2006).

Arsenic concentrations in the surface-water samples collected during the current study period ranged from an estimated 0.9 to 7.8 µg/L (table 10) and were less than the drinking water MCL for arsenic. The median arsenic concentration in surface-water samples was less than 1.9 µg/L.

Ground-water arsenic concentrations ranged from 0.2 to 30 µg/L (table 11, fig. 12), with a median concentration of less than 1.9 µg/L. The largest concentration came from well MW06 and was three times the MCL for arsenic. The other two concentrations from this well were about twice the MCL. The reason for the unusually large concentrations of arsenic in water from well MW06 currently (2007) is not known. Arsenic was detected in water from the nine other monitoring wells but at concentrations substantially less than the MCL.

Boron is a minor constituent in ground water and usually is found in evaporate deposits as sodium or calcium borate salt (Hem, 1992). It is an essential element for the growth of plants, but there is no evidence that it is required by animals (Pais and Jones, 1997). Total boron essentially is conserved during wastewater treatment and may be used to determine whether a water sample contains wastewater effluent (Quarud and others, 2004). USEPA established a lifetime DWA of 600 µg/L (concentration in drinking water that is not expected to cause any adverse effects for a lifetime of exposure) (U.S. Environmental Protection Agency, 2006).

Boron concentrations in surface-water samples collected during the current study period ranged from 30 to 80 µg/L, with a median concentration of 50 µg/L (table 10). The largest detection of 80 µg/L occurred on November 19, 2003, in a water sample from site LSC06 and may be attributable to the upstream sewage-treatment lagoon.

Concentrations of boron in ground-water samples ranged from 20 to 880 µg/L, with a median concentration of 70 µg/L (table 11). The largest concentration was in a sample from well MW03 collected on July 26, 2004, and corresponds to the large concentrations of calcium, magnesium, and sodium and several anions contributing to the large dissolved-solids concentration in water from this well (table 7).

Iron is an abundant element in the Earth's outer crust, but it typically occurs in small concentrations in water (Hem, 1992). Iron's chemical activity and its solubility in water depend largely on the oxygen in the system as well as the pH of the water (Hem, 1992). Large amounts of iron are undesirable in water supplies because it forms a red oxyhydroxide precipitate that stains laundry and plumbing fixtures (Hem, 1992). USEPA (2006) has established a SDWR of 300 µg/L for iron in treated drinking water.

Iron concentrations in surface-water samples ranged from an estimated 3 to 70 µg/L, with a median concentration of 10 µg/L (table 10). All concentrations in surface-water samples were substantially less than the USEPA SDWR.

Iron concentrations in ground-water samples ranged from an estimated 2 to 5,700 µg/L, with a median concentration of 45 µg/L (table 11, fig. 13). The three largest iron

Table 10. Results of analysis of trace elements in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.

[µg/L, micrograms per liter; MCL, Maximum Contaminant Level; DWA, Drinking-Water Advisory; SDWR, Secondary Drinking-Water Regulation; --, not determined or not applicable; E, estimated; <, less than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Arsenic, dissolved (µg/L)	Boron, dissolved (µg/L)	Iron, dissolved (µg/L)	Selenium, dissolved (µg/L)
Water-quality criteria ¹			10 (MCL)	600 (DWA)	300 (SDWR)	50 (MCL)
Little Soldier Creek Basin						
LSC03	Little Soldier Creek, O Road near Mayetta	11/19/03	--	--	--	--
		02/25/04	E1.4	30	10	E1.4
		05/19/04	E1.1	40	20	<2.6
		08/25/04	E1.6	50	20	<2.6
		12/08/04	E1.2	50	E6	<2.6
		02/10/05	E1.0	40	10	<2.6
		06/01/05	<1.9	70	10	<2.6
		08/16/05	<1.9	70	E4	E1.3

Table 10. Results of analysis of trace elements in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[µg/L, micrograms per liter; MCL, Maximum Contaminant Level; DWA, Drinking-Water Advisory; SDWR, Secondary Drinking-Water Regulation; --, not determined or not applicable; E, estimated; <, less than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Arsenic, dissolved (µg/L)	Boron, dissolved (µg/L)	Iron, dissolved (µg/L)	Selenium, dissolved (µg/L)
Little Soldier Creek Basin—Continued						
LSC03	Little Soldier Creek, O Road near Mayetta	11/09/05	1.5	60	10	0.3
		02/22/06	vc	50	10	.3
		06/06/06	2.1	60	<6	.4
		08/02/06	--	--	--	--
LSC04	Little Soldier Creek, 134 Road near Mayetta	11/19/03	--	--	--	--
		02/25/04	E1.7	30	10	<2.6
		05/19/04	E1.2	40	40	<2.6
		08/25/04	<1.9	40	10	<2.6
		12/08/04	<1.9	50	E4	<2.6
		02/10/05	<1.9	40	10	<2.6
		05/11/05	E1.5	30	30	<2.6
		08/16/05	E1.4	60	<6	<2.6
		11/09/05	1.5	60	20	.3
		02/22/06	1.0	50	10	.4
		06/06/06	2.2	60	<6	.5
		08/02/06	--	--	--	--
		LSC06	Big Elm Creek, 134 Road near Hoyt	11/19/03	2.2	80
02/25/04	3.0			50	10	E2.4
05/19/04	E1.2			40	70	<2.6
LSC06	Big Elm Creek, 134 Road near Hoyt	08/25/04	2.8	50	E5	<2.6
		12/08/04	2.8	40	10	<2.6
		02/10/05	E1.3	30	10	E1.5
		06/01/05	E1.4	50	10	<2.6
		08/16/05	2.4	70	10	<2.6
		11/09/05	2.0	60	20	.4
		02/22/06	2.1	60	20	.6
		06/06/06	2.1	50	E4	.6
08/02/06	--	--	--	--		

Table 10. Results of analysis of trace elements in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[µg/L, micrograms per liter; MCL, Maximum Contaminant Level; DWA, Drinking-Water Advisory; SDWR, Secondary Drinking-Water Regulation; --, not determined or not applicable; E, estimated; <, less than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Arsenic, dissolved (µg/L)	Boron, dissolved (µg/L)	Iron, dissolved (µg/L)	Selenium, dissolved (µg/L)
Soldier Creek Basin						
SC03	Soldier Creek near Saint Clere	11/19/03	E1.2	70	10	<2.6
		02/25/04	E1.2	30	10	<2.6
		05/19/04	E1.8	40	10	<2.6
		08/25/04	E1.4	60	<6	<2.6
		12/08/04	E1.1	50	10	<2.6
		02/10/05	<1.9	40	10	<2.6
		06/01/05	E1.4	50	<6	<2.6
		08/16/05	2.9	60	<6	<2.6
		11/09/05	1.7	50	E5	.8
		02/22/06	1.4	50	20	.9
SC07	Soldier Creek, I Road near Delia	11/19/03	2.4	70	10	<2.6
		02/25/04	E1.8	30	10	E1.4
		05/19/04	2.2	40	10	<2.6
		08/25/04	2.8	50	E5	4.1
		12/08/04	E1.6	50	10	<2.6
SC07	Soldier Creek, I Road near Delia	02/10/05	<1.9	40	E4	<2.6
		06/01/05	2.0	60	<6	<2.6
		08/16/05	2.7	60	<6	E1.6
		11/09/05	1.9	60	10	1.0
		02/22/06	1.4	50	30	1.1
		06/06/06	3.3	60	<6	.7
		08/02/06	7.8	70	E4	.7

¹Water-quality criteria established by the U.S. Environmental Protection Agency (2006).

Table 11. Results of analysis of trace elements in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.

[µg/L, micrograms per liter; MCL, Maximum Contaminant Level; DWA, Drinking-Water Advisory; SDWR, Secondary Drinking-Water Regulation; E, estimated; <, less than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Arsenic, dissolved (µg/L)	Boron, dissolved (µg/L)	Iron, dissolved (µg/L)	Selenium, dissolved (µg/L)
	Water-quality criteria ¹		10 (MCL)	600 (DWA)	300 (SDWR)	50 (MCL)
MW01	Monitoring well #1	7/28/2004	E1.4	70	1,000	<2.6
		7/11/2005	E1.4	70	1,100	<2.6
		8/16/2006	1.4	60	880	<.1
MW02	Monitoring well #2	7/27/2004	<1.9	110	30	<2.6
		7/11/2005	<1.9	100	60	<2.6
		8/15/2006	.2	90	30	E.1
MW03	Monitoring well #3	7/26/2004	<1.9	880	3,600	<2.6
		7/12/2005	<1.9	870	3,400	<2.6
		8/15/2006	1.6	860	3,600	E.1
MW04	Monitoring well #4	7/29/2004	<1.9	60	<6	<2.6
		7/14/2005	E1.3	50	<6	<2.6
		8/16/2006	.2	50	<6	.6
MW06	Monitoring well #6	7/29/2004	19	100	4,100	<2.6
		7/13/2005	22	100	3,800	<2.6
		8/14/2006	30	90	5,700	<.1
MW07	Monitoring well #7	7/27/2004	<1.9	90	40	<2.6
		7/13/2005	<1.9	80	50	<2.6
		8/15/2006	.5	70	50	.3
MW08	Monitoring well #8	7/27/2004	<1.9	100	120	<2.6
		7/12/2005	<1.9	90	340	<2.6
		8/14/2006	1.2	70	330	.2
MW09	Monitoring well #9	7/29/2004	<1.9	30	E6	<2.6
		7/14/2005	<1.9	30	<6	<2.6
		8/17/2006	.2	20	<6	.5
MW10	Monitoring well #10	7/28/2004	<1.9	40	E4	E1.3
		7/14/2005	<1.9	40	E2	E1.7
		8/16/2006	.3	30	<6	1.9
MW11	Monitoring well #11	7/26/2004	E1.3	60	E4	<2.6
		7/14/2005	<1.9	50	<6	<2.6
		8/18/2006	1.5	60	<6	1.0

¹Water-quality criteria established by the U.S. Environmental Protection Agency (2006).

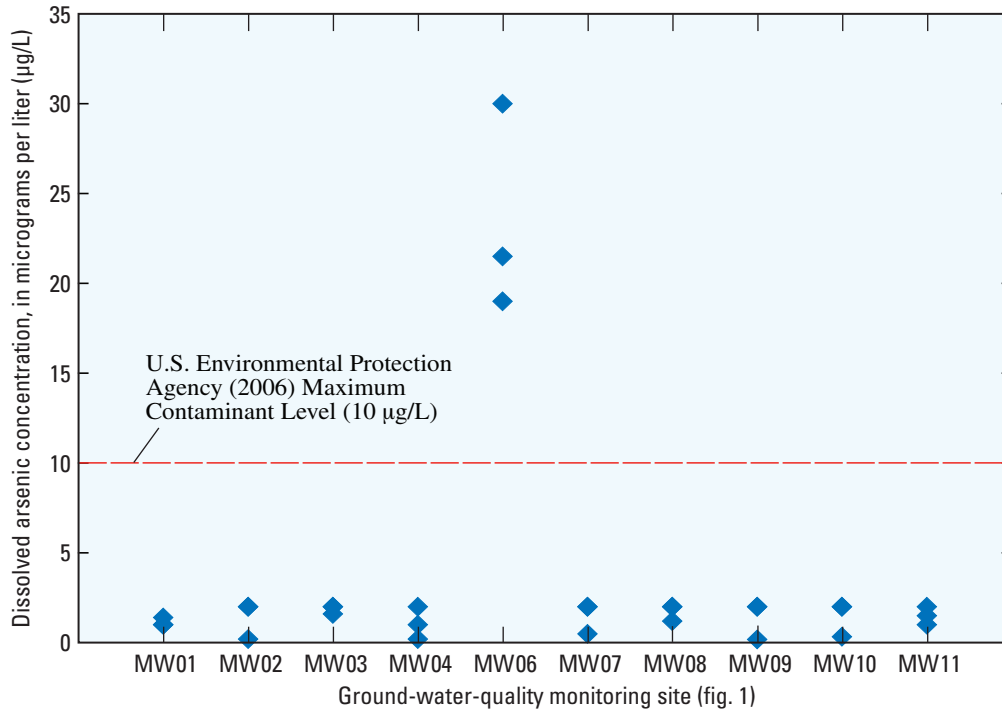


Figure 12. Concentrations of dissolved arsenic in ground-water-quality samples, July 2004, July 2005, and August 2006.

concentrations were detected in samples from well MW06, which corresponds to larger arsenic concentrations. Iron concentrations in water from wells MW01, MW03, MW06, and MW08 (two samples) exceeded the USEPA SDWR of 300 µg/L. Iron concentrations in samples from the remainder of the wells were substantially less than the SDWR.

Selenium is a naturally occurring mineral element that is relatively rare, and geochemical factors tend to limit its aqueous mobility (Hem, 1992). Selenium was detected in extremely small concentrations, less than the reporting level in most surface- and ground-water samples (tables 10 and 11). The largest concentration was 4.1 µg/L, detected in a surface-water sample from site SC07 on August 25, 2004. The MCL for selenium is 50 µg/L (U.S. Environmental Protection Agency, 2006).

Pesticides

The use of pesticides on the reservation is characteristic of pesticide use in all agricultural regions throughout Kansas. Atrazine, one of the triazine herbicides, has been used since the 1950s in the production of corn and grain sorghum in the area. Another potential source of atrazine may be its use in controlling weeds along railroad rights-of-way and along roads and highways. It is the most frequently detected herbicide in Kansas (Stamer and Zelt, 1994).

Triazine herbicides were analyzed in both surface- and ground-water samples. Triazine herbicides and their degradates are listed on the USEPA Contaminant Candidate List (U.S. Environmental Protection Agency, 2006). The herbicides are applied pre- and post-emergence and are subject to runoff if applied before large rainfalls. Fifty-five surface-water

samples collected during November 2003 through August 2006 were analyzed using the ELISA (enzyme-linked immunosorbent assay) triazine herbicide screen. The triazine herbicide screen ELISA is a reliable indicator of atrazine (fig. 14). Christensen and Ziegler (1998) found that at least 80 percent of the triazine herbicide concentration determined by ELISA is atrazine.

During June 1996 through August 2006, 282 surface-water samples collected from the reservation were analyzed for triazine herbicides by ELISA; 78 of these had atrazine concentrations confirmed by GC/MS (gas chromatography/mass spectrometry) analysis (see previous "Methods" section). Data from June 1996 through November 1998 are presented in Trombley (1999, table 5); data from February 1999 through February 2001 are presented in Trombley (2001, table 11); and data from May 2001 through August 2003 are presented in Schmidt (2004, table 12).

The relation between the triazine herbicide screen and atrazine is presented in figure 14; the correlation between results obtained from ELISA analysis and GC/MS analysis is apparent and has a coefficient of determination (R^2) of 0.91. Therefore, results from the triazine screen can be compared to the drinking-water MCL of 3.0 µg/L as an annual average established by USEPA for atrazine, with the understanding that, by regression analysis, 86 percent (slope of the regression) of the ELISA triazine screen concentration is atrazine.

Of 55 surface-water samples collected from November 2003 through August 2006 and analyzed by ELISA, concentrations of triazine herbicides ranged from less than 0.1 to 3.4 µg/L, with a median concentration of 0.2 µg/L (table 12, fig. 15). Triazine herbicides were detected in one surface-water sample at a concentration greater than the MCL of

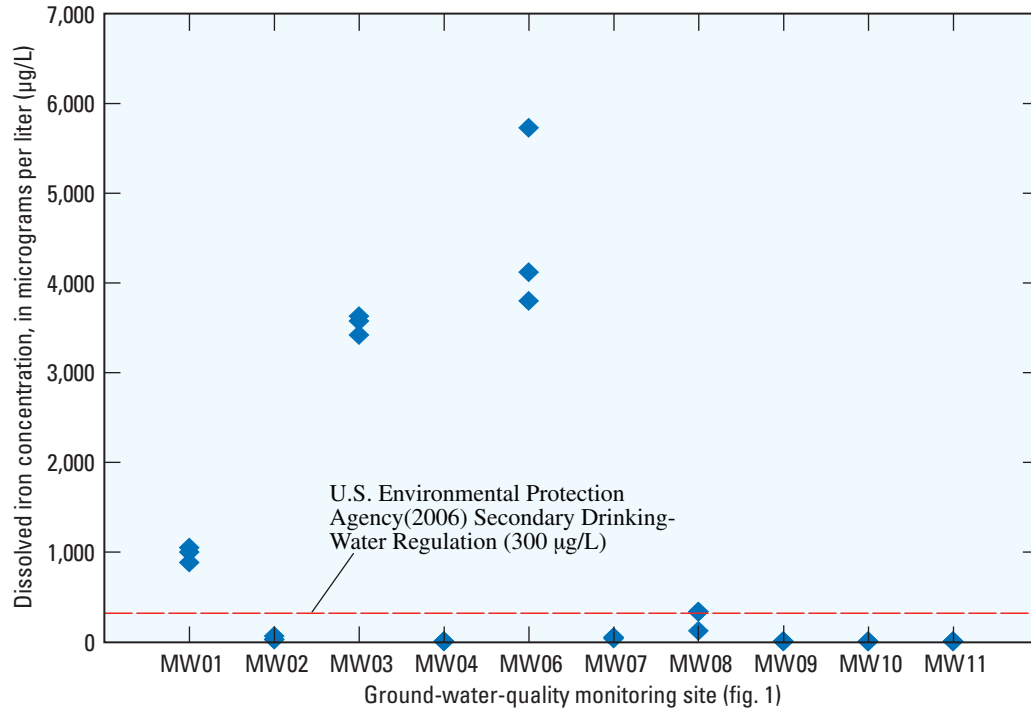


Figure 13. Concentrations of dissolved iron in ground-water-quality samples, July 2004, July 2005, and August 2006.

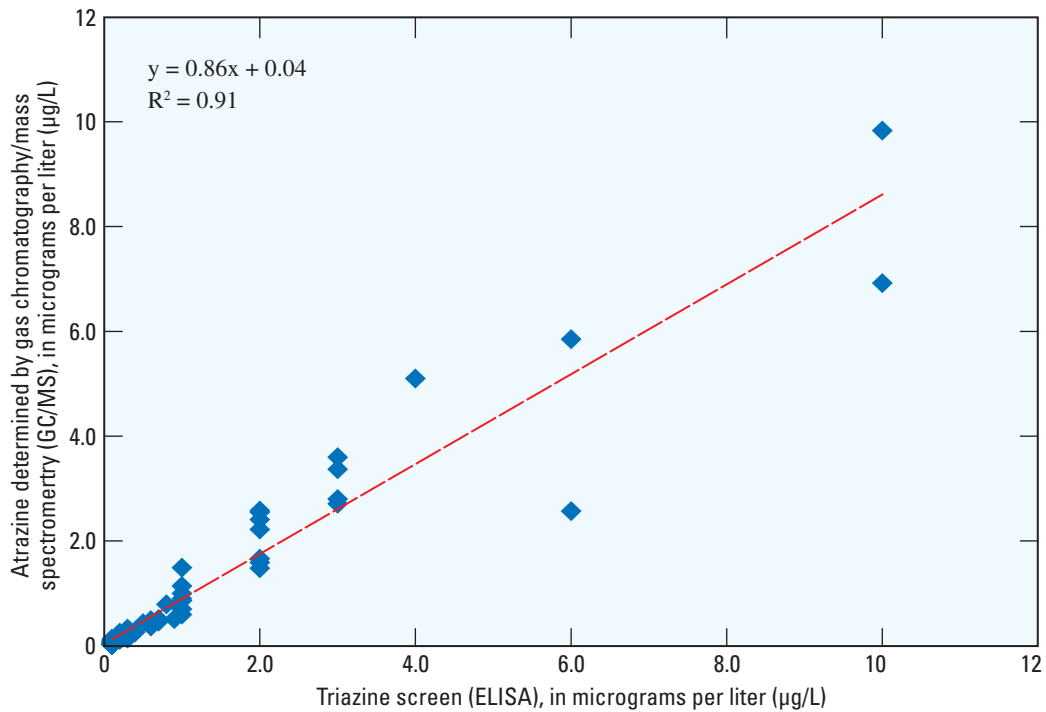


Figure 14. Relation between triazine herbicide concentrations determined by enzyme-linked immunosorbent assay (ELISA) and atrazine concentrations determined by gas chromatography/mass spectrometry (GC/MS) for samples collected from surface-water monitoring sites during June 1996 through August 2006.

Table 12. Results of analysis of pesticides in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[ELISA, enzyme-linked immunosorbent assay; µg/L, micrograms per liter; --, not determined or not applicable; <, less than; E, estimated; MCL, Maximum Contaminant Level]

Monitor- ing-site identifier (fig. 1)	Site name	Date of sam- ple collection (month/day/ year)	Flufenacet, dissolved (µg/L)	Metolachlor, dissolved (µg/L)	Metribuzin, dissolved (µg/L)	Pendi- methalin, dissolved (µg/L)	Prome- ton, dis- solved (µg/L)	Prom- etryn, dis- solved (µg/L)	Propa- chlor, dissolved (µg/L)	Propa- zine, dissolved (µg/L)	Sima- zine, dissolved (µg/L)	Terbutryn, dissolved (µg/L)
Soldier Creek Basin—Continued												
SC03	Soldier Creek near Saint Clerc	08/16/05	--	--	--	--	--	--	--	--	--	--
		11/09/05	--	--	--	--	--	--	--	--	--	--
		02/22/06	--	--	--	--	--	--	--	--	--	--
		06/06/06	--	--	--	--	--	--	--	--	--	--
		08/02/06	--	--	--	--	--	--	--	--	--	--
SC07	Soldier Creek, I Road near Delia	11/19/03	--	--	--	--	--	--	--	--	--	--
		02/25/04	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		05/19/04	--	--	--	--	--	--	--	--	--	--
		08/25/04	--	--	--	--	--	--	--	--	--	--
		12/08/04	--	--	--	--	--	--	--	--	--	--
		02/10/05	--	--	--	--	--	--	--	--	--	--
		06/01/05	--	--	--	--	--	--	--	--	--	--
		08/16/05	--	--	--	--	--	--	--	--	--	--
		11/09/05	--	--	--	--	--	--	--	--	--	--
		02/22/06	--	--	--	--	--	--	--	--	--	--
		06/06/06	--	--	--	--	--	--	--	--	--	--
		08/02/06	--	--	--	--	--	--	--	--	--	--

¹Water-quality criteria established by the U.S. Environmental Protection Agency (2006).

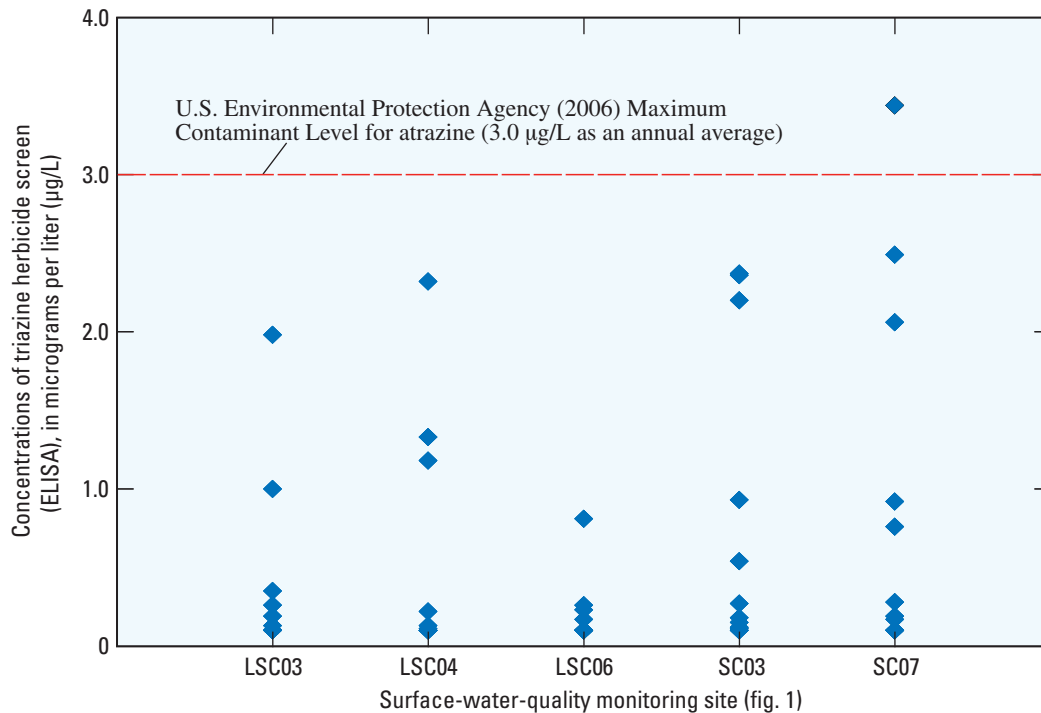


Figure 15. Concentrations of triazine herbicide screen determined using enzyme-linked immunosorbent assay (ELISA) in surface-water-quality samples, November 2003 through August 2006.

3.0 µg/L for atrazine. That sample was collected from a site on Soldier Creek (site SC07) on February 25, 2004. However, the actual atrazine concentration in this sample probably was less than the MCL when the slope of the regression (fig. 14) is considered. Also, the 3.4 µg/L concentration was not verified as atrazine as a result of GC/MS analysis of this sample, which determined an atrazine concentration of 2.7 µg/L (table 12).

Four surface-water samples collected between February 2004 and May 2004 were analyzed for specific triazine herbicides and other pesticides by GC/MS (table 12). Four of the triazine herbicides and other pesticides analyzed were detected in these surface-water samples. Atrazine was detected in the four surface-water samples analyzed by GC/MS at concentrations ranging from 0.79 to 2.7 µg/L, with a median concentration of 2.4 µg/L. All four surface-water samples also had detections of metolachlor, a general-use pesticide, with concentrations that ranged from 0.05 to 0.71 µg/L.

Atrazine, one atrazine metabolite (2-chloro-4-isopropyl-amino-6-amino-s-triazine), and (or) cyanazine amide were detected in the ground-water samples collected August 16–18, 2006, from monitoring wells MW04, MW10, and MW11 (table 13). There were no other detections of pesticides in water from these wells in previous samples during the current study period. All detected concentrations were small relative to laboratory reporting levels and established water-quality criteria.

Chemical Oxygen Demand and Volatile Organic Compounds

The chemical oxygen demand (COD) of a water sample is a measure of the amount of oxygen needed to oxidize the reactive chemicals in a water system (Hem, 1992). If the COD of a sample is high as that water moves through a system, it will consume dissolved oxygen from the surrounding water to complete chemical reactions. Decreases in dissolved oxygen in a system can destroy aerobic organisms and cause changes in the redox environment of a system, which could release redox sensitive chemicals such as arsenic and iron into the water. COD also is used as a quantitative measure of organic pollution in a water sample (Hem, 1992). The COD in the water sample from well MW04 was 10 mg/L (equivalent to the laboratory reporting level) for the sample collected on July 14, 2005 (table 14). In a sample collected a year later from the same well, the COD was less than 10 mg/L. As this water moves through the ground-water system, it probably will not consume a substantial amount of dissolved oxygen in the aquifer downgradient from the well.

Volatile organic compounds (VOCs) are compounds that have a high vapor pressure and low water solubility. Many VOCs are synthetic chemicals that are used and produced in the manufacture of paints, pharmaceuticals, and refrigerants. VOCs typically are industrial solvents, fuel oxygenates, or by-products produced by chlorination in water treatment. VOCs often are components of petroleum fuels, hydraulic fluids,

Table 13. Results of analysis of pesticides in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	2-Chloro-4-isopropyl-amino-6-amino-s-triazine, dissolved (µg/L)	2-Chloro-6-ethylamino-4-amino-s-triazine, dissolved (µg/L)	Aceto-chlor, dissolved (µg/L)	Alachlor, dissolved (µg/L)	Ametryn, dissolved (µg/L)	Atrazine, dissolved (µg/L)	Cyanazine, dissolved (µg/L)	Cyanazine amide, dissolved (µg/L)	Dimethenamid, dissolved (µg/L)
Water-quality criteria ^a											
			--	--	--	2.0 (MCL)	--	3.0 (MCL)	--	--	--
MW01	Monitoring well #1	7/28/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		7/11/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		8/16/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MW02	Monitoring well #2	7/27/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		7/11/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		8/15/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MW03	Monitoring well #3	7/26/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		7/12/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		8/15/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MW04	Monitoring well #4	7/29/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		7/14/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		8/16/2006	.09	<0.05	<0.05	<0.05	<0.05	.06	<0.05	.11	<0.05
MW06	Monitoring well #6	7/29/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		7/13/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		8/14/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MW07	Monitoring well #7	7/27/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		7/13/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		8/15/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

[µg/L, micrograms per liter; --, not determined or not applicable; <, less than; MCL, Maximum Contaminant Level]

Table 13. Results of analysis of pesticides in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006—Continued

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Flufenacet dissolved (µg/L)	Metolachlor dissolved (µg/L)	Methidathion dissolved (µg/L)	Prometon dissolved (µg/L)	Prometryn dissolved (µg/L)	Propachlor dissolved (µg/L)	Propazine dissolved (µg/L)	Simazine dissolved (µg/L)	Terbutryn dissolved (µg/L)	
Water-quality criteria ¹												
MW01	Monitoring well #1	7/28/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		7/11/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		8/16/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
MW02	Monitoring well #2	7/27/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		7/11/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		8/15/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
MW03	Monitoring well #3	7/26/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		7/12/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		8/15/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
MW04	Monitoring well #4	7/29/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		7/14/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		8/16/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
MW06	Monitoring well #6	7/29/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		7/13/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		8/14/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
MW07	Monitoring well #7	7/27/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		7/13/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		8/15/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
MW08	Monitoring well #8	7/27/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		7/12/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
		8/14/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

[µg/L, micrograms per liter; --, not determined or not applicable; <, less than; MCL, Maximum Contaminant Level]

Table 13. Results of analysis of pesticides in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006—Continued
[µg/L, micrograms per liter; --, not determined or not applicable; <, less than; MCL, Maximum Contaminant Level]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Flufenacet, dissolved (µg/L)	Metolachlor, dissolved (µg/L)	Me-tribuzin, dissolved (µg/L)	Pendi-methalin, dissolved (µg/L)	Prometon, dissolved (µg/L)	Prometryn, dissolved (µg/L)	Propachlor, dissolved (µg/L)	Propazine, dissolved (µg/L)	Simazine, dissolved (µg/L)	Terbutryn, dissolved (µg/L)
MW09	Monitoring well #9	7/29/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		7/14/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		8/17/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MW10	Monitoring well #10	7/28/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		7/14/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		8/16/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MW11	Monitoring well #11	7/26/2004	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		7/14/2005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		8/18/2006	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

¹Water-quality criteria established by the U.S. Environmental Protection Agency (2006).

Table 14. Results of analysis of chemical oxygen demand and volatile organic compounds in ground-water-quality samples from monitoring wells MW04 and MW07 on Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.

[mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; E, estimated; --, not determined]

Constituent and unit of measurement	Concentration for indicate sample date			
	Monitoring well MW04			Monitoring well MW07
	7/29/04	7/14/05	8/16/06	7/27/04
Chemical oxygen demand, total, mg/L	--	10	<10	--
1,1,1,2-Tetrachloroethane, total, µg/L	<0.03	<.03	<0.03	<0.03
1,1,1-Trichloroethane, total, µg/L	<.032	<.032	<.032	<.032
1,1,2,2-Tetrachloroethane, total, µg/L	<.16	<.08	<.08	<.16
1,1,2-Trichloro-1,2,2-trifluoroethane, total, µg/L	<.04	<.04	<.04	<.04
1,1,2-Trichloroethane, total, µg/L	<.06	<.04	<.04	<.06
1,1-Dichloroethane, total, µg/L	<.035	<.035	<.035	<.035
1,1-Dichloroethene, total, µg/L	<.02	<.02	<.02	<.02
1,1-Dichloropropene, total, µg/L	<.03	<.03	<.03	<.03
1,2,3,4-Tetramethylbenzene, total, µg/L	<.1	<.1	<.1	<.1
1,2,3,5-Tetramethylbenzene, total, µg/L	<.1	<.1	<.2	<.1
1,2,3-Trichlorobenzene, total, µg/L	<.3	<.2	<.2	<.3
1,2,3-Trichloropropane, total, µg/L	<.18	<.18	<.18	<.18
1,2,3-Trimethylbenzene, total, µg/L	<.1	<.1	<.1	<.1
1,2,4-Trichlorobenzene, total, µg/L	<.1	<.1	<.1	<.1
1,2,4-Trimethylbenzene, total, µg/L	<.056	<.056	<.056	<.056
1,2-Dibromo-3-chloropropane, total, µg/L	<.5	<.5	<.5	<.5
1,2-Dibromoethane, total, µg/L	<.036	<.036	<.036	<.036
1,2-Dichlorobenzene, total, µg/L	<.05	<.05	<.05	<.05
1,2-Dichloroethane, total, µg/L	<.1	<.1	<.1	<.1
1,2-Dichloropropane, total, µg/L	<.029	<.029	<.029	<.029
1,3,5-Trimethylbenzene, total, µg/L	<.044	<.044	<.044	<.044
1,3-Dichlorobenzene, total, µg/L	<.03	<.03	<.03	<.03
1,3-Dichloropropane, total, µg/L	<.12	<.12	<.12	<.12
1,4-Dichlorobenzene, total, µg/L	<.03	<.03	<.03	<.03
2,2-Dichloropropane, total, µg/L	<.05	<.05	<.05	<.05
2-Chlorotoluene, total, µg/L	<.04	<.04	<.04	<.04
2-Ethyltoluene, total, µg/L	<.06	<.06	<.06	<.06
3-Chloropropene, total, µg/L	<.50	<.50	<.50	<.50
4-Chlorotoluene, total, µg/L	<.05	<.05	<.05	<.05

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Table 14. Results of analysis of chemical oxygen demand and volatile organic compounds in ground-water-quality samples from monitoring wells MW04 and MW07 on Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.—Continued

[mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; E, estimated; --, not determined]

Constituent and unit of measurement	Concentration for indicate sample date			
	Monitoring well MW04			Monitoring well MW07
	7/29/04	7/14/05	8/16/06	7/27/04
4-Isopropyltoluene, total, µg/L	<0.08	<0.08	<0.08	<0.08
Acetone, total, µg/L	<6	<6	<6	<6
Acrylonitrile, total, µg/L	<1	<.8	<.8	<1
Benzene, total, µg/L	<.02	<.02	<.02	<.02
Bromobenzene, total, µg/L	<.03	<.03	<.03	<.03
Bromochloromethane, total, µg/L	<.12	<.12	<.12	<.12
Bromodichloromethane, total, µg/L	<.03	<.03	<.03	<.03
Bromoethene, total, µg/L	<.1	<.1	<.1	<.1
Bromomethane, total, µg/L	<.26	<.26	<.26	<.26
Carbon disulfide, total, µg/L	<.04	<.04	<.04	<.04
Chlorobenzene, total, µg/L	<.028	<.028	<.028	<.028
Chloroethane, total, µg/L	<.12	<.12	<.12	<.12
Chloromethane, total, µg/L	<.17	<.17	<.17	<.17
cis-1,2-Dichloroethene, total, µg/L	<.02	<.02	<.02	<.02
cis-1,3-Dichloropropene, total, µg/L	<.05	<.05	<.05	<.05
Dibromochloromethane, total, µg/L	<.1	<.1	<.1	<.1
Dibromomethane, total, µg/L	<.05	<.05	<.05	<.05
Dichlorodifluoromethane, total, µg/L	<.18	<.18	<.18	<.18
Dichloromethane, total, µg/L	<.1	<.1	<.1	<.1
Diethyl ether, total, µg/L	<.1	<.1	<.1	E.1
Diisopropyl ether, total, µg/L	<.10	<.10	<.10	<.10
Ethyl methacrylate, total, µg/L	<.18	<.18	<.18	<.18
Ethyl methyl ketone, total, µg/L	<4.0	<2.0	<2.0	<4.0
Ethylbenzene, total, µg/L	<.03	<.03	<.03	<.03
Hexachlorobutadiene, total, µg/L	<.14	<.14	<.14	<.14
Hexachloroethane, total, µg/L	<.1	<.1	<.1	<.1
Iodomethane, total, µg/L	<.35	<.50	<.50	<.35
Isobutyl methyl ketone, total, µg/L	<.37	<.37	<.37	<.37
Isopropylbenzene, total, µg/L	<.04	<.04	<.04	<.04
Methacrylonitrile, total, µg/L	<.8	<.4	<.4	<.8

Table 14. Results of analysis of chemical oxygen demand and volatile organic compounds in ground-water-quality samples from monitoring wells MW04 and MW07 on Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.—Continued

[mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; E, estimated; --, not determined]

Constituent and unit of measurement	Concentration for indicate sample date			
	Monitoring well MW04			Monitoring well MW07
	7/29/04	7/14/05	8/16/06	7/27/04
Methyl acrylate, total, µg/L	<2.0	<1.0	<1.0	<2.0
Methyl methacrylate, total, µg/L	<.3	<.2	<.2	<.3
Methyl tert-pentyl ether, total, µg/L	<.08	<.04	<.04	<.08
m-Xylene plus p-xylene, total, µg/L	<.06	<.06	<.06	<.06
Naphthalene, total, µg/L	<.5	<.5	<.5	<.5
n-Butyl methyl ketone, total, µg/L	<.7	<.4	<.4	<.7
n-Butylbenzene, total, µg/L	<.1	<.1	<.1	<.1
n-Propylbenzene, total, µg/L	<.042	<.042	<.042	<.042
o-Xylene, total, µg/L	<.04	<.04	<.04	<.04
sec-Butylbenzene, total, µg/L	<.06	<.06	<.06	<.06
Styrene, total, µg/L	<.042	<.042	<.042	<.042
tert-Butyl ethyl ether, total, µg/L	<.05	<.03	<.03	<.05
Methyl tert-butyl ether, total, µg/L	<.2	<.1	<.1	<.2
tert-Butylbenzene, total, µg/L	<.06	<.06	<.08	<.06
Tetrachloroethene, total, µg/L	<.06	<.03	<.03	<.06
Tetrachloromethane, total, µg/L	<.06	<.06	<.06	<.06
Tetrahydrofuran, total, µg/L	<2	<1	<1	<2
Toluene, total, µg/L	<.05	<.02	<.02	<.05
trans-1,2-Dichloroethene, total, µg/L	<.032	<.032	<.032	<.032
trans-1,3-Dichloropropene, total, µg/L	<.09	<.09	<.09	<.09
trans-1,4-Dichloro-2-butene, total, µg/L	<.7	<.7	<.7	<.7
Tribromomethane, total, µg/L	<.10	<.10	<.10	<.10
Trichloroethene, total, µg/L	<.038	<.038	<.038	<.038
Trichlorofluoromethane, total, µg/L	<.16	<.08	<.08	<.16
Trichloromethane, total, µg/L	<.024	<.024	<.024	<.024
Vinyl chloride, total, µg/L	<.11	<.11	<.11	<.11

paint thinners, and dry cleaning agents (Daly and Lindsey, 1996).

During the current study period, all three samples from well MW04 and the July 27, 2004, water sample from well MW07 were analyzed for the presence of VOCs. The samples from well MW04 were analyzed because of its proximity to a construction and demolition landfill (fig. 1); the sample from well MW07 was analyzed as a reference site for comparison to results from well MW04. During the previous study period (Schmidt, 2004, table 14), carbon disulfide, ethyl methyl ketone, and tetrahydrofuran were detected in a water sample from well MW04. Of the 85 VOCs analyzed in water samples from the two wells for the current study period, only one compound was detected—diethyl ether, found in the sample from well MW07 at an estimated concentration of 0.1 µg/L (table 14). Diethyl ether is used as a solvent, general anesthetic, and as a starting fluid for diesel and gasoline engines. No drinking-water criteria have been established for exposure to diethyl ether.

Bacteria

Fecal coliform, *Escherichia coli* (*E. coli*), fecal streptococcus, and enterococci bacteria are indigenous to the intestinal tract of warmblooded animals (Holt and others, 1993). The fecal coliform bacteria group can include any combination of *E. coli* and species of the *Klebsiella*, *Enterobacter*, and *Citrobacter* genera (Gleeson and Gray, 1997). The presence of large concentrations of these organisms in surface water indicates fecal contamination and also may indicate the presence of disease-causing organisms. Potential sources of these bacteria on the reservation include sewage lagoons, runoff, and seepage from livestock areas, such as pastures and confined feedlots, and from wildlife populations.

USEPA has established water-quality criteria on the basis of full-body contact and single-sample allowable density for water bodies defined as moderately used, lightly used, and infrequently used (U.S. Environmental Protection Agency, 2002b). Primary contact use is defined as activities where the body is immersed in water to the extent that some inadvertent ingestion of the water is probable. These activities include boating, mussel harvesting, swimming, skin diving, water skiing, and wind surfing (Kansas Department of Health and Environment, 2001). These criteria are presented in table 15. USEPA currently (2007) has no recommended criteria for secondary contact (U.S. Environmental Protection Agency, 2002b); however, the Kansas Department of Health and Environment has set maximums for both primary and secondary contact recreation in public-access streams for the State of Kansas (Kansas Department of Health and Environment, 2004). Secondary contact activities include wading, fishing, trapping, and hunting where the ingestion of water is not probable (Kansas Department of Health and Environment, 2001). Tribal members primarily use the streams on the reservation

for hunting and fishing; therefore, ingestion of water is not probable during these activities.

Fecal coliform bacteria densities ranged from less than 3 to 32,000 col/100 mL in surface-water samples from the reservation (table 16). The largest density of fecal coliform colonies was in a sample collected on May 11, 2005, from site LSC04. The median density of fecal coliform bacteria in all samples from the surface-water sites was 230 col/100 mL. Fecal coliform bacteria were detected six times in ground-water samples from monitoring wells (table 17). The two largest densities were 34 col/100 mL from monitoring well MW02 on July 11, 2005, and an estimated 10 col/100 mL from monitoring well MW11 on August 18, 2006.

E. coli is the dominant bacteria of the fecal coliform group (Rasmussen and Ziegler, 2003). Rasmussen and Ziegler (2003) found that the ratio of *E. coli* to fecal coliform in the Soldier Creek Basin is 0.73, meaning that out of every 100 colonies of fecal coliform in a surface-water sample, 73 of the colonies are *E. coli* bacteria. This relation is important when comparing historic fecal coliform bacteria densities to the current (2007) USEPA bacteria water-quality criteria, which are based on *E. coli* densities.

The densities of *E. coli* colonies in surface-water samples ranged from less than 3 to 31,000 col/100 mL, with a median density of 170 col/100 mL (table 16). The largest density of *E. coli* colonies was detected in the sample collected from site LSC04 on May 11, 2005. Of 55 surface-water samples analyzed for *E. coli* bacteria, 22 samples (40 percent) exceeded the criterion established by the U.S. Environmental Protection Agency (2002b) for primary contact (illness rate of 8 per 1,000 swimmers, table 15) in moderately used water bodies (298 col/100 mL), 18 samples (33 percent) exceeded the criterion for lightly used water bodies (406 col/100 mL), and 16 samples (29 percent) exceeded the criterion for infrequently used water bodies (576 col/100 mL). In addition, 11 of 27 samples (41 percent) exceeded the KDHE (Kansas Department of Health and Environment, 2004) single-sample maximum for primary contact in public access bodies of water (1,198 col/100 mL for samples collected between April 1 and October 31), and 4 of 55 samples (7 percent) exceeded the KDHE single-sample maximum for secondary contact in public access bodies of water (9,760 col/100 mL; applicable year round).

E. coli was detected in eight samples (27 percent) of ground water (table 17). Most were at small estimated densities. The largest density of 23 col/100 mL was detected in a sample from well MW02 on July 11, 2005. This corresponds to the largest detected density of fecal coliform bacteria.

Fecal streptococci bacteria densities in surface-water samples ranged from 130 to 140,000 col/100 mL, with a median density of 1,100 col/100 mL (table 16). The largest density occurred in the May 19, 2004, sample from site LSC06. All 13 samples analyzed during the current study period had detectable densities of fecal streptococci bacteria. Ground-water samples were not analyzed for fecal streptococci bacteria.

Table 15. U.S. Environmental Protection Agency (2002b) recommended water-quality criteria for fecal-indicator bacteria.

[All values are in colonies per 100 milliliters of water]

Indicator bacteria type	Illness rate (per 1,000 swimmers)	Primary contact recreation ¹		
		Single-sample maximum allowable density		
		Moderately used full-body contact	Lightly used full-body contact	Infrequently used full-body contact
<i>Escherichia coli</i> (<i>E. coli</i>)	8	298	406	576
	9	381	524	736
	10	487	669	941
	11	622	855	1,202
	12	795	1,092	1,536
	13	1,016	1,396	1,962
	14	1,298	1,783	2,507
Enterococci	8	78	107	151
	9	100	137	193
	10	128	175	246
	11	163	224	315
	12	208	286	402
	13	266	365	514
	14	340	467	656

¹Recreation during which the body is immersed in surface water to the extent that some inadvertent ingestion of water is probable.

Enterococci bacteria are a subgroup of the fecal streptococci bacteria and are a valuable bacterial indicator for determining the extent of fecal contamination of recreational surface water. Studies at marine and freshwater bathing beaches indicated that swimming-associated gastroenteritis is related directly to the quality of the bathing water, and enterococci are the most efficient bacterial indicator of water quality (American Public Health Association and others, 1992). USEPA has established water-quality criteria (table 15) that are based on enterococci bacteria densities in recreational water (U.S. Environmental Protection Agency, 2002b).

Enterococci bacteria densities in surface-water samples from the reservation ranged from an estimated 8 to 290,000 col/100 mL, with a median density of 1,500 col/100 mL (table 16). The largest density was detected in a sample from site LSC04 on May 11, 2005, and corresponds with the largest densities of fecal coliform and *E. coli* bacteria. USEPA criteria that are based on an illness rate of 8 per 1,000 swimmers and the single-sample maximum allowable density were used for comparison purposes (table 15). Of 55 surface-water samples analyzed for enterococci bacteria, 50 samples (91 percent) exceeded the criteria for primary

contact in both moderately used water bodies and lightly used water bodies (78 and 107 col/100 mL, respectively), and 48 samples (87 percent) exceeded the primary contact criterion for infrequently used water bodies (151 col/100 mL).

Enterococci bacteria were the most frequently detected bacteria in ground-water samples (table 17). Enterococci were detected in 16 of 30 ground-water samples (53 percent), and densities in all 30 samples ranged from less than 1 to an estimated 230 col/100 mL. The largest density of enterococci bacteria was estimated in a water sample from monitoring well MW02 on August 15, 2006.

Figure 16 shows median densities of fecal-indicator bacteria in surface-water samples during spring, summer, fall, and winter as well as median streamflow measured at the time of sample collection. Only quarterly samples were used in comparison, with the May and June samples defined as “spring,” August samples defined as “summer,” November and December samples defined as “fall,” and February samples defined as “winter.” Median densities of all indicator bacteria were largest during the summer months, except for fecal streptococci, which was not measured in any summer samples for the current study period because analyses of samples for fecal

Table 16. Results of analysis of fecal-indicator bacteria in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.

[Other water-quality criteria listed in table 15. col/100 mL, colonies per 100 milliliter of water; --, not determined or not applicable; E, estimated; <, less than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Fecal-indicator bacteria					
			Fecal coliform (col/100 mL)	<i>Escherichia coli</i> (col/100 mL)	Fecal streptococci (col/100 mL)	Enterococci (col/100 mL)		
Water-quality criterion			--	¹ 9,760	--	--		
Little Soldier Creek Basin								
LSC03	Little Soldier Creek, O Road near Mayetta	11/19/03	--	--	--	--		
		02/25/04	230	170	640	E9,800		
		05/19/04	6,100	5,500	25,000	20,000		
		08/25/04	8,700	5,700	--	21,000		
		12/08/04	430	240	--	E4,200		
		02/10/05	E200	100	--	E2,200		
		06/01/05	930	930	--	5,500		
		08/16/05	2,000	190	--	600		
		11/09/05	160	120	--	360		
		02/22/06	E3	E3	--	E30		
		06/06/06	80	E50	--	280		
		08/02/06	--	--	--	--		
		LSC04	Little Soldier Creek, 134 Road near Mayetta	11/19/03	--	--	--	--
				02/25/04	670	600	550	2,200
05/19/04	15,000			16,000	82,000	140,000		
08/25/04	12,000			7,700	--	26,000		
12/08/04	230			220	--	1,900		
02/10/05	160			70	--	E3,500		
05/11/05	32,000			31,000	--	290,000		
08/16/05	460			350	--	1,200		
11/09/05	310			170	--	460		
02/22/06	E42			E41	--	E28		
06/06/06	360			410	--	580		
08/02/06	--			--	--	--		
LSC06	Big Elm Creek, 134 Road near Hoyt			11/19/03	180	100	1,600	2,500
				02/25/04	190	100	890	1,900
		05/19/04	19,000	22,000	140,000	130,000		
		08/25/04	2,200	3,400	--	19,000		
		12/08/04	930	640	--	2,400		
		02/10/05	E52	E20	--	800		
		06/01/05	430	350	--	E2,000		
		08/16/05	2,000	730	--	1,500		

Table 16. Results of analysis of fecal-indicator bacteria in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[Other water-quality criteria listed in table 15. col/100 mL, colonies per 100 milliliter of water; --, not determined or not applicable; E, estimated; <, less than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Fecal-indicator bacteria			
			Fecal coliform (col/100 mL)	<i>Escherichia coli</i> (col/100 mL)	Fecal streptococci (col/100 mL)	Enterococci (col/100 mL)
LSC06	Big Elm Creek, 134 Road near Hoyt	11/09/05	280	220	--	1,000
		02/22/06	E30	E15	--	240
		06/06/06	410	340	--	1,000
		08/02/06	--	--	--	--
Soldier Creek Basin						
SC03	Soldier Creek near St. Clere	11/19/03	50	37	280	460
		02/25/04	E33	E24	1,000	E3,800
		05/19/04	19,000	10,000	20,000	49,000
		08/25/04	1,000	620	--	7,400
		12/08/04	E30	E53	--	770
		02/10/05	E38	E9	--	730
		06/01/05	240	330	--	1,200
		08/16/05	170	110	--	210
		11/09/05	110	E53	--	150
		02/22/06	<3	<3	--	E8
		06/06/06	470	140	--	350
		08/02/06	1,700	1,700	--	E2,300
		SC07	Soldier Creek, I Road near Delia	11/19/03	E16	E16
02/25/04	E33			E26	1,100	E4,000
05/19/04	7,300			8,000	28,000	22,000
08/25/04	1,000			1,400	--	3,200
12/08/04	120			E47	--	E5,300
02/10/05	80			E57	--	E3,500
06/01/05	64			E71	--	E220
08/16/05	E54			E65	--	170
11/09/05	E23			E47	--	150
02/22/06	E3			E3	--	E8
06/06/06	100			110	--	54
08/02/06	550			470	--	900

¹Single-sample maximum set by the Kansas Department of Health and Environment (2004) for secondary contact recreation in public-access bodies of water.

Table 17. Results of analysis of fecal-indicator bacteria in ground-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, July 2004, July 2005, and August 2006.

[Water-quality criteria listed in table 15. col/100 mL, colonies per 100 milliliter of water; E, estimated; <, less than]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Fecal-indicator bacteria		
			Fecal coliform (col/100 mL)	<i>Escherichia coli</i> (col/100 mL)	Enterococci (col/100 mL)
MW01	Monitoring well #1	7/28/2004	<1	<1	<1
		7/11/2005	<1	<1	<1
		8/16/2006	E1	E1	E10
MW02	Monitoring well #2	7/27/2004	<1	<1	E16
		7/11/2005	34	23	E150
		8/15/2006	E3	E7	E230
MW03	Monitoring well #3	7/26/2004	<1	<1	<1
		7/12/2005	<1	<1	<1
		8/15/2006	<1	<1	<1
MW04	Monitoring well #4	7/29/2004	<1	<1	43
		7/14/2005	<3	E3	<3
		8/16/2006	<1	<1	<1
MW06	Monitoring well #6	7/29/2004	<1	<1	E4
		7/13/2005	<1	<1	E1
		8/14/2006	<1	<1	E1
MW07	Monitoring well #7	7/27/2004	E1	<1	<1
		7/13/2005	<1	E1	<1
		8/15/2006	<1	<1	<1
MW08	Monitoring well #8	7/27/2004	<1	<1	E3
		7/12/2005	<1	<1	E1
		8/14/2006	<1	<1	<1
MW09	Monitoring well #9	7/29/2004	<1	<1	<1
		7/14/2005	<1	<1	E1
		8/17/2006	<3	<3	<3
MW10	Monitoring well #10	7/28/2004	<1	<1	E2
		7/14/2005	<1	E1	E1
		8/16/2006	<1	<1	<1
MW11	Monitoring well #11	7/26/2004	<3	<3	E42
		7/14/2005	E8	E1	140
		8/18/2006	E10	E2	E27

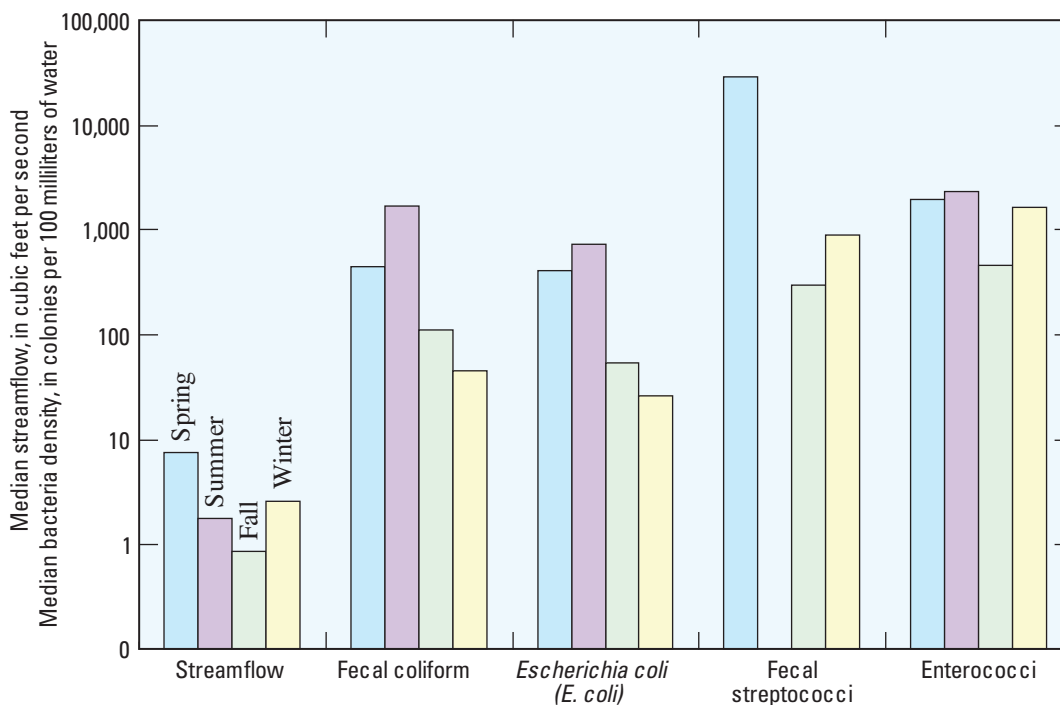


Figure 16. Seasonal distribution of median streamflow and median densities of fecal-indicator bacteria in surface-water samples, November 2003 through August 2006.

streptococci bacteria were discontinued after the spring 2004 sampling period. The bacteria densities were not necessarily larger during times of larger median streamflow.

Sediment

Fluvial sediment is defined as fragmentary material that originates mostly from weathering rocks and is transported by, suspended in, or deposited from water; it includes chemical and biological precipitates and decomposed organic material, such as humus (Federal Inter-Agency Sedimentation Project, 1963).

Fluvial sediment in surface-water samples collected for this study was measured by two different analytical methods—suspended-sediment concentration (SSC) and total suspended solids (TSS). SSC data were collected by measuring the dry weight of all the sediment from a known volume of a water-sediment mixture (Gray and others, 2000). TSS data were determined by measuring the dry weight of sediment from a known volume of a subsample of the original sample (Gray and others, 2000).

SSCs in surface-water samples ranged from 3 to 6,500 mg/L, with a median concentration of 47 mg/L (table 18). The largest SSC was detected in a sample from site LSC04 collected on May 11, 2005, and corresponds to the largest TSS concentration. Suspended sediment was measured in all of the surface-water samples.

Concentrations of TSS were analyzed in all surface-water samples collected during this study and ranged from less than 10 to an estimated 5,200 mg/L, with a median concentration of 16 mg/L (table 18). The largest concentration occurred in a water sample collected on May 11, 2005, from site LSC04 and corresponds to the largest densities of fecal coliform bacteria, *E. coli*, and enterococci bacteria detected during the current study period. TSS concentrations were greater than 10 mg/L in 62 percent of surface-water samples.

The median concentration of TSS in the 24 samples from the two Soldier Creek sites (SC03 and SC07, fig. 1) was larger than the median concentration in the 20 samples from two of the three Little Soldier Creek sites (LSC03 and LSC04, fig. 1), 28 and 18 mg/L, respectively. Median concentrations of suspended sediment were larger in samples collected from the two Little Soldier Creek sites than the two Soldier Creek sites (73 and 56 mg/L, respectively). Median concentrations were small relative to the potential range in concentrations (table 18, fig. 17) and probably are a reflection of the low streamflow conditions under which most surface-water-quality samples were collected during the current study period. Concentrations of SSC and TSS were much smaller in samples from the monitoring site on Big Elm Creek (LSC06, fig. 1), 8 and 10 mg/L respectively, which probably is due to the small amount of sediment discharge from the upstream wastewater-treatment plant (Schmidt, 2004).

Table 18. Results of analysis of suspended sediment and total suspended solids in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.

[mg/L, milligrams per liter; --, not determined; <, less than; E, estimated]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Suspended-sediment concentration (mg/L)	Total suspended solids (mg/L)
Little Soldier Creek Basin				
LSC03	Little Soldier Creek, O Road near Mayetta	11/19/03	--	--
		02/25/04	57	44
		05/19/04	190	160
		08/25/04	120	120
		12/08/04	41	23
		02/10/05	14	15
		06/01/05	26	13
		08/16/05	47	<10
		11/09/05	220	<10
		02/22/06	120	<10
		06/06/06	57	26
		08/02/06	--	--
		LSC04	Little Soldier Creek, 134 Road near Mayetta	11/19/03
02/25/04	23			13
05/19/04	540			210
08/25/04	230			180
12/08/04	8			<10
02/10/05	24			22
05/11/05	6,500			E5,200
08/16/05	18			<10
11/09/05	210			<10
02/22/06	120			<10
06/06/06	58			35
08/02/06	--			--
LSC06	Big Elm Creek, 134 Road near Hoyt			11/19/03
		02/25/04	11	16
		05/19/04	730	300
		08/25/04	35	25
		12/08/04	4	<10

Table 18. Results of analysis of suspended sediment and total suspended solids in surface-water-quality samples from Prairie Band Potawatomi Reservation, northeastern Kansas, November 2003 through August 2006.—Continued

[mg/L, milligrams per liter; --, not determined; <, less than; E, estimated]

Monitoring-site identifier (fig. 1)	Site name	Date of sample collection (month/day/year)	Suspended-sediment concentration (mg/L)	Total suspended solids (mg/L)		
Little Soldier Creek Basin						
LSC06	Big Elm Creek, 134 Road near Hoyt	02/10/05	8	<10		
		06/01/05	6	<10		
		08/16/05	3	<10		
		11/09/05	210	<10		
		02/22/06	90	<10		
		06/06/06	4	<10		
		08/02/06	--	--		
Soldier Creek Basin						
SC03	Soldier Creek near St. Clere	11/19/03	7	<10		
		02/25/04	41	26		
		05/19/04	240	170		
		08/25/04	67	69		
		12/08/04	20	<10		
		02/10/05	41	12		
		06/01/05	63	61		
		08/16/05	35	25		
		11/09/05	170	<10		
		02/22/06	24	<10		
		06/06/06	43	41		
		08/02/06	43	18		
		SC07	Soldier Creek, I Road near Delia	11/19/03	19	<10
				02/25/04	68	29
05/19/04	500			230		
08/25/04	89			85		
12/08/04	17			13		
02/10/05	41			34		
06/01/05	71			66		
08/16/05	33			36		
11/09/05	150			11		
02/22/06	120			<10		
06/06/06	140			74		
08/02/06	47			38		

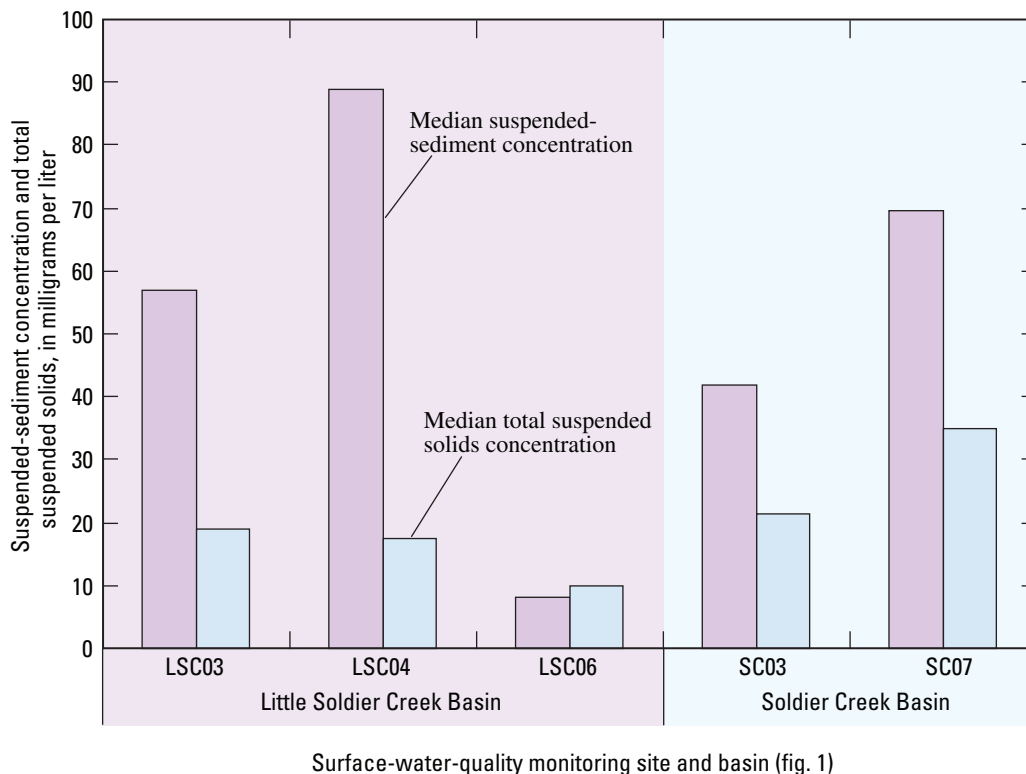


Figure 17. Median concentrations of suspended sediment and total suspended solids in surface-water-quality samples, November 2003 through August 2006.

Comparison of Water-Quality Results to Previous Study Periods

This report describes surface- and ground-water quality on the Prairie Band Potawatomi Reservation from November 2003 through August 2006, and a comparison of results from this study period to results in previous water-quality reports published as a part of this ongoing study is presented in this section. During previous study periods, surface-water samples were collected for analysis of physical properties, nutrients, pesticides, and fecal-indicator bacteria (Trombley, 1999, 2001). Results from these study periods found total phosphorus, triazine herbicides, and fecal-indicator bacteria exceeding their respective water-quality criteria. Previous study-period assessments collected ground-water samples from domestic supply wells and a pumping well installed for a pump test conducted as a part of exploration for development of the tribe's water supply. These ground-water samples were analyzed for physical properties, major ions, dissolved solids, nutrients, trace elements, pesticides, and bacteria, and results identified dissolved solids, sodium, sulfate, boron, iron, and manganese as exceeding their respective water-quality criteria (Trombley, 1999, 2001).

During the May 2001 through August 2003 study period, additional analyses for dissolved solids, major ions, trace elements, and suspended-sediment concentration were conducted

(Schmidt, 2004). Results from this study period found that total phosphorus and triazine herbicide concentrations and fecal-indicator bacteria densities continued to occasionally exceed their respective water-quality criteria at some surface-water monitoring sites on the reservation. Ranges of total phosphorus concentrations generally remained similar to the previous study periods with occasional samples exceeding the water-quality criteria. However, total phosphorus concentrations did increase at site LSC06 from the June 1996 through November 1998 study period (fig. 10 in Trombley, 1999) to the February 1999 through February 2001 study period (fig. 9 in Trombley, 2001). This increase in total phosphorus could be attributed to installation of a sewage-treatment lagoon upstream from the monitoring site in 1998. The range of total phosphorus concentrations for the current study period reported herein was similar to the May 2001 through August 2003 study period (Schmidt, 2004).

The median triazine herbicide concentration (triazine screen by ELISA) for the current study period was equal to or slightly less than past study periods—0.20 µg/L reported in Trombley (1999), 0.50 µg/L reported in Trombley (2001), 0.40 µg/L reported in Schmidt (2004), and 0.20 µg/L during the current study period. In addition, surface-water samples during the current study period did not exceed the USEPA MCL of 3.0 µg/L for atrazine (by GC/MS or regression-predicted ELISA results) as an annual average. Four surface-water samples collected during the first study period (June

1996–November 1998), nine surface-water samples collected during the second study period (February 1999–February 2001), and two surface-water samples collected during the third study period (May 2001–August 2003) exceeded the USEPA MCL for atrazine.

The median density of fecal coliform bacteria in surface-water samples during the current study period was similar to the third study period (Schmidt, 2004) but less than the first two periods (Trombley, 1999, 2001). The median concentration for the June 1996 through November 1998 study period was 290 col/100 mL; the median concentration for the February 1999 through February 2001 study period was 570 col/100 mL; and the median concentration for the May 2001 through August 2003 study period was 190 col/100 mL. For the current study period, the median concentration for fecal coliform bacteria was 230 col/100 mL.

Trombley (2001) found dissolved solids, sodium, sulfate, boron, iron, and manganese concentrations in selected ground-water samples exceeding their respective water-quality criteria. It is not possible to infer trends in ground-water quality across all study periods because the first two study periods consisted of ground-water samples collected from domestic wells and one pumping well. Ground-water sample results presented herein and in the third study (Schmidt, 2004) were collected from dedicated monitoring wells installed across the reservation. The May 2001 through August 2003 study period (Schmidt, 2004) found that dissolved solids, sodium, and sulfate were present in ground-water samples at concentrations greater than their respective water-quality criteria. The current study period found that dissolved solids, sodium, sulfate, and chloride were again present in concentrations that exceeded their respective water-quality criteria and were larger than the previous study period. Results from these two most recent study periods show that arsenic concentrations continue to exceed the USEPA MCL in samples from monitoring well MW06 but do not show a substantial increase in concentration from the 2003 (Schmidt, 2004) to the current study period.

Summary and Conclusions

This report describes surface- and ground-water quality data collected on the Prairie Band Potawatomi Reservation in northeastern Kansas from November 2003 through August 2006 (hereinafter referred to as the “current study period”). Data from this study period are compared to results from June 1996 through August 2003, which are published in previous reports as part of a multiyear cooperative study with the Prairie Band Potawatomi Nation. Surface and ground water are important to the Prairie Band Potawatomi Nation to serve the hunting and fishing needs of tribal members and as a possible ground-water supply to support expanding commercial enterprise and development. Under the Federal Clean Water Act of 1977, an Indian tribe is sovereign for the purposes of delegating the authority to regulate water within

the reservation boundaries. To establish water-quality baseline concentrations with a goal of developing water-quality criteria to help manage the water resources on the reservation, the tribe, in cooperation with the U.S. Geological Survey, began a water-quality monitoring program in 1996.

A subset of 5 of the original 20 surface-water sites was sampled approximately quarterly from November 2003 through August 2006. All surface-water samples were analyzed for physical properties, dissolved solids, major ions, nutrients, trace elements, pesticides, fecal-indicator bacteria, suspended-sediment concentration, and total suspended solids. Ground water was sampled three times during this current study period from 10 dedicated ground-water monitoring wells completed on the reservation in August 2002 and July 2003. All ground-water samples were analyzed for physical properties, dissolved solids, major ions, nutrients, trace elements, pesticides, and fecal-indicator bacteria. Chemical oxygen demand and volatile organic compounds were analyzed in all three samples from one ground-water monitoring well located near a construction and demolition landfill on the reservation (monitoring well MW04) and in one sample from another well in the Soldier Creek drainage basin (well MW07).

Previous reports published as a part of this ongoing study identified total phosphorus, triazine herbicides, and fecal coliform bacteria as exceeding their respective water-quality criteria in surface water on the reservation. Previous ground-water assessments identified occasional sample concentrations of dissolved solids, sodium, sulfate, boron, iron, and manganese as exceeding their respective water-quality criteria.

During the current study period, dissolved-solids concentrations exceeded the Secondary Drinking-Water Regulation of 500 mg/L established by the U.S. Environmental Protection Agency (USEPA) in surface-water samples from site LSC06 located on Big Elm Creek downstream from a sewage-treatment lagoon and in samples from site SC03 on Soldier Creek. In general, larger concentrations of dissolved solids may occur downstream from wastewater-treatment facilities when compared to upstream concentrations. Twenty percent of dissolved-solids concentrations in ground-water samples were equal to or greater than the Secondary Drinking-Water Regulation.

Sodium concentrations exceeded the Drinking-Water Advisory of 20 mg/L established by USEPA in some surface-water samples from every site (almost 50 percent of all surface-water samples) and in ground-water samples from wells MW01, MW03, MW04, MW08, and MW11 (total of 50 percent of ground-water samples). Sulfate and chloride concentrations exceeded the Secondary Drinking-Water Regulation of 250 mg/L established by USEPA in 10 percent of ground-water samples, including all three samples from well MW03.

Detections of nitrite plus nitrate in ground-water samples from well MW11 exceeded the USEPA Maximum Contaminant Level of 10 mg/L. Fifty-six percent of the 55 surface-water samples analyzed for total phosphorus exceeded the aquatic-life goal of 0.10 mg/L established by USEPA.

Three detections of arsenic in ground-water samples from well MW06 exceeded the USEPA Maximum Contaminant Level of 10 µg/L. Boron also exceeded the USEPA Drinking-Water Advisory of 600 µg/L in three samples from one well (MW03), and iron concentrations were larger than the Secondary Drinking-Water Regulation (300 µg/L) in four wells.

A triazine herbicide screen was used on 55 surface-water samples, and triazine herbicides, specifically, were detected frequently, although concentrations did not exceed the USEPA Maximum Contaminant Level of 3.0 µg/L as an annual average. Triazine herbicide compounds were not detected frequently in samples collected from ground-water monitoring wells. Triazine herbicides and their degradates are listed on the USEPA Contaminant Candidate List.

One volatile organic compound, diethyl ether, was detected in a water sample collected from well MW07. There are no USEPA drinking-water regulations for this compound.

Fecal-indicator bacteria (fecal coliform, *E. coli*, fecal streptococci, and enterococci) were detected in the majority of surface-water samples. Water-quality criterion have been established by USEPA and the Kansas Department of Health and Environment (KDHE) for densities of *E. coli*. Densities of *E. coli* in surface-water samples exceeded USEPA primary-contact water-quality criterion for moderately used water bodies (illness rate of 8 per 1,000 swimmers; 298 col/100 mL) in 40 percent of samples and exceeded KDHE single-sample maximum criterion for primary contact in public-access bodies of water (1,198 col/100mL for samples collected between April 1 and October 31) in 41 percent of samples. Median concentrations of both suspended sediment and total suspended solids in water samples from Soldier and Little Soldier Creek sites were small and reflect the low streamflow conditions under which most samples were collected.

Water quality on the Prairie Band Potawatomi Reservation generally meets water-quality criteria established by USEPA. Surface-water quality on the reservation is affected by agricultural runoff (triazine herbicides and fecal-indicator bacteria), seepage from septic systems or sewage lagoons serving a rural population, and wastewater discharge from documented point sources (dissolved solids and sodium). Sources of total phosphorus in streams can be attributed to both agricultural activities and human and animal waste. Ground-water quality on the reservation probably is affected by agricultural practices with the detections of nitrite plus nitrate, and elevated dissolved-solids and arsenic concentrations in ground water likely are from dissolution of sedimentary rocks. Concentrations of dissolved solids and sulfate in some ground-water samples exceeded their respective Secondary Drinking-Water Regulations, and concentrations exceeded the taste threshold of the USEPA's Drinking-Water Advisory Level for sodium. Consequently, in the event that ground water on the reservation is to be used as a drinking-water source, additional treatment may be necessary to remove excess dissolved solids, sulfate, sodium, chloride, nitrite plus nitrate, and arsenic.

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