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Analysis of Environmental Setting, Surface-Water and Groundwater Data, and Data Gaps for the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, Through 2011

Scientific Investigations Report 2013–5010

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

Cover:

Left, Water tower located in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Shawnee, Oklahoma (photograph by Michael Dotson, Citizen Potawatomi Nation).

Right, Pond at the Grand Casino, Citizen Potawatomi Nation Tribal Jurisdictional Area, Shawnee, Oklahoma (photograph by Richard Kunze, Director of Public Works, Citizen Potawatomi Nation).

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U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785	cubic meter (m^3)
	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)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
	Specific capacity	
gallon per minute per foot [(gal/min)/ft)]	0.2070	liter per second per meter [(L/s)/m]
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	0.0002642	million gallons (Mgal)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
liter per second (L/s)	15.85	gallon per minute (gal/min)
cubic meter per second (m^3/s)	22.83	million gallons per day (Mgal/d)
millimeter per year (mm/yr)	0.03937	inch per year (in/yr)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)
	Specific capacity	
liter per second per meter [(L/s)/m]	4.831	gallon per minute per foot [(gal/min)/ft]
	Hydraulic conductivity	
meter per day (m/d)	3.281	foot per day (ft/d)

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

°F=(1.8×°C)+32

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

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Altitude, as used in this report, refers to distance above the vertical datum.

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).

Analysis of Environmental Setting, Surface-Water and Groundwater Data, and Data Gaps for the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, Through 2011

By William J. Andrews, Christopher R. Harich, S. Jerrod Smith, Jason M. Lewis, Molly J. Shivers, Christian H. Seger, and Carol J. Becker

Abstract

The Citizen Potawatomi Nation Tribal Jurisdictional Area, consisting of approximately 960 square miles in parts of three counties in central Oklahoma, has an abundance of water resources, being underlain by three principal aquifers (alluvial/terrace, Central Oklahoma, and Vamoosa-Ada), bordered by two major rivers (North Canadian and Canadian), and has several smaller drainages. The Central Oklahoma aquifer (also referred to as the Garber-Wellington aquifer) underlies approximately 3,000 square miles in central Oklahoma in parts of Cleveland, Logan, Lincoln, Oklahoma, and Pottawatomie Counties and much of the tribal jurisdictional area. Water from these aquifers is used for municipal, industrial, commercial, agricultural, and domestic supplies.

The approximately 115,000 people living in this area used an estimated 4.41 million gallons of fresh groundwater, 12.12 million gallons of fresh surface water, and 8.15 million gallons of saline groundwater per day in 2005. Approximately 8.48, 2.65, 2.24, 1.55, 0.83, and 0.81 million gallons per day of that water were used for domestic, livestock, commercial, industrial, crop irrigation, and thermoelectric purposes, respectively. Approximately one-third of the water used in 2005 was saline water produced during petroleum production. Future changes in use of freshwater in this area will be affected primarily by changes in population and agricultural practices. Future changes in saline water use will be affected substantially by changes in petroleum production. Parts of the area periodically are subject to flooding and severe droughts that can limit available water resources, particularly during summers, when water use increases and streamflows substantially decrease.

Most of the area is characterized by rural types of land cover such as grassland, pasture/hay fields, and deciduous forest, which may limit negative effects on water quality by human activities because of lesser emissions of man-made chemicals on such areas than in more urbanized areas. Much of the water in the area is of good quality, though some parts of this area have water quality impaired by very hard surface water and groundwater; large chloride concentrations in some smaller streams; relatively large concentrations of nutrients and counts of fecal-indicator bacteria in the North Canadian River; and chloride, iron, manganese, and uranium concentrations that exceed primary or secondary drinking-water standards in water samples collected from small numbers of wells.

Substantial amounts of hydrologic and water-quality data have been collected in much of this area, but there are gaps in those data caused by relatively few streamflow-gaging stations, uneven distribution of surface-water quality sampling sites, lack of surface-water quality sampling at high-flow and low-flow conditions, and lack of a regularly measured and sampled groundwater network. This report summarizes existing water-use, climatic, geographic, hydrologic, and water-quality data and describes several means of filling gaps in hydrologic data for this area.

Introduction

Water-resources information is needed by the Citizen Potawatomi Nation and other interested parties to better understand those resources in their tribal jurisdictional area in central Oklahoma. Data analysis by the U.S. Geological Survey, in cooperation with the Citizen Potawatomi Nation, was done to provide information about geographic, hydrologic, and environmental features of the area and identifies gaps in data that, if filled, would provide better information about the water resources of this area. Information about previously collected data and gaps in data can be used for designing hydrologic sampling networks and for planning future uses of water in this tribal jurisdictional area. Additional details about characteristics of this area are presented later in this report.

Purpose and Scope

The purposes of this report are to inventory and evaluate existing data and reports from Native-American Tribes (the Citizen Potawatomi Nation and the Kickapoo Tribe of Oklahoma), the U.S. Geological Survey (USGS), and other government agencies to summarize what types of water-use, climatic, land-cover, hydrologic, and water-quality data have been collected; and the locations and dates of those data being collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area of central Oklahoma. This report includes information from previous studies, well logs, climatological descriptions, and data collected from long-term monitoring of streamflow, groundwater, and water quality in this area. This report also identifies "gaps" or deficiencies in those data in regards to geographic and temporal distribution and physical properties and constituents measured.

Location of the Study Area

The Citizen Potawatomi Nation Tribal Jurisdictional Area is a 960-square-mile area in central Oklahoma in parts of three counties: Cleveland, Oklahoma, and Pottawatomie (fig. 1). The North Canadian and Canadian Rivers form the northern and southern boundaries of the area (fig. 1).

Methods of Analysis

For this report, previously compiled geographic, climatic, geologic, hydrologic, and water-use data collected by a variety of agencies were summarized with maps and graphs and computation of summary and comparative statistics. Gaps in time, place, and types of those previously collected data also are summarized in this report.

Selection of Climatic and Geographic Data

Climatic data, including annual precipitation and mean annual temperature from January 1964 through December 2010, were obtained for weather stations operated by the National Weather Service at Shawnee, Okla. (north of the tribal jurisdictional area), and Seminole, Okla. (east of this area), from the National Weather Service (written communs., 1964–2010) and summaries in Oklahoma Climatological Survey (2011a) (fig. 1). Although there are other weather stations in this area, these two stations had the longest continuous records of precipitation amounts or temperature. Geographic data, including topographic, land-cover, soils, and other locational data, were obtained from Gesch and others (2002), Gesch (2007), Fry and others (2011), Natural Resources Conservation Service (2006), and U.S. Geological Survey (2012a).

Selection of Streamflow Data

For this report, streamflow data from four long-term USGS streamflow-gaging stations (station numbers in parentheses) in or on the boundaries of the jurisdictional area were analyzed: North Canadian River near Harrah, Okla. (07241550), North Canadian River at Shawnee, Okla. (07241800), Little River near Tecumseh, Okla. (07230500), and Canadian River at Purcell, Okla. (07229200). These stations were associated with a decade or more of continuous streamflow measurements through 2011. Periodic water-quality sampling by the USGS and other agencies was conducted at all of these stations except the North Canadian River at Shawnee, Okla., station.

To represent recent data, streamflow and water-quality data from these stations were summarized for the period October 1985 through September 2011 (North Canadian River near Harrah, Okla., Little River near Tecumseh, Okla.), October 1985 through September 2010 (Canadian River at Purcell, Okla.), and October 2001–September 2011 (North Canadian River at Shawnee, Okla.). Streamflow data for these stations were obtained from the USGS National Water Information System (NWIS) database (U.S. Geological Survey, 2012b). Streamflow data were summarized by monthly minimum, mean, and maximum streamflows, seasonal streamflow distributions, recurrence intervals and exceedance probabilities, and mean annual streamflows. LOESS trend lines (Cleveland, 1979) were used to indicate changes with time in annual peak flows at selected streamflow-gaging stations using the graphing function of the TIBCO Spotfire S+ 8.1 for Windows program (TIBCO Software, Inc., 2008). Recurrence intervals were calculated using the PeakFQ program (Flynn and others, 2006), which incorporates methods described in Interagency Advisory Committee on Water Data (1982).

Selection of Groundwater Data

For this report, groundwater data including well depths, water levels, and aquifer information from three sources were analyzed: the USGS NWIS database (U.S. Geological Survey, 2012c), the Oklahoma Department of Environmental Quality (in 2012 from the STORET database maintained by the U.S. Environmental Protection Agency [USEPA]) (U.S. Environmental Protection Agency, 2012), and from online records of the Oklahoma Water Resources Board (OWRB) (Oklahoma Water Resources Board, 2012). Dates of collection of data summarized in this report ranged from October 1943 through September 2011. Analyses of these data included mapping locations of measured/documented wells by aquifer and comparing depths of wells completed in different aquifers.

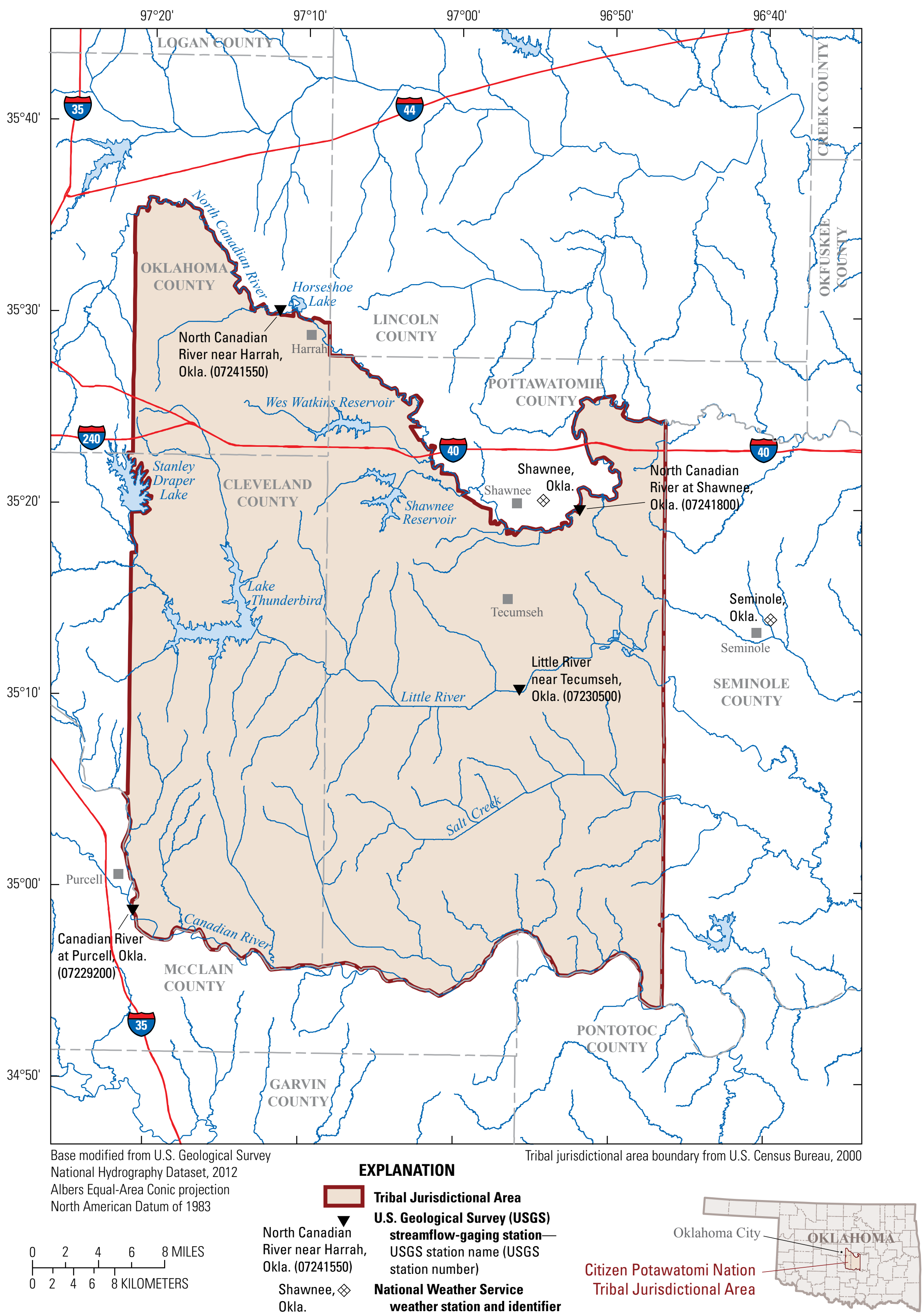


Figure 1. Location of the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, and locations of selected long-term streamflow-gaging stations and weather stations in and near that area.

Selection of Water-Quality Data

Surface-water-quality data were retrieved from the USGS NWIS database and the STORET database of the USEPA in January 2012 (U.S. Geological Survey, 2012d; U.S. Environmental Protection Agency, 2012). Additional surface-water-quality data collected in the jurisdictional area were obtained from staff of the Citizen Potawatomi Nation and the Oklahoma Corporation Commission (S. Howard, Citizen Potawatomi Nation, written commun., 2012; P. Billingsley, Oklahoma Corporation Commission, written commun., 2012). Surface-water-quality data only were summarized from sites having three or more samples collected. The Citizen Potawatomi Nation and the Kickapoo Tribe of Oklahoma collected surface-water-quality data (physical properties and some nutrients) from 2009–11 at the time that this report was written. Nutrient data collected by the Citizen Potawatomi Nation were not included in this report, as only two samples collected in late 2011 at each of nine sites were available when this report was written. Surface-water-quality data from the Oklahoma Department of Environmental Quality were composed of analyses of counts of fecal-indicator bacteria in water-quality samples collected during 2003.

The OWRB analyzed numerous water-quality properties and constituents in surface-water samples collected at 11 stations on the North Canadian River and in the Salt Creek watershed for varying periods from 1998–2005. The Oklahoma Corporation Commission collected surface-water-quality samples from 1996–2001, primarily from small streams, for analyses of values of physical properties and concentrations of major ions associated with oilfield spills and leaks and natural seepage of brines.

Groundwater-quality data were obtained from the USGS NWIS database (U.S. Geological Survey, 2012d), which contained data from more than 700 groundwater samples collected in the area from the 1940s through the early 2000s. Agencies collecting those samples included the Association of Central Oklahoma Governments (ACOG), the OWRB, the Oklahoma State Health Department, private laboratories associated with the National Uranium Resource Evaluation project of the U.S. Department of Energy in the late 1970s and early 1980s, and the USGS. The STORET system of the USEPA (U.S. Environmental Protection Agency, 2012) was queried for groundwater-quality data collected in the study area, but missing data for (1) aquifers in which 68 wells were completed in the jurisdictional area and (2) depths of those wells precluded inclusion of those data for analysis in this report. Only groundwater-quality data collected from wells with known depths completed in known aquifers were included in this report for comparing groundwater quality between major aquifers (alluvial/terrace, Central Oklahoma, and Vamoosa-Ada) in the jurisdictional area and investigating relations of groundwater quality to well depth. To evenly weight water-quality data from each well in summary statistics (and not overweight data from more frequently sampled wells) and to portray the most recent groundwater quality, data from the last water sample collected from each well are summarized in this report.

All of the surface-water-quality data in this report are limited by the range of discharges at which they were collected. Surface-water quality at high flows can be substantially different than at low flow (Esralew and others, 2011a, b), with much of the annual loads of some constituents, such as suspended sediments and phosphorus, being transported at high flows. Because high streamflows occur for a very small percentage of the time, regularly-spaced (such as the second Tuesday of every month) sampling done by many agencies rarely coincides with peak streamflows. Some agencies also may avoid sampling at peak streamflows because of access and safety issues. The USGS has been collecting approximately six base-flow and six high-flow samples since 2005 at the North Canadian River near Harrah, Okla., streamflow-gaging station to better characterize surface-water quality at high-flow conditions. But even such “targeted” sampling for high flows may not represent surface-water quality across the entire range of streamflows at a particular location, as peaks in streamflow tend to be very short in duration. Water-quality data are summarized in this report primarily through tables of summary statistics and boxplots showing distribution of data; the Wilcoxon rank-sum test (Wilcoxon, 1945) was used to determine significant (at a p-value of 0.05 or less) differences in locations of distribution of data.

Estimation of Water Use

Water-use data have not been compiled specifically for this jurisdictional area but were compiled by county for 2005 (Tortorelli, 2009). Estimates of water-use data for each of the three counties with land in the Citizen Potawatomi Nation Tribal Jurisdictional Area were obtained from data compiled for the USGS National Water-use Information Program in 2005 (R. Tortorelli, U.S. Geological Survey, written commun., 2012). Because much of this jurisdictional area is rural (table 1), water-use amounts are likely to be affected by different factors. Domestic water use is likely to be proportional to the number of people residing in the parts of the counties in this area. Commercial and industrial water use in this relatively rural area would be overrepresented by simply multiplying the percentage of county area or county population by the total water use in each of these three counties, given the much more urbanized areas outside of this jurisdictional area. Conversely, agricultural water use is likely to be disproportionately larger in this rural area compared to these counties in general.

To account for these geographic differences in water use, the following methods were used to adjust 2005 water-use data for these three counties to estimate water use in this jurisdictional area:

1. Industrial and commercial water use was multiplied by the percentages of county populations in the tribal jurisdictional area (U.S. Census Bureau, 2012; table 1)

Table 1. Geographic and population data used to estimate water use in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma.

[Land-cover data from U.S. Geological Survey (2012), county populations from U.S. Census Bureau (2012)]

Data type	County		
	Cleveland	Oklahoma	Pottawatomie
County land area in jurisdictional area, in percent	62.9	19.2	81.2
Impervious area in the jurisdictional area, in percent	0.644	4.38	0.625
Impervious area in county, in percent	4.35	14.5	1.16
Tree canopy cover in the jurisdictional area, in percent	35.4	22.5	27.0
Tree canopy cover in county, in percent	25.8	17.0	24.4
County population	255,760	718,630	69,440
Population in the jurisdictional area	34,016	48,148	33,123
County population in the jurisdictional area, in percent	13.3	6.70	47.7
Population density in the jurisdictional area, in people per square mile	97	349	51

and by the ratio of percentage of impervious area in the jurisdictional area to percentage of impervious area in the counties (to correct for the more rural nature of the jurisdictional area);

2. Domestic water use was multiplied by the percentages of county populations in the tribal jurisdictional area;

3. Livestock and irrigation water use was multiplied by the percentage of county areas in the jurisdictional area and the ratio of percentage of tree-canopy cover (an indicator of rural land use) in the jurisdictional area to percentage of tree canopy cover in the counties;

4. Mining water use, which is primarily associated with petroleum production, was assumed to be uniform in the three counties and was multiplied by the percentage of county areas in the jurisdictional area; and

5. Thermoelectric water use was multiplied by the percentage of county populations in the jurisdictional area, which assumes that thermoelectric water use is proportional to the ratios of population in the three counties.

Analysis of Climatic and Geographic Data

Monthly precipitation data measured at the National Weather Service stations at Shawnee, Okla., and Seminole, Okla. (fig. 1), were summed to determine annual precipitation amounts in inches at each station. Some months, usually those with little rainfall, had missing data. Monthly precipitation data were summed for years with no more than one missing monthly precipitation value. Mean annual temperatures were not computed for years with one or more months of missing data. Mean monthly and annual temperatures were not recorded at the weather station at Shawnee, Okla.

Land-cover data were obtained from the National Land Cover database for 2006 (U.S. Geological Survey, 2012a). Among many different types of land-cover data, raster data describe the percentages of land cover for 30- by 30-meter cells. For computation of land-use percentages, the rasters were averaged over the counties and parts of the counties in the jurisdictional area using the ArcGIS “Zonal Statistics as Table” tool (Environmental Systems Research Institute, 2012).

Analysis of Hydrologic Data

Surface Water

Streamflow is measured continuously (typically at 15-minute intervals) at streamflow-gaging stations, of which there were nearly 200 in Oklahoma as of 2011. The USGS has periodically gaged streamflow at 36 streamflow-gaging stations in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area. Because streamflow data for many of these stations were discontinuous or discontinued before 2011, streamflow data from only four stations with recent and long-term streamflow-gaging records (North Canadian River near Harrah, Okla. (07241550), North Canadian River at Shawnee, Okla. (07241800), Little River near Tecumseh, Okla. (07230500), and Canadian River at Purcell, Okla. (07229200) are summarized in this report. The North Canadian River near Harrah, Okla., streamflow-gaging station (fig. 1) was in operation from 1968 through 2011. Data collected at that streamflow-gaging station represent streamflow and water quality along the northern boundary of the area. The North Canadian River at Shawnee, Okla., streamflow-gaging station was in operation from 2001 through 2011, with streamflow at that station representing conditions downstream from the station near Harrah, plus contributions occurring as the river flowed along much of the northern boundary of this area. The Little River near Tecumseh, Okla., streamflow-gaging station (fig. 1), in operation from 1943 through 2011, recorded streamflow data from the primary stream flowing through the center of the jurisdictional area. The Canadian River at Purcell, Okla., streamflow-gaging station (fig. 1), in operation from September 1959 through June 1961, October 1979 through September 1983, and October 1985 to the present (2012), records streamflow entering this area on that river. The non-parametric seasonal Kendall tau test (Kendall, 1938), which is based on changes in parameter values between sequential pairs of data values, was used to estimate trends in streamflow with time at selected streamflow-gaging stations.

Groundwater

The USGS has periodically collected groundwater data from the Central Oklahoma aquifer in the jurisdictional area since the 1940s. As of 2012, 460 groundwater-level measurements were recorded in the NWIS database for this area. The OWRB database had 25 wells with water-level measurements (Oklahoma Water Resources Board, 2012). The Oklahoma Climatological Survey had groundwater-level data from three wells associated with the Oklahoma Mesonet (Oklahoma Climatological Survey, 2012). The NWIS database had 799 groundwater-quality sites and the STORET database had 47 groundwater-quality sites.

Analysis of Water-Quality Data

Analysis of water-quality data in this report includes statistical summaries and regression computations, which were graphed on x:y graphs, boxplots, and maps showing geographic locations of sampling sites. For both surface-water quality and groundwater-quality data, left-censored data (data having values less than a reporting limit) were estimated using an adjusted maximum likelihood estimator (AMLE), which is a generalization of the widely accepted minimum variance unbiased estimator (Cohn, 2005), for computation of summary statistics and data distributions in boxplots. For graphs of water-quality constituent values compared with streamflow or well depth, left-censored water-quality data values were assumed to be equal to the method reporting level. For groups of data collected sequentially from surface-water sites, serial correlation, which can affect the value of comparative statistical tests such as the Wilcoxon rank-sum test (used to compare locations of distribution of selected data sets [Wilcoxon, 1945]), was tested using the Durbin-Watson test (Durbin and Watson, 1950). Serial correlation of monthly streamflows did not occur at significance levels less than an alpha value of 0.05 for mean monthly streamflow data collected at the four streamflow-gaging stations described in this report.

Surface Water

Because different field sampling, processing, and laboratory analytical procedures used by Tribes and agencies can cause variations in accuracy and precision of water-quality data, data in this report are summarized by the collecting agency rather than being combined for each site. The USGS has periodically collected water-quality samples at 36 streamflow-gaging stations in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area. For many of those streamflow-gaging stations, however, only a few water-quality samples were collected by the USGS, most of them having been collected in the 1960s or 1970s. Surface-water-quality data collected at three USGS streamflow-gaging stations with the most numerous and recent water-quality data (North Canadian River near Harrah, Okla., 07241550, 1985–2011; Little River near Tecumseh, Okla., 07230500, 1985–2011; and Canadian River at Purcell, Okla., 07229200, 1986–2011) are summarized in this report. Of these three streamflow-gaging stations, long-term comprehensive water-quality data have been collected only at the North Canadian River near Harrah, Okla., station, with water-quality data from the other stations being limited to measurement of a few physical properties (appendix 1). Staff of the Citizen Potawatomi Nation have measured physical properties periodically at nine sites in this jurisdictional area from 2010 through 2011. Nutrient data were collected by the Citizen Potawatomi Nation staff in October and November 2011, but those data were too limited to be summarized in this report. Search of the STORET database of the U.S. Environmental Protection Agency provided additional surface-water-quality data collected by the Citizen Potawatomi Nation, the Oklahoma Department of Environmental Quality, the Kickapoo Tribe of Oklahoma, the OWRB, and the Oklahoma Corporation Commission in this area from the mid-1990s through 2011.

Groundwater

Groundwater-quality data in the NWIS database were collected in the area by the ACOG, the OWRB, private contractors of the U.S. Department of Energy, and the USGS from 1943–2005. Those data were analyzed only from wells completed in the three principal aquifers in this area to known depths. To avoid overweighting the data set with frequently sampled wells and to better represent more recent groundwater quality, only the last sample collected from each well was included in the analyzed groundwater-quality data set. Some older censored data in the USGS

NWIS database had values of zero (such as fluoride). For computational purposes, such data were transformed to values less than the smallest reported concentrations during that period or the values of left-censored data from later periods.

Quality Assurance

Quality assurance is the analysis of quality-control data to determine the quality of a process, such as manufacturing or sampling procedures. Quality-control data for water-quality samples commonly include analyses of blank and replicate samples. Blank samples typically consist of purified water processed through field-cleaned sampling equipment to determine whether equipment materials, field-cleaning, or environmental factors are contributing analytes to water samples. The USGS, the Kickapoo Tribe of Oklahoma, and the OWRB recorded some quality-contol-sample data in the NWIS and STORET databases. Some samples, such as those entered into the STORET database by the Kickapoo Tribe, included detailed descriptions of the types of quality-control samples for each sample, including field rinsate and laboratory blanks and splits and replicates for replicate samples. Because such information generally was not available for other agencies, data from quality-control samples are described only as “blanks” and “replicates” in this report. Data from blank samples are summarized in this report for minimum and maximum values and are compared to data values from field samples. For example, if the maximum concentration of a constituent in blank samples was 2 milligrams per liter (mg/L), with field-sample values ranging from 50–500 mg/L (a ratio of 25–250:1), sampling artifacts were assumed to be unlikely to affect constituent values in field samples. Blank samples were not always clearly denoted in the STORET database, though they typically could be separated from the field-sample data by having different time codes or substantially lesser constituent values than field samples (most data values being less than reporting limits).

After a lapse of a few minutes, replicate samples are collected after field samples to evaluate the variability of quality of a water source with time, water-quality changes caused by field procedures, and laboratory precision. Replicate groundwater-quality data generally were obtained by selecting groundwater-quality samples from the NWIS and STORET databases coded with sequential sample-collection times of a few minutes on the same day (for example 12:00 and 12:05). Some samples had multiple samples collected within a few minutes on the same day, representing more than one replicate per field sample.

Relative-percent differences (RPDs) indicate the degree of similarity between constituent values in field and replicate samples, with smaller relative-percent differences indicating greater similarity of data between pairs of field and replicate samples. RPDs of data from field samples and associated replicate samples were computed using the following equation:

$$RPD = (|a-b|/((a+b)/2))*\ 100\ percent$$

where

a is the constituent value of the field sample, and

b is the constituent value of the replicate sample.

RPDs can be quite large for small differences in data values, for instance, the RPD between data values of 0.2 and 0.3 is 40 percent, whereas, the RPD between data values of 3.2 and 3.3 is only 3.1 percent, though the numerical difference between both pairs of numbers is 0.1.

Evaluation of Water Use

As described in the “Methods of Analysis” section of this report, water-use data compiled for the year 2005 and several scaling factors were used to estimate water use in the Citizen Potawatomi Nation Tribal Jurisdictional Area. Scaling factors were based on the percentages of county land areas in the jurisdictional areas and measures of urban development of those areas compared to all of Cleveland, Oklahoma, and Pottawatomie Counties.

Industrial and commercial uses generally are concentrated in urbanized rather than rural areas. As the jurisdictional area generally is in less urbanized parts of Cleveland, Oklahoma, and Pottawatomie Counties, there should be smaller proportions of water use than indicated by percentages of county areas in the jurisdictional area. Generally, industries and commercial facilities located near cities use public-water supplies rather than being self-supplied with water from wells or surface-water intakes. As is typical for these counties and the jurisdictional area, industrial and commercial water users primarily used public-water supplies withdrawn from surface water (table 2). Because most of the industrial water use from public-water supplies was in Oklahoma County (table 2), but a relatively small part of that county is in the jurisdictional area, only 6.9 percent of total industrial water use in these three counties was estimated to occur in the jurisdictional area. More than 90 percent of water used by commercial facilities such as stores, offices, and schools was obtained from public-water supplies (table 2).

Domestic (household) water use normally dominates water use in urban areas and in rural areas with limited agriculture, such as the moderately forested jurisdictional area. The sum of self-supplied and public-supplied domestic water use was among the largest water-use categories in the jurisdictional area (table 2). The rural nature and relative lack of public-water supplies in much of the jurisdictional area contributed to estimates of nearly 30 percent of self-supplied domestic water use (assumed to be groundwater from wells) in these three counties being in the jurisdictional area (table 2). Future population growth in the jurisdictional area might increase the use of self-supplied and public-water supplies for domestic water use in towns and rural water districts.

Table 2. Estimated water use, by type and source type in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 2005.

[Mgal/d, million gallons per day; CPN TJSA, Citizen Potawatomi Nation Tribal Jurisdictional Area total]

Water-use type	County/area	Estimated water use (Mgal/d) (total county water use in parentheses)	
		Groundwater	Surface water
Industrial, self-supplied	Cleveland	0.00 (0.03)	0.00 (0.00)
	Oklahoma	0.003 (0.06)	0.00 (0.00)
	Pottawatomie	0.03 (0.07)	0.00 (0.00)
	CPN TJSA	0.03	0.00 (0.00)
Industrial, public water supply	Cleveland	0.02 (0.17)	0.06 (0.69)
	Oklahoma	0.10 (1.76)	1.09 (18.8)
	Pottawatomie	0.00 (0.00)	0.25 (0.56)
	CPN TJSA	0.12	1.40
Commercial, self-supplied	Cleveland	0.04 (0.40)	0.00 (0.00)
	Oklahoma	0.05 (0.87)	0.00 (0.00)
	Pottawatomie	0.00 (0.00)	0.00 (0.00)
	CPN TJSA	0.09	0.00
Commercial, public water supply	Cleveland	0.22 (2.40)	0.73 (7.80)
	Oklahoma	0.24 (4.06)	3.07 (52.90)
	Pottawatomie	0.05 (0.11)	0.18 (0.40)
	CPN TJSA	0.51	1.64
Domestic, self-supplied	Cleveland	0.14 (1.08)	0.00 (0.00)
	Oklahoma	0.08 (1.19)	0.00 (0.00)
	Pottawatomie	0.84 (1.77)	0.00 (0.00)
	CPN TJSA	1.07	0.00
Domestic, public water supply	Cleveland	0.70 (5.30)	1.69 (12.70)
	Oklahoma	0.70 (10.40)	3.12 (46.60)
	Pottawatomie	0.25 (0.53)	0.95 (1.99)
	CPN TJSA	1.65	5.76
Livestock, self-supplied	Cleveland	0.08 (0.09)	0.70 (0.81)
	Oklahoma	0.06 (0.24)	0.16 (0.62)
	Pottawatomie	0.19 (0.21)	1.46 (1.63)
	CPN TJSA	0.33	2.32
Irrigation, self-supplied	Cleveland	0.07 (0.08)	0.02 (0.02)
	Oklahoma	0.52 (2.06)	0.09 (0.35)
	Pottawatomie	0.04 (0.05)	0.09 (0.10)
	CPN TJSA	0.63	0.20
Mining/petroleum production, self-supplied (saline)	Cleveland	0.26 (0.41)	0.00 (0.00)
	Oklahoma	0.60 (3.14)	0.00 (0.00)
	Pottawatomie	7.29 (8.98)	0.00 (0.00)
	CPN TJSA	8.15	0.00
Thermoelectric, self-supplied	Cleveland	0.00 (0.00)	0.00 (0.00)
	Oklahoma	0.01 (0.13)	0.80 (7.30)
	Pottawatomie	0.00 (0.00)	0.00 (0.00)
	CPN TJSA	0.01	0.80

With less urban development in the jurisdictional area than in the whole of these three counties, a greater proportion of water is likely to be used for livestock (primarily beef cattle) and crop irrigation than in the more urbanized parts of the three counties. Approximately 75 percent of water use by livestock in the three counties was estimated to have been used in this jurisdictional area, with almost 90 percent of that water coming from surface water (ponds and streams) (table 2). Irrigation water use in the jurisdictional area was estimated to range from only approximately 30 to 40 percent of the water used for irrigation in the three counties, primarily because of the relatively large amount of water used for irrigation in Oklahoma County and the relatively small part of Oklahoma County (19.2 percent) located in the jurisdictional area (table 2).

Mining in these three counties withdrew only saline groundwater, associated with drilling and pumping for oil and gas, and reinjected into deep strata to recover additional petroleum or disposed in deep wells completed in saline-water zones below freshwater aquifers (U.S. Geological Survey, 2013). Although the use of saline water typically is not associated with freshwater resources, saline waters are of interest as potential secondary water sources (U.S. Geological Survey, 2013). The relatively large amount of oil production in these counties makes mining/oil production a substantial user of water in this area, with an estimated 8.15 million gallons per day (Mgal/d) (fig. 2, table 2).

Water is used during power generation (thermoelectric water use) to drive turbines and for cooling purposes. The Horseshoe Lake gas-fired powerplant near the City of Harrah in Oklahoma County is the only large electrical generating plant in the jurisdictional area (U.S. Energy Information Administration, 2012), relying mostly on fresh surface water (table 2).

Knowledge of the amounts of water use by type and by water source (surface water or fresh or saline groundwater) can be used for management and planning purposes. The approximately 115,000 people estimated to live in the jurisdictional area (U.S. Census Bureau, 2012), used an estimated 4.41 Mgal/d of fresh groundwater, 12.12 Mgal/d of fresh surface water, and 8.15 Mgal/d of saline groundwater in 2005. Approximately 8.48, 2.65, 2.24, 1.55, 0.83, and 0.81 Mgal/d were used for domestic, livestock, commercial, industrial, crop irrigation, and thermoelectric purposes, respectively (fig. 2, table 2).

Future increases in use of freshwater in the tribal jurisdictional area most likely will be caused by increases in population (such as eastward expansion of development from the Oklahoma City metropolitan area and expansion around the City of Shawnee) and changes in agricultural practices (such as decreases or increases in livestock and irrigated cropland). Changes in saline water use largely will be affected by new petroleum production in the coming decades, particularly to extract remaining oil and gas from the Woodford shale that underlies much of the area (Menchaca, 2012).

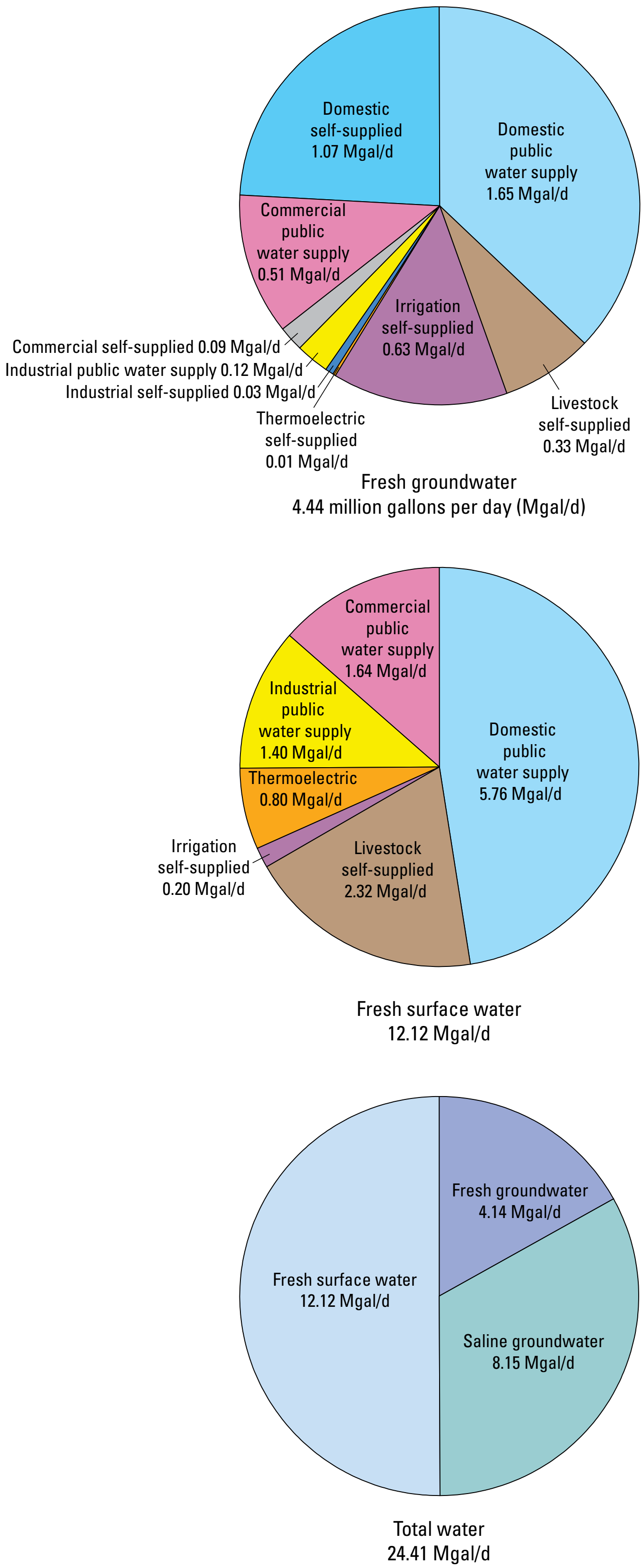


Figure 2. Estimated percentages and amounts of groundwater and surface water used in the Citizen Potawatomi Nation Tribal Jurisdictional Area by use type in Oklahoma, 2005.

Summary of Climatic and Geographic Data

Climatic data described in this report include precipitation and air temperature data collected at weather stations. Geographic data selected for and described in this report include the following data types: physiographic, soils, geologic, and land cover. All of these data can be used to evaluate factors affecting water availability and quality in this area.

Climate

This area has a temperate continental climate, receiving an average of approximately 40 inches per year (in/yr) of precipitation and having approximately 50 inches of free-surface evaporation (Oklahoma Climatological Survey, 2011b, c). Precipitation typically occurs from March through June and from September through November (Oklahoma Climatological Survey, 2011b). Monthly average air temperatures ranged from 35.9 degrees Fahrenheit (°F) in January to 81.5°F in July for 1965–2010 (Oklahoma Climatological Survey, 2011b). At weather stations in Shawnee, Okla., and Seminole, Okla., annual rainfall varied considerably from 1965–2010 (fig. 3). Most of the 1980s period was relatively wet, with annual precipitation exceeding 40 in/yr (fig. 3). The 1990s through the early 2000s period was relatively dry, with annual precipitation typically ranging from 30–40 in/yr (fig. 3). The mid- to late-2000s period had highly variable annual precipitation, exceeding 50 inches in some years and being less than 30 inches in others (fig. 3). Mean annual temperatures generally were less than 65°F during the relatively wet period of most of the 1980s, but increased to greater than 66°F at the weather station at Seminole, Okla., from the 1990s through 2010.

Physiography

The Citizen Potawatomi Nation Tribal Jurisdictional Area is in the Central Lowland Province of the Interior Plains Division described by Fenneman (1917). The area consists of gently rolling topography incised by deciduous stream drainage networks (fig. 4). The largest alluvial plains incised by streams are along the North Canadian River on the northern boundary of the area, the Little River draining from west to east in the central part of the area, Salt Creek in the southeastern part of the area, and the Canadian River along the southern border of the area (fig. 4).

Soils

The Citizen Potawatomi Nation Tribal Jurisdictional Area is underlain by soils that range in texture from fine silts to sandy loams. The Stephenville-Darnell Association,

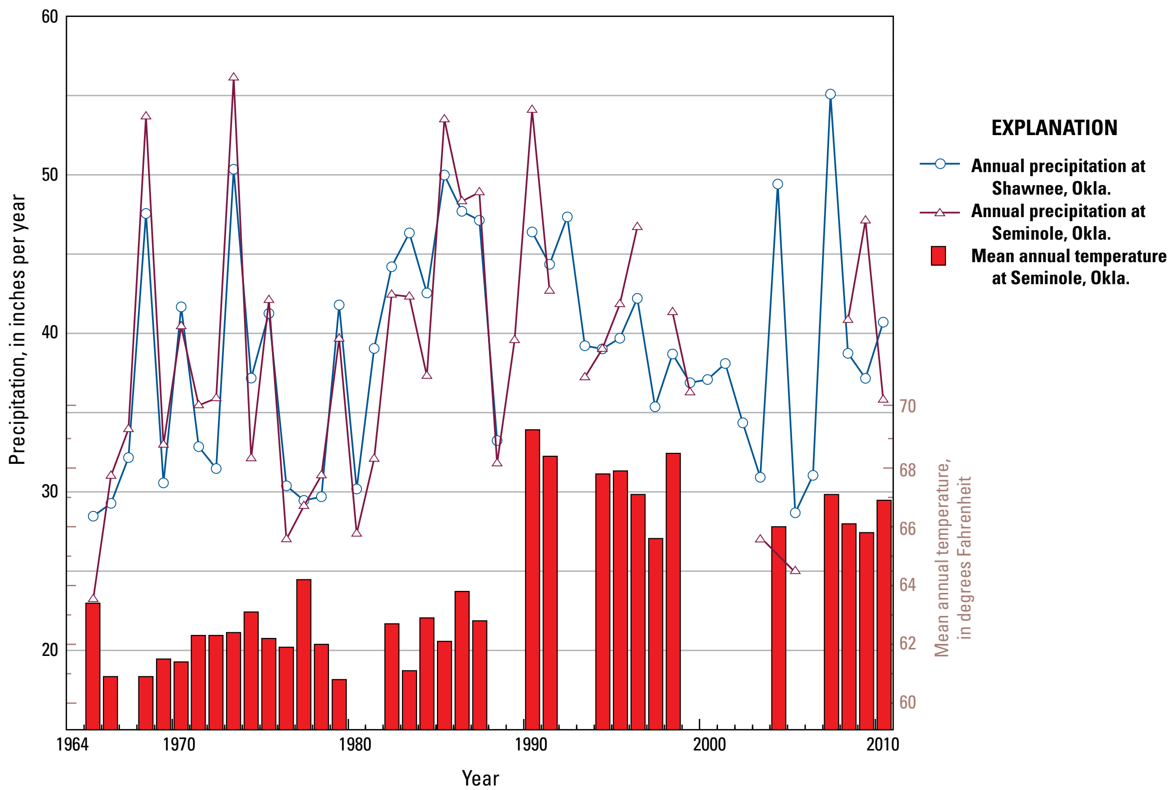


Figure 3. Annual precipitation and mean annual temperature at selected weather stations in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1965 through 2010.

which underlies most of the area (fig. 5), consists of gently to strongly sloping loamy soil on uplands (Mayhugh, 1977). Soil series of this association are deep and well-drained with high natural fertility and organic matter in the surface of this red-brown silty clay loam (Mayhugh, 1977). Soils of the Gracemore-Dale-Canadian, Yahola-Gracemore-Gaddy, and the Yahola-Keokuk-Gaddy-Asher Associations underlie alluvial plain areas adjacent to the North Canadian and Canadian Rivers (fig. 5). Soil series of those associations tend to be deep, well-drained, and nearly level to gently sloping sandy loams (Mayhugh, 1977). The relatively high-permeability, well-drained soils of much of this area are likely to provide rapid recharge to underlying alluvial/terrace and bedrock aquifers and may become excessively dry for nonirrigated crops during the hot, dry summers typical of this area (Johnson, 1983).

Geology

The Garber Sandstone and Wellington Formation of Early Permian age and the Oscar Group of Late Pennsylvanian age (between 307 and 299 million years old), which underlie the western two-thirds of this area and neighboring areas to the north and west, consist of interbedded fine-grained sandstones, shales, and conglomerates (Hart, 1974; Bingham and Moore, 1975; Johnson, 1983; Press and Siever, 1978). The Vanoss Formation, Ada Group, and Vamoosa Formation of Late Pennsylvanian age, which underlie the eastern one-third of the area, consist of fine- to very fine-grained sandstone interbedded with conglomerates, shale, siltstone, and very thin limestone layers (Hart, 1974; Bingham and Moore, 1975; Johnson, 1983; Morton, 1986). Bedrock strata in this area dip gently toward the west at less than one degree (Bingham and Moore, 1975). Alluvial and terrace materials along stream channels consist of complexly bedded unconsolidated (uncemented) gravel, sand, silt, clay, and organic detritus ranging in age from Tertiary to Holocene (less than 2.6 million years old) (Hart, 1974; Bingham and Moore, 1975; Johnson, 1983; Morton, 1986). Variable lithologies, cementation, permeabilities, and fracturing of these units indicate variable availability of groundwater for wells and base flow of streams across this area.

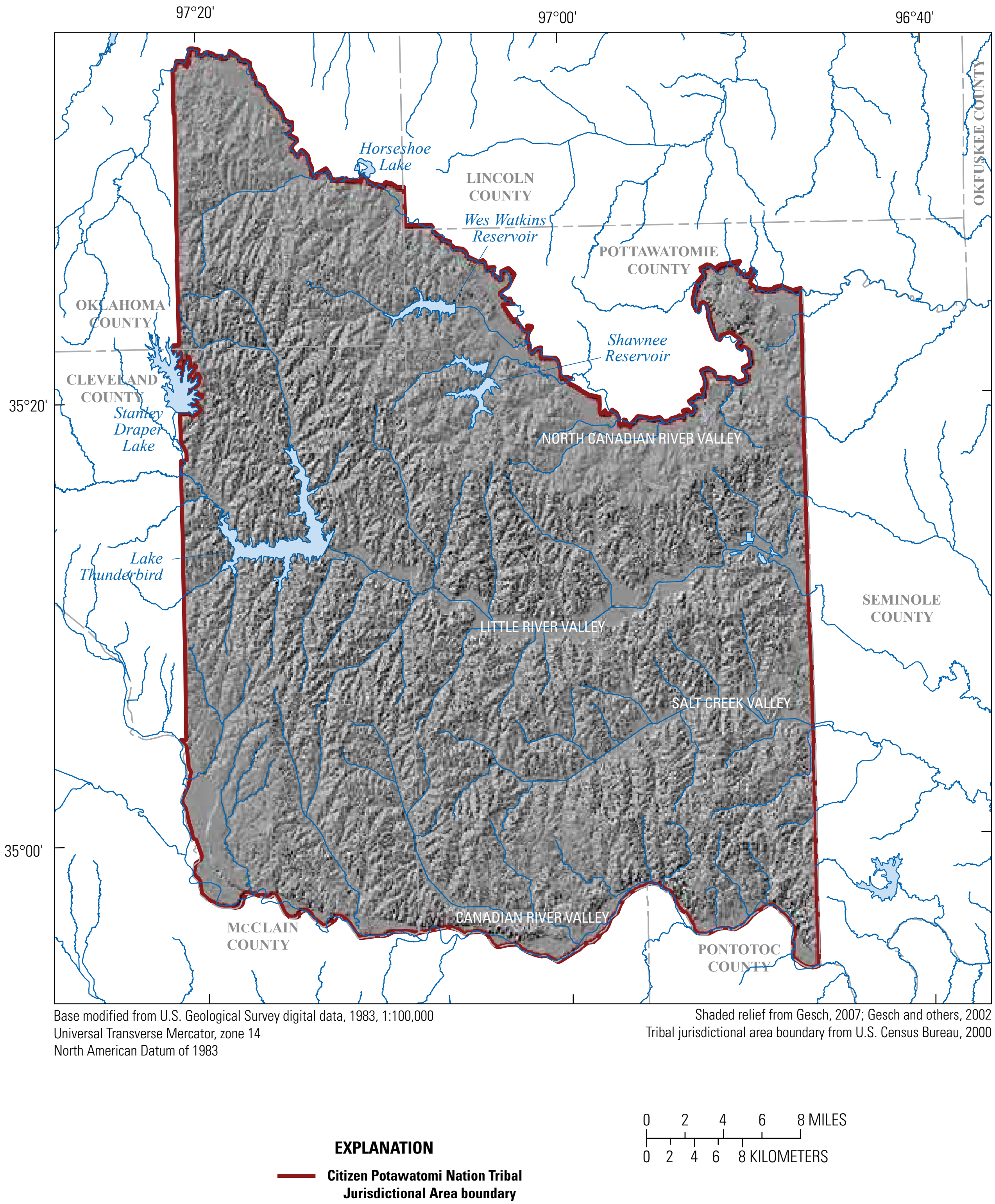


Figure 4. Land surface of the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma.

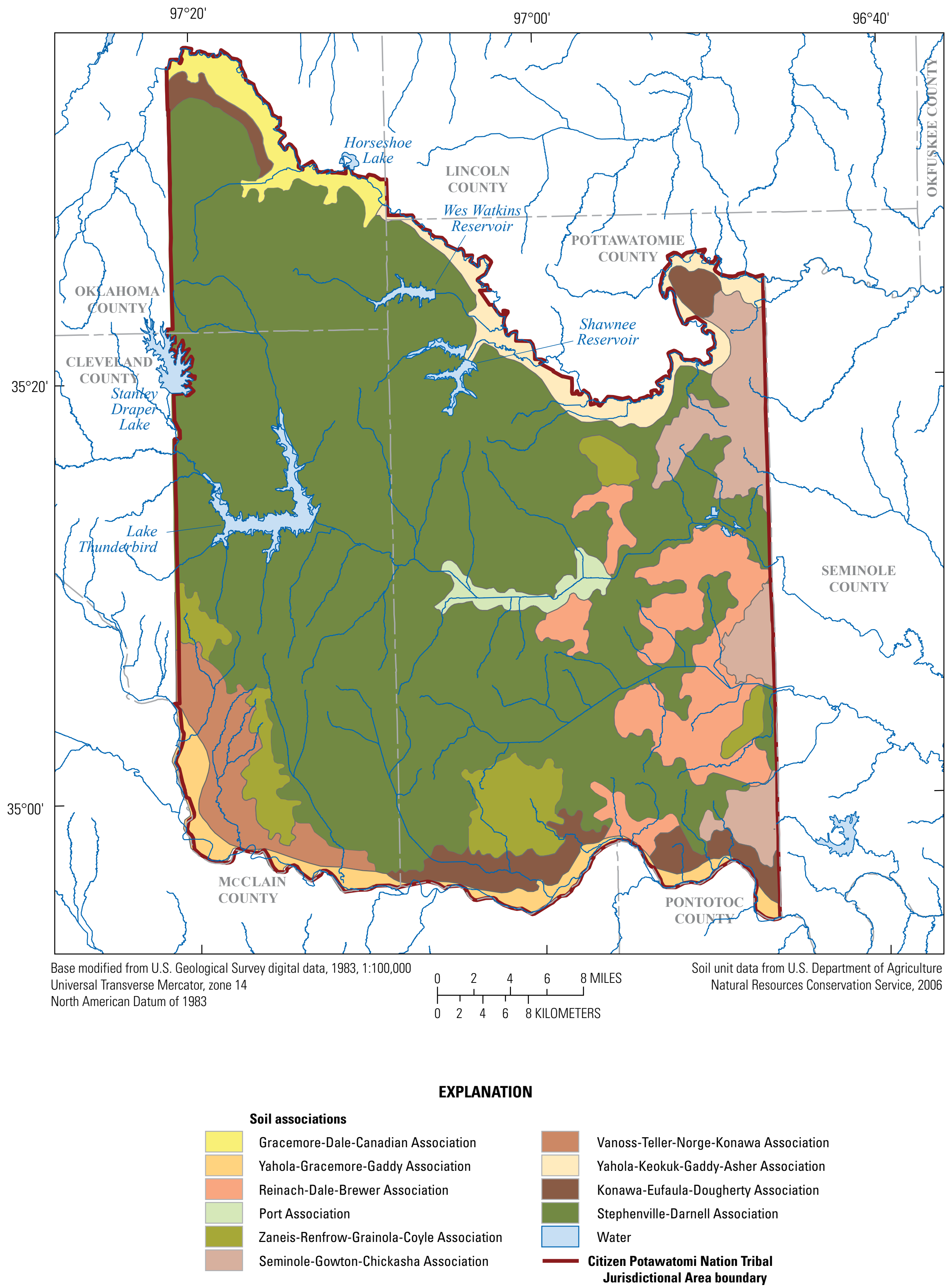


Figure 5. Soil associations in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma.

Land Cover

The predominant types of land cover in this area are deciduous forest and herbaceous vegetation (shrubs and natural grassland), which dominate the central part of the area (figs. 6 and 7). Cropland and pasture/hay are predominant land-cover types on flatter land along major streams and in the southwestern part of the area (fig. 6). The relatively rural nature of the land cover, small population densities, and limited urbanized character of this area combine to produce a relatively small demand for water compared to surrounding urban areas and limited potential sources of water-quality degradation in this area.

Evaluation of Hydrologic Data

To evaluate water resources of the Citizen Potawatomi Nation Tribal Jurisdictional Area, streamflow, groundwater-level, and well-yield data are summarized in this report. Streamflow characterization included evaluation of amounts and frequencies of high flows and low flows and general trends in streamflow with time. Groundwater characterization included showing locations of wells completed in the three principal aquifers in the area and a summary table of aquifer properties in the jurisdictional area.

Surface Water

To summarize streamflow characteristics in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, seasonality, magnitudes and frequencies of floods, low-flow characteristics, and long-term trends were summarized for four streamflow-gaging stations in or near this area using data collected by the USGS from October 1984 through September 2011 (also known as water years 1985–2011) (fig. 1). Those four long-term stations produced data used for evaluation of streamflow characteristics of three of the major streams in or bordering this area, including:

1. Along the northern boundary of the area (North Canadian River approximately 10 miles downstream from the northwestern corner of the area, North Canadian River near Harrah, Okla., streamflow-gaging station and North Canadian River approximately 8 miles upstream from the northeastern corner of the area, North Canadian River at Shawnee, Okla., streamflow-gaging station);
2. In the central part of the area (Little River approximately 10 miles before flowing out of the area, Little River near Tecumseh, Okla., streamflow-gaging station); and
3. Along the southern boundary of the area (Canadian River approximately 5 miles downstream from the southwestern corner of the area, Canadian River at Purcell, Okla., streamflow-gaging station).

Seasonality of Streamflow

Peaks in streamflow typically occur during the periods of greatest precipitation in the spring and the fall, with the largest peaks in streamflow generally being associated with intense convective storms during the spring; long periods of low flow typically occur during the summer and winter (figs. 8 and 9). Streamflow at the four long-term streamflow-gaging stations described in this report indicates different seasonal patterns in maximum, mean, and minimum monthly streamflows (fig. 9). Regulation of streamflow by upstream dams probably has modified seasonal streamflow patterns of those streams. Regulation and discharge of treated municipal and industrial wastewater upstream from the North Canadian River near Harrah, Okla., and North Canadian River at Shawnee, Okla., streamflow-gaging stations probably contribute to larger minimum streamflows during the summer than at the other two stations (Esralew and others, 2011a), and more consistent annual peaks of maximum, mean, and minimum streamflow in May through June each year (fig. 9). The Little River near Tecumseh, Okla., and Canadian River at Purcell, Okla., streamflow-gaging stations tended to have larger minimum streamflows from January through early summer, with the greatest mean and maximum streamflows occurring in May (fig. 9). Grouping mean monthly streamflow at these streamflow-gaging stations into four seasonal periods indicated that significantly greater streamflow occurred during the spring season (March through May) at the three stations on the North Canadian and Canadian Rivers (fig. 10) from October 1985 through September 2011. Except for spring, the locations of distribution of seasonal streamflow at each of those streamflow-gaging stations were not significantly different (fig. 10).

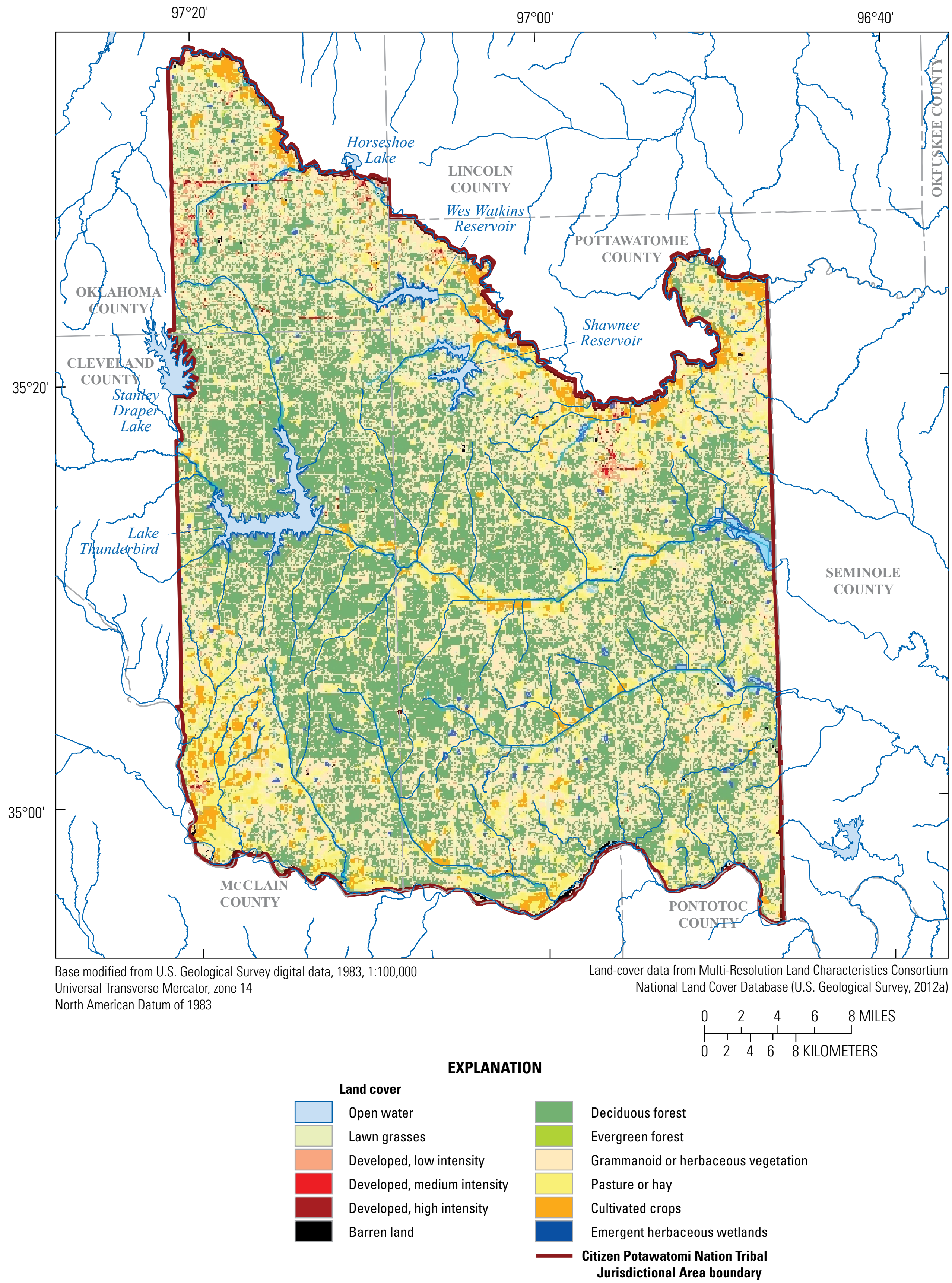


Figure 6. Land cover in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 2006.

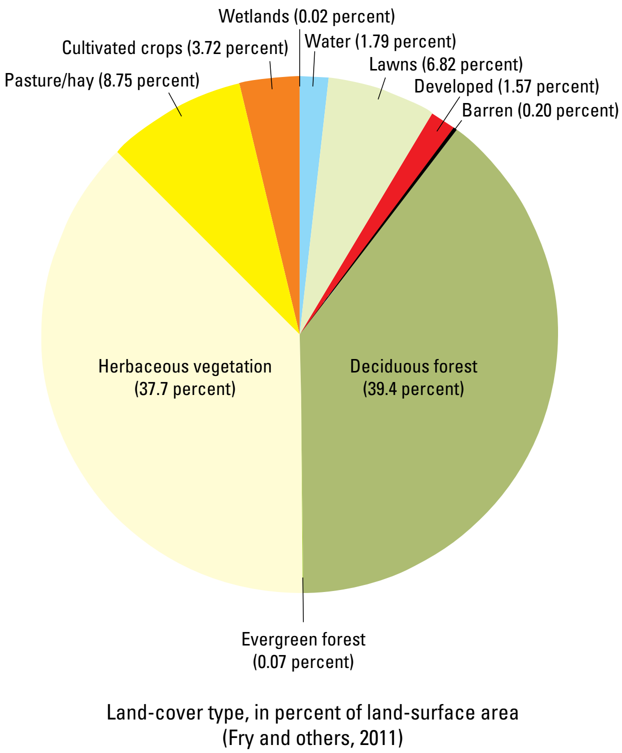


Figure 7. Percentages of land cover in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 2006.

Magnitudes and Frequencies of Floods

Knowledge of magnitudes and frequencies of floods is useful for minimizing risk to flood-plain properties and managing water utilities that use surface water to produce treated water for human consumption and other purposes. Recurrence intervals of streamflow at the four selected USGS streamflow-gaging stations (fig. 11) indicate the probability of specific streamflows in a given year. For instance, a streamflow with a 100-year recurrence interval (commonly known as a 100-year flood) has an exceedance probability or chance of being measured in any given year of 1.00 percent or 1 in 100. However, a streamflow with a 100-year recurrence interval may happen more frequently than a given recurrence interval, with several such streamflows possibly happening in one year. Streamflow associated with recurrence intervals was substantially different between these four streamflow-gaging stations, with 100-year recurrence interval streamflow ranging from approximately 15,000 cubic feet per second (ft^3/s) at the Little River near Tecumseh, Okla., streamflow-gaging station to nearly 150,000 ft^3/s at the Canadian River at Purcell, Okla., streamflow-gaging station (fig. 11).

Flood stages set by the National Weather Service for the four streamflow-gaging stations (National Weather Service, 2012) and recurrence intervals of selected streamflows indicate different frequencies of occurrence of water levels above flood stages, ranging from floods occurring more frequently than every 2 years at the Little River near Tecumseh, Okla., streamflow-gaging station to approximately once every 2.5 years at the Canadian River at Purcell, Okla., streamflow-gaging station, with flood stages being related to the morphology of banks along stream channels and flow of water outside of normal stream channels.

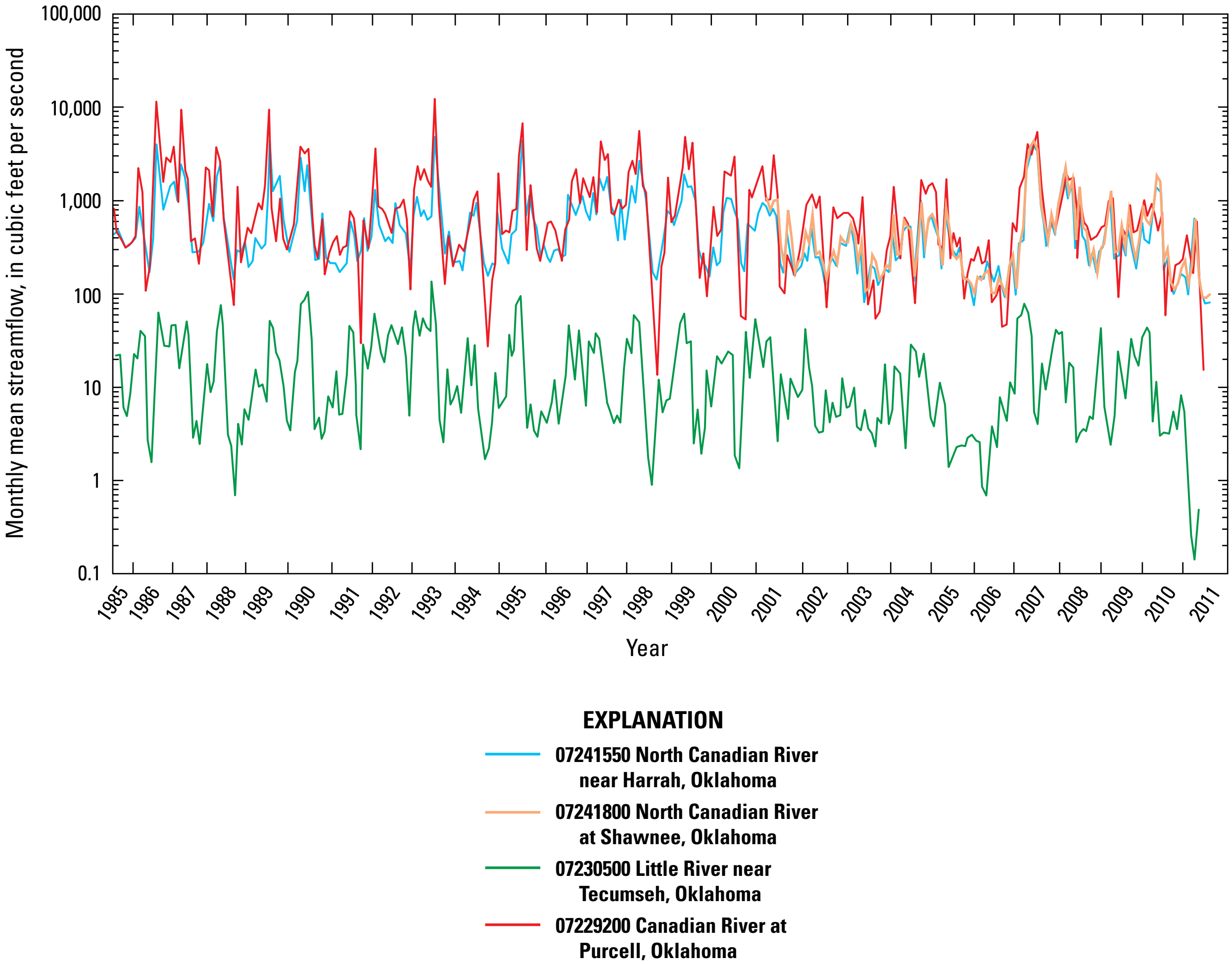


Figure 8. Monthly mean streamflow at four long-term streamflow-gaging stations in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, October 1985 through September 2011.

Low-Flow Characteristics

Low flow is a term used to describe minimal flows in streams during extended dry periods. Low-flow characteristics of streams primarily are used to manage permitted discharges of treated wastewater from municipal and industrial treatment plants and to maintain minimum streamflows needed for aquatic wildlife (known as in-stream flows or ecological flows), and for agricultural, recreational, and aesthetic purposes. As with high flows, recurrence intervals of low flows can be used for planning and management of surface-water resources. As shown on figures 8, 9, and 10, at the Little River near Tecumseh, Okla., streamflow-gaging station, there can be periods of less than 1 ft^3/s streamflow during summers. Recurrence intervals of low-flow periods for streamflow at both that station and the Canadian River at Purcell, Okla., streamflow-gaging station reach zero for one or more days every 10–20 years (fig. 12). For recurrence intervals of 5 years, which have a one-in-five chance of occurring in a given year, low flows ranged from approximately 2 ft^3/s for 1-day durations at the Little River near Tecumseh, Okla., station to about 75 ft^3/s for 30-day durations at the North Canadian River at Shawnee, Okla., station (fig. 12). Because of upstream regulation and large, relatively continuous discharges of treated wastewater upstream from the North Canadian River station, low flows at those stations maintain 50 ft^3/s or greater for all consecutive days of flow periods (fig. 12). The 7-day, 2-year discharge (7Q2) shown on figure 12, commonly is used to manage permit applications for water allocation, water-supply planning, aquatic/ecological maintenance (in-stream flow), and waste-load allocations (East, 1999).

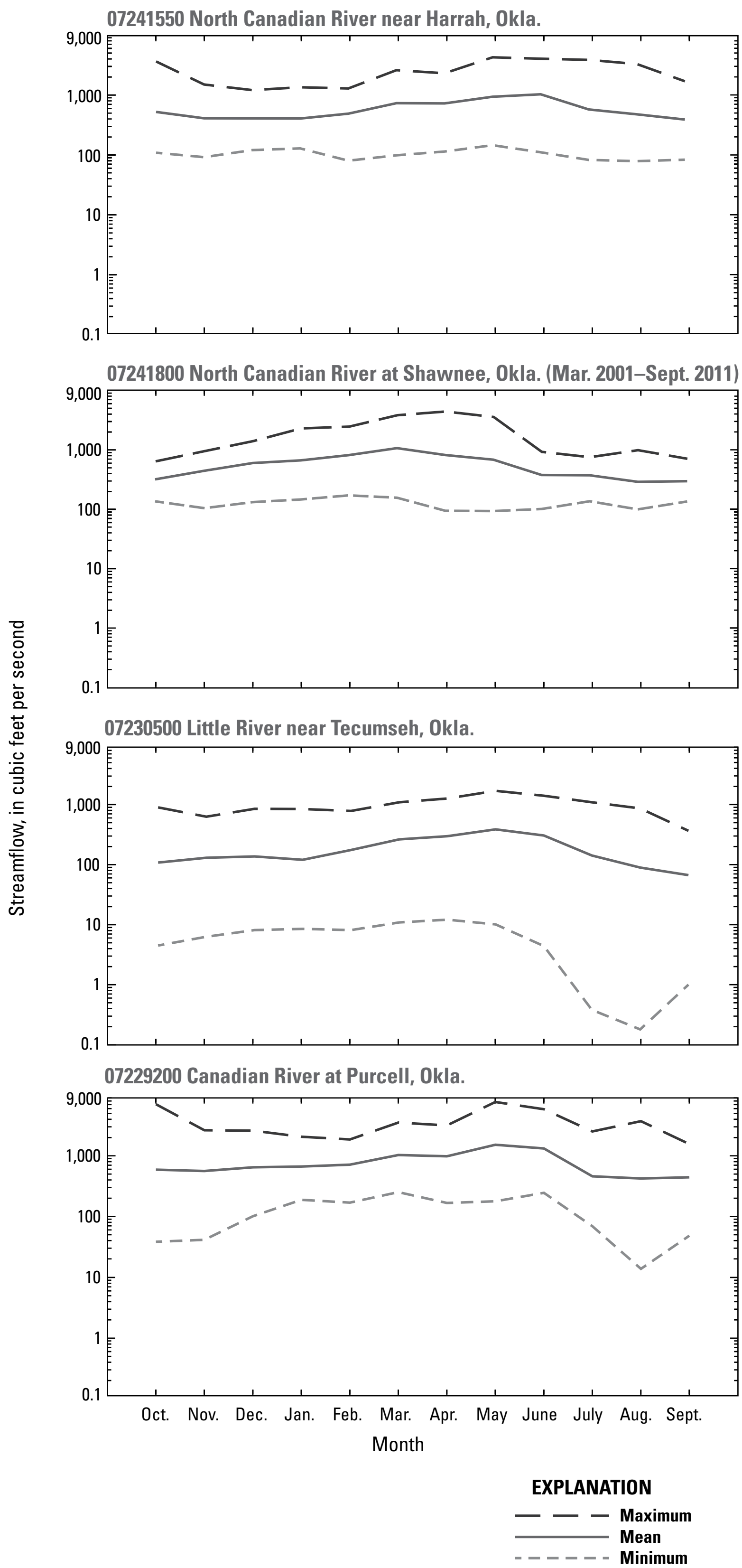


Figure 9. Monthly maximum, mean, and minimum streamflow at four long-term streamflow-gaging stations in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, October 1985 through September 2011.

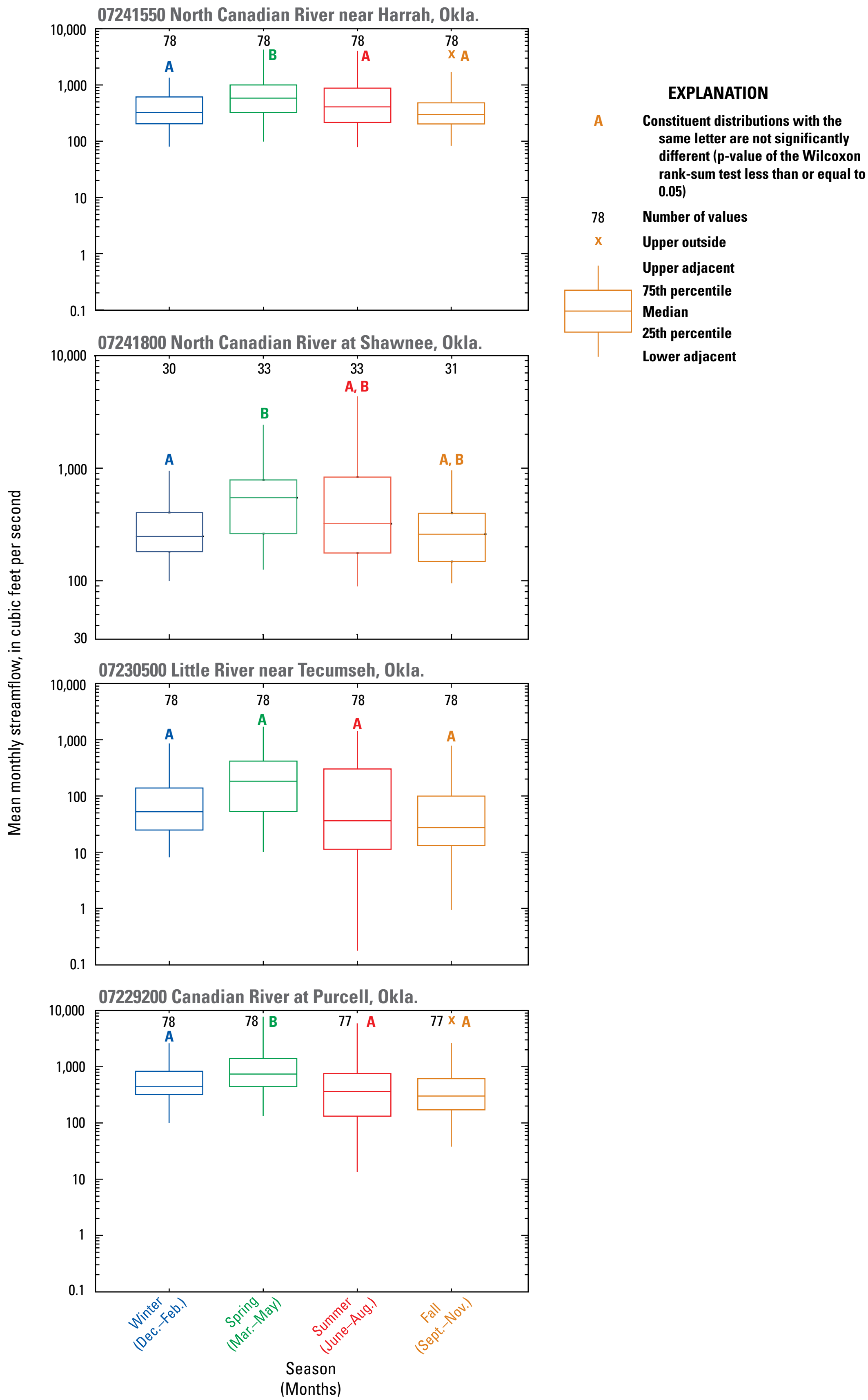
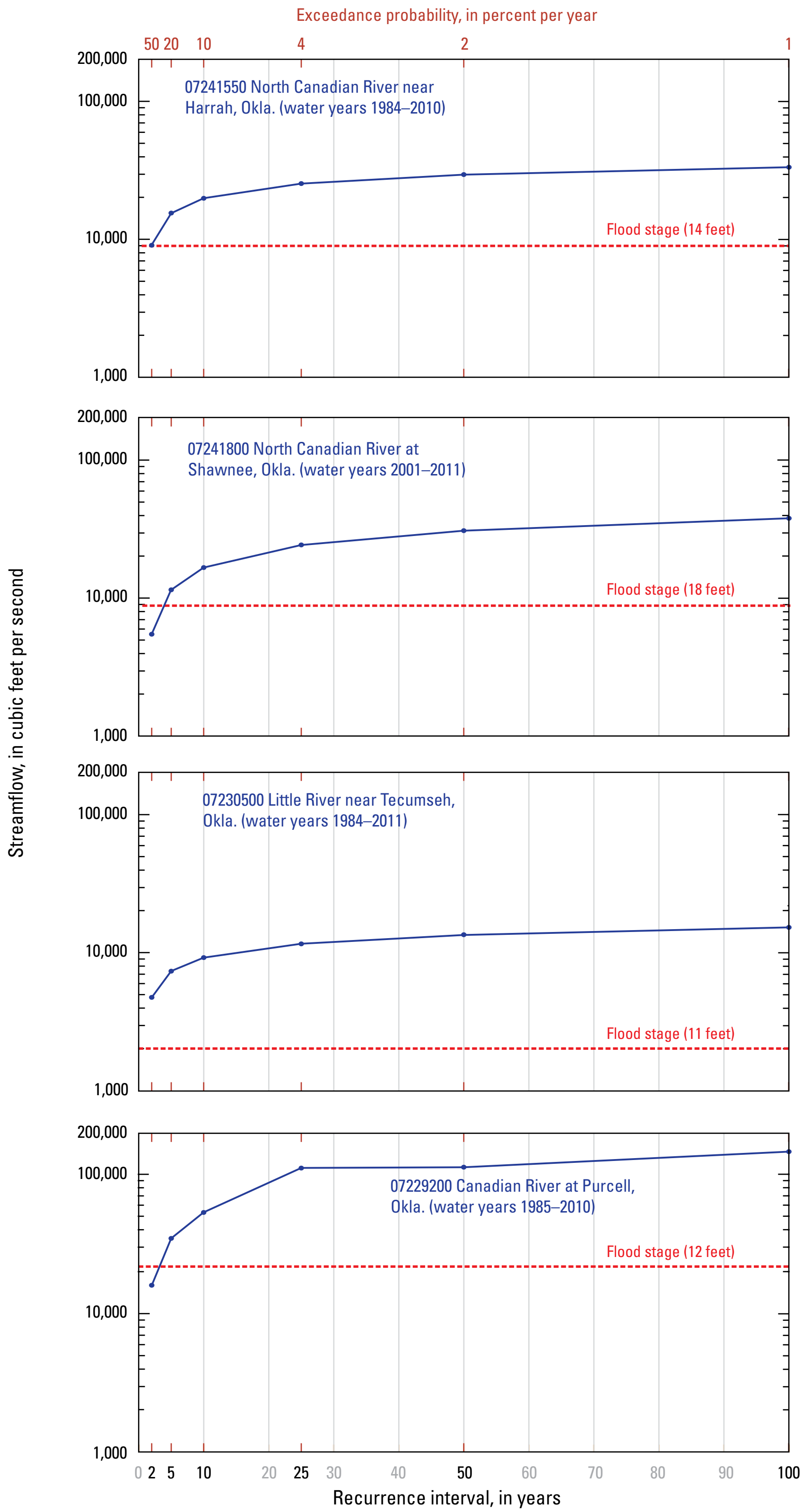


Figure 10. Distributions of streamflow by season at four long-term streamflow-gaging stations in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, October 1985 through September 2011.



Recurrence intervals computed from data obtained from U.S. Geological Survey, 2012b.
Flood stages obtained from National Weather Service, 2012.

Figure 11. Recurrence intervals and exceedance probabilities of selected streamflows at four long-term streamflow-gaging stations in and near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2010.

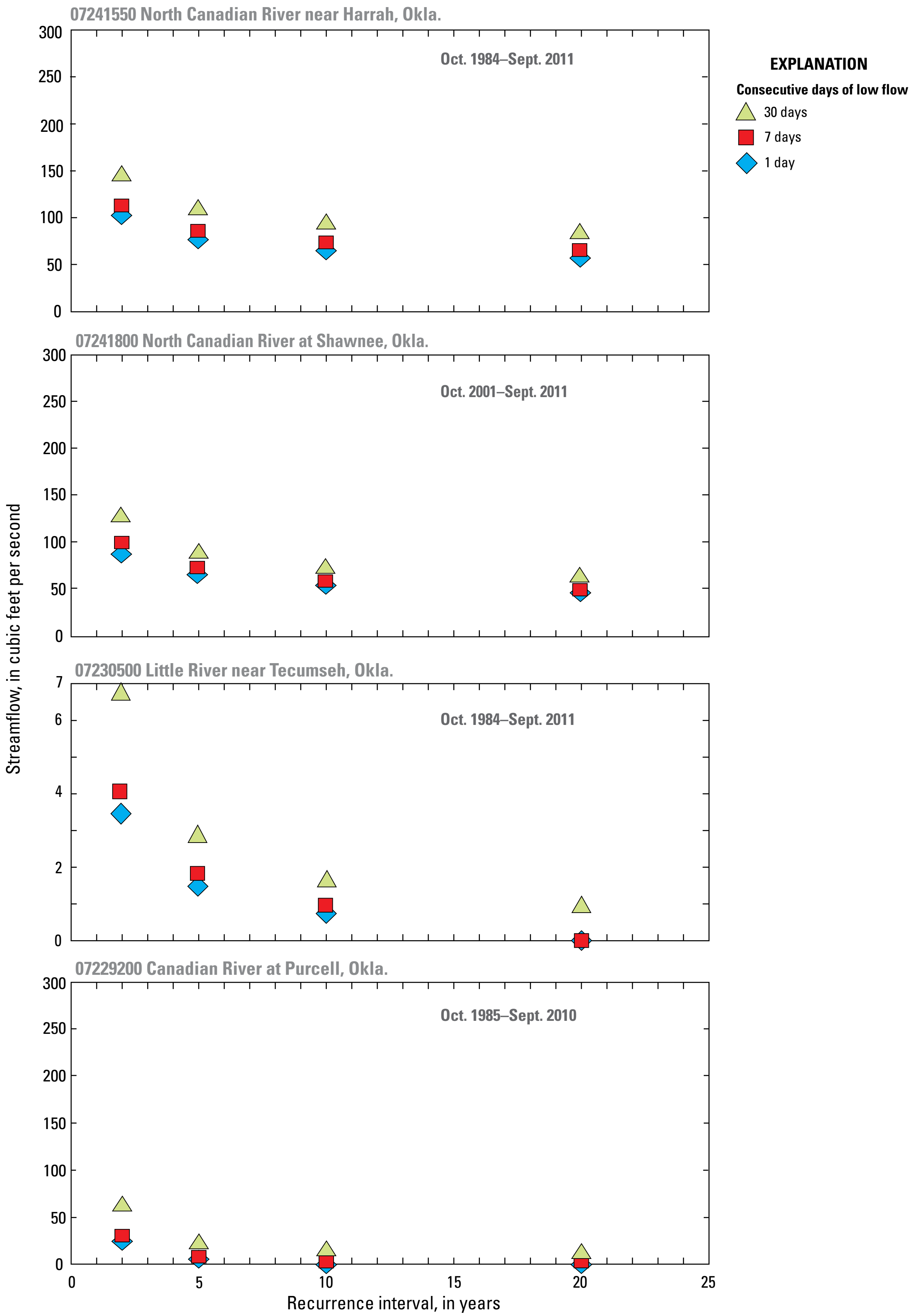


Figure 12. Recurrence intervals of low-flow streamflows by duration for four long-term streamflow-gaging stations in or near the Citizen Potawatomi Tribal Jurisdictional Area, Oklahoma.

Long-Term Trends

Mean annual streamflows in or near this area decreased from the 1940s through the 1970s, increased during the 1980s, and decreased again in the early 1990s (Esralew and Lewis, 2010). At four selected streamflow-gaging stations, mean annual streamflow has decreased since the mid-1980s, with notable short-term increases being measured in the mid-1990s and 2007, and the most substantial decreases being measured in the drought year of 2006 (Tortorelli, 2008) and 2011 (fig. 13). Those streamflow patterns generally coincided with patterns of annual precipitation recorded at the National Weather Service stations at Shawnee, and Seminole, Okla. (figs. 3 and 13). There were not enough complete mean annual temperature records at the National Weather Service station at Seminole, Okla., to make conclusions about relations between long-term temperature trends and streamflows (fig. 3).

Annual peak flow is the maximum streamflow recorded in a given year at a streamflow-gaging station. As with high-flow and low-flow characteristics, long-term changes in annual peak flow had different patterns with time at these four streamflow-gaging stations (fig. 14). Annual peak flows at the North Canadian River near Harrah, Okla., streamflow-gaging station increased from 1985 to a peak in the mid-1990s and generally have decreased since that peak (fig. 14). Relatively small decreases in peak flows, with numerous high outlier values from the mid-1990s through 2010, may have been caused by increased urbanization and impervious surface area in the upstream Oklahoma City area, causing "flashier" or more rapid runoff of water during storms. Annual peak streamflows at the North Canadian River at Shawnee station increased in the latter half of the first decade of the 2000s, coinciding with several relatively wet years (figs. 3 and 14). Similar to the monthly mean streamflows (fig. 9), annual peak streamflow at the Little River near Tecumseh, Okla., streamflow-gaging station generally decreased with time (fig. 14). After an increase in annual peak flow from 1980 through 1990, annual peak flows at the Canadian River at Purcell, Okla., streamflow-gaging stations decreased to less than 20,000 ft^3/s for most years in the 2000s, similar to the pattern of annual precipitation at local National Weather Service stations (figs. 3 and 14).

Mean annual streamflow from October 1984 through September 2011 (water years 1985–2011) at the three long-term streamflow-gaging stations on the larger rivers (North Canadian and Canadian) did not change significantly (p-value less than 0.05 for the seasonal Kendall tau test [Kendall, 1938]; table 3). Trend analysis was not done for data with the relatively short period of record at the North Canadian at Shawnee, Okla., station. Mean annual streamflow did decrease significantly at the Little River near Tecumseh, Okla., streamflow-gaging station, indicating more consistent decrease in mean annual streamflow at the station than at the other two streamflow-gaging stations (table 3).

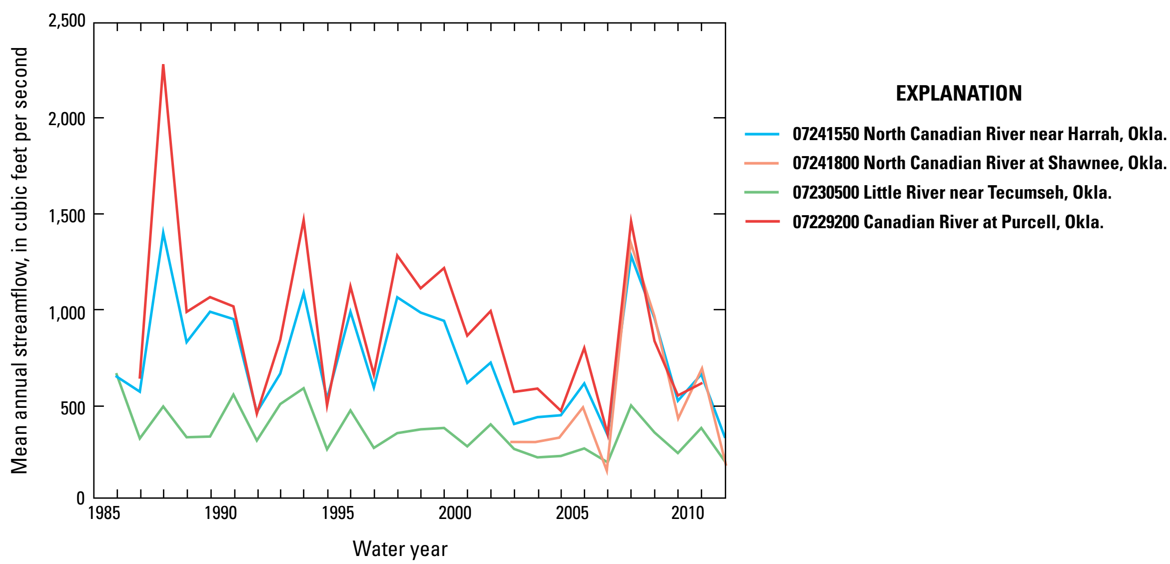


Figure 13. Mean annual streamflow at four long-term streamflow-gaging stations in and near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, October 1985 through September 2011.

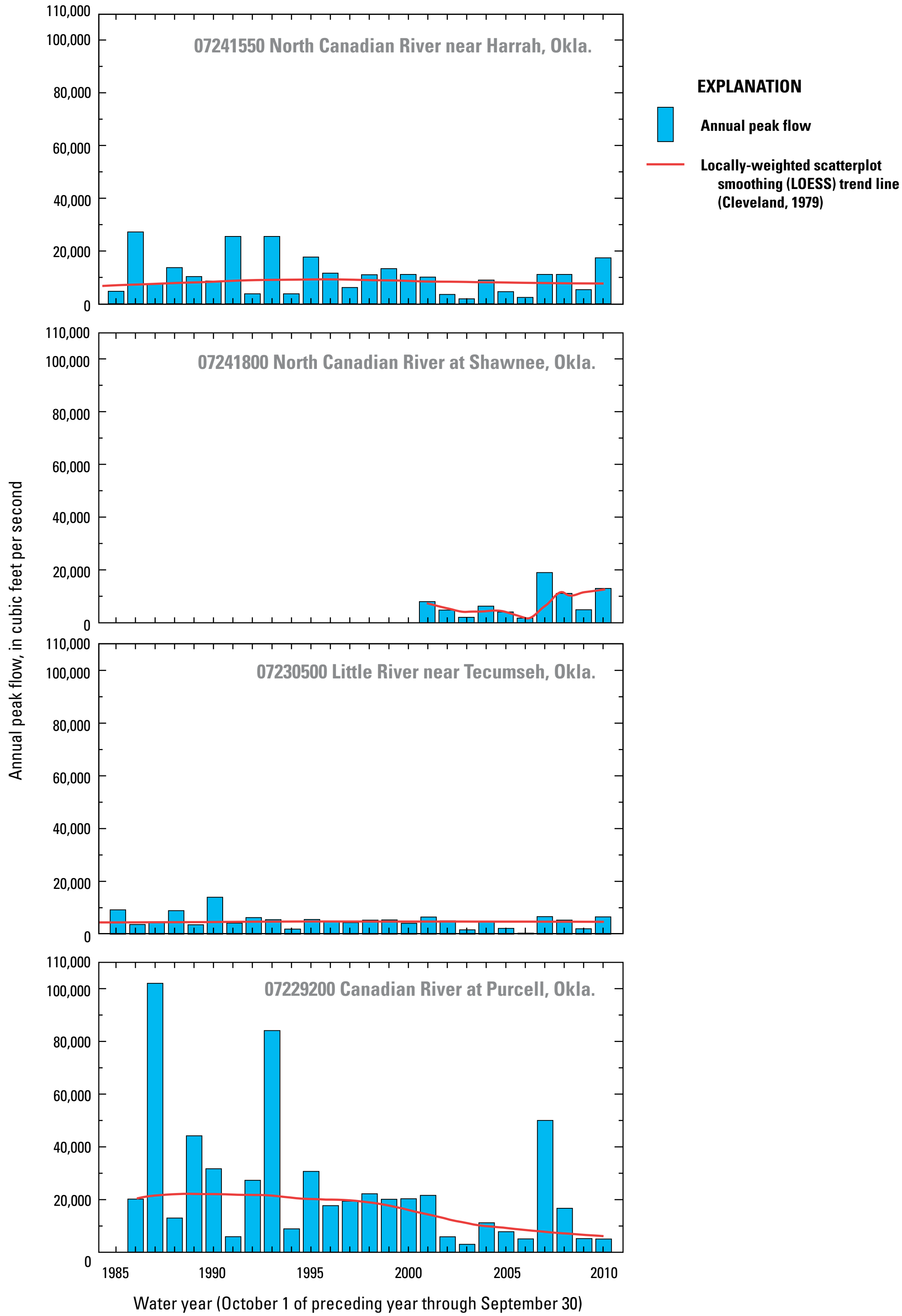


Figure 14. Annual peak flows and LOESS trend lines for selected periods at four long-term streamflow-gaging stations in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2010.

Table 3. Statistics of seasonal Kendall tau tests of trends in mean annual streamflow with time at selected streamflow-gaging stations in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, October 1984 to October 2011.

[bold font, significant trend at alpha level less than or equal to 0.05]

Streamflow-gaging station	Tau correlation coefficient	S-value	Z-value	P-value	Estimated trend equation
07241550 North Canadian River near Harrah, Oklahoma	-0.254	-89	-1.84	0.067	Q = -12.75(Year)+683.0
07230500 Little River near Tecumseh, Oklahoma	**-0.339**	**-119**	**-2.46**	**0.014**	**Q = -7.606(Year)+257.4**
07229200 Canadian River at Purcell, Oklahoma[1]	-0.227	-68	-1.56	0.118	Q = -19.36(Year)+950.6

[1]Data only available for water years 1986–2010.

Groundwater

The principal aquifers in this jurisdictional area are alluvial and terrace aquifers along the North Canadian and Canadian Rivers, referred to herein as "alluvial aquifers," the Central Oklahoma aquifer in the western two-thirds of the area, and the Vamoosa-Ada aquifer in the eastern one-third of the area (fig. 15). Different textures and degrees of cementation of these aquifer materials produce varying hydrologic properties.

Alluvial aquifers are the thinnest aquifers in the area, generally being less than 100 feet (ft) thick, compared to several hundred to more than 1,000 ft of bedrock aquifers underlying the area. Despite being relatively thin, alluvial aquifers in the area produce some of the highest well yields, in some cases exceeding 1,000 gallons per minute (gal/min; table 4). Wells completed in the Central Oklahoma aquifer in the western part of the area generally produce 25–50 gal/min, whereas wells completed in the Vamoosa-Ada aquifer in the eastern part of the area generally produce less than 25 gal/min (Bingham and Moore, 1975). Specific capacity, the well yield per unit of drawdown, ranged from 0.29 gallons per minute per foot [(gal/min)/ft] for the North Canadian alluvial aquifer in northwestern Oklahoma to 0.36–1.3 (gal/min)/ft for the Central Oklahoma aquifer to 0.48–1.3 (gal/min)/ft for the Vamoosa-Ada aquifer in Osage County, Okla. (Davis and Christenson, 1981; Parkhurst and others, 1996; Abbott and DeHay, 2008). Johnson (1983) described the part of the areas underlain by the alluvial and Central Oklahoma aquifers as being likely recharge areas, whereas the area underlain by the Vamoosa-Ada aquifer was a "potential recharge area."

The Central Oklahoma aquifer underlies much of this jurisdictional area (fig. 15). Groundwater flow in the Central Oklahoma aquifer probably is confined by the Hennessey Group, which is composed mostly of shales and mudstones with relatively small transmissivities. The Central Oklahoma aquifer also is considered to be confined at the contact with the Late Pennsylvanian-age Vanoss Formation. Groundwater flow also is likely to be limited at the base of the aquifer as indicated by the presence of saline groundwater (Parkhurst and others, 1996; Christenson and others, 1998).

Regional groundwater flow can be inferred from potentiometric-surface maps of the Central Oklahoma aquifer. A potentiometric surface is defined as the level to which water will rise in tightly cased wells. Multiple potentiometric surfaces can occur in an aquifer with substantial vertical groundwater flow. Most of the deep wells completed in this aquifer are constructed with long gravel packs and multiple open intervals (screens, slots, or perforations) that are completed in more than one sandstone layer, with each containing water at different head elevations. The potentiometric surfaces described in this report approximate only the upper zone of saturation in the Central Oklahoma aquifer, referred to as the "water table." Two synoptic water-level measurement efforts have been performed in the Central Oklahoma aquifer. The first potentiometric measurements in this area were made in 1986–87 as part of studies about the geochemistry in the aquifer. Those studies of the Central Oklahoma aquifer produced maps of the 1986–87 potentiometric surface in the aquifer (Christenson and others, 1992, fig. 2; Parkhurst and others, 1996, fig. 24). An additional series of measurements of groundwater levels in this aquifer were made in 2009 for compilation of a groundwater flow model of the Central Oklahoma aquifer. For that study, groundwater levels were measured in 280 wells between February 17, 2009, and March 13, 2009 (Mashburn and Magers, 2011). Well depths and completion information for wells used in the 1986–87 and 2009 potentiometric-surface maps can be found at the USGS National Water Information System website http://nwis.waterdata.usgs.gov/ok/nwis/gwlevels. The potentiometric surfaces from 1986–87 and 2009 measurements of the Central Oklahoma aquifer can be compared to generally characterize long-term changes in groundwater levels for those time periods. The water levels compared in this section are only from those wells measured in the 1986–87 and 2009 time periods (169 wells, fig. 15). This comparison does not take into account the variability of water levels between 1986–87 and 2009. Various factors also play a role in water-level changes and some factors may affect water levels on a diurnal, seasonal, or annual timescale. These factors include earth and moon tides, barometric-pressure changes, groundwater gains from precipitation and streamflows, and groundwater losses to withdrawals and streamflows.

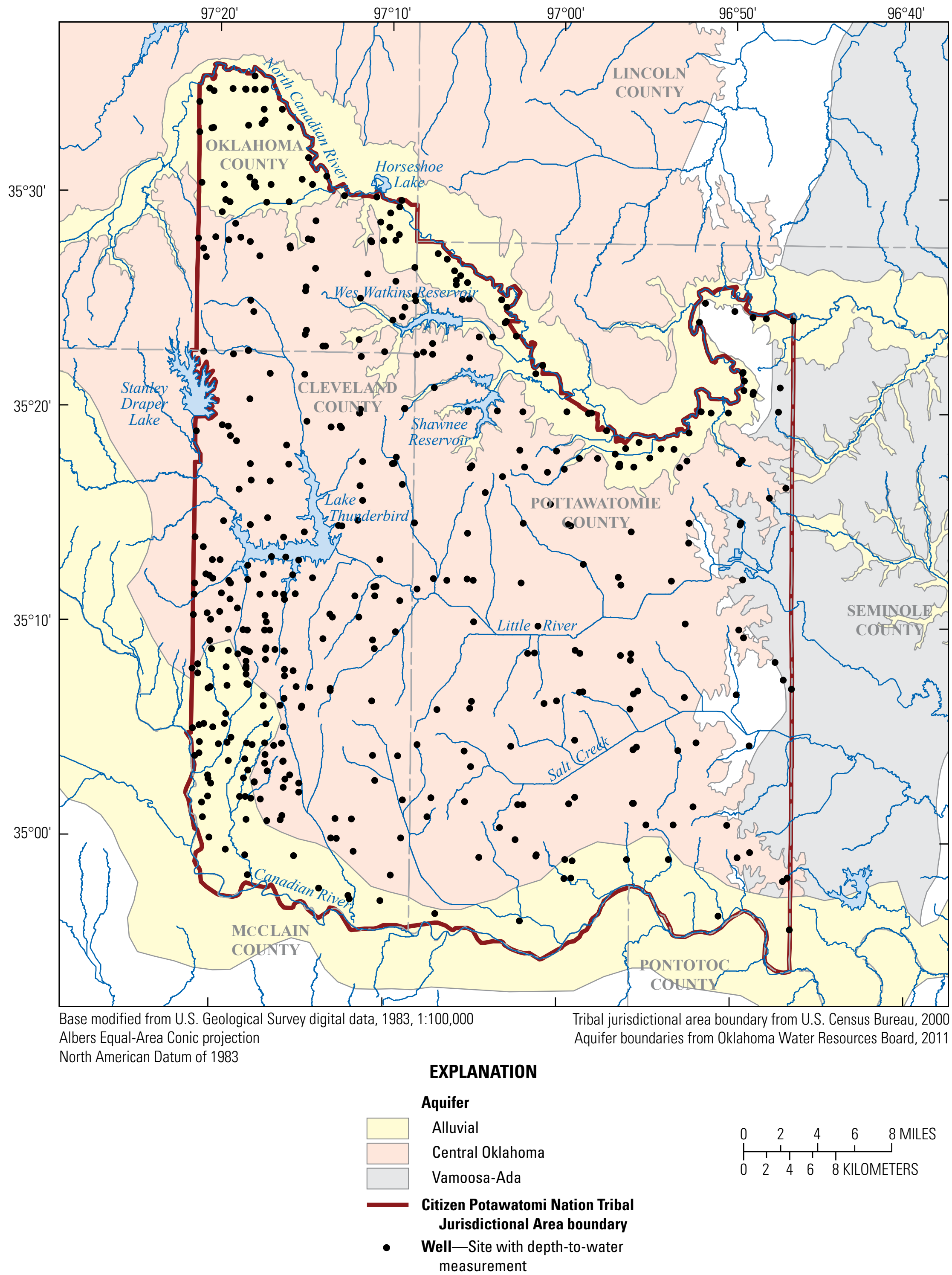


Figure 15. Principal aquifers and locations of 460 wells having depth-to-water measurements collected by the U.S. Geological Survey in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, as of 2011.

Table 4. Properties of aquifers underlying the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma.

[ft, feet; gal/min, gallons per minute; >, greater than]

Aquifer	Thickness range (ft)	Well yield range (gal/min)	Specific capacity range (gal/min/ft)
Alluvial	[1,2]10–100	[1,2]10–>1,000	[3]0.29
Central Oklahoma	[1,2]450–1,100	[1,2]25–400	[4]0.36–1.3
Vamoosa-Ada	[1,2]200–800	[1,2]25–300	[5]0.48–1.3

[1]Bingham and Moore (1983).

[2]Johnson (1983).

[3]Davis and Christensen (1981).

[4]Parkhurst and others (1996).

[5]Abbott and DeHay (2008).

The 2009 potentiometric-surface map (Mashburn and Magers, 2011) showed similar features as the 1986–87 potentiometric-surface map (Christenson and others, 1992, fig. 2). Regional slope was west to east and, based on no deviation of potentiometric lines near the North Canadian River, there appeared to be little or no exchange between the Central Oklahoma aquifer and the North Canadian River (Mashburn and Magers, 2011). Greater exchange between groundwater and the North Canadian River probably occurs in overlying alluvial aquifers. The 1986–87 water levels, or depths to water, in feet below land surface, ranged from 1.5 to 177 with a median value of 32 ft (Christenson and others, 1992, fig. 2). The 2009 water levels, in feet below land surface, ranged from 3.1 to 233.7 with a median value of 35.8 ft (Mashburn and Magers, 2011).

Evaluation of Water-Quality Data

The quality of surface water and groundwater in the Citizen Potawatomi Nation Tribal Jurisdictional Area is described in this report through summaries and analyses of values and concentrations of selected physical properties, major ions, nutrients, and metals in surface water and groundwater during the past several decades. Boxplots are used to graphically display distributions of those data values from different surface-water sites and aquifers.

Surface-Water Quality

Surface-water quality typically ranges from being similar to local groundwater during low-flow conditions to being similar to stormwater runoff during high-flow conditions. Water quality in streams generally is correlated with streamflow, with some constituents occurring in greater or lesser values or concentrations at high-flow or low-flow conditions, respectively, depending on the source of a constituent and interactions with other water-quality constituents. With the exception of the data from the USGS and the Citizen Potawatomi Nation, most surface-water-quality samples did not have accompanying streamflow data, limiting comparison between streamflow and surface-water quality in this report. Comparisons made between water-quality data collected at different stations by different agencies are limited by a number of possible factors, including differences in: sample-collection methods, measurement instrumentation and calibration procedures, collection periods, and streamflows during sample measurement and collection. Another limitation of the surface-water-quality data available for analysis was the dominance of sampling sites along the North Canadian River (fig. 16, table 5). Water quality in the North Canadian River is of interest to several tribes and agencies because it is one of the larger rivers flowing through their areas of interest or jurisdiction. The river is downstream from many municipal- and industrial-treatment outfalls (Esralew and others, 2011a, fig. 1) and is a source of water supply for several cities in Oklahoma County (Tortorelli, 2009). Relatively few sites were sampled on other streams in this area, limiting surface-water-quality interpretation in other streams in this area.

Tribes and agencies have sampled surface-water quality in this area for a variety of reasons, including monitoring of general water quality (USGS, the Citizen Potawatomi Nation, the Kickapoo Tribe of Oklahoma, and the OWRB); monitoring for effects of specific activities, such as petroleum production and municipal wastewater discharges (USGS and the Oklahoma Corporation Commission); and conducting short-term surveys of limited numbers of constituents, such as monitoring for fecal-indicator bacteria for several months at five sites by the Oklahoma Department of Environmental Quality (appendixes 1–6). Such variation in sampling programs provides useful data about surface-water quality, but interpretation of those data is limited by not being consistent in: (1) sampling methods, (2) measurement methods and equipment, (3) spatial coverage, (4) temporal coverage, and (5) constituents measured.

Water Properties

Water properties include thermal and electrical properties of water and measurements of acidity (pH), dissolved gas, and total dissolved solids. Water properties summarized in this report include dissolved oxygen concentration, pH, specific conductance, water temperature, turbidity, biochemical oxygen demand, chemical oxygen demand, total dissolved solids, hardness, and suspended solids.

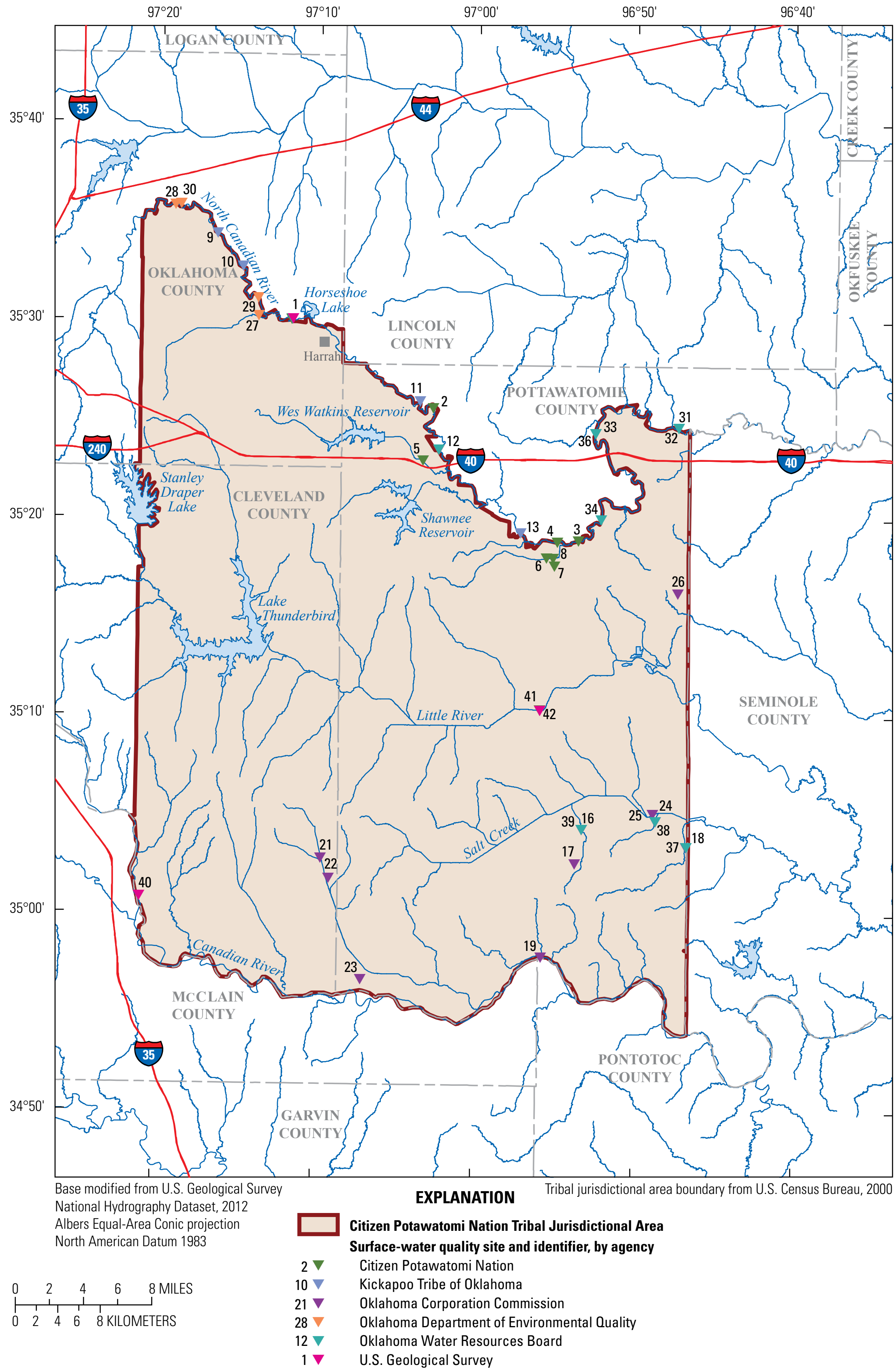


Figure 16. Locations of selected surface-water-quality sampling sites in and near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma.

Table 5. Names and locations of selected surface-water quality sites and weather stations sampled or measured in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

[Map numbers from figure 17 of this report, sites sharing the same map numbers are colocated, horizontal base for latitudes and longitudes is the North American Datum of 1983]

Map number	Sampling agency	Site name	North decimal latitude	Decimal longitude
1	Citizen Potawatomi Nation	North Canadian River at Luther Road	35.500	-97.195
1	U.S. Geological Survey	North Canadian River near Harrah, Okla. (07241550)	35.500	-97.194
1	Oklahoma Water Resources Board	520510000110-01	35.500	-97.194
2	Citizen Potawatomi Nation	North Canadian River at Giverney 14SE	35.426	-97.046
3	Citizen Potawatomi Nation	North Canadian River at Knight 21	35.315	-96.893
4	Citizen Potawatomi Nation	North Canadian River at Knight 29	35.314	-96.915
5	Citizen Potawatomi Nation	North Deer Creek at Firelake Grand Casino	35.382	-97.0561
6	Citizen Potawatomi Nation	Squirrel Creek at Tribal Administration Building	35.301	-96.926
7	Citizen Potawatomi Nation	Squirrel Creek at Tribal Environmental Office	35.301	-96.919
8	Citizen Potawatomi Nation	Un-named tributary to Squirrel Creek	35.294	-96.918
9	Kickapoo Tribe of Oklahoma	NCR01	35.572	-97.273
10	Kickapoo Tribe of Oklahoma	NCR02	35.544	-97.246
11	Kickapoo Tribe of Oklahoma	NCR04	35.432	-97.060
12	Kickapoo Tribe of Oklahoma	NCR05	35.391	-97.039
12	Oklahoma Water Resources Board	520510000110-07	35.391	-97.040
12	Oklahoma Department of Environmental Quality	NC08	35.391	-97.040
13	Kickapoo Tribe of Oklahoma	NCR07	35.321	-96.953
14	National Weather Service	Seminole, Okla.	35.233	-96.667
15	National Weather Service	Shawnee, Okla.	35.350	-96.900
16	Oklahoma Corporation Commission	Blacksmith Creek	35.073	-96.887
17	Oklahoma Corporation Commission	Blacksmith Creek tributary	35.044	-96.894
18	Oklahoma Corporation Commission	Bruno Creek	35.058	-96.779
19	Oklahoma Corporation Commission	Canadian River at U.S. Highway 177	34.965	-96.929
21	Oklahoma Corporation Commission	Helsel Creek	35.047	-97.159
22	Oklahoma Corporation Commission	Pond Creek	35.030	-97.150
23	Oklahoma Corporation Commission	Pond Creek tributary	34.945	-97.116
24	Oklahoma Corporation Commission	Popshego Creek	35.080	-96.810
25	Oklahoma Corporation Commission	Salt Creek	35.086	-96.813
26	Oklahoma Corporation Commission	Wewoka Creek headwater tributary	35.271	-96.789
27	Oklahoma Department of Environmental Quality	CW01	35.502	-97.230
28	Oklahoma Department of Environmental Quality	NC06	35.595	-97.318
29	Oklahoma Department of Environmental Quality	NC07	35.518	-97.230
30	Oklahoma Department of Environmental Quality	OC01	35.596	-97.312
31	Oklahoma Water Resources Board	520510000110-02	35.411	-96.789
32	Oklahoma Water Resources Board	520510000110-03	35.411	-96.789
33	Oklahoma Water Resources Board	520510000110-04	35.405	-96.876
34	Oklahoma Water Resources Board	520510000110-05	35.333	-96.869
35	Oklahoma Water Resources Board	520510000110-06	35.400	-96.670
36	Oklahoma Water Resources Board	520510000110-1S	35.405	-96.876
37	Oklahoma Water Resources Board	520800030070-01	35.058	-96.778
38	Oklahoma Water Resources Board	520800030080-01	35.080	-96.810
39	Oklahoma Water Resources Board	520800030120-01	35.073	-96.887
40	U.S. Geological Survey	Canadian River at Purcell, Okla. (07229200)	35.014	-97.347
41	U.S. Geological Survey	Little River near Tecumseh, Okla. (07230500)	35.173	-96.932
42	Citizen Potawatomi Nation	Little River at U.S. Highway 177	35.173	-96.932

Flowing surface water typically has greater than 7 mg/L dissolved oxygen concentration because of direct contact with oxygen in the atmosphere, photosynthetic emission of oxygen by aquatic plants during daylight hours, and turbulent flow entraining atmospheric oxygen (Vaccari and others, 2006; Drever, 1988). Dissolved oxygen, like other gases, generally occurs in lesser concentrations as water temperature increases (Hem, 1985). Dissolved oxygen concentration in water is used to evaluate whether there is sufficient oxygen available for respiration of fish, amphibians, and other aquatic biota; and whether organic loading by treated wastewater discharges or through eutrophic growth of aquatic plants, which compose part of chemical and biological oxygen demand, are substantial in a stream (Drever, 1988).

Most surface-water samples collected in this area from 1985–2011 had dissolved oxygen concentrations greater than the lower limits of criteria for coldwater (6.5 mg/L) and warmwater (5.5 mg/L) aquatic organisms in ambient water-quality criteria defined by the USEPA (fig. 17; Chapman, 1986). In two small streams, Squirrel Creek and North Deer Creek, 25 to 50 percent of water samples collected by the Citizen Potawatomi Nation had dissolved oxygen concentrations less than both criteria (fig. 17), indicating potential limitation of those streams for aquatic biota caused by diminished oxygen concentration. Although there are no known discharges of treated wastewater upstream from those sampling sites (figs. 17 and 18, table 5), the North Deer Creek sampling site is downstream from the Wes Watkins Reservoir and water in reservoirs periodically has low dissolved oxygen concentrations, particularly in deep water (Vaccari and others, 2006). Both streams are relatively small and such streams can have nearly no flow during parts of the year, which can lead to stagnation and lesser dissolved oxygen concentrations.

Most of the surface-water-quality samples described in this report were collected during daylight hours. Continuous monitoring of dissolved oxygen concentration at the North Canadian River near Harrah, Okla., streamflow-gaging station and elsewhere indicates periodic lesser concentrations of dissolved oxygen (fig. 19) probably caused by cessation of photosynthetic oxygen emission at night, and ongoing plant and microbial respiration, which consumes dissolved oxygen in water. Periodic anoxic conditions can kill aquatic organisms and change assemblages of aquatic species and aquatic ecosystem function (Ecological Society of America, 2012; Egan, 2008).

The acid or alkaline characteristic of water is denoted by pH, with a pH value of 7 being neutral, lesser values being increasingly acidic, and greater values being increasingly alkaline. Natural waters typically have near neutral pH (Hem, 1985), similar to values measured in most surface-water samples collected in this area (fig. 20). The USEPA has set minimum and maximum limits for pH of 6.5 and 9.0, respectively, both for continuous criteria concentration of surface water and secondary drinking-water standards to protect the health of aquatic organisms from water that is strongly acidic or alkaline, both of which can be corrosive to animal tissues, and for aesthetic reasons and minimization of metal concentrations in drinking water (U.S. Environmental Protection Agency, 2002, 2011b). Only two surface-water samples collected from 1985–2011 in the area had pH values exceeding (below) the acidic limit of 6.5 (fig. 20). A few surface-water samples, primarily collected at sites on the North Canadian and Canadian Rivers, had pH values greater than the top continuous criteria concentration and secondary drinking-water standard of 9.0 (figs. 16 and 20, table 5). Values of pH can change substantially and seasonally (fig. 20), caused by inputs of groundwater and runoff to the river and processes in the river, such as respiration and photosynthesis of plants. Differences in pH measured by the three agencies sampling at the North Canadian River near Harrah, Okla., streamflow-gaging station may have been caused by different sampling periods and streamflow conditions when those samples were collected (fig. 20).

Specific conductance is an indirect indicator of the total amount of soluble substances dissolved in water samples denoted by “total dissolved solids.” As with dissolved oxygen and pH, specific conductance can substantially change diurnally and seasonally (fig. 19), caused by the processes previously described for pH. Large concentrations of total dissolved solids can cause precipitation of minerals in irrigated soils and in water pipelines and appliances and cause a salty taste in drinking water. For these reasons, the USEPA set a secondary drinking-water standard of 500 mg/L for total dissolved solids (U.S. Environmental Protection Agency, 2011b). At the 22 surface-water sites sampled by the USGS, OWRB, Kickapoo Tribe of Oklahoma, and the Oklahoma Corporation Commission from 1985–2011, more than 50 percent of samples had total dissolved solids concentrations exceeding the secondary drinking-water standard at all but one site (Pond Creek tributary) (fig. 21, table 5). The surface-water samples having the largest total dissolved solids concentration were collected at sites in the Salt Creek watershed from Bruno, Blacksmith, and Popshego Creek in the southeastern part of this area (figs. 16 and 21, table 5), with most samples collected at those sites having total dissolved solids concentrations greater than 1,000 mg/L.

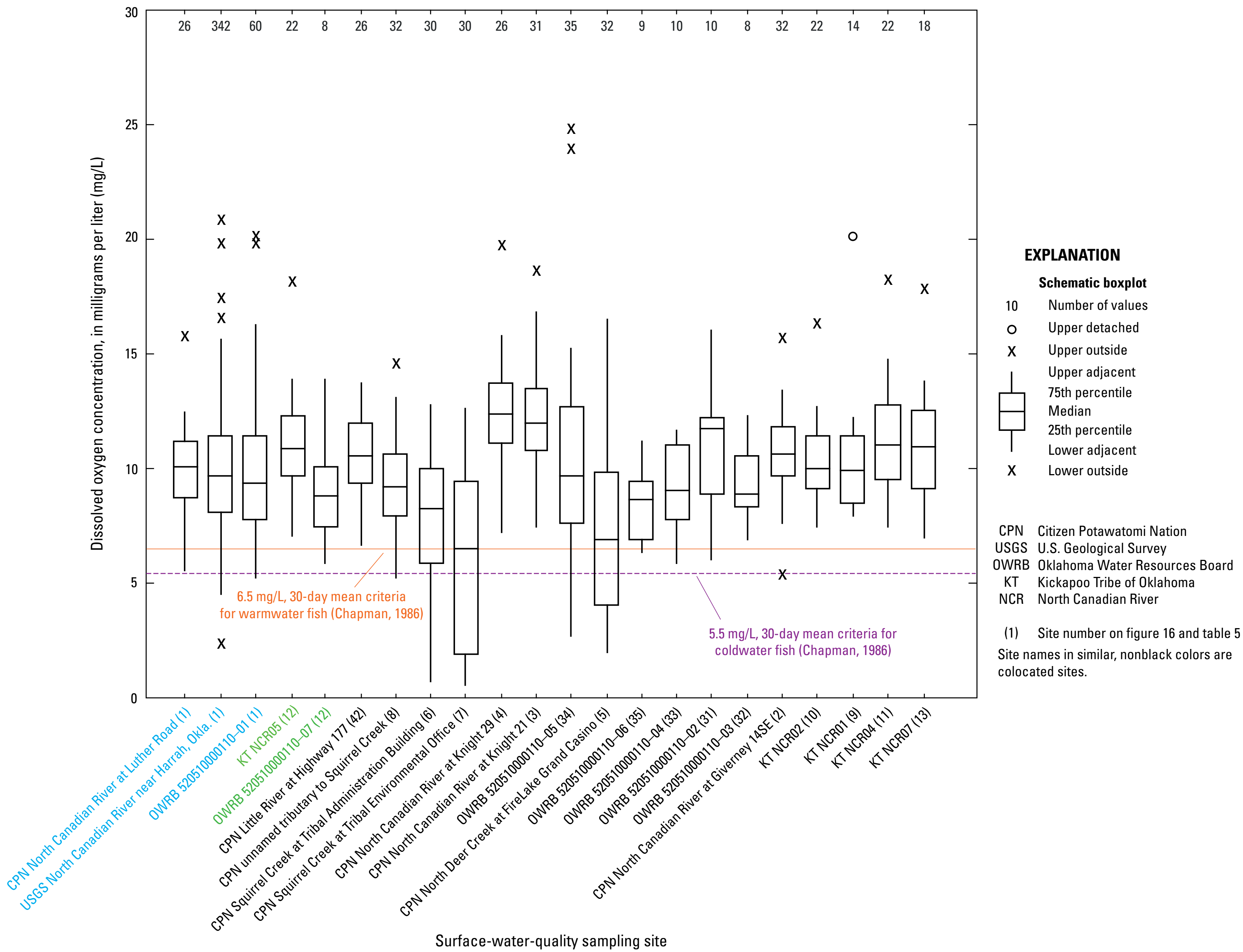


Figure 17. Distribution of dissolved oxygen concentration in surface-water samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

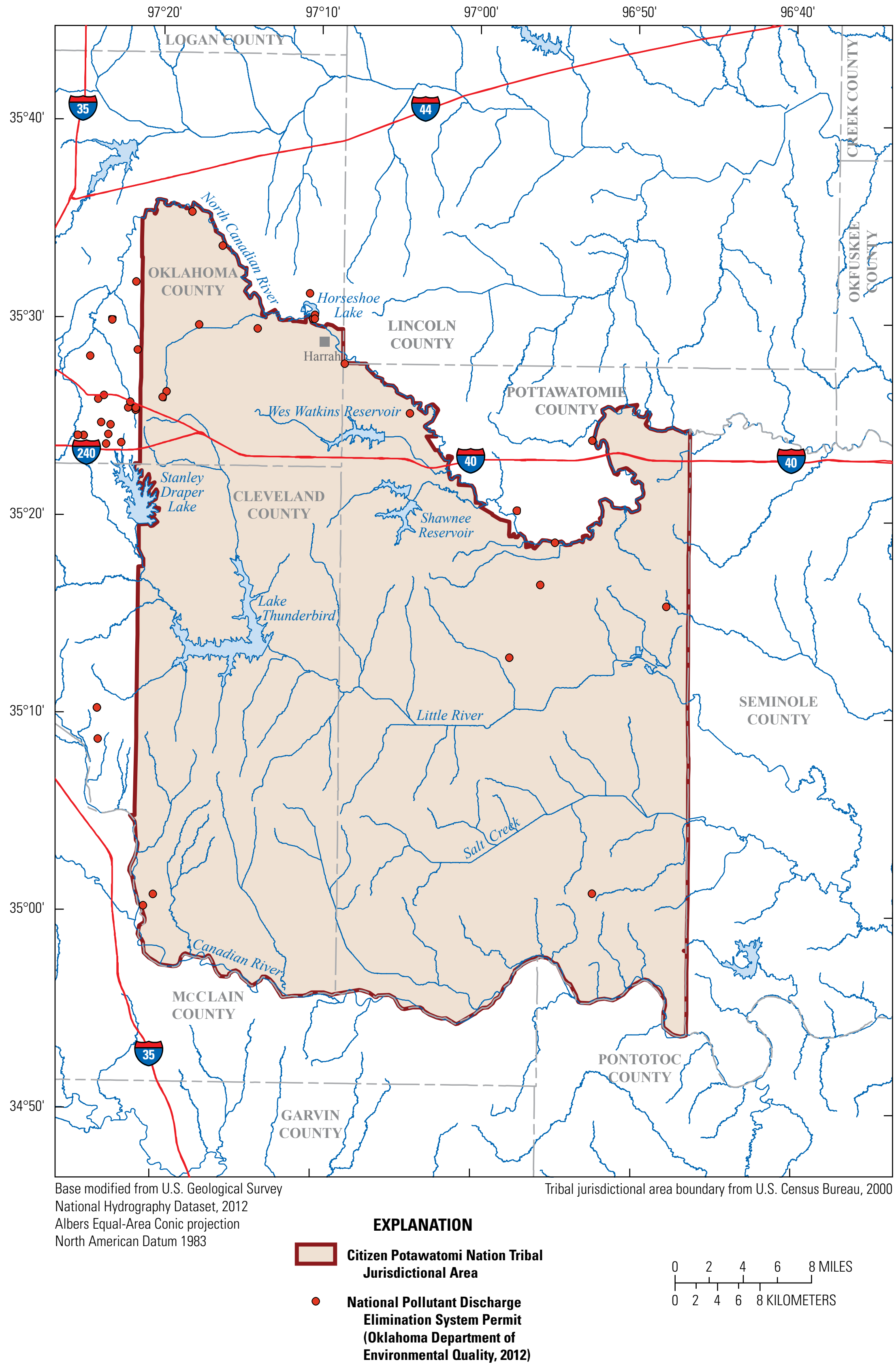


Figure 18. Locations of National Pollutant Discharge Elimination System permit locations in and near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 2012.

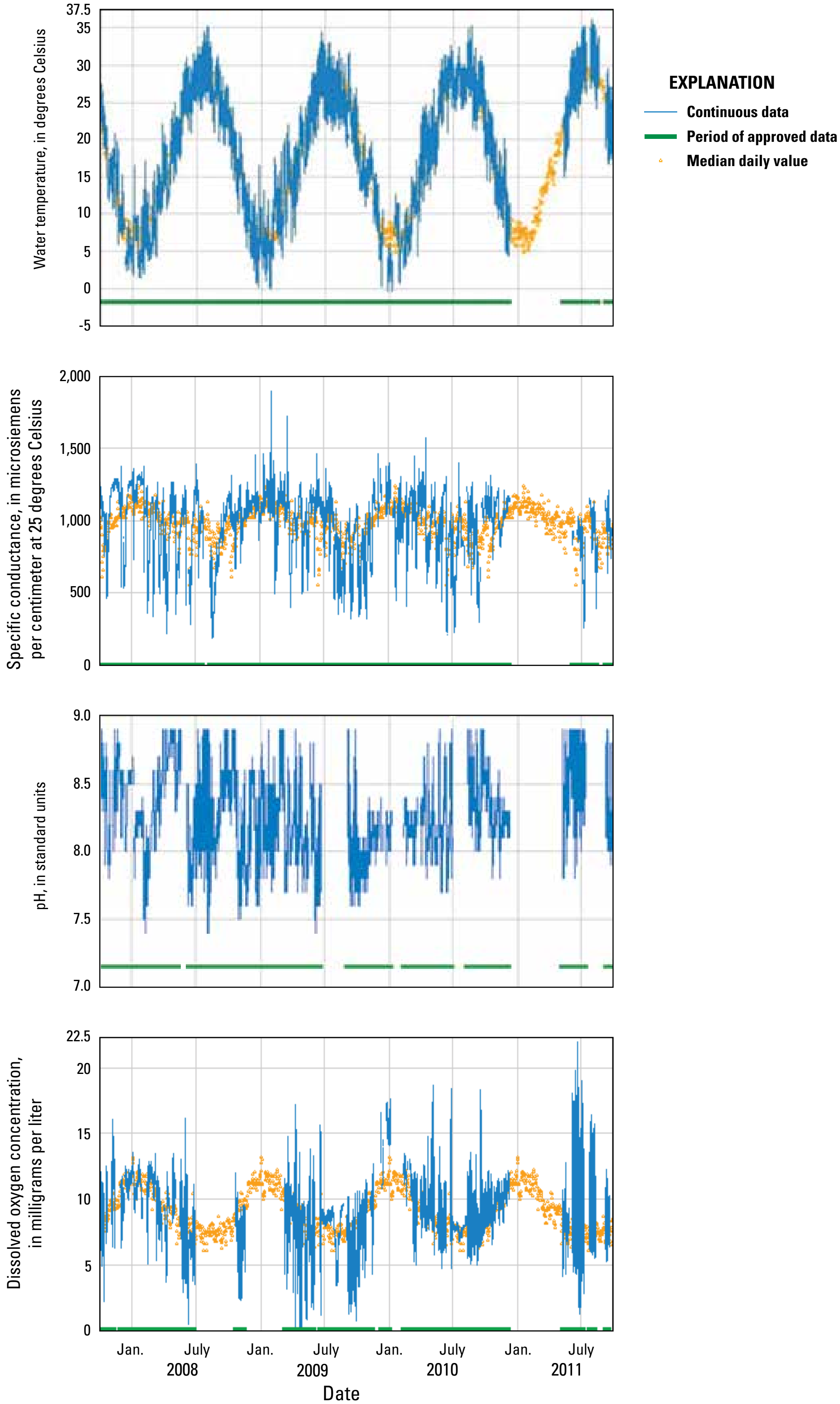


Figure 19. Water-quality data from continuous monitor at the North Canadian River near Harrah, Oklahoma, streamflow-gaging station, October 2007 through September 2011.

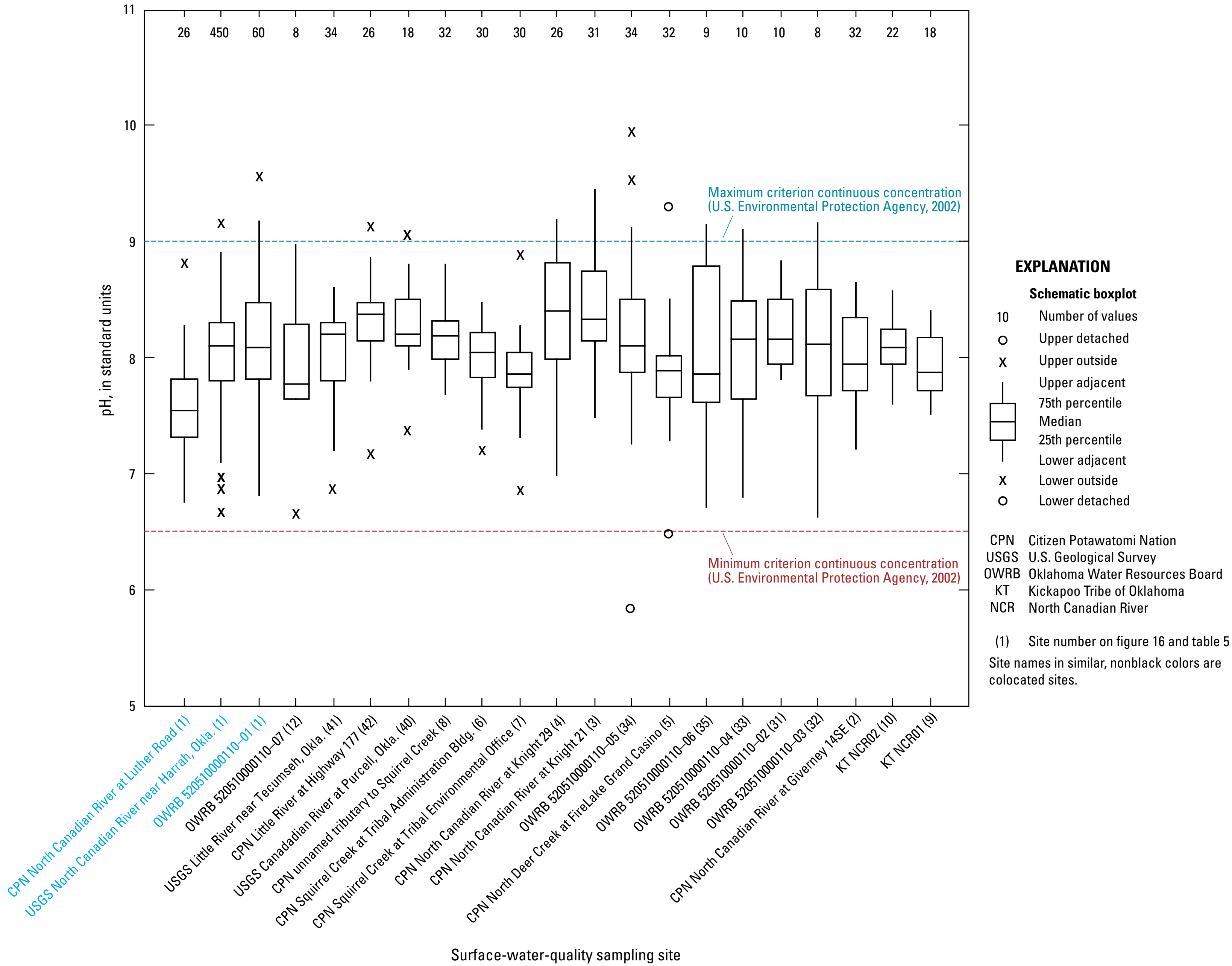


Figure 20. Distribution of pH in surface-water samples collected in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

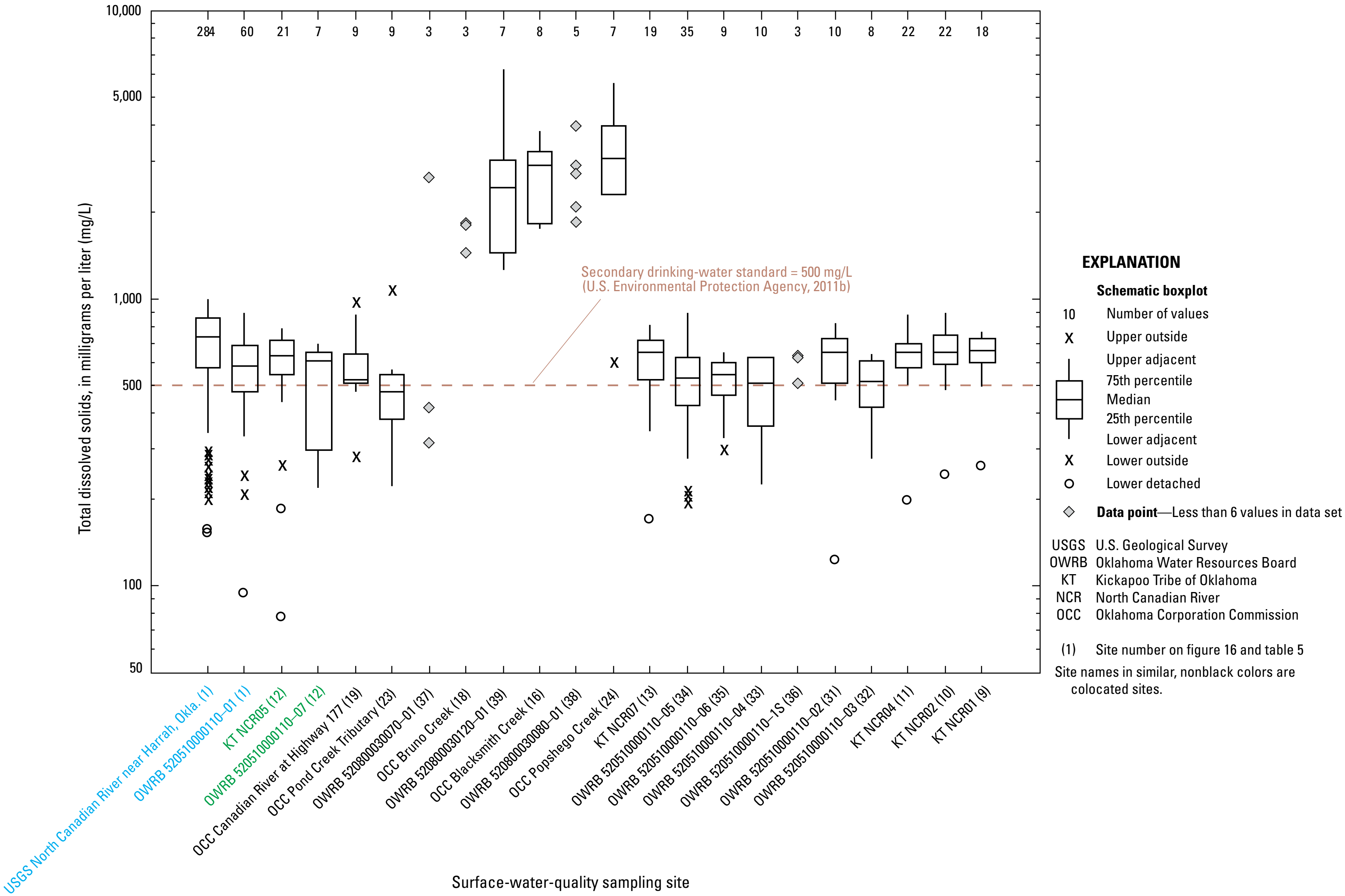


Figure 21. Distribution of total dissolved solids concentration in surface-water samples collected in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

Water hardness, expressed as milligrams per liter of calcium carbonate, is the sum of milliequivalents per liter concentrations of calcium, magnesium, iron, and manganese multiplied by 50 (Hem, 1985). Hardness was measured primarily in surface-water samples collected from the North Canadian River and its tributaries, primarily in the north or central part of this area (figs. 16 and 22, table 5). Hardness can limit the use of water for some purposes. Hard water requires more soap and synthetic detergents for cleaning and contributes to buildup of mineral “scale” in boilers and other industrial equipment (U.S. Geological Survey, 2011). Water can be categorized as being soft (61 to 120 mg/L of hardness), moderately hard (121–180 mg/L of hardness), or very hard (greater than 180 mg/L of hardness) (U.S. Geological Survey, 2011). Using these hardness categories, more than 75 percent of surface-water samples collected in this area were very hard and none were soft (fig. 22).

Major Ions

Major ions are electrically charged atoms or molecules, including calcium, magnesium, sodium, potassium, chloride, bicarbonate, and sulfate, that are the principal dissolved substances in most natural waters (Hem, 1985). Chloride is one of the major ions substantially affecting water quality in this area. Much of this area is underlain by groundwater having dissolved solids concentrations exceeding 1,000 mg/L, with sodium being the predominant cation (positively charged ion) and chloride being the predominant anion (negatively charged ion) (Bingham and Moore, 1975; Morton, 1986). Substances common in brines, particularly sodium and chloride, may be derived from solution of salt in the Vamoosa-Ada aquifer, solution of saltbeds in Permian-age units to the west of the study area, upwelling of brines caused by groundwater pumpage, and drawing up and disposal of brines from oil and gas production (Morton, 1986).

Large concentrations of chloride can harm plants, including many types of plants used to feed livestock and humans (Maas, 1987). Water containing relatively large concentrations of sodium and chloride can be problematic when used for drinking water or aquatic habitat by humans, livestock, and wildlife, contributing salty taste, causing elevation in blood pressure (at sodium chloride concentrations greater than 2,500 mg/L), and causing other metabolic effects (Wesson, 1969; Fadeeva, 1971). Chloride also increases corrosivity of water to metal pipes, which can increase concentrations of iron, manganese, lead, and copper in drinking water (World Health Organization, 1996). For these reasons, the USEPA has set a secondary drinking-water standard of 250 mg/L and a continuous criterion concentration of 230 mg/L for chloride in surface water (U.S. Environmental Protection Agency, 2002, 2011b). As with total dissolved solids, the greatest concentrations of chloride were measured at sites in the Salt Creek watershed in the southeastern part of this area (figs. 16 and 23, table 5). Most surface-water samples collected from sites in that watershed exceeded the secondary drinking-water standard and the criterion continuous concentration for chloride (fig. 23).

Nutrients

Compounds of nitrogen and phosphorus are known as nutrients in water because they are vital substances for the growth of plants, including those that form the base of aquatic food chains. Increases of nutrient concentrations in surface water lead to increased plant growth (known as eutrophication), which can affect ecological and aesthetic qualities of lakes and streams. Most freshwater systems are “phosphorus-limited,” meaning that they have a lesser proportion of phosphorus to nitrogen than typically occurs in plant tissues (Vaccari and others, 2006). Additions of phosphorus to such systems through disposal of treated wastewater, erosion of sediments from streambanks, dredging of streambed sediments, runoff from agricultural and urban areas, or contribution from other sources can substantially increase growth of aquatic plants. Because of the risk of eutrophication, many States have established water-quality standards for total phosphorus concentrations in streams. In Oklahoma, a standard of 0.037 mg/L of total phosphorus concentration was established to protect water quality and aquatic habitat in Scenic Rivers (State of Oklahoma, 2006). In Wisconsin, a standard of 0.075 mg/L of total phosphorus concentration was established for most streams, with some streams having higher standards of 0.200 mg/L (State of Wisconsin, 2010).

Most surface-water-quality samples collected in this area from 1985–2011 had considerably greater total phosphorus concentrations than those standards (fig. 24). All of the surface-water sites sampled for phosphorus in this area were on the North Canadian River, generally to monitor effects on water quality and attenuation of upstream urban runoff and discharge of treated wastewater (Esralew and others, 2011a). Additional monitoring for phosphorus concentration in other streams in this area would provide more complete information about the occurrence and distribution of phosphorus concentrations in surface water. Water-quality data from the North Canadian River near Harrah, Okla., streamflow-gaging station, the site with the greatest number of paired streamflow measurements and nutrient analyses in this area, indicate decreases in concentrations of total nitrogen and phosphorus with increasing streamflow, up to approximately 1,000 ft^3/s, above which a few samples indicate that concentrations of these nutrients may level off (fig. 25). Total nitrogen and phosphorus concentrations generally followed a linear relation (fig. 25). Such relations of these nutrient concentrations with streamflow and with each other indicate that point sources are substantial contributors of these nutrients, with greater streamflows diluting nutrient concentrations and similar ratios of these nutrients being measured across the recorded range of streamflow. Such point sources can include dischargers of treated industrial and municipal wastewater, which are numerous upstream from this streamflow-gaging station (fig. 18).

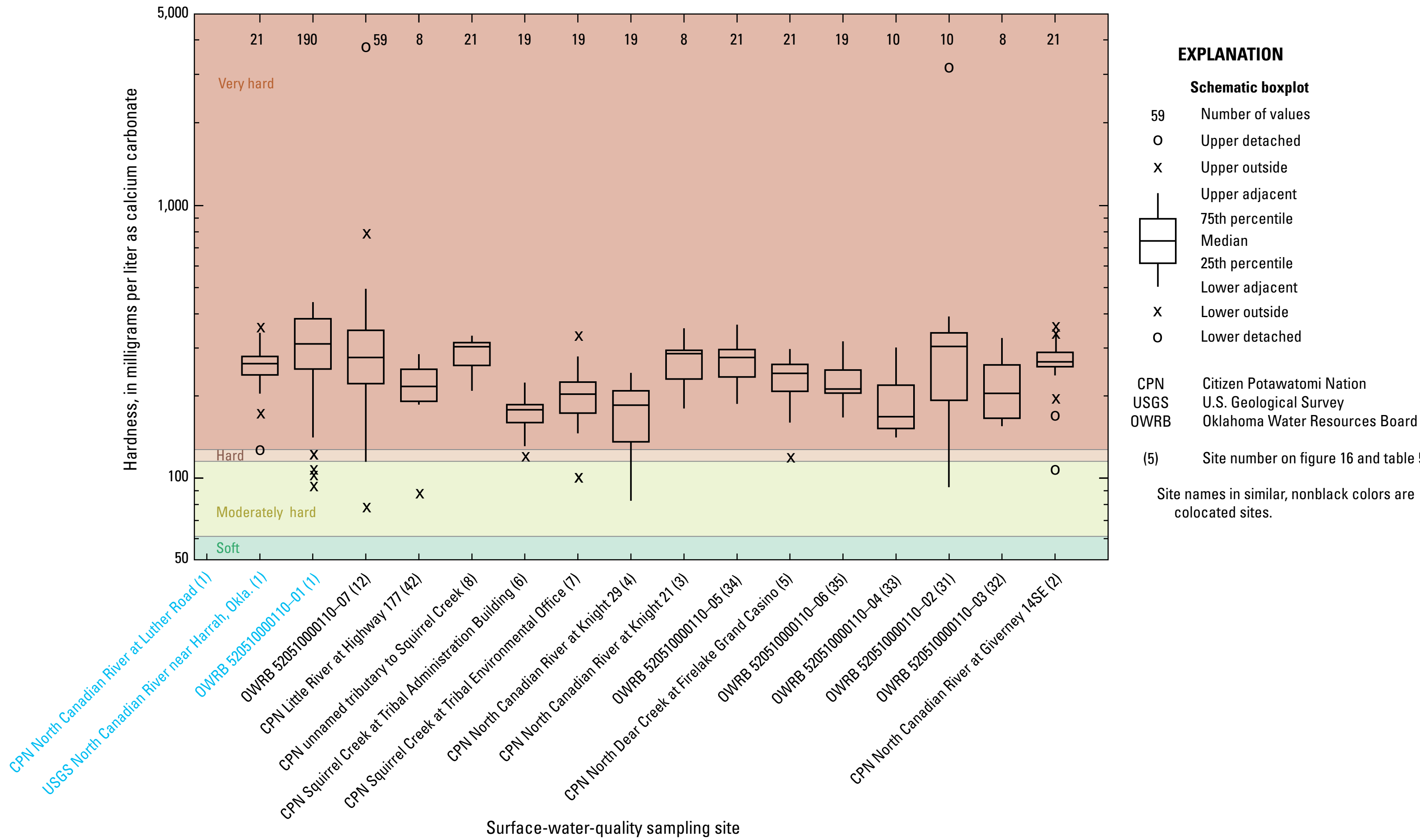


Figure 22. Distribution of hardness in surface-water samples collected in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

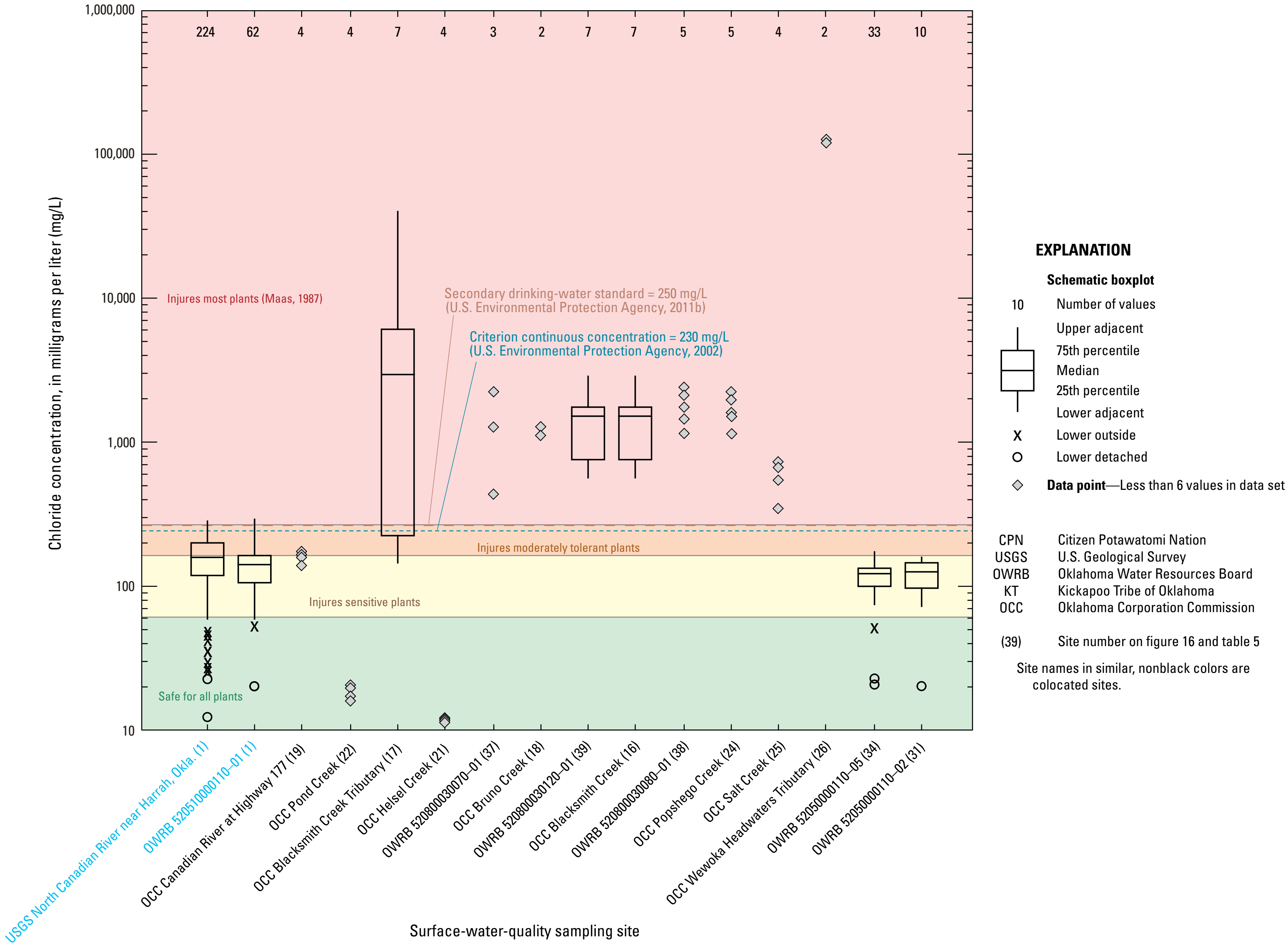


Figure 23. Distribution of chloride concentration in surface-water samples collected in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

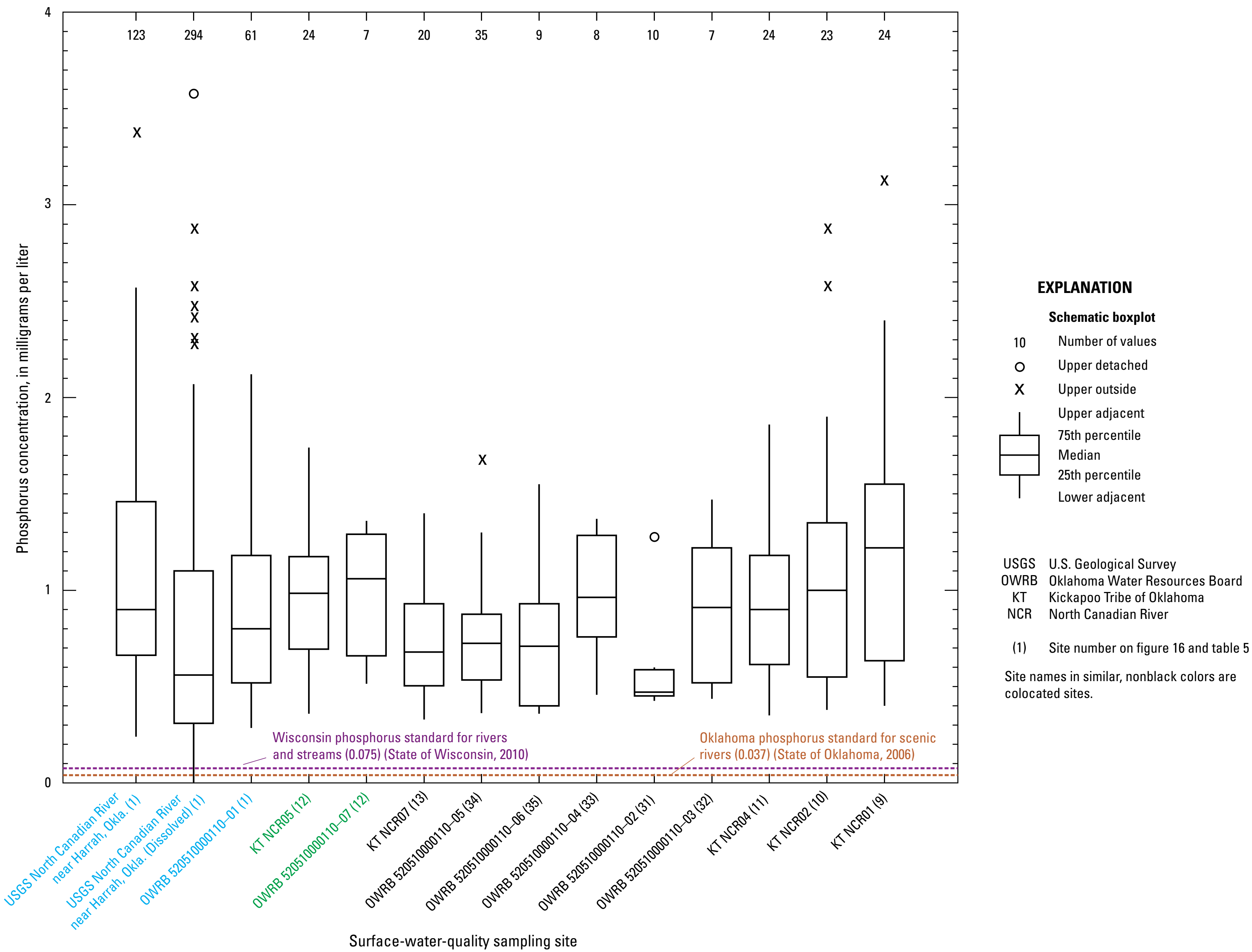


Figure 24. Distribution of phosphorus concentration in surface-water samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

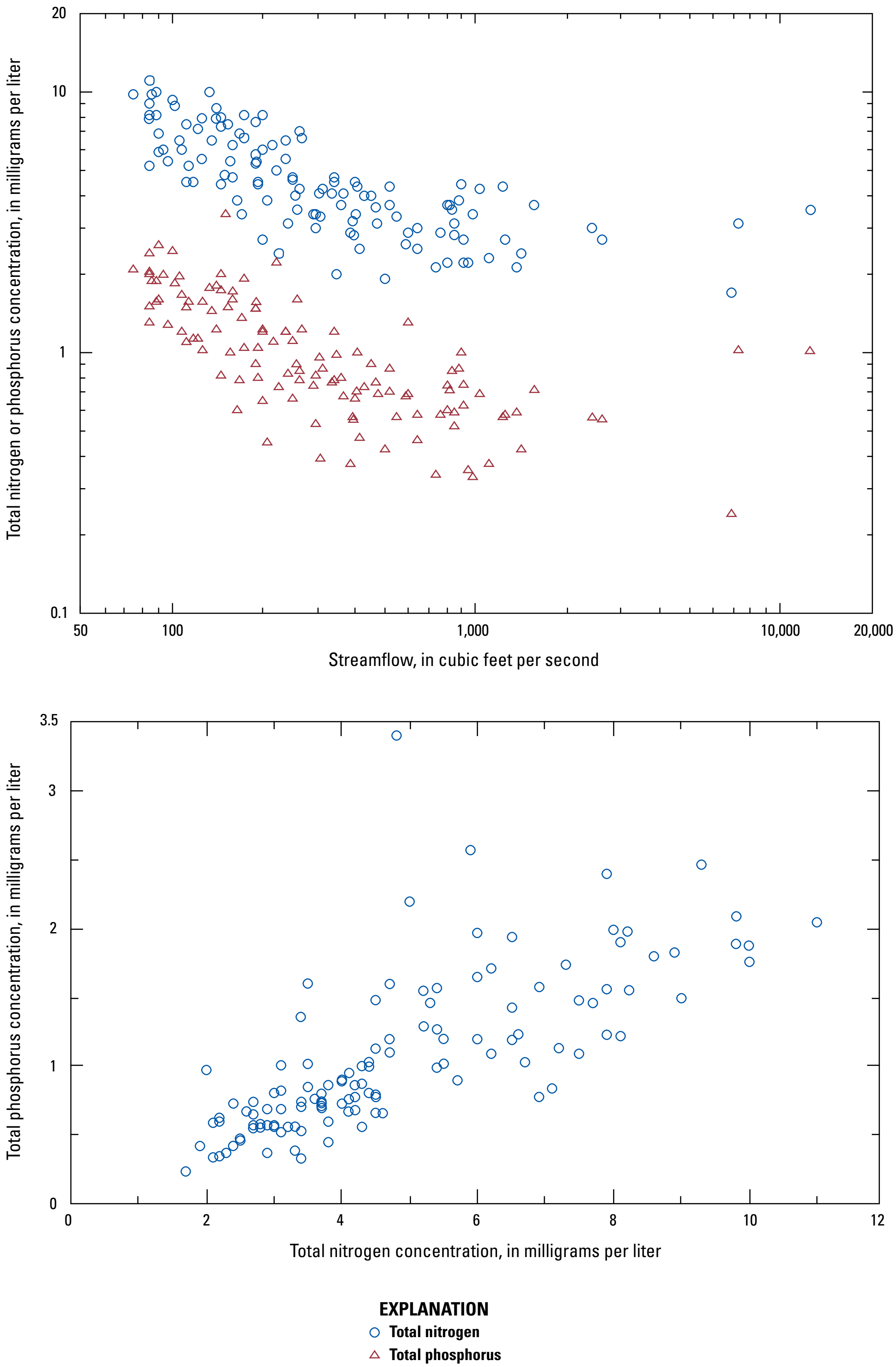


Figure 25. Relations between total nitrogen concentration, total phosphorus concentration, and streamflow in surface-water samples collected at the North Canadian River near Harrah, Oklahoma, streamflow-gaging station, 1985 through 2011.

Metals

Metals naturally occur in streams and lakes and can be increased in concentrations through human activities, such as transportation, electric power generation, mining, and waste disposal. In sufficient concentrations, metals can be toxic to aquatic organisms in streams and lakes and to terrestrial organisms such as humans and livestock.

Arsenic is a metal long known to be toxic, having been used as a pesticide and poison for hundreds of years (Agency for Toxic Substances and Disease Registry, 2007). Because of the toxicity of arsenic, the USEPA set a criterion chronic concentration of 150 µg/L for this metal for surface water (U.S. Environmental Protection Agency, 2002). Arsenic concentrations in groundwater exceed the primary drinking-water standard of 10 µg/L (also known as “parts per billion”) in parts of the Central Oklahoma aquifer west of this area (U.S. Environmental Protection Agency, 2011a; Smith, 2005; Christenson and others, 1998). Arsenic concentration in 1 of 127 water samples collected at the North Canadian River near Harrah, Okla., exceeded the primary drinking-water standard, and none of the detected concentrations exceeded the criterion chronic concentration for this metal (fig. 26; appendixes 1 and 5), indicating that arsenic concentrations are unlikely to cause notable health problems for humans or aquatic wildlife in the upstream part of the North Canadian River in this area, but that additional sampling would be needed at other sites in this area to extend that conclusion.

Chromium is a metal that naturally occurs in water and can come from polluted sites and metal components of plumbing systems. Chromium in water typically occurs as trivalent or hexavalent ions (Cr^{+3} or Cr^{+6}). The trivalent form of chromium, in small amounts, is a nutrient in the human diet (Agency for Toxic Substances and Disease Registry, 2011a). The hexavalent form of chromium (chromium [VI]) is considerably more toxic than the trivalent form, being associated with digestive system damage, reproductive problems, birth defects, and cancer (Agency for Toxic Substances and Disease Registry, 2011a). As of 2011, the primary drinking-water standard of 100 µg/L did not differentiate between the ionic forms of chromium, but toxicologic and epidemiologic data led the State of California to establish a public health goal of 0.02 µg/L for chromium (VI) in drinking water to minimize long-term risk to public health from ingestion of that substance in drinking water (California Environmental Protection Agency, 2011). To protect aquatic biota from toxic effects of chromium, criterion continuous concentrations of 75 and 11 µg/L have been set for chromium (III) and chromium (VI), respectively (U.S. Environmental Protection Agency, 2002). Chromium has been detected in groundwater in parts of the Central Oklahoma aquifer, which supplies part of the base flow of most streams in this area (Christenson and others, 1998; Reiger, 2010). Only a few surface-water samples had chromium concentrations exceeding the previously mentioned standards in samples collected at the four surface-water sites sampled for chromium in this area (fig. 26).

Lead in water can be naturally occurring or associated with disposal of lead-acid batteries, combustion of fossil fuels, and transportation (Connor and others, 1972; Agency for Toxic Substances and Disease Registry, 2011b). Lead has no known nutritive values for plants or animals, and ingestion of lead has been associated with damage to the brain and central nervous system, kidneys, the male reproductive system, the immune system, and premature births, with some lead compounds being carcinogenic (Kabata-Pendias and Pendias, 1984; Canfield and others, 2003; Lin and others, 2003; Lanphear and others, 2005; Coon and others, 2006; Agency for Toxic Substances and Disease Registry, 2011b). The primary drinking-water standards for lead are concentrations of zero or nondetect, with a treatment-technique or action level of 15 µg/L (U.S. Environmental Protection Agency, 2011a). Most of the surface-water samples collected in this area had lead concentrations less than reporting limits, which ranged from 0.5 to 100 µg/L (fig. 26). From 5 to 7 percent of the surface-water samples collected in this area had lead concentrations exceeding criterion continuous concentrations set to protect aquatic organisms (appendixes 1 and 5). The limited number of analyses for lead and large proportions of censored data for those samples preclude evaluation of the occurrence and distribution of lead in surface water in this area.

Fecal-Indicator Bacteria

Fecal-indicator bacteria are types or species of bacteria typically associated with animal feces. Although only a small portion of these bacteria may be pathogenic (disease causing), they may be associated with a large variety of other pathogenic micro-organisms related to animal feces, such as other types of pathogenic bacteria (*Salmonella* sp., *Clostridium* sp., and *Listeria* sp.), protozoans (*Giardia* sp., *Amoeba* sp., and *Cryptosporidium* sp.), viruses (*Norovirus*), and fungi (*Apsergillus* sp., and *Histoplasma* sp.) (Haack, 2007). Public-water supplies typically are filtered and disinfected sufficiently to prevent transmission of such micro-organisms. Owners of private wells and people having recreational contact with microbially contaminated water may be more likely to be infected by such pathogens. Because of such health risks, a primary drinking-water standard of zero total coliform bacteria per 100 milliliters (mL) has been set for public-water supplies (U.S. Environmental Protection Agency, 2011a) and the State of Oklahoma has established primary contact standards to protect people in recreational contact with water of monthly geometric mean values from at least five samples of 200, 126, and 33 colonies per 100 mL for fecal coliform, *Escherichia coli*., and enterococci (similar to streptococci) bacteria, respectively (State of Oklahoma, 2006). From 10 to 70 percent of surface-water samples from nine sites sampled in this area from 1985 to 2011 individually exceeded the primary contact standard for fecal coliform bacteria (fig. 27) with lesser rates of exceedance for *Escherichia coli*. and greater rates of exceedance for enterococci bacteria (appendixes 3 and 5). The sites sampled for bacteria were only on the North Canadian River, limiting knowledge of the occurrence and distribution of these bacteria in other streams in this area.

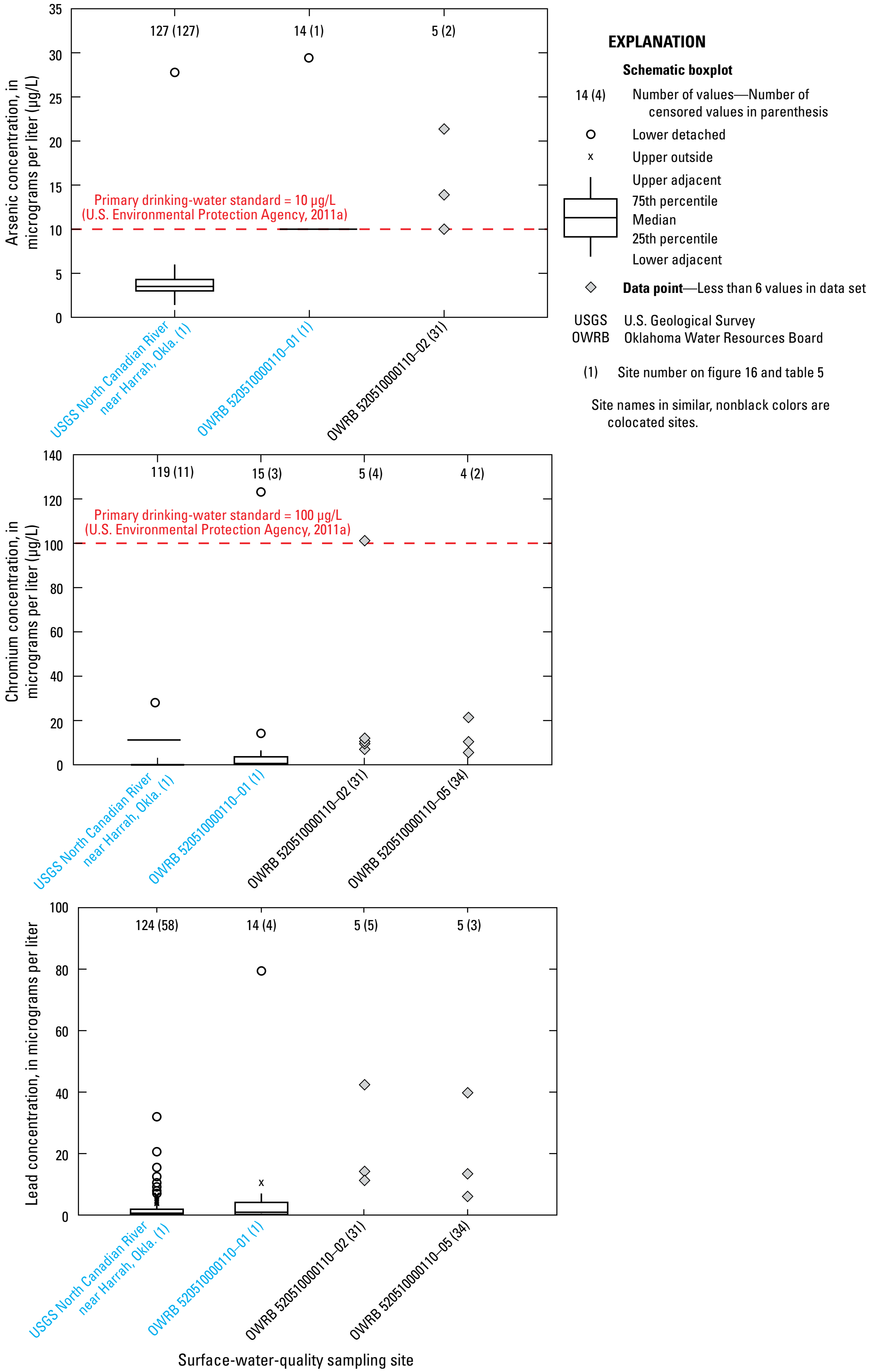


Figure 26. Distribution of selected metals concentrations in surface-water samples collected in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

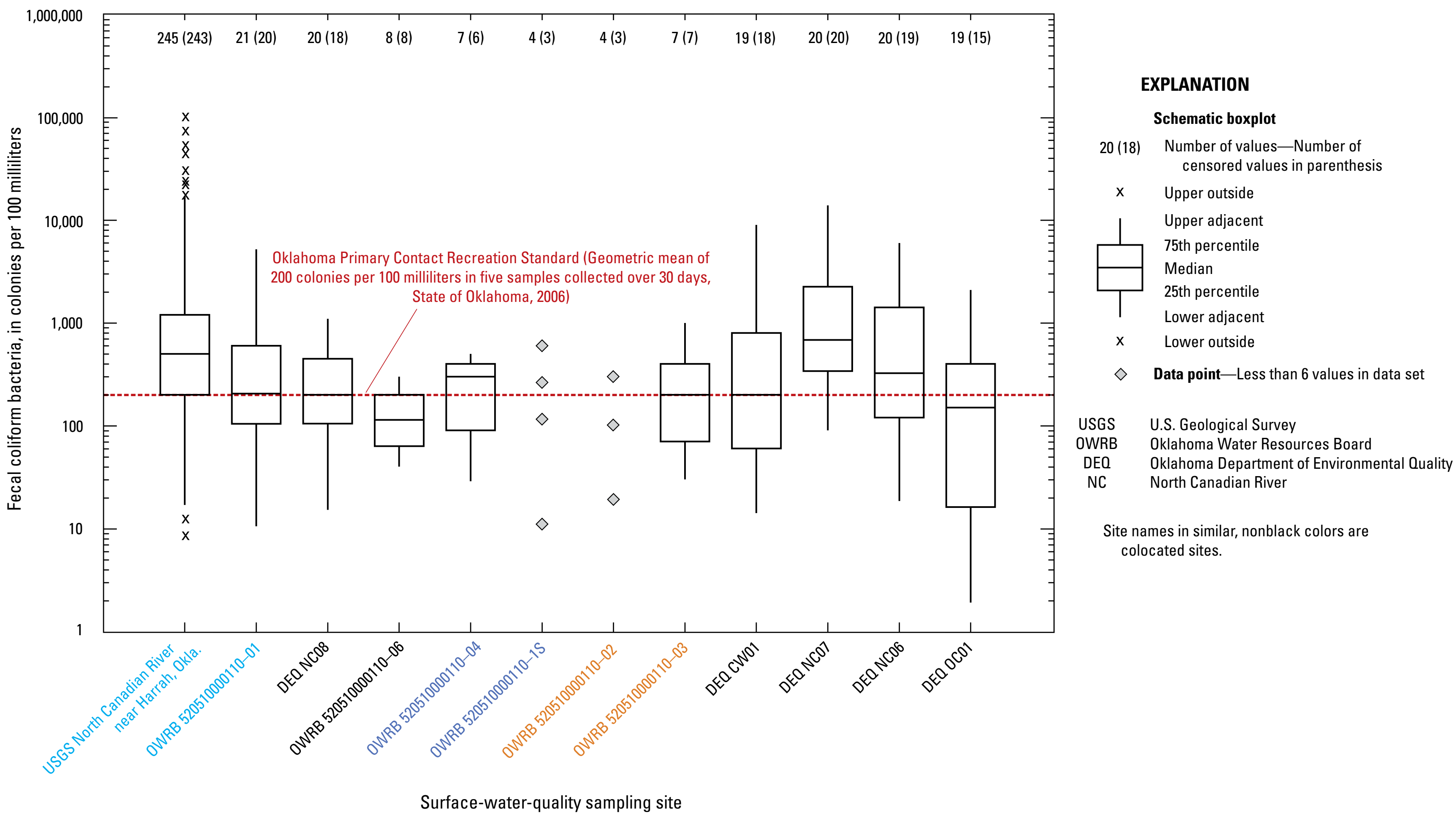


Figure 27. Distribution of fecal coliform bacteria in surface-water samples collected from the North Canadian River in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

Quality Assurance

The USGS, Kickapoo Tribe of Oklahoma, and OWRB compiled data for quality-control samples related to surface-water-quality samples in the NWIS and STORET databases (appendixes 7 and 8). Blank samples collected in the jurisdictional area in association with surface-water samples did not have detectable concentrations of the major ions and nutrients analyzed or had much smaller concentrations (typically 10 percent or less) than were measured in field water-quality samples (figs. 24–25, 27; appendixes 1 and 7). Such differences in data from analyses of field blanks compared to field water-quality samples indicated small likelihood of contamination of field samples from sampling equipment and other environmental factors when the blanks were collected. Median relative-percent differences of water-quality constituents measured in the field and replicate samples generally were less than 25 percent (appendix 8), indicating relatively good reproducibility of water-quality data. Larger relative-percent differences primarily were associated with small numbers near reporting limits, for example, a field sample and a replicate sample having measured concentrations of a constituent of 0.1 and 0.2, respectively, which produce a relative-percent difference of 66.7 percent but is a relatively small difference in units of measurement.

Collection of about 120 replicates and about 95 blanks for approximately 1,100 surface-water samples represents moderate frequency of quality-control sample collection. Generally, each type of quality-control sample is collected at frequencies ranging from 5 to 10 percent of the number of field water-quality samples, with some of these sample groups having larger frequencies of quality-control sample collection (appendixes 1, 2, 3, 6, 7, 8, and 9).

Groundwater Quality

Measurement of water properties and concentrations of major ions, nutrients, and metals in groundwater can provide indications of groundwater recharge rates and flow paths, interactions between groundwater and surface water, health threats that may be posed by natural or manmade compounds in drinking water, and suitability of water for use in commercial and industrial processes. Previously published reports indicate that groundwater quality in most of this tribal jurisdictional area is good (contains less than 500 mg/L of dissolved solids), but that an area of approximately 30 square miles in the southeastern corner of Pottawatomie County has fair to poor water quality (containing greater than 500 mg/L or greater than 1,000 mg/L of dissolved solids, respectively) (Hart, 1974; Bingham and Moore, 1975).

Water-quality data obtained by sampling 294 wells completed in three principal aquifers (alluvial, Central Oklahoma, and Vamoosa-Ada) in this area are described in this report. Those wells, from which the last samples were collected from 1943 to 2005, are distributed relatively evenly across the area (fig. 28), with the majority of the sampled wells (186) completed in the Central Oklahoma aquifer, which underlies the western two-thirds of the area. Depths of the wells sampled in the three principal aquifers in the area ranged from less than 10 ft to nearly 1,000 ft below land surface (fig. 29). Wells completed in alluvial aquifers generally were significantly shallower than those completed in the Central Oklahoma and Vamoosa-Ada aquifers (fig. 29). Wells completed in the Vamoosa-Ada aquifer tended to be deeper than those completed in the Central Oklahoma aquifer but were not deeper at a significance level of 0.05 of the Wilcoxon rank-sum test (fig. 29). Depending on the permeability of soils and aquifer materials, the quality of water from shallower wells are more likely to be affected sooner by land-surface activities than groundwater that is deep below the land surface.

Water Properties

Water properties can indicate chemical reactions occurring in aquifers and residence time of groundwater in aquifers. For instance, increasing residence time in aquifers generally is associated with greater salinity (increased concentrations of sodium, potassium, and chloride) (Zouari and others, 2011; Cartwright and others, 2012). Lesser concentrations of dissolved oxygen also may be associated with greater residence time or contact with organic substances in soils and aquifer materials. Greater acidity (lesser pH) can be associated with increased concentrations of many metals in groundwater and greater corrosivity of water. Some metals, such as arsenic, chromium, selenium, and uranium, can occur in greater concentrations in groundwater having alkaline pH in the Central Oklahoma aquifer (Parkhurst and others, 1994).

Groundwater in the area generally is well oxygenated (fig. 30, appendix 9), though pumps and pressure tanks in sampled wells may have introduced some of the dissolved oxygen measured in those water samples. Water in the Central Oklahoma aquifer had significantly greater dissolved oxygen concentration than water in alluvial aquifers (fig. 30). Greater dissolved oxygen concentration in water in the Central Oklahoma aquifer may be attributable to greater organic carbon concentrations in alluvial aquifer materials that cause oxygen consumption through aerobic metabolism of microbiota or greater oxygenation caused during pumping from the generally deeper wells completed in the Central Oklahoma aquifer (figs. 29 and 30). Dissolved oxygen concentration in water from wells completed in the Vamoosa-Ada aquifer spanned the range of both the alluvial and Central Oklahoma aquifers (fig. 30).

The pH measured in groundwater samples generally was near neutral. However, 20–25 percent of the samples collected from alluvial aquifers and the Central Oklahoma aquifer were more acidic than the secondary drinking-water standard of 6.5 set by the USEPA to minimize corrosion of pipes in water distribution systems and indirectly to reduce metals concentrations in drinking water (fig. 30, appendix 9, U.S. Environmental Protection Agency, 2011a, 2011b).

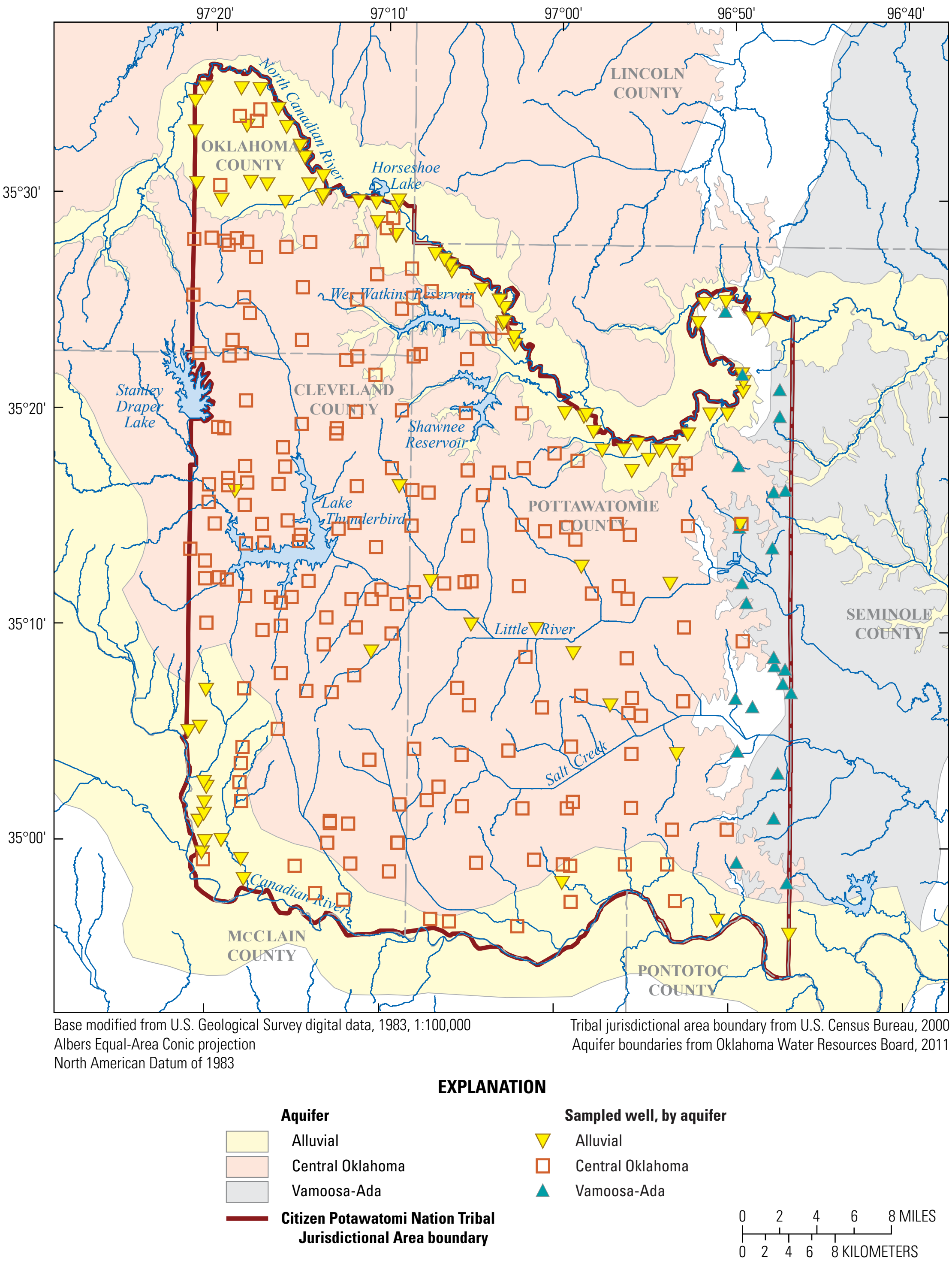


Figure 28. Principal aquifers and locations of sampled wells in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma.

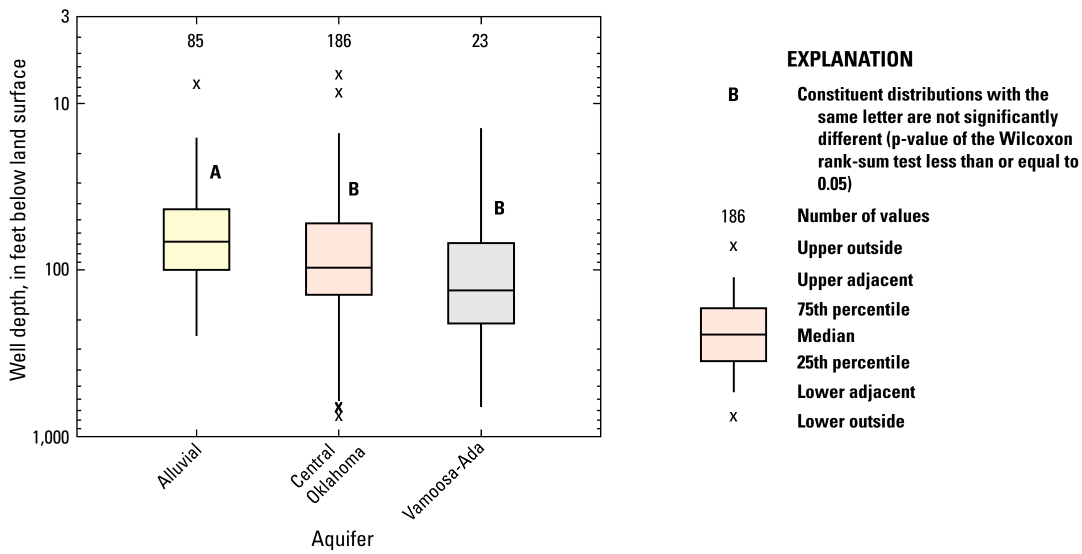


Figure 29. Distribution of depths of wells sampled from 1943 through 2005 by aquifer in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma.

Specific conductance, an indirect measurement of dissolved ionic constituents in water (Hem, 1985), generally ranged from approximately 100 to as much as 5,000 microsiemens per centimeter at 25 degrees Celsius in water samples collected from the three principal aquifers in this jurisdictional area from 1947 through 2004 (fig. 30, appendix 9). Specific conductance was significantly greater in the 22 water samples collected from the Vamoosa-Ada aquifer than in water samples collected from alluvial and Central Oklahoma aquifers in the area (fig. 30), which may be related to differing mineralogies and greater depths below land surface being associated with greater residence time of water in the Vamoosa-Ada aquifer (fig. 30).

Dissimilar from specific conductance, total dissolved solids concentrations were smallest in 32 water samples collected from the Central Oklahoma aquifer compared to those measured in samples collected from the alluvial and the Vamoosa-Ada aquifers in the area (fig. 30). The much smaller number of samples analyzed for total dissolved solids than for specific conductance may have skewed the total dissolved substances data for these aquifers.

Similar to specific conductance, alkalinity was similar in water samples collected from the alluvial and Central Oklahoma aquifers, with water samples collected from the Vamoosa-Ada aquifer having significantly greater alkalinity (fig. 30). If bicarbonate is a major component of both alkalinity and dissolved solids in these aquifers, which is not uncommon, then alkalinity concentrations would have similar relations between sampled aquifers as specific conductance, which is an indirect measurement of dissolved ionic substance concentration.

Hardness of water samples collected from these three aquifers generally was “very hard,” similar to hardness measured in surface water in this area (figs. 23 and 30). Water samples from wells completed in alluvial aquifers and the Central Oklahoma aquifer typically were very hard (fig. 30), though some samples from both aquifers were soft. Approximately 30 percent of the water samples collected from the Vamoosa-Ada aquifer, however, were soft (hardness less than or equal to 60 mg/L as calcium carbonate).

Major Ions

Concentrations and proportions of major ions can indicate different: (1) sources of groundwater, (2) chemical properties of aquifer materials, and (3) residence times of water along groundwater flow paths and chemical properties of aquifer materials along flow paths. Major ions are readily and inexpensively analyzed and provide similar answers to contaminant sources that can be provided by much more expensive isotopic and organic-chemical analyses (Schlottmann and others, 2000).

Calcium is an abundant element in carbonate and silicate rocks that typically occurs as a divalent cation (Ca^{+2}) in water (Hem, 1985). Although calcium concentrations tended to decrease, in order, from the alluvial to the Central Oklahoma to the Vamoosa-Ada aquifer (figs. 31 and 32), calcium concentrations were not significantly different between the aquifers.

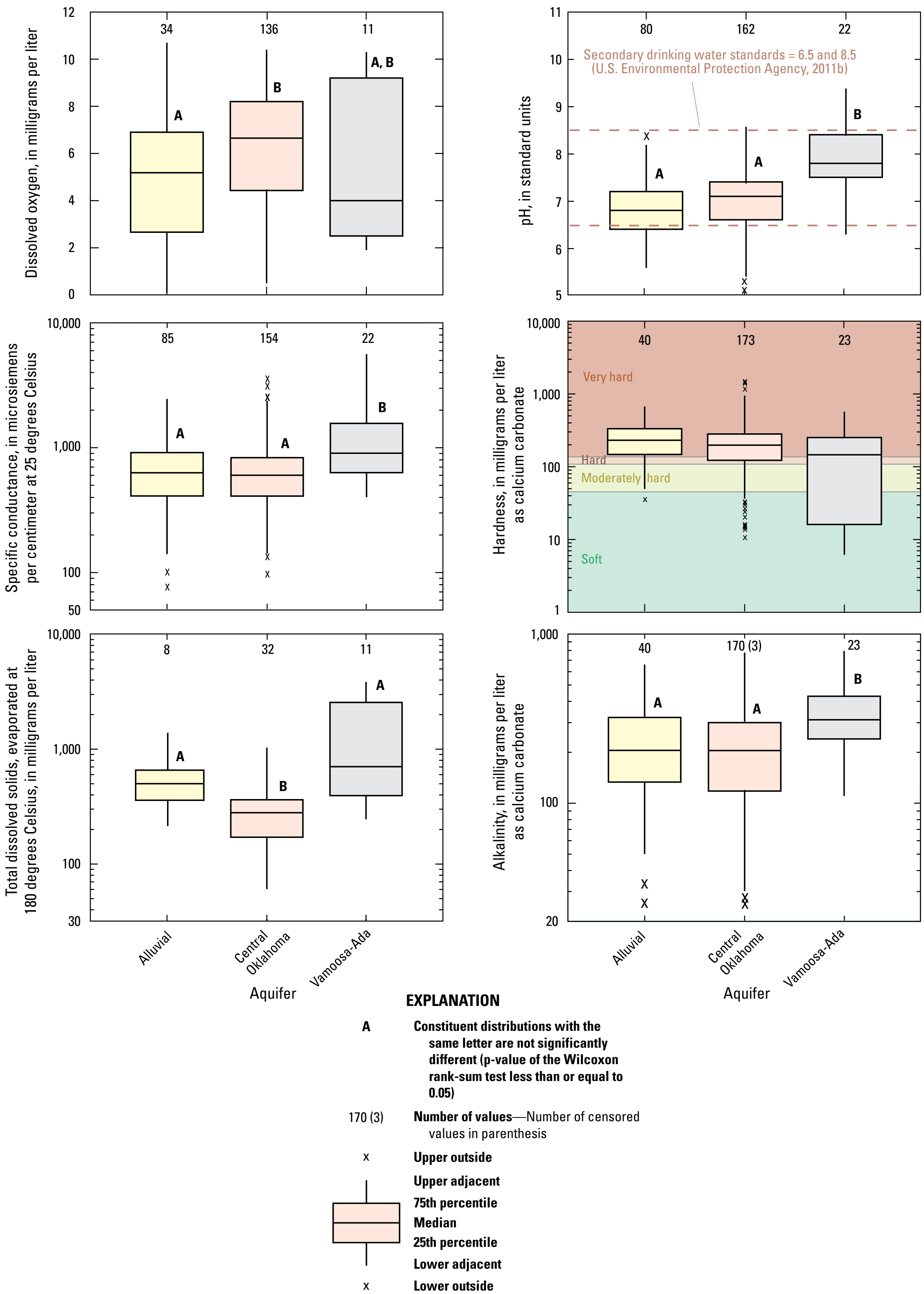


Figure 30. Distribution of values of selected water-quality constituents and properties by aquifer in groundwater samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1943 through 2011.

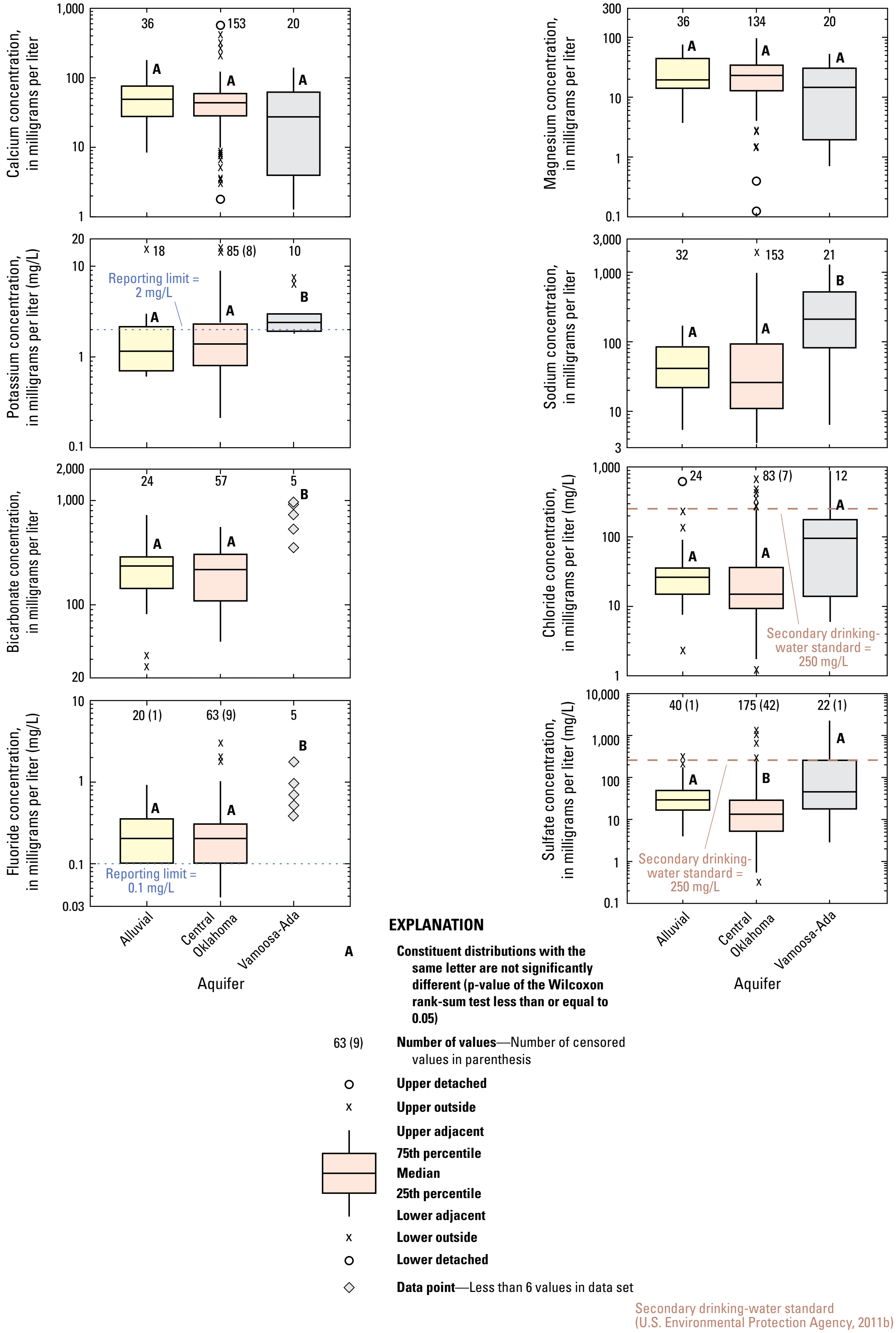


Figure 31. Distribution of concentrations of major ions in groundwater samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1943 through 2005.

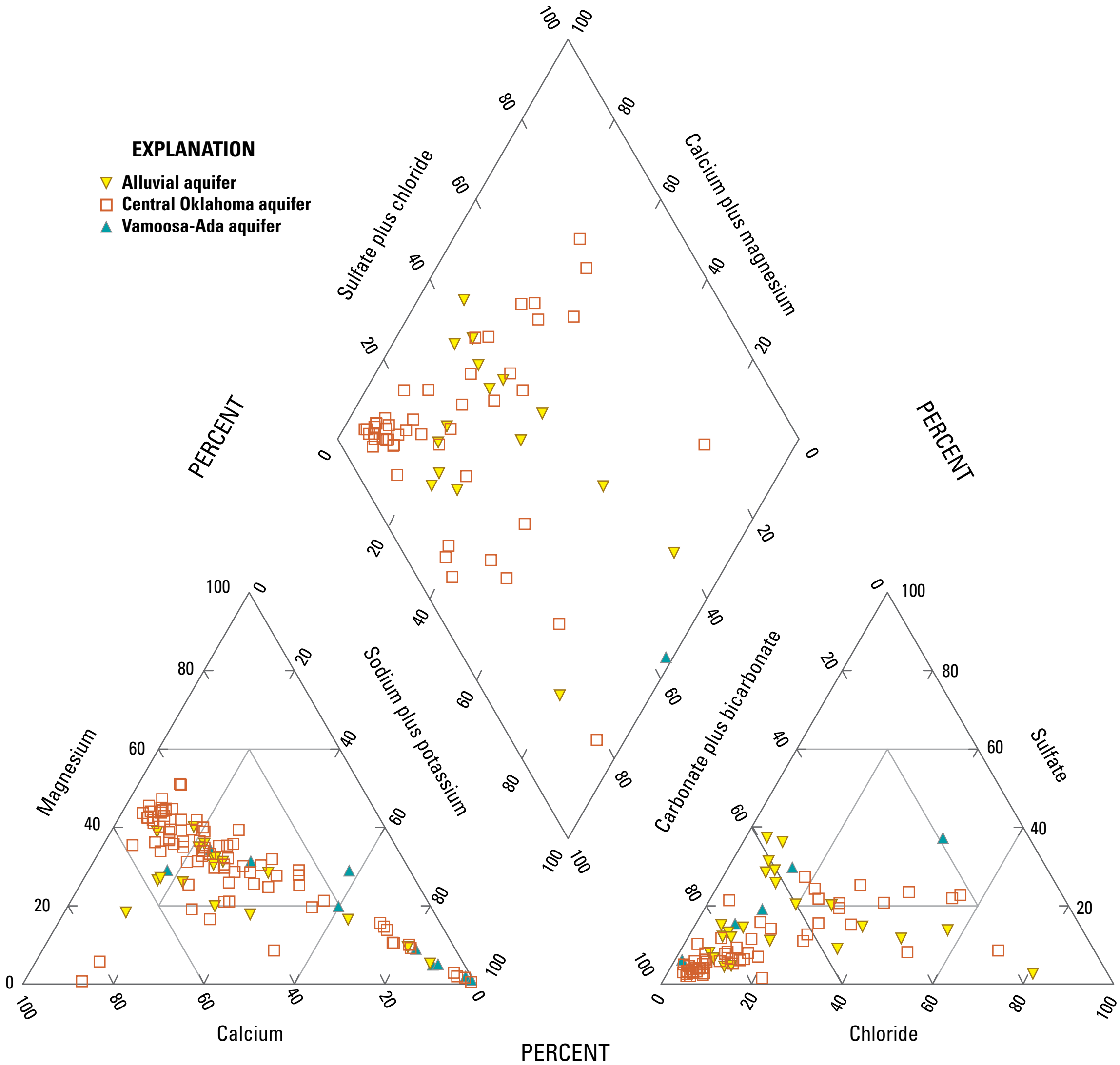


Figure 32. Proportions of major ions by aquifer in groundwater samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1943 through 2005.

Magnesium also is dissolved in water as a divalent cation (Mg^{+2}) and like calcium is associated with dissolution of carbonate and silicate rocks (Hem, 1985). Similar to calcium, the distributions of magnesium concentrations were not significantly different between water samples collected from the three aquifers, but slightly lesser magnesium concentrations were measured in water samples collected from the Vamoosa-Ada aquifer (fig. 31).

Potassium and sodium occur as monovalent cations (K^+ and Na^+) in water and are derived from dissolution of igneous rocks and from connate (fossil) water that may be in rocks deposited in marine environments (Hem, 1985). At several hundred feet below the land surface, the area is underlain by water that has increasing dissolved-solids content (salinity) with depth (Bingham and Moore, 1975). Consistent with greater depth of sampled wells completed in the Vamoosa-Ada aquifer, potassium and sodium concentrations were significantly greater in water samples collected from that aquifer than in the samples collected from the alluvial and Central Oklahoma aquifers (figs. 29 and 31). In this area, the base of freshwater (defined as containing less than 5,000 mg/L dissolved solids) ranges from as shallow as 300 ft to greater than 900 ft below land surface (Hart, 1966). Progression from waters relatively enriched in calcium and magnesium to waters enriched in potassium and sodium may be associated with longer residence times in deeper groundwater (figs. 32 and 33; Zouari and others, 2011; Cartwright and others 2012), but also may have been caused by local upward seepage of brines and brine spills associated with petroleum production (Morton, 1986). Relations between groundwater quality and well depth were not definitive (figs. 29, 31, and 33). Some water-quality constituents and physical properties, such as sodium in the Vamoosa-Ada aquifer and dissolved solids in alluvial aquifers, generally increased with well depths, indicating possible increases in sodium and dissolved solids concentrations along flow paths in those aquifers.

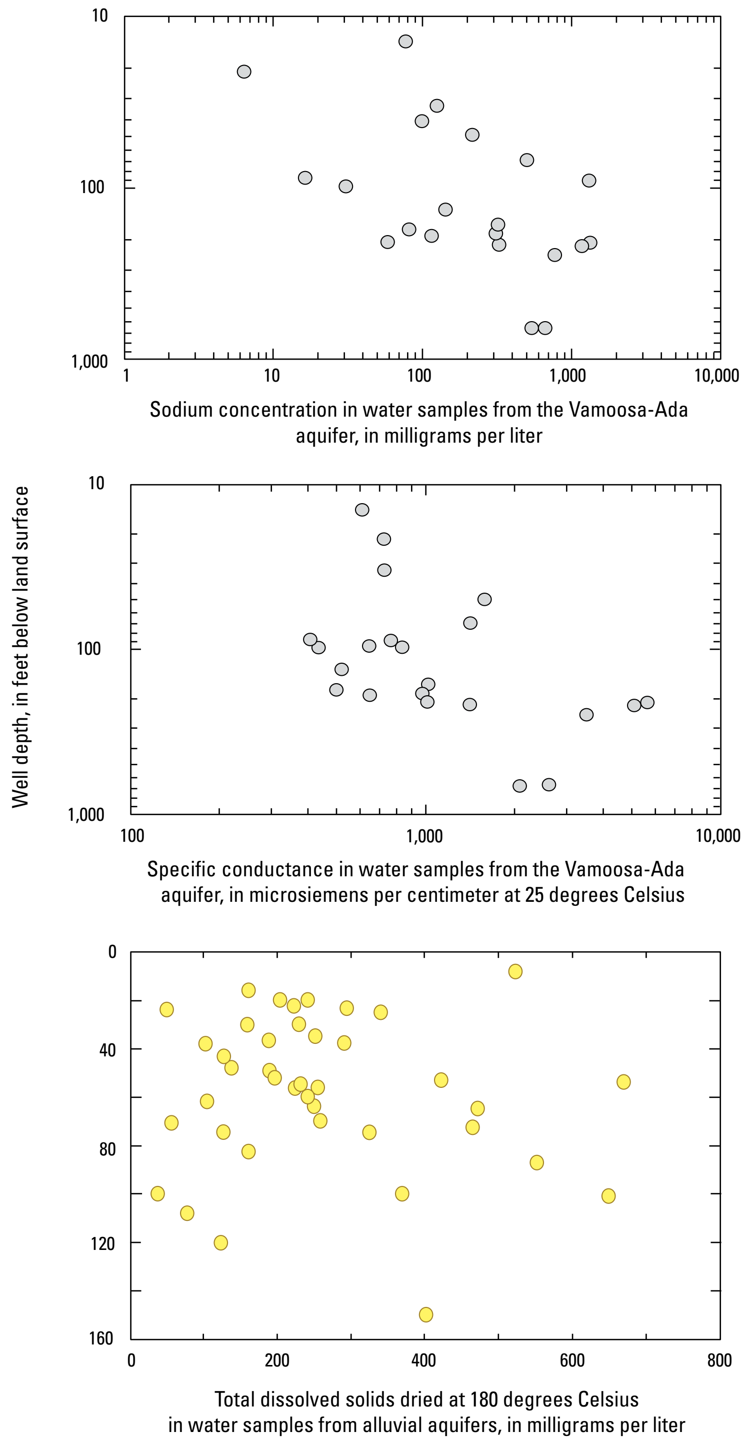


Figure 33. Concentrations of selected water-quality constituents and properties with depth below land surface in groundwater samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1943 through 2005.

Bicarbonate (HCO_3^-) is an anion derived from dissolution of carbonate rocks and oxidation of organic matter in aquifers (Hem, 1985). Similar to potassium and sodium, bicarbonate concentration and proportion were significantly greater in water samples from the Vamoosa-Ada aquifer than in samples from the alluvial and Central Oklahoma aquifers (figs. 31 and 32, appendix 9). Water in all three aquifers ranges from calcium-magnesium-bicarbonate dominated water to water with greater proportions of sulfate and chloride, perhaps associated with greater depths and residence times (fig. 32).

Chloride (Cl^-) and fluoride (F^-) are anions derived from dissolution of igneous rocks and connate seawater in rocks deposited in marine environments (Hem, 1985). Although chloride concentration tended to be slightly greater in water samples from the Vamoosa-Ada aquifer than in water samples from the alluvial and Central Oklahoma aquifers, those differences were not significant at an alpha level less than 0.05 (fig. 31). Similar to bicarbonate, potassium, and sodium, fluoride concentrations were significantly greater in water samples from the Vamoosa-Ada aquifer than the alluvial and Central Oklahoma aquifers in this area (fig. 31). Approximately 10 percent of samples from the alluvial and Central Oklahoma aquifers and approximately 20 percent of samples from the Vamoosa-Ada aquifer exceeded the secondary drinking-water standard of 250 mg/L for chloride (U.S. Environmental Protection Agency, 2011b).

Sulfate (SO_4^{-2}) is a divalent anion associated with dissolution of igneous rocks, gypsum, and oxidation of metallic sulfide minerals and organic matter in aquifers (Hem, 1985). Similar to chloride, sulfate concentrations were generally greater in water samples from the Vamoosa-Ada aquifer and less in water samples from the alluvial and Central Oklahoma aquifers (fig. 31). Unlike chloride, the concentration of sulfate was significantly less in water samples collected from the Central Oklahoma aquifer than in the other two principal aquifers in the area, perhaps because of lesser amounts of sulfate minerals in the aquifer or binding of sulfate in barite deposits common in the Central Oklahoma aquifer (fig. 31; Christenson and others, 1998). Similar to chloride, approximately 10 percent of samples from the alluvial and Central Oklahoma aquifers and approximately 20 percent of samples from the Vamoosa-Ada aquifer exceeded the secondary drinking-water standard of 250 mg/L for sulfate (U.S. Environmental Protection Agency, 2011b).

Nutrients

Nutrients in groundwater are not directly associated with increased plant growth, which occurs in surface water, but because groundwater provides base-flow seepage of water to streams and lakes, increased concentrations of nutrients in groundwater can affect the quality of adjoining surface water and the suitability of surface-water bodies for recreational purposes. Although small concentrations of nitrate support the growth of plants and animals, concentrations of nitrate-nitrogen (NO_3^--N) exceeding the primary drinking-water standard of 10 mg/L have been associated with health problems in humans and livestock, including methemoglobinemia (also known as “blue-baby” syndrome) (Kross and others, 1993; Bruning-Fann and Kaneene, 1993), and increased rates of stillbirth, low birth weight, slow weight gain, and death in cattle (National Research Council, 1972). Of the 59 water samples from the Central Oklahoma aquifer analyzed for nitrate, only 2 exceeded the primary drinking-water standard. Nitrate concentrations were similar in water samples collected from the three aquifers in this area (fig. 34).

Phosphorus also is a nutrient for plants and animals that is associated with eutrophication of surface water. In many freshwater bodies, phosphorus is the limiting nutrient for plant growth, meaning that small additions of phosphorus can cause large increases in plant growth. Because of concerns related to eutrophication of Scenic Rivers in Oklahoma, a water-quality standard of 0.037 mg/L was set for phosphorus concentration in those streams (State of Oklahoma, 2006). Because of a relatively high reporting limit of 0.04 mg/L for many of the samples, only a few samples (approximately 12 percent of the samples collected from the Central Oklahoma aquifer) were known to have exceeded that standard (fig. 34). Exceedance of that standard in only a few groundwater samples indicates that much of the phosphorus in streams in the area is not from groundwater seepage, with elevated concentrations and loads of phosphorus in surface water more commonly being associated with erosion of soils, livestock wastes, and resuspension of streambed sediments (Andrews and others, 2009a).

Metals

Metals occur naturally in aquifer materials and groundwater, with some human activities increasing metals concentrations in groundwater. Because many metals form low-solubility oxide and hydroxide minerals in the presence of oxygen, many metals are more likely to be dissolved in water with no dissolved oxygen (anoxic conditions) (Elder, 1988).

Arsenic is a semi-metallic element commonly associated with iron that occurs in water in the forms of arsenate (As^{+5} in $H_2AsO_4^-$ or $HAsO_4^{-2}$) and arsenite (As^{+3} in $HAsO_2$) (Hem, 1985). Arsenic can be dissolved from soils and rocks and also is associated with pressure-treated wood and pesticides (Agency for Toxic Substances and Disease Registry, 2007). In groundwater, arsenic typically is adsorbed to iron oxide particles, but pH greater than 8.0 and anoxic conditions facilitate desorption of arsenic compounds from those solids, increasing arsenic concentrations in water (Hinkle and Polette, 1999). Because of the numerous toxic effects and carcinogenicity of arsenic, particularly the arsenite form of arsenic (Grund and others, 2008), a primary drinking-water standard of 10 µg/L has been set for arsenic (U.S. Environmental Protection Agency, 2011a). Groundwater containing arsenic at concentrations greater than that standard commonly occur in the western part of the Central Oklahoma aquifer, at least 10 miles west of the western boundary of

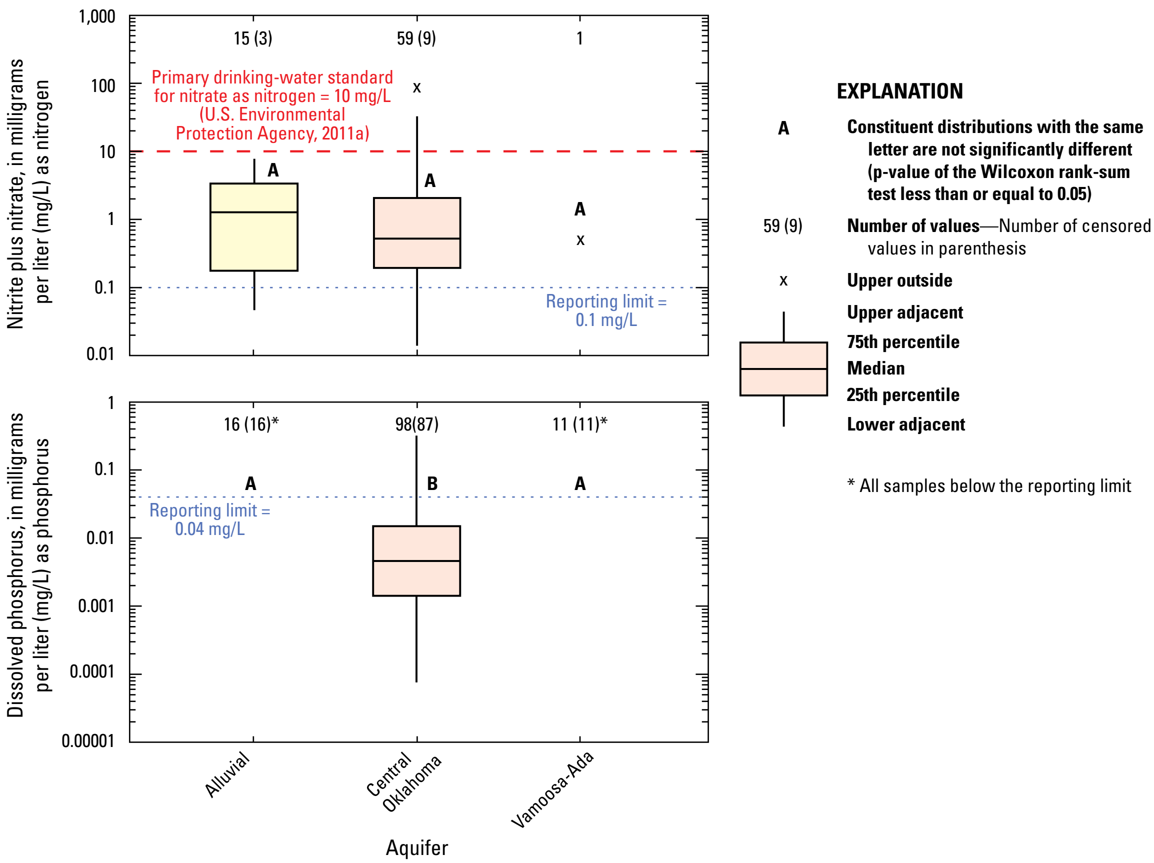


Figure 34. Distribution of concentrations of nitrite plus nitrate-nitrogen and dissolved phosphorus by aquifer in groundwater samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1943 through 2005.

the tribal jurisdictional area (Smith, 2005). None of the groundwater samples collected in this area had arsenic concentrations exceeding that standard, with the distribution of arsenic concentrations being similar between the principal aquifers and typically ranging from less than 0.5 to 5 µg/L (fig. 35).

Chromium can occur naturally in groundwater and also can be found at polluted industrial or commercial sites (Hem, 1985; U.S. Environmental Protection Agency, 2011a). No groundwater samples collected in the area contained a chromium concentration exceeding the primary drinking-water standard of 100 µg/L (U.S. Environmental Protection Agency, 2011a). Most of the samples did not contain detectable chromium (fig. 35). As of 2011, the primary drinking-water standard did not differentiate between the ionic forms of chromium, but the toxicologic and epidemiologic data led the State of California to establish a public health goal of 0.02 µg/L for chromium (VI) in drinking water to minimize long-term risk to public health from ingestion of the substance in drinking water (California Environmental Protection Agency, 2011). To determine if drinking-water supplies in this area and elsewhere exceed such small concentrations, smaller reporting limits than the 1 µg/L associated with groundwater samples collected in this area would be necessary (fig. 35, appendix 9).

Iron in groundwater is associated with dissolution of minerals in igneous rocks, oxidation of organic matter, and contamination at industrial and mining sites. The most common type of iron dissolved in groundwater is the divalent form known as ferrous iron (Fe^{+2}), with ferric (Fe^{+3}) iron occurring in acidic waters (Hem, 1985). In oxic alkaline waters, iron generally precipitates in a series of oxide, oxyhydroxide, hydroxide, and carbonate minerals. In anoxic water containing sulfide, the minerals pyrite and marcasite (two forms of FeS) commonly precipitate. Approximately 10 percent of water samples from the alluvial and Central Oklahoma aquifers in this area contained iron concentrations exceeding the secondary drinking-water standard of 250 µg/L, established by the USEPA to minimize metallic taste and staining of plumbing fixtures (fig. 35). Although water samples collected from the Central Oklahoma aquifer appeared to have lesser concentrations of iron than water from the other two aquifers, there were no significant differences in iron concentrations between the aquifer groups, with most of the sample concentrations being censored (nondetects) (fig. 35).

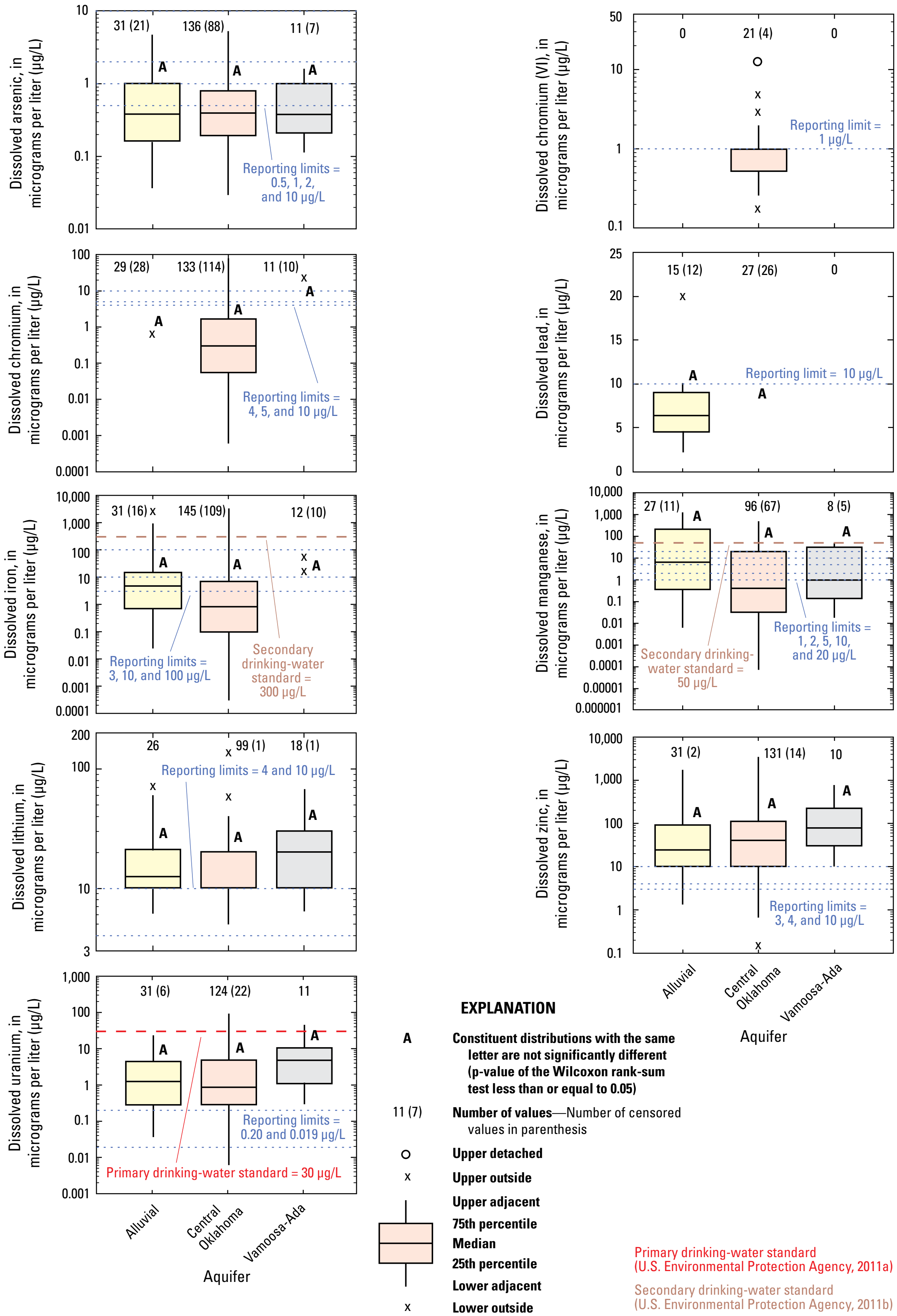


Figure 35. Distribution of concentrations of selected metals by aquifer in groundwater samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1947 through 2005.

The primary drinking-water standards for lead are zero (nondetect) with a treatment technique or action level of 15 µg/L (U.S. Environmental Protection Agency, 2011a). Most of the groundwater samples collected in the area from 1987 through 1989 had lead concentrations less than the reporting limit of 10 µg/L, though 1 of the 15 samples collected from alluvial aquifers in this area had a lead concentration of 20 µg/L (fig. 35). The limited number of analyses for lead and large number of nondetects preclude evaluation of the occurrence and distribution of lead in groundwater in this area.

Lithium concentrations were approximately an order of magnitude greater than lead concentrations, with few censored values of lithium concentrations in water samples from the three aquifers (fig. 35). Lithium is dissolved from lithium-containing minerals in igneous rocks and occurs in evaporite rocks, such as gypsum, and in natural brines (Hem, 1985). Concentrations of lithium greater than 60 µg/L can damage some species of trees (Hem, 1985). Symptoms of lithium toxicity in humans include gastric distress, dehydration, dizziness, weakness, tremors, seizures, and slurred speech (National Institutes of Health, 2011). Lithium has been prescribed as a mood stabilizer for several decades, with therapeutic dosages of 15–20 milligrams per kilogram per day (mg/kg/d) of body weight (up to approximately 1,400 mg/150 pound adult) producing *in vivo* concentrations slightly less than those producing toxic symptoms (Semple, 2005). Distributions of lithium concentrations in water samples from the three principal aquifers in this area were similar, ranging from less than 4 to 140 µg/L (fig. 35, appendix 9). Ingestion of 3 liters of water per day at the maximum measured concentration of 140 µg/L would provide considerably less than therapeutic or toxic doses of this metal.

Manganese commonly is associated with iron in water. Like iron, the most common form of manganese is the divalent ion (Mg^{+2}) (Hem, 1985). Manganese concentrations were similar in water samples collected from the three aquifers in the area (fig. 35, appendix 9). The secondary drinking-water standard for manganese of 50 µg/L, established primarily to minimize metallic taste and black staining of plumbing fixtures (U.S. Environmental Protection Agency, 2011b), was exceeded in approximately one-third of the water samples collected from alluvial aquifers and less than one-fourth of the water samples collected from the Central Oklahoma and Vamoosa-Ada aquifers in this area (fig. 35, appendix 9). The U.S. Environmental Protection Agency (2004) indicates that although small amounts of manganese in the human diet are nutritive, a secondary drinking-water standard less than 50 µg/L may be needed to minimize neurologic effects from ingestion of the metal in drinking water.

Uranium, a naturally occurring radioactive element dissolved from many types of rocks and soils and used in some commercial products, is the primary source of radioactivity in natural water (Hem, 1985; Agency for Toxic Substances and Disease Registry, 2011c). There is no known nutritive role for uranium for plants and animals, with ingestion of uranium being associated with decreases in fertility, kidney damage, and skin damage (Agency for Toxic Substances and Disease Registry, 2011c). Although there has been no association of cancer with ingestion of water with uranium, radiation associated with drinking water containing uranium and other radioactive elements has been associated with increased incidence of cancer (U.S. Environmental Protection Agency, 2011c). Because of negative health effects from ingestion of radionuclides such as uranium, the USEPA set a primary drinking-water standard of 30 µg/L for uranium (U.S. Environmental Protection Agency, 2011b). Of the 124 water samples analyzed for uranium concentration from the Central Oklahoma aquifer and the 11 water samples collected from the Vamoosa-Ada aquifer, 5 samples and 1 sample, respectively, exceeded the primary drinking-water standard for uranium. Those samples were collected in the eastern half of the area (fig. 36).

Similar to iron and manganese, zinc is a nutrient for plants and animals that typically occurs in water as a divalent cation (Zn^{+2}). Zinc can be dissolved from soils and many types of rocks and is commonly used in pipe coatings, batteries, and alloys (Hem, 1985; Agency for Toxic Substances and Disease Registry, 2005). Zinc commonly is associated with lead in deposits of metallic sulfides, such as those of the abandoned Picher mining district of northeastern Oklahoma (Andrews and others, 2009b). Excessive ingestion of zinc can cause digestive system distress, anemia, and increased concentrations of LDL cholesterol in blood (Agency for Toxic Substances and Disease Registry, 2005). A secondary drinking-water standard of 5 µg/L (5,000 mg/L) of zinc has been set to minimize metallic taste of water (U.S. Environmental Protection Agency, 2011b). None of the groundwater samples collected in the area had a zinc concentration exceeding that secondary drinking-water standard, and the locations of distribution of zinc concentration were similar for the three sampled aquifers (fig. 35, appendix 9).

Quality Assurance

Collection of quality-control samples, such as replicates and blanks, was not common prior to the late 1980s. The NWIS database had data for 12 groundwater replicates and 5 field blanks collected in this area from 1986 through 2004 and from 2003 through 2004, respectively. Mean relative-percent differences of water-quality constituents measured in the field and replicate samples generally were less than 25 percent (table 6), indicating relatively good reproducibility of data. Larger relative-percent differences primarily were associated with small numbers near reporting limits; for example, a field sample and a replicate sample having measured concentrations of a constituent of 0.1 and 0.2, respectively, that produce a relative-percent difference of 66.7 percent, which is a relatively small difference in units of measurement.

Blank samples collected in this area in association with groundwater samples did not have detectable concentrations of the major ions and metals summarized in this report (table 7), indicating small likelihood of contamination of field samples from sampling equipment and other environmental factors when the blanks were collected. Physical properties and some metals typically are not measured in field blanks (table 7).

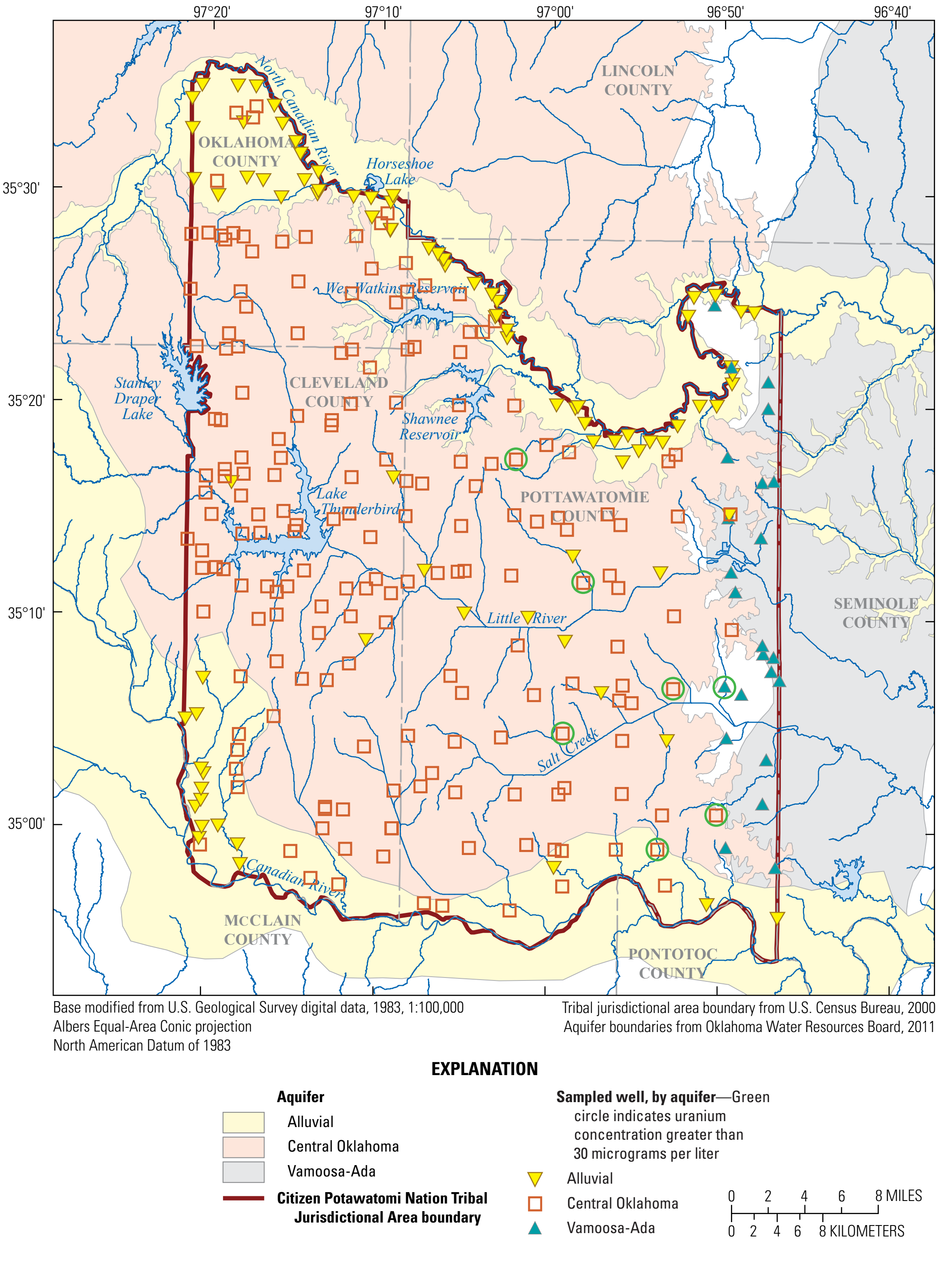


Figure 36. Locations of sampled wells with uranium concentrations exceeding the primary drinking-water standard in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma.

Table 6. Relative percent differences of constituents measured in replicate groundwater samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 2003 through 2004.

[Censored data values computed as being equal to the censoring level, data from U.S. Geological Survey National Water Information System database; mg/L, milligrams per liter; µg/L, micrograms per liter; relative percent differences in percent; Dissolved, concentration of a constituent after filtration through a 0.45 micron pore-size filter]

Water-quality constituent	Number of samples	Range of relative percent difference values	Mean relative percent difference
Physical properties			
Dissolved oxygen concentration, in mg/L	3	0	0
pH, in standard units	12	0–9.40	2.30
Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	12	0–120	18.9
Water temperature, in degrees Celsius	3	0	0
Dissolved solids, dried at 180 degrees Celsius, in mg/L	2	0	0
Hardness, in mg/L as calcium carbonate	9	1.59–68.7	25.7
Major ions			
Dissolved calcium, in mg/L	11	0–179	19.7
Dissolved magnesium, in mg/L	12	0–75.0	20.0
Dissolved potassium, in mg/L	12	0–40.0	9.03
Dissolved bicarbonate, in mg/L	9	1.75–38.4	14.8
Dissolved sodium, in mg/L	12	0–94.3	18.3
Dissolved chloride, in mg/L	11	0–83.3	18.0
Dissolved fluoride, in mg/L	12	0–58.8	12.1
Dissolved sulfate, in mg/L	12	0–194	36.6
Nutrient			
Nitrate plus nitrite, in mg/L as nitrogen	12	0–185	78.3
Metals			
Dissolved arsenic, in mg/L	3	0	0
Dissolved, chromium, in µg/L	12	0–18.2	1.5
Dissolved chromium VI, in µg/L	1	66.7	66.7
Dissolved iron, in µg/L	12	0–182	74.9
Dissolved lithium, in µg/L	1	106	106
Dissolved lead, in µg/L	1	0	0
Dissolved manganese, in µg/L	10	0–165	65.9
Dissolved uranium, in µg/L	1	0	0
Dissolved zinc, in µg/L	3	0	0

Table 7. Constituent concentrations measured in blank samples associated with groundwater samples collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 2003 through 2004.

[Data from U.S. Geological Survey National Water Information System database; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; relative percent differences in percent; Dissolved, concentration of a constituent after filtration through a 0.45 micron pore-size filter]

Water-quality constituent	Number of samples	Range of values	Mean value
Physical properties			
Dissolved solids, dried at 180 degrees Celsius, in mg/L	5	<10	<10
Major ions			
Dissolved calcium, in mg/L	5	<1	<1
Dissolved magnesium, in mg/L	5	<1	<1
Dissolved potassium, in mg/L	5	<1	<1
Dissolved sodium, in mg/L	5	<1	<1
Dissolved chloride, in mg/L	5	<10	<10
Dissolved fluoride, in mg/L	5	<1	<1
Dissolved sulfate, in mg/L	5	<10	<10
Nutrient			
Nitrate plus nitrite, in mg/L as nitrogen	5	<0.05	<0.05
Metals			
Dissolved arsenic, in mg/L	5	<2	<2
Dissolved, chromium, in µg/L	5	<10	<10
Dissolved iron, in µg/L	5	<10	<10
Dissolved manganese, in µg/L	5	<10	<10
Dissolved zinc, in µg/L	5	<10	<10

Collection of only 12 replicates and 5 blanks for 294 wells sampled is a small frequency of quality-control sample collection, with collection of the quality-control samples having been done toward the end of the sampling period described in this report. Since 1990, each type of quality-control sample typically has been collected at frequencies ranging from 5 to 10 percent of the number of field water-quality samples, an issue to be considered for future sampling programs.

Data Gaps

Gaps in data coverage temporally, spatially, and in measured physical properties and constituents produce an incomplete, and in some areas, insufficient measure of the quantity and quality of available water resources in the tribal jurisdictional area. Some of the major gaps in hydrologic data for the area are apparent after review of existing data, and means of filling the gaps include:

1. There is a lack of information about streamflow and groundwater levels caused by having only four long-term streamflow-gaging stations and no long-term groundwater-level measurement network. If the Citizen Potawatomi Nation is interested in improving monitoring of streamflow, installation of at least one additional streamflow-gaging station on the Canadian River in the southeastern part of the jurisdictional area would be useful. A groundwater-level monitoring network of 20 wells per principal aquifer, measured at least once per year during low water pumpage in the winter, would provide information about groundwater flow direction and depth to groundwater that currently is not being collected. Having continuous water-level monitoring by pressure transducers installed in wells in areas of special interest would provide information about response of local groundwater levels to climatic patterns and seasonal pumpage and long-term trends in groundwater levels in selected areas of the jurisdictional area.
2. The available data provide limited information about surface-water quality, as most surface-water-quality sampling has been done in the North Canadian River with relatively little sampling of other rivers and streams. Periodic water-quality sampling, such as 10–12 times per year, at additional sites for greater numbers of

water-quality constituents across local ranges of streamflow would provide more comprehensive understanding of surface-water quality across the jurisdictional area; the effects of local land uses, geologic settings, and streamflow conditions on water quality; and would provide the ability to reliably determine loads and yields of selected constituents through regression relations and evaluate areas producing anomalous amounts of selected constituents.

3. There is a lack of knowledge in trends of groundwater quality and recent groundwater quality based on limited sampling periods and distribution of sampled wells. Consistent annual sampling for a relatively large number of water-quality constituents of a network of 20 or more wells per major aquifer distributed across the jurisdictional area would provide the ability to consistently characterize the quality of groundwater and to eventually determine trends in groundwater quality across the area.

4. There has been a lack of consistent collection of water properties and constituents by different agencies across the jurisdictional area. With limited budgets and different priorities, lack of consistent data collection by different agencies probably will continue into the future. However, coordination of water-quality sampling among agencies would establish goals for properties and constituents to be measured in water resources in the area and would help to provide more robust data for characterization of local water quality. Collection of continuous streamflow data in conjunction with collection of surface-water-quality data would be useful for investigating relations between water-quality property values and constituent concentrations and streamflow as well as providing means to better investigate effects of seasons on surface-water quality. To the extent that budgets allow, collection for additional “nontraditional” water-quality constituents, such as emerging contaminants (pharmaceuticals, household chemicals, and some pesticides) would enable better determination of the effects of wastewater discharges from wastewater-treatment plants and onsite septic systems on the quality of surface water and groundwater in this area.

Summary

The Citizen Potawatomi Nation Tribal Jurisdictional Area, comprising approximately 960 square miles in parts of three counties in central Oklahoma, has an abundance of water resources, being bordered by two major rivers (North Canadian and Canadian), having several smaller streams, and being underlain by three principal aquifers (alluvial, Central Oklahoma, and Vamoosa-Ada). The area periodically is subject to flooding and drought, which may limit available water resources, particularly during the summer when water use increases and streamflows can decrease substantially. This report summarizes existing water-use, climatic, geographic, hydrologic, and water-quality data and describes several means of filling gaps in hydrologic data for this area.

Approximately 115,000 people estimated to live in this area used 4.41 million gallons of fresh groundwater, 12.12 million gallons of fresh surface water, and 8.15 million gallons of saline groundwater per day in 2005. Approximately 8.48, 2.65, 2.24, 1.55, 0.83, and 0.81 million gallons per day of water were used for domestic, livestock, commercial, industrial, crop irrigation, and thermoelectric purposes, respectively. Approximately one-third of the water withdrawn in this area in 2005 was saline water produced during petroleum production. Future increases in use of freshwater in this area will be affected by changes in population and changes in agricultural practices. Changes in saline water use largely will be affected by future petroleum production.

Land cover in this area is primarily grassland, pasture/hay fields, and deciduous forest, in a dominantly rural setting. Such lack of urban development may limit water-quality effects from human activities. Much of the water in the area is of good quality, though water quality is impaired in some areas by very hard surface water and groundwater; large chloride concentrations in some of the smaller streams in the southeastern part of the area; relatively large concentrations of nutrients and counts of fecal-indicator bacteria in the North Canadian River; and chloride, iron, manganese, and uranium concentrations that exceed primary or secondary drinking-water standards in samples from a small number of wells.

Substantial amounts of hydrologic and water-quality data have been collected in and near this area, but gaps in those data remain, including:

1. Lack of continuous information about streamflow and groundwater levels caused by having only four long-term streamflow-gaging stations and no long-term groundwater-level measurement network,

2. Limited knowledge of streamflow and surface-water quality because most surface-water quality sampling has been done in the North Canadian River,

3. Lack of knowledge of patterns and trends of concentrations of surface-water-quality constituents because of lack of sampling at high-flow and low-flow conditions over time,

4. Lack of groundwater quality and recent groundwater-quality data based on limited sampling periods, and

5. Lack of consistent collection of water-quality constituents by different Tribes and agencies in and near the area.

These data gaps largely would be filled by:

1. Establishing additional long-term streamflow-gaging stations to measure streamflow and as sites for water-quality measurements as streams enter and leave this jurisdictional area,

2. Sampling streams at low-flow and high-flow conditions 10–12 times per year at selected surface-water-quality sites to develop reliable regression relations of changes of water quality with streamflow, and
3. Establishing a network of at least 20 wells per principal aquifer in this area from which annual measurements of groundwater levels and water quality could be made.

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Glossary

aquatic Life forms or substances in water.

aquifer A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield large quantities of water to wells and springs (New Mexico Office of State Engineer, 1999).

base flow Streamflow derived from ground-water seepage, synonymous with "low flow".

climate The sum total of the meteorological elements that characterize the average and extreme condition of the atmosphere during a long period of time at any one place or region of the earth's surface (Langbein and Iseri, 1960).

concentration The mass of a substance dissolved per unit volume of liquid or contained in a unit mass of solid.

criterion A number or narrative statement assigned to protect a designated beneficial use. A water-quality standard set by the state.

cubic feet per second A unit expressing rates of discharge. One cubic foot per second is equal to the discharge of a stream of rectangular cross section, one foot wide and one foot deep, with water flowing at an average velocity of one foot per second (Langbein and Iseri, 1960).

ecosystem A natural unit including all life forms and non-living physical elements that function together.

eutrophication Nutrient enrichment (particularly of nitrogen and phosphorus) in aquatic ecosystems that leads to increased productivity, including excessive growth of algae and other aquatic plants (Graham and others, 2008). Excessive eutrophication changes aquatic habitat by changes in dissolved oxygen concentration, water temperature, availability of spawning beds, and visibility for predator fish. Aesthetic effects of hypereutrophication include degradation of water quality for swimming and other recreational activities and increases in concentrations of taste-and-odor-producing organic compounds in drinking water.

gage A device used to measure and record the elevation of water in a stream or lake in a semi-continuous manner. In a flowing stream, comparisons of measured streamflows to surface-water elevations are used to estimate streamflow, commonly at 15-minute intervals.

load The mass of a substance flowing past a given point in a stream per unit of time, derived from multiplying streamflow by the aqueous concentration of a substance by unit correction factors. Loads are typically expressed in pounds or kilograms per day.

milliequivalents per liter (meq/L) The amount of material that will release or react with a millimole of electrical charges on particles such as OH-, H+, or electrons. Milliequivalents per liter are computed by multiplying the concentration of an ionic substance by the atomic mass of the ionic substance and the charge of the ion.

milligrams per liter (mg/L) Milligrams of a substance dissolved in one liter of water, that is the same as a part per million in freshwater because one liter of distilled water weighs one million milligrams (one kilogram).

nutrient An element such as nitrogen or phosphorus needed for growth of plants and animals.

point source The source of contaminant(s) discharged from any identifiable point, including wastewater discharges from ditches, channels, sewers, tunnels, and containers of various kinds (New Mexico State Office of Engineer, 2005).

precipitation Includes atmospheric hail, mist, rain, sleet and snow that descend upon the earth; the quantity of water accumulated from these events (New Mexico Office of State Engineer, 1999).

primary body contact recreation criteria Water-quality criteria set by the state to protect humans having direct body contact with the water where a possibility of ingestion exists, swimming being one example.

recharge Addition of water to an aquifer by infiltration, either directly into the aquifer or indirectly through another rock formation. Recharge may be natural, as when precipitation infiltrates to the water table, or artificial, as when water is injected through wells or spread over permeable surfaces for the purpose of recharging an aquifer (modified from New Mexico Office of State Engineer, 1999).

runoff That part of the precipitation that appears in surface streams (Langbein and Iseri, 1960).

sediment Fragmented rock and organic materials that are transported by, suspended in, or deposited by water or air. Sediments tend to accumulate in horizontal layers/beds in still or slow-flowing water.

streamflow Discharge in a natural channel of a surface stream course (New Mexico Office of State Engineer, 1999).

total nitrogen The sum of concentrations of ammonium, nitrate, nitrite, and organic forms of nitrogen, expressed as the concentration of nitrogen, in a water sample.

total phosphorus The sum of concentrations of phosphorus in the forms of orthophosphate (PO^{4-3}), polyphosphate (phosphate polymers linked by hydroxyl (OH^-) groups and hydrogen atoms), organically bound phosphate ($OP(OR)^{+3}$), and other forms of phosphorus, expressed as the concentration of phosphorus, in a water sample.

wastewater Water that contains dissolved or suspended solids as a result of human use (New Mexico Office of State Engineer, 1999).

wastewater treatment Processing of wastewater for the removal or reduction in the concentration of dissolved solids or other undesirable constituents (modified from New Mexico Office of State Engineer, 1999).

Appendixes 1–9

Appendix 1. Summary statistics of selected surface-water-quality data collected by the U.S. Geological Survey in or near the Citizen Potawatomi Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; L, liter; <, less than; >, greater than; --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; highest level of minimum reporting limits used for summary statistics, Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values, CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a); all constituents analyzed in unfiltered samples unless identified as "dissolved" or "filtered"]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
North Canadian River near Harrah, Okla. (07241550)												
Dissolved oxygen, in mg/L	2.50	8.10	9.70	11.4	21.0	--	--	10/1985	9/2011	342	342	100
pH (field), in standard units	6.70	7.80	8.10	8.30	9.20	--	--	10/1985	9/2011	449	449	100
Specific conductance, in µS/cm at 25 degrees Celsius	277	950	1,160	1,340	1,780	--	--	10/1985	9/2011	441	441	100
Water temperature, in degrees Celsius	0.0	10.4	18.0	25.1	34.3	--	--	10/1985	9/2011	448	448	100
Turbidity, in nephelometric turbidity units	<0.50	10.0	27.0	55.5	410	--	--	5/1987	9/2004	167	167	99.4
Five-day biochemical oxygen demand, in mg/L at 20 degrees Celsius	<2.00	2.30	4.10	7.15	33.0	--	--	10/1985	9/2011	244	239	98.0
Chemical oxygen demand, in mg/L	<10	30.0	40.0	50.0	80.0	--	--	10/1985	9/1987	41	39	95.1
Dissolved solids dried at 180 degrees Celsius, in mg/L	159	573	730	854	1,000	--	--	10/1985	9/2011	284	284	100
Hardness, in mg/L calcium carbonate	95.6	250	310	383	441	--	--	10/1985	9/2011	190	190	100
Suspended solids, in mg/L	1.00	27.0	63.0	138	1,830	--	--	10/1985	9/2011	311	311	100
Dissolved calcium, in mg/L	28.0	61.2	77.0	94.0	110	--	--	10/1985	9/2011	190	190	100
Dissolved magnesium, in mg/L	6.16	23.0	29.0	36.0	42.0	--	--	10/1985	9/2011	190	190	100
Dissolved potassium, in mg/L	1.00	6.35	7.40	8.6	14.0	--	--	10/1985	9/2011	167	167	100
Dissolved sodium, in mg/L	12.9	95.8	120	140	180	--	--	10/1985	9/2011	190	190	100
Total acid neutralizing capacity, in mg/L as calcium carbonate	86.0	162	199	224	306	--	--	10/1985	9/2011	376	376	100

Appendix 1. Summary statistics of selected surface-water-quality data collected by the U.S. Geological Survey in or near the Citizen Potawatomi Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.—Continued

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; L, liter; <, less than; >, greater than; --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; highest level of minimum reporting limits used for summary statistics, Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values, CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a); all constituents analyzed in unfiltered samples unless identified as "dissolved" or "filtered"]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
North Canadian River near Harrah, Okla. (07241550)—Continued												
Alkalinity, filtered, in mg/L as calcium carbonate	72.0	148	183	212	300	--	--	7/1991	9/2011	240	240	100
Dissolved bicarbonate, in mg/L	88.0	173	217	254	453	--	--	7/1991	9/2011	239	239	100
Bicarbonate, in mg/L	105	219	240	268	312	--	--	10/1985	7/1988	56	56	100
Carbon dioxide, in mg/L	0.20	2.00	3.10	6.05	72.0	--	--	10/1985	9/2011	399	399	100
Dissolved carbonate, in mg/L	<1	<1	<1	3.00	37.0	--	--	7/1991	9/2011	240	112	46.7
Total carbonate, in mg/L	<1	<1	<1	2.00	22.0	--	--	10/1985	7/1988	56	3	5.36
Dissolved chloride, in mg/L	13.4	120	160	198	280	230	6.25	10/1985	9/2011	224	224	100
Dissolved fluoride, in mg/L	0.26	0.58	0.70	0.80	1.21	--	--	8/1988	9/2011	94	94	100
Dissolved silica, in mg/L	1.10	7.81	9.86	12.0	16.0	--	--	1/1988	9/2011	118	118	100
Dissolved sulfate, in mg/L	20.0	102	157	210	270	--	--	10/1985	9/2011	198	198	100
Dissolved ammonia plus organic nitrogen, in mg/L as nitrogen	0.20	0.60	0.79	1.10	4.90	--	--	10/1985	9/2011	279	278	99.6
Total ammonia plus organic nitrogen, in mg/L as nitrogen	0.60	1.10	1.40	1.50	3.80	--	--	10/1987	9/2011	122	122	100
Dissolved nitrate plus nitrite, in mg/L as nitrogen	<0.10	1.20	2.18	3.80	14.0	--	--	10/1985	9/2011	317	316	99.7
Total nitrate plus nitrite, in mg/L as nitrogen	0.60	0.90	1.15	2.20	4.10	--	--	11/1987	7/1988	18	18	100
Dissolved nitrate, in mg/L as nitrogen	0.06	1.16	2.14	3.72	14.0	--	--	10/1985	9/2011	317	317	100
Nitrate, in mg/L as nitrogen	0.56	0.90	1.15	2.20	4.10	--	--	11/1987	7/1988	17	17	100
Dissolved nitrite, in mg/L as nitrogen	<0.010	0.028	0.043	0.085	2.25	--	--	10/1985	9/2011	317	314	99.1
Nitrite, in mg/L as nitrogen	0.02	0.05	0.10	0.15	0.36	--	--	11/1987	7/1988	17	17	100

Appendix 1. Summary statistics of selected surface-water-quality data collected by the U.S. Geological Survey in or near the Citizen Potawatomi Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.—Continued

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; L, liter; <, less than; >, greater than; --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; highest level of minimum reporting limits used for summary statistics, Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values, CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a); all constituents analyzed in unfiltered samples unless identified as “dissolved” or “filtered”]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
North Canadian River near Harrah, Okla. (07241550)—Continued												
Dissolved organic nitrogen, in mg/L	<1.40	<1.40	<1.40	<1.40	3.80	--	--	10/1985	9/2011	278	240	86.3
Total organic nitrogen, in mg/L	<2.10	<2.10	<2.10	<2.10	2.70	--	--	2/2003	9/2011	104	87	83.6
Dissolved phosphorus, in mg/L	0.003	0.31	0.56	1.10	3.60	--	--	10/1985	9/2011	294	294	100
Phosphorus, in mg/L	0.24	0.67	0.90	1.46	3.40	--	--	11/1985	9/2011	123	123	100
Dissolved nitrogen, in mg/L	<0.3	2.10	3.20	4.90	15.0	--	--	10/1985	9/2011	277	276	99.6
Total nitrogen, in mg/L	1.70	3.22	4.30	6.20	11.0	--	--	10/1987	9/2011	122	122	100
Fecal coliform bacteria count, in colonies per 100 milliliters	<200	<200	500	1,200	110,000	--	--	10/1985	9/2011	245	243	99.2
Fecal streptococcal bacteria, in colonies per 100 milliliters	<10	107	240	767	80,000	--	--	10/1985	9/2011	254	252	99.2
Chlorophyll *a* in phytoplankton uncorrected for pheophytin, in µg/L	<1	11.0	27.0	60.0	181	--	--	10/1989	6/1996	69	68	98.6
Dissolved barium, in µg/L	44.1	120	134	160	230	--	--	12/1987	9/2011	118	118	100
Dissolved copper, in µg/L	<10	<10	<10	<10	13.0	--	--	11/1985	9/2011	124	26	21.0
Dissolved iron, in µg/L	<10	<10	10.2	16.0	730	1,000	0.0	11/1985	9/2011	125	109	87.2
Dissolved lead, in µg/L	<100	<100	<100	<100	<100	$e^{\{1.273[\ln(hardness)]-4.705\}}$ (1.46203-[(ln hardness(1.45712)]	4.8	11/1985	9/2011	124	58	46.8
Dissolved lithium, in µg/L	6.0	20.2	26.5	33.0	46.0	--	--	12/1987	9/2011	118	118	100
Dissolved manganese, in µg/L	<4.00	<4.00	8.40	16.0	190	--	--	11/1985	9/2011	125	118	94.4
Dissolved mercury, in µg/L	<0.2	<0.2	<0.2	0.026	1.70	0.77	1.5	11/1985	9/2011	119	29	24.4

Appendix 1. Summary statistics of selected surface-water-quality data collected by the U.S. Geological Survey in or near the Citizen Potawatomi Tribal Jurisdictional Area, Oklahoma, 1985 through 2011.—Continued

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; L, liter; <, less than; >, greater than; --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; highest level of minimum reporting limits used for summary statistics, Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values, CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a); all constituents analyzed in unfiltered samples unless identified as "dissolved" or "filtered"]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
North Canadian River near Harrah, Okla. (07241550)—Continued												
Dissolved molybdenum, in µg/L	<60	<60	<60	<60	<60	--	--	12/1987	9/2011	118	27	22.9
Dissolved nickel, in µg/L	<53	<53	<53	<53	<53	$e^{(0.8460*(\ln(\text{hardness}))-0.0584)}$ (0.997)	0.0	12/1987	9/2011	118	36	30.5
Dissolved strontium, in µg/L	202	686	847	972	1,200	--	--	12/1987	9/2011	118	118	100
Dissolved vanadium, in µg/L	<10.0	<10.0	<10.0	<10.0	14.0	--	--	12/1987	9/2011	118	82	69.5
Dissolved zinc, in µg/L	<3	5.09	8.7	14.7	47.0	$e^{(0.8473*(\ln(\text{hardness}))-0.884)}$ (0.986)	8.0	11/1985	9/2011	125	103	82.4
Dissolved arsenic, in µg/L	1.40	3.00	3.50	4.25	28.0	150	0.0	10/1985	9/2011	127	127	100
Dissolved selenium, in µg/L	<2.00	<2.00	<2.00	<2.00	4.00	5	0.0	2/1986	9/2011	126	49	38.9
Suspended sediment, in mg/L	53.0	71.0	100	187	573	--	--	10/1985	3/1986	9	9	100
Little River near Tecumseh, Okla. (07230500)												
pH (field), in standard units	6.90	7.82	8.20	8.30	8.60	--	--	1/1986	8/1990	34	34	100
Specific conductance, in µS/cm at 25 degrees Celsius	153	432	835	1,000	7,610	--	--	1/1986	8/1990	34	34	100
Water temperature, in degrees Celsius	3.5	10.2	15.2	24.0	34.0	--	--	1/1986	6/1990	34	34	100
Canadian River at Purcell, Okla. (07229200)												
pH (field), in standard units	7.40	8.10	8.20	8.48	9.10	--	--	12/1985	6/1990	18	18	100
Specific conductance, in µS/cm at 25 degrees Celsius	615	1190	1,520	1,795	3,080	--	--	1/1986	8/1990	19	19	100
Water temperature, in degrees Celsius	4.5	12.8	25.2	30.5	33.5	--	--	12/1985	8/1990	18	18	100

Appendix 2. Summary statistics of selected surface-water-quality data collected by the Citizen Potawatomi Nation, Oklahoma, 2009 through 2011.

[mg/L, milligrams per liter; L, µS/cm, microsiemens per centimeter; liter; all constituents analyzed in unfiltered samples, data from samples collected in October and November, 2011 for analyses of total nitrogen and total phosphorus not summarized in this table]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples
Station "North Deer Creek at FireLake Grand Casino"								
Dissolved oxygen concentration, in mg/L	1.94	4.08	6.88	9.74	16.5	10/2009	11/2011	32
pH (field), in standard units	6.52	7.66	7.89	8.01	9.34	10/2009	11/2011	32
Specific conductance, in µS/cm at 25 degrees Celsius	451	603	688	713	763	9/2010	11/2011	21
Water temperature, in degrees Celsius	4.1	6.1	13.7	20.7	29.6	10/2009	11/2011	32
Turbidity, in nephelometric turbidity units	5.44	14.1	24	44	185	10/2009	11/2011	32
Hardness, in mg/L as calcium carbonate	122	207	241	260	296	9/2010	11/2011	21
Alkalinity, in mg/L as calcium carbonate	160	194	240	256	275	10/2009	11/2011	21
Station "North Canadian River at Giverny 14 SE"								
Dissolved oxygen concentration, in mg/L	5.52	9.74	10.6	11.8	15.9	10/2009	11/2011	32
pH (field), in standard units	7.21	7.74	7.94	8.34	8.64	10/2009	11/2011	32
Specific conductance, in µS/cm at 25 degrees Celsius	273	949	1,050	1,170	1,370	9/2010	11/2011	21
Water temperature, in degrees Celsius	4.9	8.0	14.3	19.4	30.9	10/2009	11/2011	32
Turbidity, in nephelometric turbidity units	4.1	16.5	24.1	45.4	822	11/2009	11/2011	31
Hardness, in mg/L as calcium carbonate	110	255	266	288	370	9/2010	11/2011	21
Alkalinity, in mg/L as calcium carbonate	113	159	183	205	256	9/2010	11/2011	21
Station "Un-named Tributary to Squirrel Creek (outfall of city of Tecumseh wastewater treatment plant)"								
Dissolved oxygen concentration, in mg/L	5.21	7.96	9.18	10.6	14.8	10/2009	11/2011	32
pH (field), in standard units	7.69	7.99	8.19	8.31	8.81	10/2009	11/2011	32
Specific conductance, in µS/cm at 25 degrees Celsius	354	545	600	678	1,000	9/2010	11/2011	21
Water temperature, in degrees Celsius	4.7	10.8	15.1	23.2	32.2	10/2009	11/2011	32
Turbidity, in nephelometric turbidity units	3.9	5.45	8.17	14.8	194	12/2009	11/2011	30
Hardness, in mg/L as calcium carbonate	123	159	177	185	223	9/2010	11/2011	21
Alkalinity, in mg/L as calcium carbonate	122	145	175	205	246	9/2010	11/2011	21
Station "Squirrel Creek at Tribal Administration Building"								
Dissolved oxygen concentration, in mg/L	0.68	5.96	8.22	9.92	12.8	10/2009	11/2011	30
pH (field), in standard units	7.23	7.84	8.04	8.22	8.48	10/2009	11/2011	30
Specific conductance, in µS/cm at 25 degrees Celsius	268	477	531	646	1,100	9/2010	11/2011	19

Appendix 2. Summary statistics of selected surface-water-quality data collected by the Citizen Potawatomi Nation, Oklahoma, 2009 through 2011.—Continued

[mg/L, milligrams per liter; L, µS/cm, microsiemens per centimeter; liter; all constituents analyzed in unfiltered samples, data from samples collected in October and November, 2011 for analyses of total nitrogen and total phosphorus not summarized in this table]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples
Station "Squirrel Creek at Tribal Administration Building"—Continued								
Water temperature, in degrees Celsius	2.1	6	11.8	17.1	28.1	10/2009	11/2011	30
Turbidity, in nephelometric turbidity units	2.68	5.31	8.18	26.2	158	10/2009	11/2011	30
Hardness, in mg/L as calcium carbonate	103	176	202	224	342	9/2010	11/2011	19
Alkalinity, in mg/L as calcium carbonate	108	180	222	249	402	9/2010	11/2011	19
Station "North Canadian River at Knight 21"								
Dissolved oxygen concentration, in mg/L	7.47	11	12	13.1	18.8	11/2009	11/2011	31
pH (field), in standard units	7.49	8.15	8.33	8.71	9.45	11/2009	11/2011	31
Specific conductance, in µS/cm at 25 degrees Celsius	566	863	1,000	1,080	1,280	9/2010	11/2011	21
Water temperature, in degrees Celsius	6.8	9.3	16.5	24.2	34.2	11/2009	11/2011	31
Turbidity, in nephelometric turbidity units	9.16	17.4	30	62.6	476	11/2009	11/2011	31
Hardness, in mg/L as calcium carbonate	186	234	276	295	364	9/2010	11/2011	21
Alkalinity, in mg/L as calcium carbonate	151	170	297	222	258	9/2010	11/2011	21
Station "Squirrel Creek at Tribal Environmental Office"								
Dissolved oxygen concentration, in mg/L	0.56	1.92	6.48	9.38	12.6	10/2009	11/2011	30
pH (field), in standard units	6.89	7.75	7.86	8.04	8.93	10/2009	11/2011	30
Specific conductance, in µS/cm at 25 degrees Celsius	180	400	499	556	747	9/2010	11/2011	19
Water temperature, in degrees Celsius	2.4	5.5	11.8	17.8	27.5	10/2009	11/2011	30
Turbidity, in nephelometric turbidity units	2.96	6.34	13.5	46.8	101	12/2009	11/2011	28
Hardness, in mg/L as calcium carbonate	82.0	136	184	203	242	9/2010	11/2011	19
Alkalinity, in mg/L as calcium carbonate	89.0	144	180	213	276	9/2010	11/2011	19
Station "North Canadian River at Knight 29"								
Dissolved oxygen concentration, in mg/L	7.2	11.1	12.4	13.6	20.0	4/2010	11/2011	26
pH (field), in standard units	7.0	8.0	8.4	8.8	9.2	4/2010	11/2011	26
Specific conductance, in µS/cm at 25 degrees Celsius	574	875	1,010	1,090	1,280	9/2010	11/2011	21
Water temperature, in degrees Celsius	6.6	12.2	19.1	25.7	26.0	4/2010	11/2011	26
Turbidity, in nephelometric turbidity units	8.7	19.5	28.5	62.6	555	4/2010	11/2011	26
Hardness, in mg/L as calcium carbonate	179	230	285	293	353	9/2010	11/2011	21
Alkalinity, in mg/L as calcium carbonate	150	177	197	217	249	9/2010	11/2011	21

Appendix 2. Summary statistics of selected surface-water-quality data collected by the Citizen Potawatomi Nation, Oklahoma, 2009 through 2011.—Continued

[mg/L, milligrams per liter; L, µS/cm, microsiemens per centimeter; liter; all constituents analyzed in unfiltered samples, data from samples collected in October and November, 2011 for analyses of total nitrogen and total phosphorus not summarized in this table]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples
Station "North Canadian River at Luther Road (USGS streamflow-gaging station 07241550)"								
Dissolved oxygen concentration, in mg/L	5.5	8.7	10.1	11.2	15.9	4/2010	11/2011	26
pH (field), in standard units	6.8	7.3	7.5	7.8	8.9	4/2010	11/2011	26
Specific conductance, in µS/cm at 25 degrees Celsius	250	922	1,040	1,100	1,400	9/2010	11/2011	21
Water temperature, in degrees Celsius	6.2	9.2	17.0	23.3	32.0	4/2010	11/2011	26
Turbidity, in nephelometric turbidity units	5.9	13.7	24.1	37.3	1,000	4/2010	11/2011	26
Hardness, in mg/L as calcium carbonate	130	238	262	278	367	9/2010	11/2011	21
Alkalinity, in mg/L as calcium carbonate	124	151	182	206	241	9/2010	11/2011	21
Station "Little River at U.S. Highway 177"								
Dissolved oxygen concentration, in mg/L	7	9	11	12	14	4/2010	11/2011	26
pH (field), in standard units	7	8	8	8	9	4/2010	11/2011	26
Specific conductance, in µS/cm at 25 degrees Celsius	712	917	1,000	1,350	2,200	9/2010	11/2011	21
Water temperature, in degrees Celsius	7	10	21	25	37	4/2010	11/2011	26
Turbidity, in nephelometric turbidity units	3	5	7	21	76	4/2010	11/2011	26
Hardness, in mg/L as calcium carbonate	208	258	302	313	332	9/2010	11/2011	21
Alkalinity, in mg/L as calcium carbonate	175	249	282	293	304	9/2010	11/2011	21

Appendix 3. Summary statistics of surface-water-quality data collected by the Oklahoma Department of Environmental Quality in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 2003.

[Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least five samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minmum value	25th percentile	50th percentile	75th percentile	Maximum value	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measure-ments	Percentage of samples with detected measure-ments
Station NC08												
Fecal coliform bacteria	<10	105	200	450	1,100	200	40.0	5/2003	9/2003	20	18	90.0
Escherichia coli. bacteria	<10	17	74	140	400	126	30.0	5/2003	9/2003	20	15	75.0
Enterococcus bacteria	41.00	100	265	405	1,500	33	100	5/2003	9/2003	20	20	100
Station CW01												
Fecal coliform bacteria	<10	60	200	800	9,000	200	47.4	5/2003	9/2003	19	18	94.7
Escherichia coli. bacteria	<10	30	63	223	689	126	42.1	5/2003	9/2003	19	18	94.7
Enterococcus bacteria	90	200	300	700	4,000	33	100	5/2003	9/2003	19	19	100
Station NC07												
Fecal coliform bacteria	90	345	685	2,250	14,000	200	80.0	5/2003	9/2003	20	20	100
Escherichia coli. bacteria	<10	31	201	268	3,076	126	55.0	5/2003	9/2003	20	18	90.0
Enterococcus bacteria	<10	300	850	2,200	16,000	33	95.0	5/2003	9/2003	20	19	95.0
Station NC06												
Fecal coliform bacteria	<10	120	355	1,500	6,000	200	55.0	5/2003	9/2003	20	19	95.0
Escherichia coli. bacteria	<10	15	41	127	1,935	126	25.0	5/2003	9/2003	20	18	90.0
Enterococcus bacteria	60	350	2,900	41,500	312,000	33	100	5/2003	9/2003	20	20	100
Station OC01												
Fecal coliform bacteria	<10	16	150	400	2,100	200	31.6	6/2003	9/2003	19	15	78.9
Escherichia coli. bacteria	<10	52	96	216	4,611	126	26.3	6/2003	9/2003	19	16	84.2
Enterococcus bacteria	<10	7	40	60	400	33	52.6	6/2003	9/2003	19	12	63.2

Appendix 4. Summary statistics of surface-water-quality data collected by the Kickapoo Tribe of Oklahoma in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 2009 through 2011.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; L, liter; all constituents analyzed in unfiltered samples]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples
Station "NCR2"								
Dissolved oxygen concentration, in mg/L	7.47	9.10	10.0	11.4	16.5	7/2009	7/2011	22
pH (field), in standard units	7.60	7.94	8.09	8.24	8.57	7/2009	7/2011	22
Specific conductance, in µS/cm at 25 degrees Celsius	395	920	1,040	1,160	1,390	7/2009	7/2011	23
Water temperature, in degrees Celsius	9.0	13.0	21.7	25.6	30.4	7/2009	7/2011	23
Turbidity, in nephelometric turbidity units	7.40	13.2	33	63.4	259	8/2009	7/2011	20
Dissolved solids, in mg/L	253	592	652	738	888	7/2009	7/2011	22
Ammonia, in mg/L as nitrogen	<0.1	<0.1	<0.1	<0.1	0.75	10/2010	7/2011	10
Ammonia plus organic nitrogen, in mg/L as nitrogen	<0.1	<0.1	<0.1	1	2.63	10/2010	7/2011	10
Nitrite plus nitrate as nitrogen, in mg/L	1.04	3.52	5	6	8.38	7/2009	7/2011	23
Phosphorus, in mg/L	0.38	0.56	1.00	2	3.15	7/2009	7/2011	23
Escherichia coli. bacteria, in colonies per 100 milliliters	<1	51	248	579	2,420	7/2009	6/2011	21
Station "NCR1"								
Dissolved oxygen concentration, in mg/L	7.45	8.20	9.14	11.2	20.3	7/2009	7/2011	22
pH (field), in standard units	7.51	7.74	7.88	8.16	8.40	7/2009	7/2011	22
Specific conductance, in µS/cm at 25 degrees Celsius	425	933	1,020	1,140	1,270	7/2009	7/2011	21
Water temperature, in degrees Celsius	10.1	17.8	22.4	26.4	28.2	7/2009	7/2011	21
Turbidity, in nephelometric turbidity units	5.80	9.51	20.0	66.4	241	8/2009	7/2011	16
Dissolved solids, in mg/L	272	597	654	718	768	7/2009	7/2011	18
Ammonia, in mg/L as nitrogen	<0.1	<0.1	<0.1	<0.1	0.95	10/2010	7/2011	10
Ammonia plus organic nitrogen, in mg/L as nitrogen	<0.1	<0.1	<0.1	0.95	2.89	10/2010	7/2011	10
Nitrite plus nitrate as nitrogen, in mg/L	1.21	3.44	5.00	6.40	8.78	7/2009	7/2011	24
Phosphorus, in mg/L	0.40	0.69	1.22	1.55	3.15	7/2009	7/2011	24
Escherichia coli. bacteria, in colonies per 100 milliliters	<1	42	128	248	1,990	7/2009	7/2011	25
Station "NCR4"								
Dissolved oxygen concentration, in mg/L	7.40	9.62	11.0	12.7	18.4	7/2009	7/2011	22
Specific conductance, in µS/cm at 25 degrees Celsius	322	904	1,020	1,110	1,370	7/2009	7/2011	22
Water temperature, in degrees Celsius	3.2	12.4	20.1	28.2	31	7/2009	7/2011	23
Turbidity, in nephelometric turbidity units	19.4	25.5	58.4	120	901	8/2009	7/2011	20
Dissolved solids, in mg/L	206	579	644	696	878	7/2009	7/2011	22

Appendix 4. Summary statistics of surface-water-quality data collected by the Kickapoo Tribe of Oklahoma in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 2009 through 2011.—Continued

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; L, liter; all constituents analyzed in unfiltered samples]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples
Station "NCR4"—Continued								
Ammonia, in mg/L as nitrogen	<0.1	<0.1	<0.1	<0.1	1	10/2010	7/2011	10
Ammonia plus organic nitrogen, in mg/L as nitrogen	<0.1	<0.1	<0.1	2.42	3.05	10/2010	7/2011	10
Nitrite plus nitrate as nitrogen, in mg/L	0.76	2.32	3.66	4.67	6.15	7/2009	7/2011	24
Phosphorus, in mg/L	0.35	0.62	0.90	1.17	1.86	7/2009	7/2011	24
Escherichia coli. bacteria, in colonies per 100 milliliters	<1	21	115	260	921	7/2009	3/2011	20
Station "NCR5"								
Dissolved oxygen concentration, in mg/L	7.05	9.80	10.8	12.2	18.3	7/2009	7/2011	22
Specific conductance, in µS/cm at 25 degrees Celsius	305	888	1,010	1,140	1,340	7/2009	7/2011	22
Water temperature, in degrees Celsius	4.2	10.6	19.3	25.7	32.1	7/2009	7/2011	22
Turbidity, in nephelometric turbidity units	17.8	28.8	50.8	106	621	9/2009	7/2011	20
Dissolved solids, in mg/L	81.2	542	632	702	785	9/2009	7/2011	19
Ammonia, in mg/L as nitrogen	<0.1	<0.1	<0.1	<0.1	<0.1	10/2010	7/2011	11
Ammonia plus organic nitrogen, in mg/L as nitrogen	<0.1	<0.1	<0.1	2.54	4.03	10/2010	7/2011	11
Nitrite plus nitrate as nitrogen, in mg/L	0.60	2.57	3.28	4.28	5.90	7/2009	7/2011	24
Phosphorus, in mg/L	0.36	0.70	0.98	1.16	1.74	7/2009	7/2011	24
Escherichia coli. bacteria, in colonies per 100 milliliters	<1	13	45	131	579	7/2009	3/2011	19
Station "NCR7"								
Dissolved oxygen concentration, in mg/L	6.93	9.17	11.0	12.5	18.0	11/2009	7/2011	18
Specific conductance, in µS/cm at 25 degrees Celsius	274	826	1,040	1,110	1,260	11/2009	7/2011	20
Water temperature, in degrees Celsius	5.3	9.3	15.4	25.4	32.5	11/2009	7/2011	20
Turbidity, in nephelometric turbidity units	21.9	29.8	43.0	146	990	11/2009	7/2011	18
Dissolved solids, in mg/L	176	526	645	708	810	11/2009	7/2011	19
Ammonia, in mg/L as nitrogen	<0.1	<0.1	<0.1	<0.1	<0.1	10/2010	7/2011	11
Ammonia plus organic nitrogen, in mg/L as nitrogen	<0.1	<0.1	<0.1	2.58	2.77	10/2010	7/2011	10
Nitrite plus nitrate as nitrogen, in mg/L	<0.2	1.61	2.74	3.78	7.44	11/2009	7/2011	20
Phosphorus, in mg/L	0.33	0.51	0.68	0.91	1.40	11/2009	7/2011	20
Escherichia coli. bacteria, in colonies per 100 milliliters	<1	7	25	117	613	11/2009	3/2011	17

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-01														
Dissolved oxygen, in mg/L	5.22	7.81	9.36	11.4	20.3	NA	NA	NA	NA	2/1999	9/2005	60	60	100
pH, in standard units	6.82	7.82	8.10	8.46	9.60	NA	NA	NA	NA	2/1999	9/2005	60	60	100
Specific conductance, in µS/cm at 25 degrees Celsius	153	761	997	1,190	1,390	NA	NA	NA	NA	11/1998	9/2005	60	60	100
Water temperature, in degrees Celsius	1.3	12.9	19.7	28.0	34.3	NA	NA	NA	NA	11/1998	9/2005	60	60	100
Turbidity, in nephelometric turbidity units	6.0	21.2	46.0	89.0	1,000	NA	NA	NA	NA	11/1998	9/2005	59	59	100
Dissolved solids, in mg/L	98.0	472	583	680	892	NA	NA	NA	NA	11/1998	9/2005	60	60	100
Suspended solids, in mg/L	5.0	60.5	121	317	1,520	NA	NA	NA	NA	11/1998	12/2000	19	19	100
Hardness, in mg/L as calcium carbonate	1.92	221	275	343	3,950	NA	NA	NA	NA	2/1999	9/2005	60	60	100
Alkalinity, in mg/L as calcium carbonate	82.0	134	164	196	262	NA	NA	NA	NA	11/1998	9/2005	60	60	100
Chloride, in mg/L	21.5	106	140	162	290	230	1.61	NA	NA	11/1998	9/2005	62	62	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-01—Continued														
Sulfate, in mg/L	119	276	397	519	3,890	NA	NA	NA	NA	11/1998	9/2005	62	62	100
Ammonia, in mg/L as nitrogen	<0.05	<0.05	0.10	0.18	1.71	NA	NA	NA	NA	2/1999	9/2005	56	39	69.6
Ammonia plus organic nitrogen, in mg/L	0.50	1.19	1.43	1.82	3.10	NA	NA	NA	NA	2/1999	9/2005	61	61	100
Nitrite, in mg/L as nitrogen	<0.05	0.06	0.09	0.12	0.45	NA	NA	NA	NA	11/1998	2/2005	57	45	78.9
Nitrate, in mg/L as nitrogen	<0.05	0.80	1.67	3.03	6.66	NA	NA	NA	NA	11/1998	2/2005	57	56	98.2
Phosphate, in mg/L as phosphorus	0.063	0.305	0.447	0.834	1.90	NA	NA	NA	NA	11/1998	9/2005	61	61	100
Phosphorus, in mg/L	0.28	0.52	0.80	1.18	2.12	NA	NA	NA	NA	11/1998	9/2005	61	61	100
Arsenic, in µg/L	<10	<10	<10	<10	26	150	0.0	NA	NA	5/1999	9/2004	14	13	92.9
Chromium, in µg/L	<5	<5	<5	<5	124	11	13.3	NA	NA	5/1999	9/2004	15	3	20.0
Copper, in µg/L	<5	<5	<5	<10	54	9	7.14	NA	NA	5/1999	9/2004	14	3	21.4
Lead, in µg/L	<10	<10	<10	<10	80	$e^{\{1.273[\ln(hardness)]-4.705\}}$ (1.46203-[(ln hardness (1.45712)]	7.14	NA	NA	5/1999	9/2004	14	4	28.6

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-01—Continued														
Mercury, in µg/L	<0.5	<0.5	<0.5	<0.5	1	77	0.0	NA	NA	5/1999	9/2004	15	1	6.67
Nickel, in µg/L	<25	<25	<25	<25	73	$e^{(0.8460*(\ln(hardness))-0.0584)}$ (0.997)	20.0	NA	NA	5/1999	9/2004	10	4	40.0
Selenium, in µg/L	<5	<5	<5	<5	<5	5	0.0	NA	NA	5/1999	9/2004	10	0	0.0
Silver, in µg/L	<10	<10	<10	<10	<10	3.2	0.0	NA	NA	5/1999	9/2004	10	0	0.0
Thallium, in µg/L	<10	<10	<10	<10	<10	NA	NA	NA	NA	5/1999	9/2004	10	2	20.0
Zinc, in µg/L	<5	14	21	37	212	$e^{(0.8473*(\ln(hardness))-0.884)}$ (0.986)	7.14	NA	NA	5/1999	2/2005	14	1	7.14
Fecal coliform bacteria	<10	100	200	600	5,000	NA	NA	200	47.6	6/2001	6/2004	21	20	95.0
Escherichia coli. bacteria	<10	<10	36	200	355	NA	NA	126	30.0	6/2001	6/2004	20	12	60.0
Enterococcus bacteria	40	100	300	850	12,000	NA	NA	33	100	6/2001	6/2004	20	20	100
Station 520510000110-02														
Dissolved oxygen, in mg/L	5.99	9.50	11.8	12.2	16.0	NA	NA	NA	NA	10/2000	2/2002	10	10	100
pH, in standard units	7.82	7.96	8.16	8.46	8.83	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Specific conductance, in µS/cm at 25 degrees Celsius	199	829	1,010	1,110	1,280	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Water temperature, in degrees Celsius	3.5	9.9	19.0	27.1	34.0	NA	NA	NA	NA	10/2000	2/2002	10	10	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-02—Continued														
Turbidity, in nephelometric turbidity units	38.0	110	162	342	1,000	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Dissolved solids, in mg/L	127	532	648	715	816	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Suspended solids, in mg/L	10	372	735	1,100	1,460	NA	NA	NA	NA	10/2000	12/2000	2	2	100
Hardness, in mg/L as calcium carbonate	92.0	204	303	336	3,320	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Alkalinity, in mg/L as calcium carbonate	80.0	163	188	220	260	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Chloride, in mg/L	21.6	103	126	146	158	230	0.0	NA	NA	10/2000	2/2002	10	10	100
Sulfate, in mg/L	213	303	406	471	518	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Ammonia, in mg/L as nitrogen	<0.05	<0.05	0.10	0.19	0.27	NA	NA	NA	NA	10/2000	2/2002	8	5	62.5
Ammonia plus organic nitrogen, in mg/L	1.03	1.14	1.42	1.87	2.70	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Nitrite, in mg/L as nitrogen	<0.05	0.06	0.08	0.14	0.27	NA	NA	NA	NA	10/2000	2/2002	9	8	88.9
Nitrate, in mg/L as nitrogen	<0.05	0.64	0.65	1.23	1.76	NA	NA	NA	NA	10/2000	2/2002	9	0	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-02—Continued														
Phosphate, in mg/L as phosphorus	0.100	0.210	0.270	0.396	0.501	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Phosphorus, in mg/L	0.426	0.452	0.472	0.580	1.30	NA	NA	NA	NA	10/2000	2/2002	10	10	100
Arsenic, in µg/L	<10	<10	<10	13	22	150	0.0	NA	NA	10/2000	8/2001	5	2	40.0
Chromium, in µg/L	<5	7.0	10	12	102	11	40.0	NA	NA	10/2000	8/2001	5	4	80.0
Copper, in µg/L	<5	6.0	8.0	13	46	9	40.0	NA	NA	10/2000	8/2001	5	4	80.0
Lead, in µg/L	10	10	10	15	43	$e^{\{1.273[\ln(hardness)]-4.705\}}$ (1.46203-[(ln hardness) (1.45712)]	80.0	NA	NA	10/2000	8/2001	5	4	80.0
Mercury, in µg/L	<0.05	<0.05	<0.05	<0.05	1.0	77	0.0	NA	NA	10/2000	8/2001	5	1	20.0
Nickel, in µg/L	10	10	13	15	66	$e^{(0.8460*(\ln(hardness))-0.0584)}$ (0.997)	20.0	NA	NA	10/2000	8/2001	5	5	100
Selenium, in µg/L	<10	<10	<10	<10	<10	5	0.0	NA	NA	10/2000	8/2001	5	0	0.0
Silver, in µg/L	<5	<5	<5	<5	<5	3.2	0.0	NA	NA	10/2000	8/2001	5	0	0.0
Thallium, in µg/L	<10	<10	<10	<10	<10	NA	NA	NA	NA	10/2000	8/2001	5	0	0.0
Zinc, in µg/L	10	21	34	47	156	$e^{(0.8473*(\ln(hardness))-0.884)}$ (0.986)	40.0	NA	NA	10/2000	8/2001	5	5	100
Fecal coliform bacteria	<10	58	200	300	300			200	47.4	6/2001	2/2002	4	3	75.0

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-02—Continued														
Escherichia coli. bacteria	<10	<10	<10	<10	183			126	42.1	6/2001	8/2001	3	1	33.0
Enterococcus bacteria	100	100	100	1,050	2,000			33	100	6/2001	8/2001	3	3	100
Station 520510000110-03														
Dissolved oxygen, in mg/L	6.91	8.35	8.90	10.1	12.3	NA	NA	NA	NA	3/2002	9/2003	9	9	100
pH, in standard units	6.63	7.67	7.89	8.58	9.16	NA	NA	NA	NA	3/2002	1/2003	7	7	100
Specific conductance, in µS/cm at 25 degrees Celsius	435	658	744	928	986	NA	NA	NA	NA	3/2002	1/2003	7	7	100
Water temperature, in degrees Celsius	5.0	12.6	14.1	21.6	26	NA	NA	NA	NA	3/2002	1/2003	7	7	100
Turbidity, in nephelometric turbidity units	33.0	54.0	58.0	87.0	1,000	NA	NA	NA	NA	3/2002	1/2003	7	7	100
Dissolved solids, in mg/L	278	439	518	594	639	NA	NA	NA	NA	3/2002	9/2003	8	8	100
Hardness, in mg/L as calcium carbonate	154	166	204	258	325	NA	NA	NA	NA	3/2002	9/2003	8	8	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
						Station 520510000110-03—Continued								
Alkalinity, in mg/L as calcium carbonate	103	110	132	147	154	NA	NA	NA	NA	3/2002	9/2003	8	8	100
Ammonia, in mg/L as nitrogen	<0.05	<0.05	<0.05	0.49	0.55	NA	NA	NA	NA	3/2002	9/2003	7	3	42.8
Ammonia plus organic nitrogen, in mg/L	0.42	0.95	2.26	2.94	3.73	NA	NA	NA	NA	3/2002	9/2003	7	7	100
Nitrite, in mg/L as nitrogen	<0.05	<0.05	0.08	0.08	0.32	NA	NA	NA	NA	3/2002	9/2003	7	5	71.4
Nitrate, in mg/L as nitrogen	<0.05	0.59	0.92	1.72	2.63	NA	NA	NA	NA	3/2002	9/2003	7	6	85.7
Phosphate, in mg/L as phosphorus	0.029	0.302	0.507	0.934	0.975	NA	NA	NA	NA	3/2002	9/2003	7	7	100
Phosphorus, in mg/L	0.437	0.692	0.910	1.18	1.47	NA	NA	NA	NA	3/2002	9/2003	7	7	100
Fecal coliform bacteria	30	75	200	350	1,000	NA	NA	200	42.9	8/2002	9/2003	7	7	100
Escherichia coli. bacteria	<10	<10	20	85	98	NA	NA	126	0	8/2002	9/2003	7	4	57.1
Enterococcus bacteria	100	150	200	250	1,400	NA	NA	33	100	8/2002	9/2003	7	7	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-04														
Dissolved oxygen, in mg/L	5.82	7.98	9.05	10.7	11.7	NA	NA	NA	NA	3/2002	9/2003	10	10	100
pH, in standard units	6.80	7.65	8.16	8.47	9.10	NA	NA	NA	NA	3/2002	9/2003	10	10	100
Specific conductance, in µS/cm at 25 degrees Celsius	350	600	780	939	983	NA	NA	NA	NA	3/2002	9/2003	10	10	100
Water temperature, in degrees Celsius	5.0	12.6	17.2	24.3	27.3	NA	NA	NA	NA	3/2002	9/2003	10	10	100
Turbidity, in nephelometric turbidity units	23.0	41.8	48.0	85.0	1,000	NA	NA	NA	NA	3/2002	9/2003	10	10	100
Dissolved solids, in mg/L	224	384	506	593	621	NA	NA	NA	NA	3/2002	9/2003	10	10	100
Hardness, in mg/L as calcium carbonate	140	153	167	214	300	NA	NA	NA	NA	3/2002	9/2003	10	10	100
Alkalinity, in mg/L as calcium carbonate	104	116	130	152	149	NA	NA	NA	NA	3/2002	9/2003	10	10	100
Ammonia, in mg/L as nitrogen	<0.05	<0.05	0.20	0.38	0.40	NA	NA	NA	NA	3/2002	9/2003	8	4	50.0

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-04—Continued														
Ammonia plus organic nitrogen, in mg/L	0.42	1.04	2.22	3.31	3.66	NA	NA	NA	NA	3/2002	9/2003	8	8	100
Nitrite, in mg/L as nitrogen	<0.05	0.06	0.08	0.26	0.28	NA	NA	NA	NA	3/2002	9/2003	7	6	85.7
Nitrate, in mg/L as nitrogen	0.29	0.68	1.32	2.18	2.62	NA	NA	NA	NA	3/2002	9/2003	7	7	100
Phosphate, in mg/L as phosphorus	0.065	0.416	0.774	0.939	1.27	NA	NA	NA	NA	3/2002	9/2003	8	8	100
Phosphorus, in mg/L	0.458	0.859	0.962	1.26	1.37	NA	NA	NA	NA	3/2002	9/2003	8	8	100
Mercury, in µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	NA	NA	NA	NA	4/2002	4/2002	1	0	0.0
Fecal coliform bacteria	<10	90	300	400	500	NA	NA	200	57.1	8/2002	9/2003	7	6	85.7
Escherichia coli. bacteria	<10	20	41	146	148	NA	NA	126	28.6	8/2002	9/2003	7	6	85.7
Enterococcus bacteria	70	105	170	3,100	8,000	NA	NA	33	100	8/2002	9/2003	7	7	100
Station 520510000110-05														
Dissolved oxygen, in mg/L	2.64	7.68	9.67	12.4	25.0	NA	NA	NA	NA	1/2002	9/2005	35	35	100
pH, in standard units	5.87	7.88	8.10	8.50	9.98	NA	NA	NA	NA	1/2002	9/2005	34	34	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-05—Continued														
Specific conductance, in µS/cm at 25 degrees Celsius	314	667	809	968	1,309	NA	NA	NA	NA	1/2002	9/2005	34	34	100
Water temperature, in degrees Celsius	0.0	10.6	17.0	25.6	34.4	NA	NA	NA	NA	1/2002	9/2005	35	35	100
Turbidity, in nephelometric turbidity units	15.0	32.3	54.0	116	1,000	NA	NA	NA	NA	1/2002	9/2005	35	35	100
Dissolved solids, in mg/L	201	427	527	616	888	NA	NA	NA	NA	1/2002	9/2005	35	35	100
Hardness, in mg/L as calcium carbonate	146	216	260	308	449	NA	NA	NA	NA	1/2002	9/2005	34	34	100
Alkalinity, in mg/L as calcium carbonate	109	138	157	187	244	NA	NA	NA	NA	1/2002	9/2005	33	33	100
Chloride, in mg/L	22.6	98.7	123	135	171	NA	NA	NA	NA	2/2002	9/2005	33	33	100
Sulfate, in mg/L	166	232	341	482	4,610	NA	NA	NA	NA	2/2002	9/2005	33	33	100
Ammonia, in mg/L as nitrogen	<0.05	<0.05	0.09	0.20	0.81	NA	NA	NA	NA	1/2002	9/2005	35	28	80.0
Ammonia plus organic nitrogen, in mg/L	0.59	1.39	1.82	2.50	4.86	NA	NA	NA	NA	1/2002	9/2005	35	35	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-05—Continued														
Nitrite, in mg/L as nitrogen	<0.05	<0.05	0.07	0.11	0.22	NA	NA	NA	NA	1/2002	2/2005	30	19	63.3
Nitrate, in mg/L as nitrogen	0.28	0.75	1.67	3.29	6.25	NA	NA	NA	NA	1/2002	2/2005	30	30	100
Phosphate, in mg/L as phosphorus	0.103	0.245	0.360	0.602	1.36	NA	NA	NA	NA	1/2002	9/2005	35	35	100
Phosphorus, in mg/L	0.362	0.538	0.725	0.868	1.70	NA	NA	NA	NA	1/2002	9/2005	35	35	100
Arsenic, in µg/L	<10	<10	<10	<10	<10	150	0.0	NA	NA	4/2002	9/2004	4	0	0.0
Chromium, in µg/L	<5	<5	<5	13	24	11	50.0	NA	NA	4/2002	9/2004	4	2	50.0
Copper, in µg/L	<5	<5	<5	14	18	9	50.0	NA	NA	4/2002	9/2004	4	2	50.0
Lead, in µg/L	<5	<5	<5	13	28	$e^{\{1.273[\ln(hardness)]-4.705\}}$ (1.46203-[(ln hardness)(1.45712)])	25.0	NA	NA	4/2002	9/2004	4	2	50.0
Mercury, in µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	77	0.0	NA	NA	4/2002	9/2004	4	0	0.0
Nickel, in µg/L	7	7	10	15	21	$e^{(0.8460*(\ln(hardness))-0.0584)}$ (0.997)	0.0	NA	NA	4/2002	9/2004	4	4	100
Selenium, in µg/L	<5	<5	<5	<5	<5	5	0.0	NA	NA	4/2002	9/2004	4	0	0.0
Silver, in µg/L	<2	<2	<2	<2	<2	3.2	0.0	NA	NA	4/2002	9/2004	4	0	0.0
Thallium, in µg/L	<5	<5	<5	6	9	NA	0.0	NA	NA	4/2002	9/2004	4	0	0.0

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

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Station 520510000110-05—Continued														
Zinc, in µg/L	10	14	30	52	70	$e^{(0.8473*(\ln(\text{hardness}))-0.884)}$ (0.986)	25.0	NA	NA	4/2002	9/2004	4	4	100
Fecal coliform bacteria	20	110	370	700	6,000	NA	NA	200	53.8	1/2002	6/2004	13	13	100
Escherichia coli. bacteria	<10	20	52	175	298	NA	NA	126	27.3	8/2002	6/2004	11	9	81.8
Enterococcus bacteria	<10	20	200	900	5,000	NA	NA	33	72.7	8/2002	6/2004	11	8	72.7
Station 520510000110-06														
Dissolved oxygen, in mg/L	6.36	6.86	8.65	9.41	11.2	NA	NA	NA	NA	3/2002	9/2003	9	9	100
pH, in standard units	6.71	7.61	7.86	8.79	9.15	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Specific conductance, in µS/cm at 25 degrees Celsius	477	722	847	900	1,010	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Water temperature, in degrees Celsius	5.1	12.0	16.5	22.2	25.0	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Turbidity, in nephelometric turbidity units	38.0	55.0	83.0	100	1,000	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Dissolved solids, in mg/L	305	462	543	598	647	NA	NA	NA	NA	3/2002	9/2003	9	9	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-06—Continued														
Hardness, in mg/L as calcium carbonate	166	204	211	248	316	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Alkalinity, in mg/L as calcium carbonate	104	115	133	146	240	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Ammonia, in mg/L as nitrogen	<0.05	<0.05	<0.05	0.15	0.45	NA	NA	NA	NA	3/2002	9/2003	9	4	44.4
Ammonia plus organic nitrogen, in mg/L	0.43	0.89	1.15	2.70	4	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Nitrite, in mg/L as nitrogen	<0.05	<0.05	<0.05	0.10	0.37	NA	NA	NA	NA	3/2002	9/2003	9	4	44.4
Nitrate, in mg/L as nitrogen	<0.05	0.36	0.93	1.57	3	NA	NA	NA	NA	3/2002	9/2003	9	8	88.9
Phosphate, in mg/L as phosphorus	0.025	0.213	0.378	0.547	0.931	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Phosphorus, in mg/L	0.359	0.401	0.710	0.930	1.55	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Fecal coliform bacteria	40	72	115	200	300	NA	NA	200	12.5	8/2002	9/2003	8	8	100
Escherichia coli. bacteria	<10	<10	<10	20	63	NA	NA	126	0	8/2002	9/2003	8	3	37.5
Enterococcus bacteria	70	175	250	725	1,000	NA	NA	33	100	8/2002	9/2003	8	8	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 52050000110-07														
Dissolved oxygen, in mg/L	5.84	7.61	8.76	9.52	13.9	NA	NA	NA	NA	3/2002	9/2003	9	9	100
pH, in standard units	6.69	7.65	7.77	8.24	8.97	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Specific conductance, in µS/cm at 25 degrees Celsius	477	722	847	900	1,010	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Water temperature, in degrees Celsius	5.1	12.0	16.5	22.2	25.0	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Turbidity, in nephelometric turbidity units	38.0	55.0	83.0	100	1,000	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Dissolved solids, in mg/L	305	462	543	598	647	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Hardness, in mg/L as calcium carbonate	166	204	211	248	316	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Alkalinity, in mg/L as calcium carbonate	104	115	133	146	240	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Ammonia, in mg/L as nitrogen	<0.05	<0.05	<0.05	0.15	0	NA	NA	NA	NA	3/2002	9/2003	9	4	44.4

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 52050000110-07—Continued														
Ammonia plus organic nitrogen, in mg/L	0.43	0.89	1.15	2.70	3.97	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Nitrite, in mg/L as nitrogen	<0.05	<0.05	<0.05	0.10	0.37	NA	NA	NA	NA	3/2002	9/2003	9	4	44.4
Nitrate, in mg/L as nitrogen	<0.05	0.36	0.93	1.57	2.72	NA	NA	NA	NA	3/2002	9/2003	9	8	88.9
Phosphate, in mg/L as phosphorus	0.025	0.213	0.378	0.547	0.93	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Phosphorus, in mg/L	0.359	0.401	0.710	0.930	1.55	NA	NA	NA	NA	3/2002	9/2003	9	9	100
Fecal coliform bacteria	40	72	115	200	300	NA	NA	200	12.5	8/2002	9/2003	8	8	100
Escherichia coli. bacteria	<10	<10	<10	20	63	NA	NA	126	0	8/2002	9/2003	8	3	37.5
Enterococcus bacteria	70	175	250	725	1,000	NA	NA	33	100	8/2002	9/2003	8	8	100
Station 520510000110-1S														
Dissolved oxygen, in mg/L	4.28	5.54	6.81	6.87	6.93	NA	NA	NA	NA	7/2001	2/2002	3	3	100
pH, in standard units	8.68	8.71	8.74	8.76	8.79	NA	NA	NA	NA	7/2001	8/2001	2	2	100
Specific conductance, in µS/cm at 25 degrees Celsius	785	885	985	989	993	NA	NA	NA	NA	7/2001	2/2002	3	3	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520510000110-1S—Continued														
Water temperature, in degrees Celsius	3.30	17.2	31.2	31.5	31.8	NA	NA	NA	NA	7/2001	2/2002	3	3	100
Turbidity, in nephelometric turbidity units	23	35.8	51.5	80.0	131	NA	NA	NA	NA	7/2001	2/2002	4	4	100
Dissolved solids, in mg/L	503	566	630	635	641	NA	NA	NA	NA	7/2001	2/2002	3	3	100
Hardness, in mg/L as calcium carbonate	211	219	227	298	370	NA	NA	NA	NA	7/2001	2/2002	3	3	100
Alkalinity, in mg/L as calcium carbonate	111	152	193	196	200	NA	NA	NA	NA	7/2001	9/2001	3	3	100
Ammonia, in mg/L as nitrogen	<0.05	<0.05	<0.05	<0.05	0.38	NA	NA	NA	NA	7/2001	2/2002	4	1	25.0
Ammonia plus organic nitrogen, in mg/L	0.47	1.12	1.76	2.26	2.53	NA	NA	NA	NA	7/2001	2/2002	4	4	100
Nitrite, in mg/L as nitrogen	<0.05	<0.05	0.06	0.09	0.12	NA	NA	NA	NA	7/2001	2/2002	4	3	75.0
Nitrate, in mg/L as nitrogen	<0.05	<0.05	<0.05	<0.05	1.15	NA	NA	NA	NA	7/2001	2/2002	4	1	25.0
Phosphate, in mg/L as phosphorus	0.068	0.090	0.127	0.224	0.427	NA	NA	NA	NA	7/2001	2/2002	4	4	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
						Station 520510000110-1S—Continued								
Phosphorus, in mg/L	0.101	0.298	0.450	0.548	0.58	NA	NA	NA	NA	7/2001	2/2002	4	4	100
Fecal coliform bacteria	<10	58	150	400	600	NA	NA	200	25.0	7/2001	2/2002	4	3	75.0
Escherichia coli. bacteria	<10	<10	<10	<10	<10	NA	NA	126	0	7/2001	9/2001	3	0	0
Enterococcus bacteria	<10	<10	110	135	160	NA	NA	33	66.6	7/2001	9/2001	3	2	66.7
						Station 520800030070-01								
Dissolved solids, in mg/L	692	1,440	2,520	2,900	6,250	NA	NA	NA	NA	8/2000	2/2001	16	16	100
Barium, in mg/L	0.33	0.43	0.68	0.78	2.3	NA	NA	NA	NA	8/2000	2/2001	15	15	100
Calcium, in mg/L	58	109	118	158	172	NA	NA	NA	NA	8/2000	2/2001	16	16	100
Sodium, in mg/L	167	366	666	744	1,220	NA	NA	NA	NA	8/2000	2/2001	16	16	100
Chloride, in mg/L	306	821	1,560	1,890	2,870	230	100	NA	NA	8/2000	2/2001	16	16	100
Sulfate, in mg/L	30.2	48.0	53.1	66.5	78.1	NA	NA	NA	NA	8/2000	2/2001	16	16	100
						Station 520800030080-01								
Dissolved solids, in mg/L	1,800	2,020	2,620	2,820	3,990	NA	NA	NA	NA	8/2000	2/2001	5	5	100
Barium, in mg/L	0.56	0.72	0.78	1.20	2.39	NA	NA	NA	NA	8/2000	2/2001	4	4	100
Calcium, in mg/L	109	111	113	123	165	NA	NA	NA	NA	8/2000	2/2001	5	5	100
Sodium, in mg/L	488	565	691	718	1,220	NA	NA	NA	NA	8/2000	2/2001	5	5	100
Chloride, in mg/L	941	1,120	1,630	2,290	2,430	230	100	NA	NA	8/2000	2/2001	5	5	100
Sulfate, in mg/L	48.2	50.6	52.4	53.6	78.1	NA	NA	NA	NA	8/2000	2/2001	5	5	100

Appendix 5. Summary statistics of surface-water-quality data collected by the Oklahoma Water Resources Board in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1998 through 2005.—Continued

[mg/L, milligrams per liter, µg/L, micrograms per liter, µS/cm, microsiemens per centimeter; <, less than; NA, not applicable; Adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values; highest level of minimum reporting limits used for summary statistics, e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a), Primary contact standards from State of Oklahoma (2007), note that those standards are based on the geometric mean of at least 5 samples collected within 30-day periods, a sampling frequency not obtained for these samples; bacteria counts in colony-forming units per 100 milliliters, all constituents analyzed in unfiltered samples unless noted as dissolved, Oklahoma primary-contact standards from State of Oklahoma (2007)]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	CCC	Percent of samples in which measurement exceeded CCC	Primary Body Contact Recreation Standard	Percent of samples exceeding Primary Body Contact Recreation Standard	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Station 520800030120-01														
Dissolved solids, in mg/L	1,260	1,440	2,430	2,960	6,250	NA	NA	NA	NA	8/2000	2/2001	7	7	100
Barium, in mg/L	0.37	0.40	0.64	0.71	0.90	NA	NA	NA	NA	8/2000	2/2001	7	7	100
Calcium, in mg/L	101	110	148	159	172	NA	NA	NA	NA	8/2000	2/2001	7	7	100
Sodium, in mg/L	345	362	719	765	814	NA	NA	NA	NA	8/2000	2/2001	7	7	100
Chloride, in mg/L	571	798	1,520	1,680	2,870	230	100	NA	NA	8/2000	2/2001	7	7	100
Sulfate, in mg/L	47.1	50.0	59.0	63.3	74.5	NA	NA	NA	NA	8/2000	2/2001	7	7	100

Appendix 6. Summary statistics of surface-water-quality data collected by the Oklahoma Corporation Commission in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1999 through 2002.

[mg/L, milligrams per liter; L, liter; µS/cm, microsiemens per centimeter; <, less than; µg/L, micrograms per liter; all constituents analyzed in unfiltered samples]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples
Blacksmith Creek								
Dissolved solids, in mg/L	1,740	1,810	2,790	3,230	3,840	8/2000	2/2001	7
Calcium, in mg/L	101	110	148	159	172	8/2000	2/2001	7
Sodium, in mg/L	345	362	719	765	814	8/2000	2/2001	7
Chloride, in mg/L	571	798	1,524	1,680	2,870	8/2000	2/2001	7
Sulfate, in mg/L	15.7	16.7	20	21	25	8/2000	2/2001	7
Chromium, in µg/L	371	398	636	712	900	8/2000	2/2001	7
Blacksmith Creek tributary								
Calcium, in mg/L	27.0	118	291	484	3,680	4/2000	10/2000	7
Magnesium, in mg/L	13.0	39.0	94.0	124	809	4/2000	10/2000	7
Potassium, in mg/L	5.00	13.5	53.0	71.5	588	4/2000	10/2000	7
Sodium, in mg/L	88.0	623	2,190	2,740	19,000	4/2000	10/2000	7
Bromide, in mg/L	495.0	4,200	13,300	17,300	98,600	4/2000	10/2000	7
Chloride, in mg/L	144	1,200	2,970	5,160	39,800	4/2000	10/2000	7
Sulfate, in mg/L	6.00	8.50	10.0	30.0	79.0	4/2000	10/2000	7
Nitrate as nitrogen, in mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	4/2000	5/2000	6
Bruno Creek								
Dissolved solids, in mg/L	1,400	1,620	1,850	1,850	1,850	2/1999	12/2001	3
Calcium, in mg/L	107	118	130	142	153	2/1999	12/2001	2
Magnesium, in mg/L	77.0	77.7	78.5	79.2	80	2/1999	12/2001	2
Potassium, in mg/L	6.00	7.25	8.50	9.75	11.0	2/1999	12/2001	2
Sodium, in mg/L	630	634	638	642	646	2/1999	12/2001	2
Bromide, in mg/L	4,010	4,010	4,010	4,010	4,010	12/2001	12/2001	1
Chloride, in mg/L	1,090	1,130	1,180	1,220	1,260	2/1999	12/2001	2
Sulfate, in mg/L	28.0	29.5	31.0	32.5	34.0	2/1999	12/2001	2
Nitrite plus nitrate as nitrogen, in mg/L	<1.00	<1.00	<1.00	1.00	1.00	2/1999	12/2012	2
Canadian River at U.S. Highway 177								
Dissolved solids, in mg/L	290	510	523	640	995	5/1999	2/2000	9
Calcium, in mg/L	166	168	169	171	174	3/1999	6/1999	3
Magnesium, in mg/L	61.0	61.5	62.0	65.0	68.0	3/1999	6/1999	3

Appendix 6. Summary statistics of surface-water-quality data collected by the Oklahoma Corporation Commission in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1999 through 2002.—Continued

[mg/L, milligrams per liter; L, liter; µS/cm, microsiemens per centimeter; <, less than; µg/L, micrograms per liter; all constituents analyzed in unfiltered samples]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples
Canadian River at U.S. Highway 177—Continued								
Potassium, in mg/L	7.00	7.50	8.00	9.00	10.0	3/1999	6/1999	3
Sodium, in mg/L	116	122	129	130	132	3/1999	6/1999	3
Chloride, in mg/L	120	148	172	192	209	3/1999	1/2000	4
Sulfate, in mg/L	304	398	456	482	483	3/1999	1/2000	4
Chromium, in µg/L	268	280	291.00	328	366	3/1999	6/1999	3
Helsel Creek								
pH, in standard units	8.1	8.25	8.40	8.50	8.50	2/2002	1/2003	4
Specific conductance, in µS/cm at 25 degrees Celsius	599	606	611	620	630	2/2002	1/2003	4
Calcium, in mg/L	56.0	62.0	67.5	71.5	73.0	2/2002	1/2003	4
Magnesium, in mg/L	32.0	32.0	34.5	108	321	2/2002	1/2003	4
Potassium, in mg/L	1.00	1.00	1.00	1.00	1.00	2/2002	1/2003	4
Sodium, in mg/L	12.0	12.8	13.5	14.2	15.0	2/2002	1/2003	4
Chloride, in mg/L	10.0	10.8	11.5	12.2	13.0	2/2002	1/2003	4
Sulfate, in mg/L	9.00	10.5	13.0	16.2	20.0	2/2002	1/2003	4
Nitrite plus nitrate as nitrogen, in mg/L	<1.00	<1.00	<1.00	1.00	1.00	2/2002	1/2003	4
Boron, in mg/L	0.08	0.10	0.12	0.14	0.16	2/2002	1/2003	4
Pond Creek								
pH, in standard units	8.10	8.25	8.30	8.38	8.60	2/2002	1/2003	4
Specific conductance, in µS/cm at 25 degrees Celsius	594	599	606	624	666	2/2002	1/2003	4
Calcium, in mg/L	49.0	59.5	67.5	74.2	81.0	2/2002	1/2003	4
Magnesium, in mg/L	32.0	34.2	36.0	37.0	37.0	2/2002	1/2003	4
Potassium, in mg/L	1.0	1.0	1.5	2.0	2.0	2/2002	1/2003	4
Sodium, in mg/L	15.0	15.0	16.0	17.2	18.0	2/2002	1/2003	4
Chloride, in mg/L	14.0	14.8	16.5	19.0	22.0	2/2002	1/2003	4
Sulfate, in mg/L	11.0	11.8	13.5	22.5	45.0	2/2002	1/2003	4
Nitrite plus nitrate as nitrogen, in mg/L	<1.00	<1.00	1.00	1.00	1.00	2/2002	1/2003	4
Boron, in mg/L	0.09	0.10	0.12	0.16	0.20	2/2002	1/2003	4
Pond Creek tributary								
Dissolved solids, in mg/L	223	377	472	540	1,100	5/2000	7/2001	9

Appendix 6. Summary statistics of surface-water-quality data collected by the Oklahoma Corporation Commission in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1999 through 2002.—Continued

[mg/L, milligrams per liter; L, liter; µS/cm, microsiemens per centimeter; <, less than; µg/L, micrograms per liter; all constituents analyzed in unfiltered samples]

Constituent name	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples
Popshego Creek								
Dissolved solids, in mg/L	617	2,390	2,860	3,360	3,970	6/2000	2/2001	6
Calcium, in mg/L	109	111	113	123	165	8/2000	2/2001	5
Sodium, in mg/L	488	565	691	718	1,220	8/2000	2/2001	5
Chloride, in mg/L	941	1120	1,630	2,290	2,430	8/2000	2/2001	5
Sulfate, in mg/L	16.1	16.9	17.5	17.9	26.1	8/2000	2/2001	5
Salt Creek								
Calcium, in mg/L	82.0	92.5	109	124	129	2/1999	1/2000	4
Magnesium, in mg/L	42.0	53.2	61.5	66.5	68.0	2/1999	1/2000	4
Potassium, in mg/L	6.0	6.0	6.5	7.2	8.0	2/1999	1/2000	4
Sodium, in mg/L	155	304	362	371	372	2/1999	1/2000	4
Bromide, in mg/L	1,450	1,720	1,990	2,260	2,530	9/1999	1/2000	2
Chloride, in mg/L	299	546	674	722	729	2/1999	1/2000	4
Sulfate, in mg/L	40.0	55.8	62.5	68.5	82.0	2/1999	1/2000	4
Nitrite plus nitrate as nitrogen, in mg/L	<1.00	<1.00	<1.00	<1.00	<1.00	2/1999	1/2000	4
Wewoka Creek headwater tributary								
Calcium, in mg/L	8,840	9,000	9,160	9,310	9,470	9/2000	9/2000	2
Magnesium, in mg/L	2,120	2,160	2,200	2,250	2,290	9/2000	9/2000	2
Potassium, in mg/L	812	860	888	926	964	9/2000	9/2000	2
Sodium, in mg/L	51,500	53,000	54,500	56,000	57,500	9/2000	9/2000	2
Bromide, in mg/L	189,000	192,000	194,000	196,000	199,000	9/2000	9/2000	2
Chloride, in mg/L	114,000	118,000	121,000	124,000	128,000	9/2000	9/2000	2
Sulfate, in mg/L	511	515	518	522	526	9/2000	9/2000	2
Nitrite plus nitrate as nitrogen, in mg/L	<1.00	<1.00	<1.00	<1.00	<1.00	9/2000	9/2000	2

Appendix 7. Summary statistics of blank samples associated with surface-water-quality samples, by agency, collected in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1999 through 2011.

[µS/cm, microsiemens per centimeter, mg/L, milligrams per liter; µg/L, micrograms per liter; L, liter; mL, milliliter; <, less than; >, greater than; --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values, CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a); all constituents analyzed in unfiltered samples unless identified as "dissolved" or "filtered"]

Constituent name	Minimum value	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
U.S. Geological Survey							
pH (laboratory), in standard units	8.60	8.70	12/2005	11/2008	2	2	100
Specific conductance, in µS/cm at 25 degrees Celsius	6.00	7.00	12/2005	11/2008	2	2	100
Dissolved calcium, in mg/L	<0.02	0.17	12/2005	12/2008	3	2	66.6
Dissolved magnesium, in mg/L	<0.008	<0.012	12/2005	12/2008	3	1	33.3
Dissolved potassium, in mg/L	<0.06	<0.16	12/2005	12/2008	3	0	0
Dissolved sodium, in mg/L	<0.12	0.59	12/2005	12/2008	3	2	66.6
Dissolved chloride, in mg/L	<0.12	<0.20	12/2005	12/2008	3	0	0
Dissolved fluoride, in mg/L	<0.08	<0.10	12/2005	12/2008	3	0	0
Dissolved silica, in mg/L	0.02	2.30	12/2005	12/2008	3	3	100
Dissolved sulfate, in mg/L	<0.18	<0.18	12/2005	12/2008	3	0	0
Dissolved ammonia plus organic nitrogen, in mg/L as nitrogen	<0.02	<0.02	12/2008	12/2009	2	0	0
Ammonia plus organic nitrogen, in mg/L as nitrogen	<0.10	<0.10	12/2009	12/2009	1	0	0
Dissolved nitrate plus nitrite, in mg/L as nitrogen	<0.016	<0.016	12/2008	12/2009	2	0	0
Dissolved nitrite, in mg/L as nitrogen	<0.002	<0.002	12/2009	12/2009	1	0	0
Dissolved phosphorus, in mg/L	<0.006	<0.006	12/2009	12/2009	1	0	0
Phosphorus, in mg/L	<0.008	<0.008	12/2009	12/2009	1	0	0
Kickapoo Tribe of Oklahoma							
Ammonia, in mg/L as nitrogen	<0.1	<0.1	10/2010	7/2011	15	0	0
Ammonia plus organic nitrogen, in mg/L as nitrogen	<0.1	<0.1	10/2010	7/2011	15	0	0
Nitrate plus nitrite, in mg/L as nitrogen	<0.10	0.089	7/2009	7/2011	32	5	15.6
Phosphorus, in mg/L	<0.20	0.48	7/2009	7/2011	32	2	6
Escherichia coli. bacteria, in colonies per 100 mL	<1	<1	7/2009	7/2011	32	0	0
Oklahoma Water Resources Board							
Dissolved solids, in mg/L	<1	37	5/1999	3/2000	9	3	33.3
Hardness, in mg/L as calcium carbonate	<5	10	5/1999	3/2000	9	2	22.2
Chloride, in mg/L	<5	<10	5/1999	8/2005	31	0	0
Dissolved sulfate, in mg/L	<15	30	5/1999	8/2005	32	4	12.5

Appendix 7. Summary statistics of blank samples associated with surface-water-quality samples, by agency, collected in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1999 through 2011.—Continued

[µS/cm, microsiemens per centimeter, mg/L, milligrams per liter; µg/L, micrograms per liter; L, liter; mL, milliliter; <, less than; >, greater than; --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; adjusted maximum likelihood estimation used to estimate statistics for data sets with censored values, CCC, Criteria Continuous Concentration (U.S. Environmental Protection Agency, 2010a); all constituents analyzed in unfiltered samples unless identified as “dissolved” or “filtered”]

Constituent name	Minimum value	Maximum value	Date of first sample (month/year)	Date of last sample (month/year)	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements
Oklahoma Water Resources Board—Continued							
Ammonia, in mg/L as nitrogen	<0.05	<0.05	5/1999	8/2005	38	0	0
Ammonia plus organic nitrogen, in mg/L as nitrogen	<0.05	0.10	5/1999	9/2005	45	8	17.8
Nitrate, in mg/L as nitrogen	<0.05	0.22	5/1999	8/2004	33	2	6.1
Nitrite, in mg/L as nitrogen	<0.05	0.11	5/1999	8/2004	33	2	6.1
Phosphate, in mg/L as phosphorus	<0.005	0.016	5/1999	8/2005	32	2	6.3
Phosphorus, in mg/L	<0.005	0.023	5/1999	8/2005	46	4	8.7
Arsenic, in µg/L	<10	<10	5/1999	9/2004	13	0	0
Cadmium, in µg/L	<1	<5	5/1999	9/2004	13	0	0
Cadmium, in µg/L	<5	<10	5/1999	9/2004	13	0	0
Copper, in µg/L	<5	<10	5/1999	9/2004	13	0	0
Lead, in µg/L	<3	<10	5/1999	9/2004	13	0	0
Mercury, in µg/L	<0.05	<0.5	5/1999	9/2004	13	0	0
Nickel, in µg/L	<5	<25	5/1999	8/2003	11	0	0
Selenium, in µg/L	<5	<5	5/1999	9/2004	12	0	0
Silver, in µg/L	<1	<10	5/1999	9/2004	13	0	0
Thallium, in µg/L	<3	<10	5/1999	9/2004	13	0	0
Zinc, in µg/L	<5	9.0	5/1999	9/2004	12	1	8.3
Enterococci bacteria, in colonies per 100 mL	<10	<10	5/2003	6/2004	8	0	0
Esherichia coli. bacteria, in colonies per 100 mL	<10	<10	5/2003	6/2004	8	0	0
Fecal coliform bacteria, in colonies per 100 mL	<10	<10	5/2003	6/2004	8	0	0

Appendix 8. Summary statistics of replicate surface-water-quality samples, by agency, collected in or near the Citizen Potawatomi Nation Tribal Jurisdictional Area, Oklahoma, 1988 through 2011.

[mg/L, milligrams per liter; L, liter; µS/cm, microsiemens per centimeter; all constituents analyzed in unfiltered samples unless identified as “dissolved” or “filtered”]

Constituent name	Number of duplicate samples	Minimum relative percent difference	Median relative percent difference	Maximum relative percent difference	Date of first duplicate sample (month/year)	Date of last duplicate sample (month/year)
U.S. Geological Survey						
pH (laboratory), in standard units	27	0	0	1.2	10/1988	7/2001
Specific conductance, in µS/cm at 25 degrees celsius	23	0	0	0	10/1988	7/2001
Dissolved ammonia, in mg/L as nitrogen	22	0	42.2	188	9/1988	3/2011
Dissolved nitrate, in mg/L as nitrogen	16	0.70	15.5	87	8/1989	7/2001
Dissolved nitrite, in mg/L as nitrogen	20	0	54.5	127	2/1989	3/2011
Dissolved nitrate plus nitrite, in mg/L as nitrogen	19	0.50	12.6	106	8/1989	3/2011
Dissolved phosphate, in mg/L as phosphorus	19	0	9.50	66	2/1989	3/2011
Kickapoo Tribe of Oklahoma						
Ammonia, in mg/L as nitrogen	16	0	0	0	10/2010	7/2011
Ammonia plus organic nitrogen, in mg/L as nitrogen	15	0	8.90	185	10/2010	7/2011
Nitrate plus nitrite, in mg/L as nitrogen	33	0	1.8	14.7	8/2009	7/2011
Phosphorus, in mg/L	32	0	3.1	51.2	8/2009	7/2011
Escherichia coli. bacteria, in colonies per 100 mL	28	0	21.4	106	8/2009	7/2011
Oklahoma Water Resources Board						
Dissolved solids, in mg/L	34	0	0	17.0	4/1999	9/2005
Hardness, in mg/L as calcium carbonate	27	0	1.10	18	7/2001	9/2005
Chloride, in mg/L	34	0	0.75	200	8/2000	9/2005
Dissolved sulfate, in mg/L	34	0	0.90	186	8/2000	9/2005
Ammonia, in mg/L as nitrogen	32	0	0	46.2	7/2001	9/2005
Ammonia plus organic nitrogen, in mg/L as nitrogen	32	0.80	5.90	191	7/2001	9/2005
Nitrate, in mg/L as nitrogen	24	0	0.90	18.2	7/2001	2/2005
Nitrite, in mg/L as nitrogen	28	0	0	105	4/1999	2/2005
Phosphate, in mg/L as phosphorus	34	0	0.90	180	4/1999	9/2005
Phosphorus, in mg/L	34	0	4.10	195	4/1999	9/2005
Enterococci bacteria, in colonies per 100 mL	12	0	61.9	181	7/2001	6/2004
Esherichia coli. bacteria, in colonies per 100 mL	12	0	0	124	7/2001	6/2004
Fecal coliform bacteria, in colonies per 100 mL	12	0	62.0	187	7/2001	6/2004

Appendix 9. Summary statistics of groundwater-quality data collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, 1943–2005.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; <, less than; >, greater than; NA, not applicable, --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; all constituents analyzed in unfiltered samples unless identified as "dissolved", statistics for data with censored values compute through adjusted maximum likelihood estimation (AMLE) (Cohn, 2005)]

Constituent name	Aquifer	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Month of first sample	Month of last sample	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements	Censoring levels
Water properties												
Dissolved oxygen, in mg/L	Alluvial	0.10	2.82	5.20	6.80	10.7	11/1977	6/1990	34	34	100	NA
	Central Oklahoma	0.50	4.48	6.65	8.20	10.4	3/1978	6/2004	136	136	100	NA
	Vamoosa-Ada	1.90	2.95	5.35	4.00	10.3	11/1977	4/1978	11	11	100	NA
pH, in standard units	Alluvial	5.60	6.4	6.85	7.20	8.40	10/1954	6/1990	80	80	100	NA
	Central Oklahoma	5.10	6.62	7.10	7.40	8.60	12/1951	6/2004	162	162	100	NA
	Vamoosa-Ada	6.30	7.50	7.80	8.35	9.40	7/1951	11/1979	22	22	100	NA
Specific conductance, in µS/cm at 25 degrees Celsius	Alluvial	79	407	616	884	2,450	6/1947	6/1990	85	85	100	NA
	Central Oklahoma	100	408	595	830	3,660	6/1943	6/2004	168	168	100	NA
	Vamoosa-Ada	400	634	904	1,525	5,600	7/1951	11/1979	22	22	100	NA
Water temperature, in degrees Celsius	Alluvial	8.40	17.0	18.0	19.0	22.0	6/1947	6/1990	83	83	100	NA
	Central Oklahoma	6.80	13.9	16.0	17.0	21.0	6/1943	6/2004	156	156	100	NA
	Vamoosa-Ada	6.70	12.5	14.3	16.6	20.0	7/1966	11/1979	18	18	100	NA
Dissolved solids dried at 180 degrees Celsius, in mg/L	Alluvial	212	358	497	635	1,380	6/1947	10/1965	8	8	100	NA
	Central Oklahoma	60.0	170	278	358	1,030	6/1947	3/2005	32	32	100	NA
	Vamoosa-Ada	244	446	699	2,080	3,840	7/1951	11/1979	11	11	100	NA
Hardness, in mg/L as calcium carbonate	Alluvial	36.6	147	230	330	669	6/1947	6/1990	40	40	100	NA
	Central Oklahoma	6.55	122	197	280	1,530	6/1947	3/2005	173	172	99.4	10.0
	Vamoosa-Ada	6.13	16.0	145	250	565	7/1951	11/1979	23	23	100	NA
Alkalinity, in mg/L as calcium carbonate	Alluvial	26.0	134	206	322	662	6/1947	7/1989	40	40	100	NA
	Central Oklahoma	<15.0	118	205	300	780	6/1943	6/2004	170	167	98.2	15.0
	Vamoosa-Ada	110	240	312	430	801	7/1951	11/1979	23	23	100	NA

Appendix 9. Summary statistics of groundwater-quality data collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, 1943–2005.—Continued

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; <, less than; >, greater than; NA, not applicable, --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; all constituents analyzed in unfiltered samples unless identified as "dissolved", statistics for data with censored values compute through adjusted maximum likelihood estimation (AMLE) (Cohn, 2005)]

Constituent name	Aquifer	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Month of first sample	Month of last sample	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements	Censoring levels
						Major ions						
Dissolved calcium, in mg/L	Alluvial	8.50	28.0	49.2	75.5	180	6/1947	7/1989	36	36	100	NA
	Central Oklahoma	1.90	28.6	42.0	58.0	575	6/1947	3/2005	153	153	100	NA
	Vamoosa-Ada	1.30	4.28	27.6	59.0	140	7/1951	11/1979	20	20	100	NA
Dissolved magnesium, in mg/L	Alluvial	3.70	14.0	19.4	43.9	73.5	6/1947	7/1989	36	36	100	NA
	Central Oklahoma	0.10	13.0	22.0	32.5	95.6	6/1947	3/2005	153	153	100	NA
	Vamoosa-Ada	0.70	2.08	14.5	29.9	52.3	7/1951	11/1979	20	20	100	NA
Dissolved potassium, in mg/L	Alluvial	0.60	0.70	1.15	2.10	16.0	10/1954	7/1989	18	18	100	NA
	Central Oklahoma	0.30	0.80	1.38	2.30	16.6	12/1951	3/2005	85	76	89.4	0.10, 1.00, 2.00
	Vamoosa-Ada	1.80	1.90	2.40	3.00	7.80	7/1951	11/1979	10	10	100	NA
Dissolved sodium, in mg/L	Alluvial	5.40	23.0	40.5	78.6	170	10/1954	7/1989	32	32	100	NA
	Central Oklahoma	3.5	11.0	26.0	84.8	2,290	12/1951	3/2005	153	153	100	NA
	Vamoosa-Ada	6.40	82.0	211	520	1,290	7/2951	11/1979	21	21	100	NA
Dissolved bicarbonate, in mg/L	Alluvial	32.0	148	238	288	732	6/1947	7/1989	24	24	100	NA
	Central Oklahoma	44.0	110	218	306	562	6/1943	6/2004	57	57	100	NA
	Vamoosa-Ada	304	510	674	895	915	7/1951	11/1974	5	5	100	NA
Dissolved chloride, in mg/L	Alluvial	2.40	15.0	26.0	35.5	655	6/1947	7/1989	24	24	100	NA
	Central Oklahoma	4.50	9.18	15.0	36.0	708	6/1943	3/2005	83	76	91.6	10
	Vamoosa-Ada	6.00	15.2	95.5	183	886	7/1951	11/1979	12	12	100	NA
Dissolved fluoride, in mg/L	Alluvial	0.10	0.10	0.20	0.35	0.90	6/1947	7/1989	20	19	95.0	0.1
	Central Oklahoma	0.10	0.10	0.20	0.30	3.00	6/1947	3/2005	63	54	85.7	0.1
	Vamoosa-Ada	0.40	0.50	1.00	1.00	1.80	9/1979	11/1979	5	5	100	NA

Appendix 9. Summary statistics of groundwater-quality data collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, 1943–2005.—Continued

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; <, less than; >, greater than; NA, not applicable, --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; all constituents analyzed in unfiltered samples unless identified as "dissolved", statistics for data with censored values compute through adjusted maximum likelihood estimation (AMLE) (Cohn, 2005)]

Constituent name	Aquifer	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Month of first sample	Month of last sample	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements	Censoring levels
Major ions—Continued												
Dissolved sulfate, in mg/L	Alluvial	5.00	16.5	30.0	49.5	431	6/1947	7/1989	40	39	97.5	5.00
	Central Oklahoma	3.00	5.11	13.5	29.0	1,900	6/1943	3/2005	175	133	76.0	5.00, 10.0, 20.0
	Vamoosa-Ada	5.00	18.0	46.0	260	2,300	7/1951	11/1979	22	21	95.4	5.00
Nutrients												
Dissolved or total nitrate plus nitrite, in mg/L as nitrogen	Alluvial	<0.10	0.18	1.30	3.60	7.80	6/1989	7/1989	15	12	80.0	0.10
	Central Oklahoma	<0.05	0.20	0.53	2.10	93.5	7/1974	3/2005	59	50	84.7	0.05, 0.10, 0.50
	Vamoosa-Ada	0.49	0.490	0.490	0.49	0.49	11/1974	11/1974	1	1	100	NA
Dissolved phosphorus, in mg/L	Alluvial	<0.04	<0.04	<0.04	<0.04	<0.04	11/1977	12/1978	16	0	0	0.04
	Central Oklahoma	<0.04	0.001	0.005	0.02	0.324	1/1977	4/1978	98	11	11.2	0.04
	Vamoosa-Ada	<0.04	<0.04	<0.04	<0.04	<0.04	11/1977	4/1978	11	0	0	0.04
Metals												
Dissolved arsenic, in µg/L	Alluvial	<0.50	0.163	0.380	1.00	4.70	11/1977	7/1989	31	10	32.3	0.50, 1.00
	Central Oklahoma	<0.50	0.193	0.393	0.800	5.80	1/1977	3/2005	136	48	35.3	0.50, 1.00, 2.00, 10.0
	Vamoosa-Ada	<0.50	0.210	0.377	1.00	1.60	11/1977	4/1978	11	4	36.4	0.50
Dissolved chromium, in µg/L	Alluvial	<4.00	<4.00	<4.00	<5.00	8.00	11/1977	7/1989	29	1	3.45	4.00, 5.00
	Central Oklahoma	<4.00	0.054	0.300	1.66	80.0	1/1977	3/2005	133	19	14.3	4.00, 5.00, 10.0
	Vamoosa-Ada	<4.00	<4.00	<4.00	<4.00	20.0	11/1977	4/1978	11	1	9.09	4.00
Dissolved chromium (VI) in µg/L	Alluvial	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Central Oklahoma	<1.00	0.528	1.00	1.00	13	4/1988	7/1988	21	12	57.1	1.00
	Vamoosa-Ada	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dissolved iron, in µg/L	Alluvial	<10.0	0.692	4.65	14.5	2,800	11/1977	7/1989	31	15	48.4	10.0
	Central Oklahoma	<3.00	0.097	0.812	6.79	3,180	9/1954	3/2005	145	36	28.3	3.00, 10.0, 100
	Vamoosa-Ada	<10.0	<10.0	<10.0	<10.0	70.0	7/1951	4/1978	12	2	16.7	10.0

Appendix 9. Summary statistics of groundwater-quality data collected in the Citizen Potawatomi Nation Tribal Jurisdictional Area, 1943–2005.—Continued

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; µg/L, micrograms per liter; <, less than; >, greater than; NA, not applicable, --, not determined; e, natural exponent; ln, natural logarithm; hardness, hardness in mg/L; all constituents analyzed in unfiltered samples unless identified as "dissolved", statistics for data with censored values compute through adjusted maximum likelihood estimation (AMLE) (Cohn, 2005)]

Constituent name	Aquifer	Minimum value	25th percentile	50th percentile	75th percentile	Maximum value	Month of first sample	Month of last sample	Number of samples	Number of samples with detected measurements	Percent of samples with detected measurements	Censoring levels
Metals—Continued												
Dissolved lead, in µg/L	Alluvial	<10.0	4.48	6.35	8.98	20.0	6/1989	7/1989	15	3	20.0	10.0
	Central Oklahoma	<10	<10	<10	<10	10.0	8/1987	7/1988	27	1	3.70	10.0
	Vamoosa-Ada	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA
Dissolved lithium, in µg/L	Alluvial	6.00	10.0	12.5	21.0	73.0	11/1977	7/1989	26	26	100	NA
	Central Oklahoma	<4.00	10.0	20.0	20.0	140	11/1977	7/1988	99	98	99.0	4.00
	Vamoosa-Ada	<10.0	10.0	20.0	30.0	70.0	11/1977	11/1979	18	17	94.4	10.0
Dissolved manganese, in µg/L	Alluvial	<1	0.355	7.00	210	1,280	11/1977	7/1989	27	16	59.2	2.00, 1.00
	Central Oklahoma	<1	0.035	0.415	20.0	500	12/1970	3/2005	96	29	30.2	1.00, 2.00, 5.00, 10.0, 20.0
	Vamoosa-Ada	<1	0.158	1.08	35.0	50.0	7/1951	4/1978	8	3	37.5	2.00
Dissolved uranium, in µg/L	Alluvial	<0.200	0.300	1.30	4.60	24.1	6/1947	7/1989	31	25	80.6	0.200
	Central Oklahoma	<0.019	0.300	0.900	4.90	97.6	1/1977	7/1988	124	102	82.2	0.200, 0.019
	Vamoosa-Ada	0.3	0.700	2.80	10.9	48.2	11/1977	4/1978	11	11	100	NA
Dissolved zinc, in µg/L	Alluvial	<3	10.0	24.0	90.0	1,680	11/1977	7/1989	31	29	93.5	3.00
	Central Oklahoma	<3	10.0	40.0	110	3,400	12/1970	3/2005	131	117	89.3	3.00, 4.00, 10.0
	Vamoosa-Ada	10	30.0	80.0	220	750	11/1977	4/1978	10	10	100	NA

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