Prepared in cooperation with the Osage Tribal Council, U.S. Department of Energy, and Bureau of Indian Affairs

Surface-Water Characteristics and Quality on the Osage Reservation, Osage County, Oklahoma, 1999

Water-Resources Investigations Report 02–4060

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

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Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	43560.0	square foot (ft^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	640.0	acre
square mile (mi^2)	2.590	square kilometer (km^2)
Volume		
barrel (bbl), (petroleum, 1 barrel = 42 gal)	0.1590	cubic meter (m^3)
gallon (gal)	3.785	liter (L)
Flow rate		
foot per day (ft/d)	0.3048	meter per day (m/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

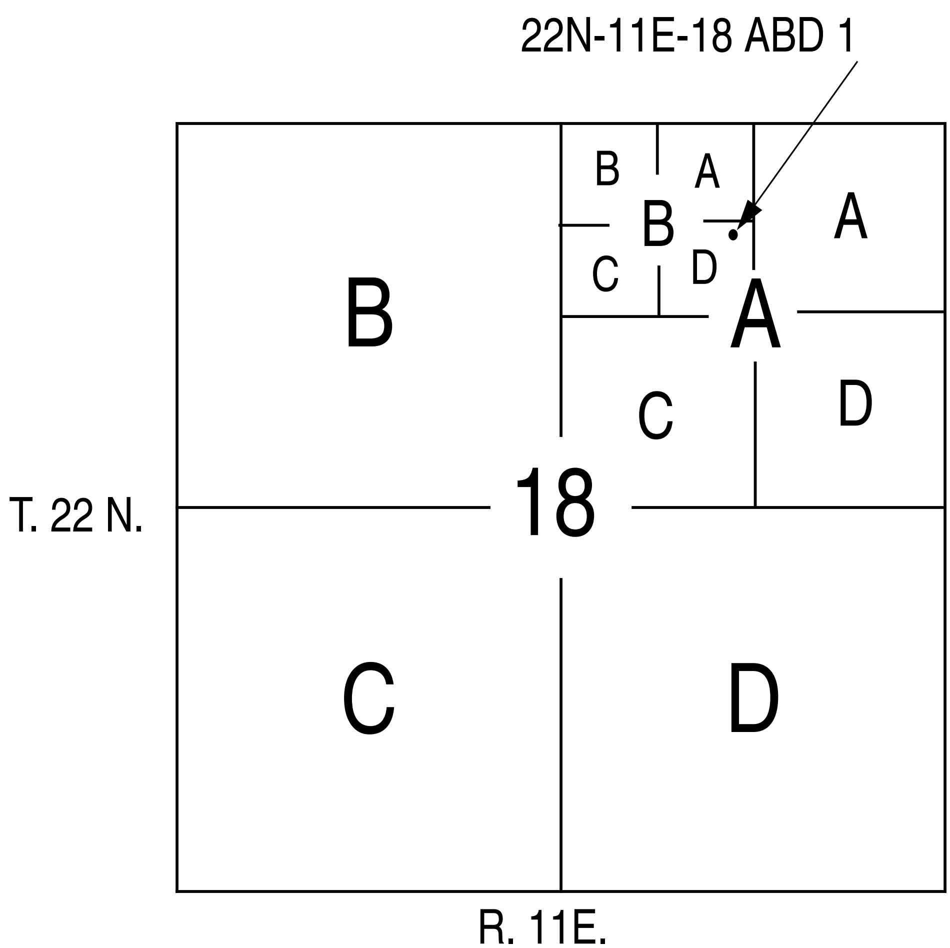
Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25°C).

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

Explanation of the Site-numbering System

The locations of the sample-collection sites and the streamflow-gaging stations are identified by a station-identification number and a local-identification number. The station number is a downstream order number of eight digits such as 07176988. The downstream ordering system is used to identify surface-water hydrologic data collection sites in this report. Station numbers are unique numbers assigned in a downstream sequence so that numbers become larger downstream. The number is unique in that it applies specifically to a given station and to no other. All stations on a tributary entering upstream from a main stream are listed before that station. A station on a tributary that enters between two mainstream stations is listed between them.

The local-identification number includes the township and range followed by the section and a series of letters that designate the quarter-section subdivisions, from the largest to the smallest. The order of the quarter-section subdivisions differs from that used by the Bureau of Land Management and the public land survey. As illustrated in the figure, the public land survey description of the site indicated by the dot as SE1/4 NW1/4 NE1/4 sec. 18, T. 22 N., R. 11E., is denoted by the local identifier number 22N–11E–18 ABD. If the sequence number is 1, the complete identifier number is 22N–11E–18 ABD 1.



Surface-Water Characteristics and Quality on the Osage Reservation, Osage County, Oklahoma, 1999

By Marvin M. Abbott and Robert L. Tortorelli

Abstract

Concern about the effects of early oil-industry practices of surface disposal of produced-brine water prompted an investigation of the surface-water quality on the Osage Reservation. About 38,600 oil wells have been drilled on the Osage Reservation since drilling began in 1896.

The Osage Reservation comprises three major drainage basins. The Caney River Basin is in the northeast, the Bird Creek Basin is in the southeast, and the Salt Creek Basin in the west. Variations in streamflow on the Osage Reservation during a year primarily result from variations in the quantity and frequency of rainfall, evapotranspiration, and reservoir operations. Most streams do not flow during low rainfall periods in late summer, early fall, and in winter. Percent of mean annual discharge is largest during March through June, averaging 54 to 62 percent and smallest during December, January, July, and August, averaging only 14 to 21 percent. The basin areas of Caney River in the reservation (251 square miles), Salt Creek (273 square miles), and Sand Creek (227 square miles) are about the same and the basin areas of the Bird Creek Basin (418 square miles) and Hominy Creek Basin (383 square miles) are similar in area.

One hundred forty surface-water sites were sampled once during either February, March, or August 1999. The surface-drainage areas, incremental basins, between sample sites along a stream, range in size from 0.26 to 123 square miles with a median of 8.6 square miles. Total number of oil wells upgradient of the sample sites is 31,432 or 80 percent of the total in the reservation. The total number of oil wells in the Caney River Basin in the reservation (2,975 wells), Salt Creek Basin (4,619 wells), and Sand Creek Basin (3,928 wells) are about the same and the total number of oil wells in the Bird Creek Basin (8,858 wells) and Hominy Creek Basin (7,842 wells) are similar. The number of oil wells per square mile in the incremental basins ranges from 0.86 to 154.

Surface-water quality monitoring had been conducted previously at two sites included in this study. Dissolved chloride concentrations for the two samples collected during 1999 were equaled or exceeded at both sites by the historical data. There is no statistically significant difference between the distribution of the dissolved chloride concentrations from the surface water and nearby ground-water samples. The surface-water quality samples had significantly lesser concentrations of dissolved solids, sulfate, and nitrite plus nitrate as nitrogen than the ground-water samples.

Chloride yield, reported in tons per day per square mile, is the chloride load divided by the basin area upstream of the sample site. The mean of the chloride yields for all the samples was 0.07 ton per day per square mile. Many sample locations where yields were greater than 0.07 ton per day per square mile were areas where dissolved chloride concentrations from surface-water samples were greater than 250 milligrams per liter in an earlier water-quality investigation.

An investigation of possible relations between the surface-water quality data and the oil-well construction data for the incremental basins and for 1-mile radial distance upstream in the incremental basins was conducted. The oil-well data also were grouped by time periods of activity into pre-1930, 1930 to 1970, and post-1970. These groups attempt to account for differences in industry drilling and producing practices associated with various periods. No statistically significant correlations were found between the surface-water quality data and the oil-well construction data.

Introduction

About 38,600 oil wells have been drilled on the Osage Reservation since drilling began in 1896 (fig. 1). The term “oil well” in this report, is an industry well drilled to oil and gas production depths and includes oil and gas producers, nonproducing wells, injection wells, salt-water disposal wells, plugged wells, and abandoned wells. About 17,600 oil wells were drilled before 1940 (Bass and others, 1942) and 3,200 of these were dry and abandoned. In 1988 about 12,680 oil wells were actively operated and 4,200 of these were classified as pressure maintenance, salt-water disposal, or water-flood injection wells. The remaining oil wells (about 26,000) are temporarily or permanently plugged and abandoned. Hydrocarbon production in the reservation is shallow by United States standards, with producing zones ranging from a few hundred to about 3,500 feet below land surface. An early industry practice was to hold produced brine water in surface pits. This was not allowed in the reservation after the late 1940s or early 1950s (Paul Yates, Bureau of Indian Affairs, Osage Agency, oral commun., 2000). Environmental problems with surface disposal of produced brine water prompted a change to underground injection of the brine. Many

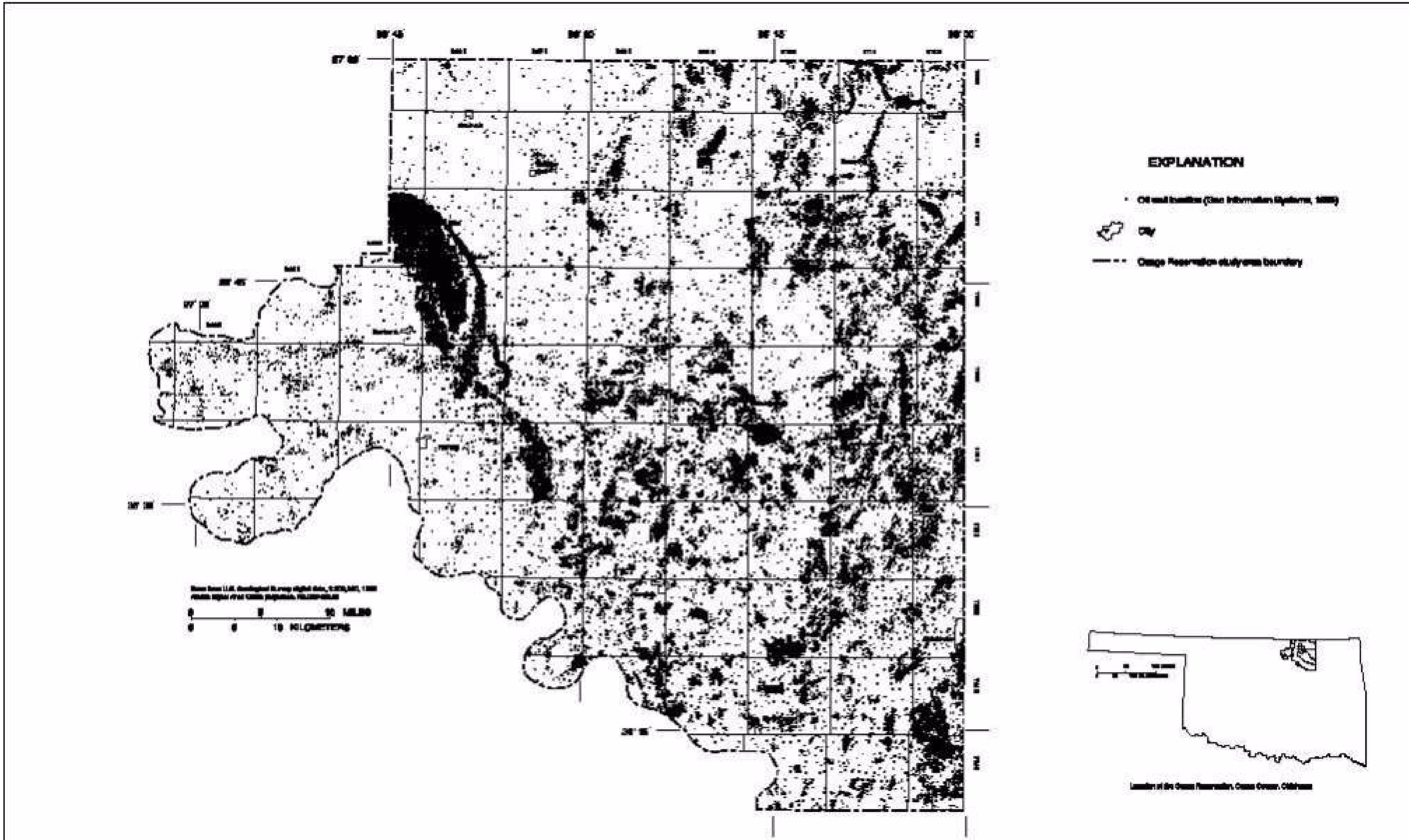


Figure 1. Oil and gas well locations on the Osage Reservation, Oklahoma.

areas of the reservation were observed to have been affected by activities related to drilling and producing oil and gas. The Osage Tribal Council is concerned about the effects that oil and gas production might have on surface-water quality on the Osage Reservation in northeastern Oklahoma (Diane Daniels, Osage Nation Environmental and Natural Resources Department, oral communication, 1998). The U.S. Geological Survey, in cooperation with the Osage Tribal Council, U.S. Department of Energy, and Bureau of Indian Affairs conducted a study of the streamflow characteristics and surface-water quality on the Osage Reservation.

Purpose and Scope

This purpose of this report is to present a brief description of streamflow characteristics for streamflow-gaging stations and water quality on and near the Osage Reservation. The streamflow characteristics in the study area are summarized by the seasonal distribution of streamflow, magnitude and frequency of floods, and annual low-flow frequency estimates. The report presents a brief description and summary statistics for selected water-quality constituents at 140 stream sites sampled in 1999 and for the sites grouped by the larger stream-drainage basins. The report compares selected water-quality constituents and properties for the surface-water quality with ground-water quality from nearby domestic supply wells and compares the surface-water quality to oil-well construction data. Comparisons of historical water-quality data to the data obtained for this study also are made.

Description of the Study Area

The Osage Reservation, otherwise known as Osage County (figs. 1 and 2), consists of about 2,300 square miles. The reservation is characterized by gently-rolling uplands with locally sharp cuestas formed by resistant sandstone and limestone ledges. The Arkansas River borders the reservation on the south and southwest. The eastern and southeastern part of the reservation is known informally as the Cross Timbers, an area characterized by open oak and hickory woodlands with scattered, grassy savannah areas. The western part of the reservation, known informally as the Bluestem Hills, is mostly open savanna. The highest altitude is about 1,350 feet above sea level along the cuesta northeast of Foraker in the northwestern part of the reservation; the lowest altitude is about 600 feet above sea level along Hominy and Delaware Creeks south of Skiatook in the southeastern part of the reservation. Mean annual precipitation across the reservation ranges from 34 inches in the west near Ponca City to 38 inches in the southeast near Tulsa (Oklahoma Climatological Survey, 2000).

The Osage Reservation comprises three major drainage basins (fig. 2). The Caney River Basin is in the northeast, with the Sand Creek flowing into the river just south of Bartlesville. Lake Hulah is the major reservoir in the basin. The Bird Creek Basin is in the southeast, with Hominy Creek flowing into Bird Creek just south of Sperry. Bluestem Lake near Pawhuska, Birch Lake near Barnsdall, and Skiatook Lake near Skiatook are the major reservoirs in the Bird Creek Basin. The Salt Creek Basin in the west flows into the Arkansas River.

Acknowledgments

The authors thank the organizations and individuals who contributed and assisted in the study. Special thanks are extended to the Osage Tribal Council, the Osage Environmental Council, Bureau of Indian Affairs, and the U.S. Department of Energy. Diane Daniels, Norma Pinney, and others at the Osage Nation Environmental and Natural Resources Department were of great help locating names and phone numbers of landowners to contact and providing other information. The authors thank the landowners who allowed access to sampling locations on their land. Thanks are extended to U.S. Geological Survey colleagues David Adams, Charles Bullock, Tony Carpenter, Dale Ferree, Ron Gist, James Greer, Rick Hanlon, Lan McCabe, and Ernie Smith for assisting in the collection of water-quality data. Thanks are extended to U.S. Geological Survey colleague Alan Rea for assisting in the geospatial data management.

Streamflow Characteristics

The streamflow characteristics in the study area are summarized by the seasonal distribution of streamflow, magnitude and frequency of floods, and annual low-flow frequency estimates. Variations in streamflow on the Osage Reservation during a year primarily result from variations in the quantity and frequency of rainfall, evapotranspiration, and reservoir operations. During some years, most streams do not flow during low rainfall periods in late summer, early fall, and in winter. Seasonal distribution of streamflow in the reservation is shown by the monthly streamflows as a percent of mean annual discharge, based on water year (October 1 - September 30). Figure 3 shows this for six selected continuous record streamflow-gaging stations. Both unregulated and regulated periods of record are shown. Percent of mean annual discharge is largest during March through June, averaging 54 to 62 percent. Percent of mean annual discharge is smallest during December, January, July, and August, averaging only 14 to 21 percent. In those stations with both unregulated and regulated periods of record, the percentage of annual discharge is about the same when grouped by the largest and smallest discharge periods (fig. 3). Mean annual discharge for selected continuous record streamflow-gaging stations within and near the reservation is shown in table 1.

A knowledge of the magnitude and frequency of floods is required for the safe and economical design of highway bridges, culverts, dams, levees, and other structures on and near streams. Flood plain management programs and flood-insurance rates also are based on flood magnitude and frequency information. The documented extreme peak discharges and flood frequency

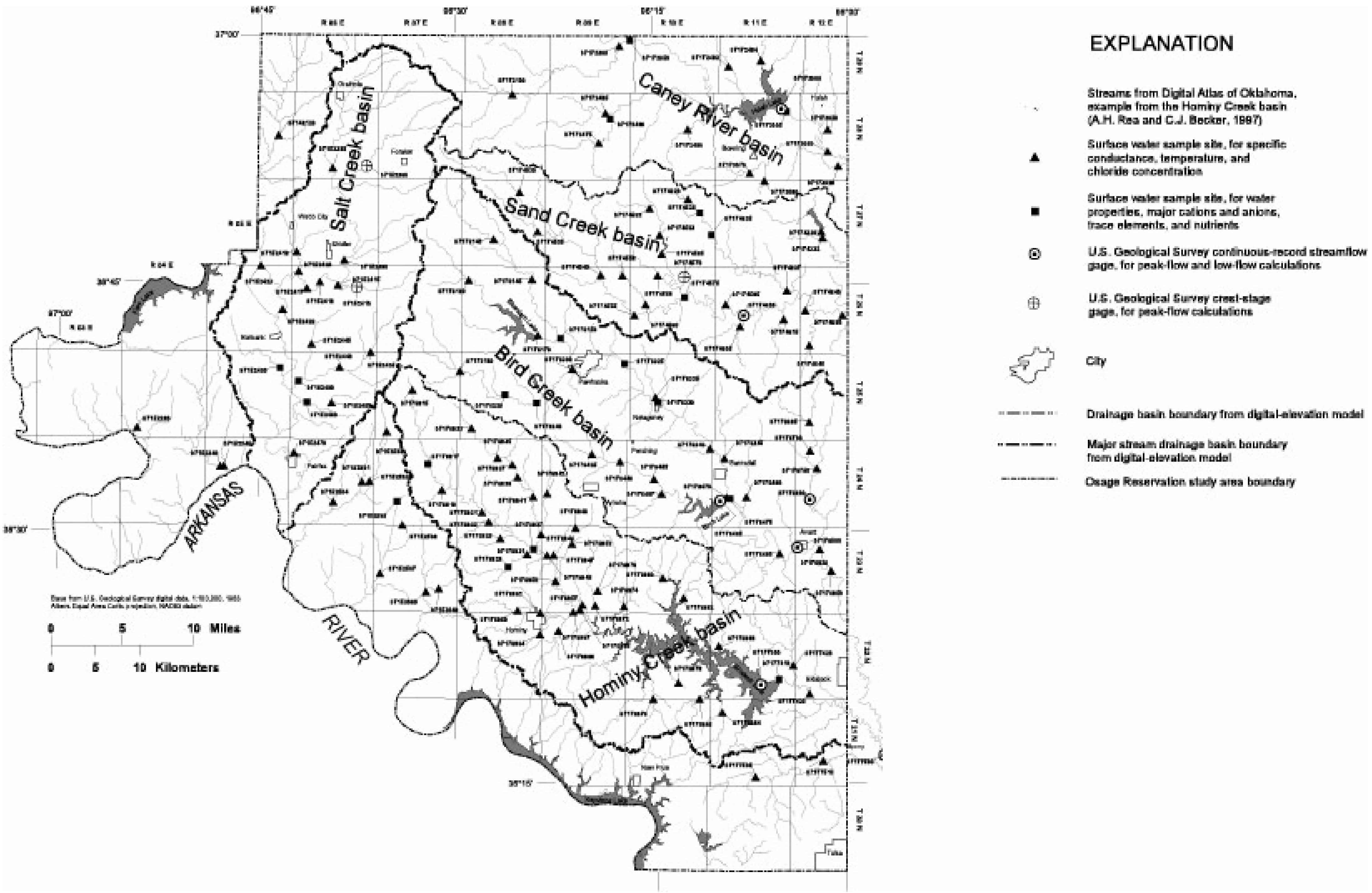


Figure 2. Surface drainage basins, surface-water-quality sites, type of samples collected, and streamflow gages on the Osage Reservation, Oklahoma.

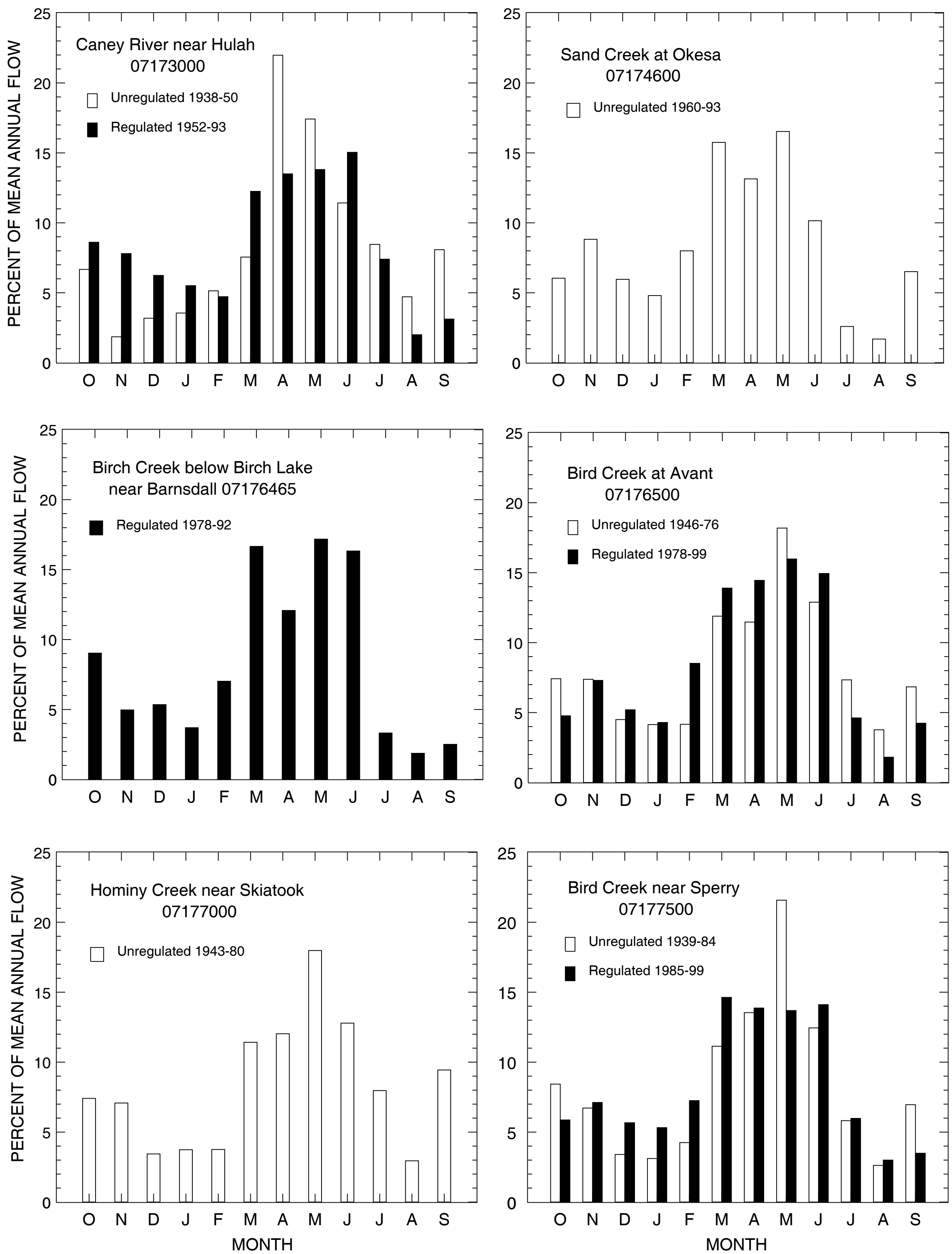


Figure 3. Monthly streamflows, as a percent of mean annual discharge, based on water year (October 1–September 30) for selected continuous record streamflow-gaging stations in and near the Osage Reservation, Oklahoma.

Table 1. Mean annual flow and annual low flow frequency estimates for selected continuous record streamflow-gaging stations with at least 10 years of streamflow data from unregulated and regulated basins on and near the Osage Reservation, Oklahoma

[mi^2, square miles; U, unregulated; R, regulated; ft^3/s, cubic feet per second; LPIII, Log-Pearson Type III; yr, year]

Station number	Station name	Contributing drainage area (mi^2)	Period of record[a]	Type of record	Mean annual flow (ft^3/s)	Consecutive days	Annual low flow LPIII frequency estimates: Discharge for indicated recurrence interval (ft^3/s)			
							2 yr	5 yr	10 yr	20 yr
07173000	Caney River near Hulah	733	1939-50	U	413	1	1.30	0.00	0.00	0.00
						3	1.32	0.00	0.00	0.00
						7	1.55	0.05	0.00	0.00
						10	1.86	0.12	0.00	0.00
			1953-93	R	401	1	1.96	0.37	0.09	0.00
						3	3.00	0.53	0.17	0.06
						7	3.63	0.92	0.38	0.17
						10	4.10	1.10	0.48	0.22
07174600	Sand Creek at Okesa	139	1961-91	U	87.0	1	0.00	0.00	0.00	0.00
						3	0.00	0.00	0.00	0.00
						7	0.00	0.00	0.00	0.00
						10	0.00	0.00	0.00	0.00
07176465	Birch Creek below Birch Lake near Barnsdall	66.0	1979-92	R	45.5	1	0.61	0.00	0.00	0.00
						3	0.65	0.12	0.00	0.00
						7	0.84	0.19	0.08	0.04
						10	1.06	0.25	0.10	0.04
07176500	Bird Creek at Avant	364	1947-76	U	200	1	0.00	0.00	0.00	0.00
						3	0.00	0.00	0.00	0.00
						7	0.00	0.00	0.00	0.00
						10	0.00	0.00	0.00	0.00
			1979-99	R	328	1	7.07	2.21	0.88	0.35
						3	7.08	2.40	1.14	0.56
						7	7.09	2.76	1.49	0.83
						10	7.46	3.05	1.74	1.04
07176800	Candy Creek near Wolco	30.6	1971-81	U	25.5	1	0.00	0.00	0.00	0.00
						3	0.00	0.00	0.00	0.00
						7	0.00	0.00	0.00	0.00
						10	0.00	0.00	0.00	0.00
07177000	Hominy Creek near Skiatook	340	1945-80	U	181	1	0.18	0.00	0.00	0.00
						3	0.21	0.00	0.00	0.00
						7	0.24	0.00	0.00	0.00
						10	0.28	0.00	0.00	0.00
07177500	Bird Creek near Sperry	905	1940-84	U	483	1	1.74	0.18	0.00	0.00
						3	1.95	0.23	0.00	0.00
						7	2.38	0.31	0.00	0.00
						10	2.86	0.40	0.00	0.00
			1986-99	R	889	1	37.0	18.0	10.9	6.89
						3	42.4	20.8	12.6	7.70
						7	46.2	22.3	13.5	8.08
						10	48.9	23.6	14.2	8.46

Table 1. Mean annual flow and annual low flow frequency estimates for selected continuous record streamflow-gaging stations with at least 10 years of streamflow data from unregulated and regulated basins on and near the Osage Reservation, Oklahoma

[mi^2, square miles; U, unregulated; R, regulated; ft^3/s, cubic feet per second; LPIII, Log-Pearson Type III; yr, year]

a.Based on climatic year starting April 1 and ending March 31 estimates (IACWD, 1982) for selected streamflow-gaging stations (fig. 2) are shown in table 2. Frequency of flooding is expressed as recurrence interval in years. Both unregulated and regulated periods of record are shown. A stream was considered regulated once 20 percent or more of the contributing drainage basin area is controlled by reservoirs (Heimann and Tortorelli, 1988). Table 3 lists the lake data for the major reservoirs on the Osage Reservation. Two sites that had both unregulated and regulated periods of record (Caney River near Hulah and Bird Creek near Sperry) indicate the estimates of flood magnitude generally decrease with regulation. However, Bird Creek at Avant shows about the same flood magnitude before and after regulation and the documented extreme peak flow at Hulah is greater than before regulation. This may be due to analysis of different periods of record, the effects of reservoir operations, and sites with small drainage basins that may have extreme peak flows from very small, intense localized storms. The magnitude and frequency of floods may be estimated for streams where streamflow-gaging stations are not available by use of regression equations (Tortorelli, 1997).

Information on the low-flow characteristics of streams is essential to water-management agencies dealing with problems related to irrigation, municipal and industrial water supplies, fish and wildlife conservation, and assessment of stream capabilities to receive and assimilate treated wastewater. The annual low-flow frequency estimates for seven selected continuous record streamflow-gaging stations are shown in table 1. Frequency of annual low flow is expressed as recurrence interval in years. Both unregulated and regulated periods of record are shown in table 1. The small streams in the reservation do not flow during periods in late summer, early fall, and in winter when no rain falls. Therefore, the unregulated annual low-flow frequency estimates (table 1) are zero or near zero for 1 to 10 consecutive days. All three sites with both unregulated and regulated periods of record (Caney River near Hulah, Bird Creek at Avant, and Bird Creek near Sperry) indicate that estimated annual low flows generally increase with regulation.

Drainage Basins

The drainage-basin data compiled include incremental basin area, basin area, number of oil wells in each incremental basin, number of oil wells in each basin, number of oil wells per square mile in each incremental basin, and number of oil wells per square mile in each basin (table 4). Incremental basin in this report refers to the surface-drainage areas between sample sites along a stream or the farthest upstream sample site (figs. 4 and 5, at the back of this report). The method of incremental basin mapping is discussed in the supplemental information at the back of this report. The summary statistics for the incremental basin area, number of oil wells per incremental basin, and number of oil wells per square mile per incremental basin are presented in tables 4-6.

Some bias is introduced when comparing basins of statistically significantly different sizes. Total drainage basin area upgradient of the sample sites is 1,783 square miles or 75 percent of the area of the reservation. The incremental basins range in size from 0.26 to 123 square miles with a median of 8.6 square miles (table 4). The basin areas of Caney River in the reservation (251 square miles), Salt Creek (273 square miles), and Sand Creek (227 square miles) are about the same, and there is no statistically significant difference in the sizes of the incremental basin areas (fig. 6a) within these larger basins. The Wilcoxon rank sum test was used to evaluate statistical significants and is discussed in the section on summary statistics of surface-water quality. The basin areas of the Bird Creek Basin (418 square miles) and Hominy Creek Basin (383 square miles) are about the same, but the incremental basin areas are statistically significantly different (fig. 6a). Incremental basin areas along Hominy Creek are smaller because of the greater number of sites sampled (fig. 2). This is due in part to accessible sites from the county road system in the Hominy Creek Basin. The incremental basin areas in the Hominy Creek Basin are not statistically different from those in the Salt Creek or Sand Creek Basins but are different from Bird Creek and Caney River Basins on the reservation (fig. 6a).

Total number of oil wells upgradient of the sample sites is 31,432 or 80 percent of the total in the reservation. The number of oil wells per incremental basin ranges from 5 to 2,311 wells (table 5). The total number of oil wells in the Caney River Basin in the reservation (2,975 wells), Salt Creek Basin (4,619 wells), and Sand Creek Basin (3,928 wells) are about the same, and there is no statistical difference in the distribution of the number of oil wells for the incremental basins for these streams (fig. 6b). The total number of oil wells in the Bird Creek Basin (8,858 wells) and Hominy Creek Basin (7,842 wells) are about the same, but the distribution of the number of oil wells per incremental basins are statistically different (fig. 6b). The number of oil wells per incremental basin in the Hominy Creek Basin is not statistically different from the number of oil wells per incremental basin in the Caney River Basin in the reservation, Salt Creek, or Sand Creek Basins (fig. 6b).

The number of oil wells per square mile in the incremental basins ranges from 0.86 to 154 wells (table 6). Some incremental basins in the Hominy, Salt, and Sand Creek Basins have oil well spacing less than 10 acres per well (fig. 6c). The maximum number of 154 wells per square mile is from a small incremental basin in Hominy Creek Basin in Section 34-T22N-R10E (fig. 1). The Caney River Basin in the reservation is statistically different from the Hominy Creek Basin for the distribution of the number of wells per square mile in the incremental basins. The distribution and median are less in the Caney River Basin in the reservation than the Hominy Creek Basin (fig. 6c). Extensive oil well drilling has occurred in the Caney River Basin in Kansas, north of the reservation, and 50 percent of the Caney River Basin is in Kansas. The Kansas data, however, are not part of this report. The distributions for the other basins are not statistically significantly different.

Table 2. Documented extreme peak discharges and flood frequency estimates for selected streamflow-gaging stations with at least eight years of annual peak-discharge data from unregulated and regulated basins on and near the Osage Reservation, Oklahoma

[CONT, continuous record site; CSG, crest-stage partial record site; mi^2, square miles; U, unregulated; R, regulated; ft^3/s, cubic feet per second; LPIII, Log-Pearson Type III; yr, year]

Station number	Station name	Type of station (CONT/ CSG)	Latitude	Longitude	Contributin g drainage area (mi^2)	Period of record[1]	Type of record	Documented extreme peak discharge: Date	Documented extreme peak discharge: Discharg e (ft^3/s)	LPIII flood frequency estimates — Peak discharge for indicated recurrence interval[2] (ft^3/s): 2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	500 yr
07152360	Elm Creek near Foraker	CSG	365208	0963650	18.2	1964-75	U	06/24/69	9,200	2,180	4,640	6,860	10,400	13,600	17,100	27,600
07152410	Rock Creek near Shidler	CSG	364450	0963730	9.13	1965-72	U	05/18/65	2,780	1,630	2,090	2,380	2,730	2,990	3,230	3,780
07173000	Caney River near Hulah	CONT	365557	0960506	733	1938-50	U	04/10/44	51,000	14,900	25,600	32,900	42,100	48,800	55,300	69,700
						1952-93	R	10/03/86	58,000	3,540	6,830	10,200	16,200	22,400	30,500	59,800
07174570	Dry Hollow near Pawhuska	CSG	364530	0961230	1.67	1965-72	U	07/14/65	660	320	607	822	1,110	1,330	1,550	2,070
07174600	Sand Creek at Okesa	CONT	364310	0960756	139	1960-93	U	05/09/93	20,200	8,260	13,300	16,600	20,400	23,100	25,600	30,900
07176465	Birch Creek below Birch Lake near Barnsdall	CONT	363200	0960943	66.0	1978-92	R	10/07/86	2,070	846	1,460	1,850	2,330	2,660	2,960	3,590
07176500	Bird Creek at Avant	CONT	362912	0960350	364	1946-76	U	10/02/59	32,400	12,500	19,300	23,900	29,700	34,000	38,200	47,900
						1978-99	R	06/10/85	27,900	16,400	23,000	27,200	32,300	35,900	39,500	47,400
07176800	Candy Creek near Wolco	CONT	363206	0960254	30.6	1970-81	U	03/10/74	9,520	5,190	7,910	9,700	11,900	13,500	15,100	18,600
07177000	Hominy Creek near Skiatook	CONT	362055	0960635	340	1943-80	U	10/03/59	35,600	8,300	12,800	16,500	21,900	26,600	31,900	46,900
07177500	Bird Creek near Sperry	CONT	361642	0955714	905	1939-84	U	10/03/59	90,000	14,200	25,600	35,900	52,900	69,000	88,600	152,000
						1985-99	R	05/10/93	30,600	16,900	24,000	28,800	35,100	39,900	44,700	56,500

[1]Based on water year starting October 1 and ending September 30

2 Recurrence interval is the reciprocal of the annual exceedance probability, and represents the average number of years between peak flow exceedances of that magnitude. For instance, a flood having an annual exceedance probability of 0.01 has a recurrence interval of 100 years. his does not imply that a 100-year flood peak will be equaled or exceeded each 100 years, but that it will be equaled or exceeded on the ***average*** of once every 100 years. (Thomas and Corley, 1977). That peak might be exceeded in successive years, or more than once in the same year.

Table 3. Lake data for major reservoirs in the Osage Reservation, Oklahoma

[--, data not available]

Lake name	Streamflow-gaging station controlled	Drainage area[1] (square miles)	Normal pool[1]		Flood pool[1]	
			Area (acres)	Capacity (acre-feet)	Area (acres)	Capacity (acre-feet)
Birch	07176465 07176500 07177500	66.0	1,137	19,200	2,339	58,200
Bluestem	07176500 07177500	47.1	762	17,000	--	--
Hulah	07173000	732	3,570	31,160	13,000	289,000
Skiatook	07177000 07177500	354	10,190	322,700	13,690	500,700

[1]Data from Oklahoma Water Resources Board, 1990

Table 4. Summary statistics for the incremental basin areas on the Osage Reservation, Oklahoma

[incremental basin area in square miles; incremental basin, surface drainage area between sample sites]

	Number of incremental basins	Mean	Minimum	Percentiles			Maximum	Total area of incremental basins
				25	50	75		
All incremental basins	140	13	0.26	5.0	8.6	15	123	1,783
Bird Creek basin	28	15	2.5	11	14	17	32	418
Caney River basin	12	21	3.7	9.5	13	21	87	251
Hominy Creek basin	41	9.4	0.39	3.9	5.7	8.1	123	383
Salt Creek basin	18	15	2.3	4.5	8.1	13	74	273
Sand Creek basin	21	11	1.1	4.5	7.0	14	30	227

Table 5. Summary statistics for the number of oil wells per incremental basin on the Osage Reservation, Oklahoma, 1900-1998

[incremental basin, surface drainage area between sample sites; oil well, any well drilled for oil and gas production purposes]

	Number of incremental basins	Mean	Minimum	Percentiles			Maximum	Total oil wells
				25	50	75		
All incremental basins	140	224	5	76	156	274	2,311	31,432
Bird Creek basin	28	316	28	189	294	399	1,137	8,858
Caney River basin	12	248	71	97	136	207	1,231	2,975
Hominy Creek basin	41	191	13	70	108	203	2,311	7,842
Salt Creek basin	18	257	25	108	186	269	936	4,619
Sand Creek basin	21	187	29	79	125	241	700	3,928

Table 6. Summary statistics for the number of oil wells per square mile per incremental basin on the Osage Reservation, Oklahoma

[incremental basin, surface drainage area between sample sites; oil well, any well drilled for oil and gas production purposes]

	Number of incremental basins	Mean	Minimum	Percentiles			Maximum
				25	50	75	
All incremental basins	140	24	0.86	11	18	32	154
Bird Creek basin	28	23	3.1	14	24	31	48
Caney River basin	12	16	2.7	6.5	11	19	55
Hominy Creek basin	41	27	5.9	14	19	33	154
Salt Creek basin	18	32	0.86	4.6	31	47	84
Sand Creek basin	21	20	4.6	9.1	18	25	70

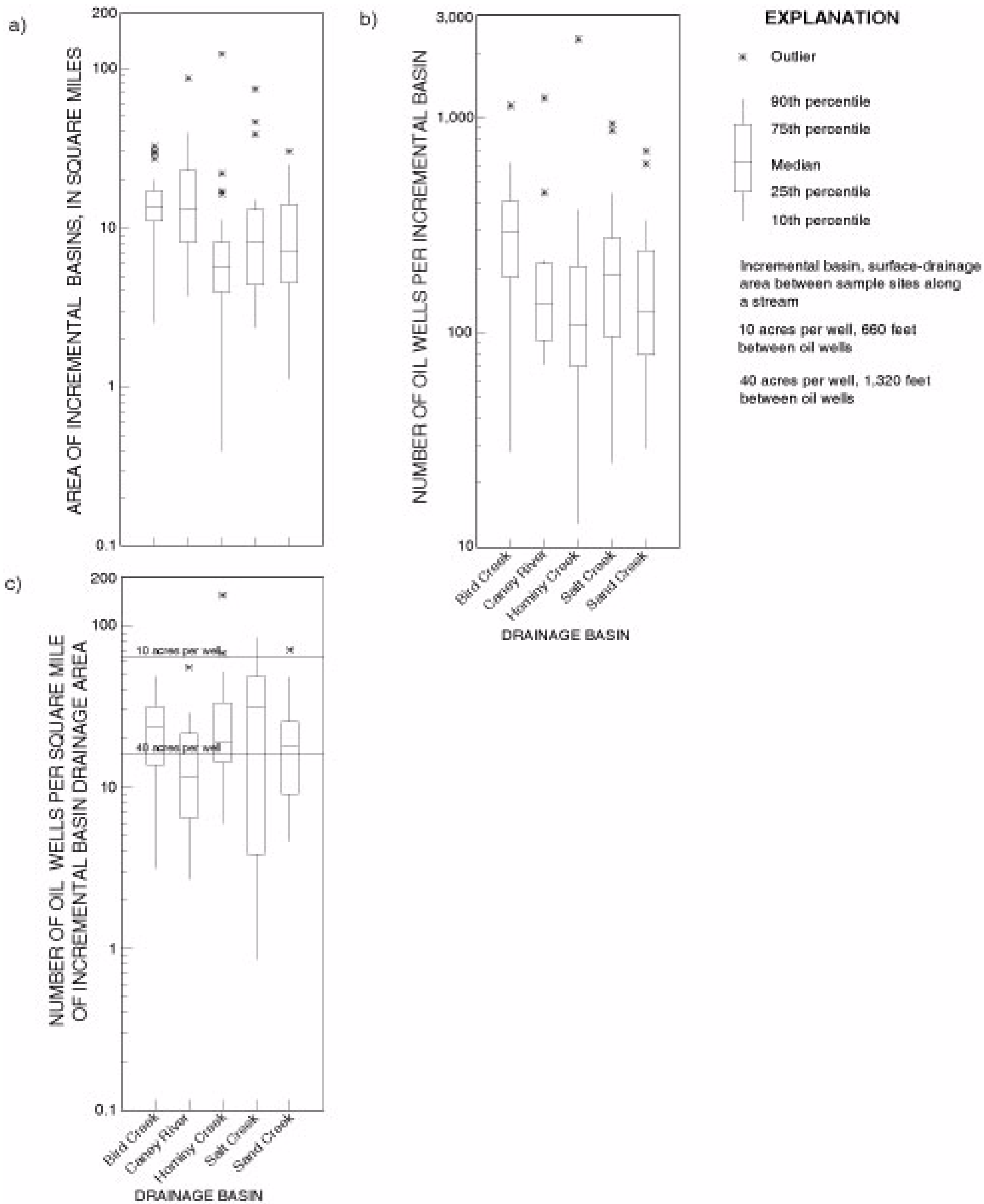


Figure 6. a) Incremental basin areas grouped by major drainage basins in the Osage Reservation, Oklahoma; b) the number of oil wells in incremental basins grouped by major drainage basins; and c) the number of oil wells per square mile in incremental basins grouped by major drainage basins.

Water Quality

Historical Water-Quality Data

Surface-water quality monitoring had been conducted previously at two sites included in this study. Hominy Creek near Hominy, 07176950, was monitored from May 1949 through November 1955. Birch Creek near Barnsdall, 07176455, was monitored from December 1964 through September 1966. The historical data for these sites for dissolved chloride concentrations are discrete samples during the monitoring periods (fig. 7). Stream discharge measurements at the time of sampling are not available for the historic water-quality data. The historic data were from months of expected greater average flow and months of expected lesser average flow. Dissolved chloride concentrations for the two samples collected during 1999 were equaled or exceeded at both sites by historical concentrations. The dissolved chloride concentrations in 1999 may or may not indicate improved surface-water quality in the reservation. Further repeated sampling at different discharges would be needed to confirm or refute this possibility.

Summary Statistics of Surface-Water Quality

Summary statistics of the 140 sampled sites for discharge measurements, dissolved chloride concentrations, and calculated chloride load and chloride yield provide information on suitability of water for different uses and possible causes of variability. These summary statistics are presented in tables 7-10 and box plots of the data illustrate the summary statistics in figures 8a, 8b, 8c, and 8d. Box plots summarize the distribution, range, skewness, and median of the data and for comparison of several data sets (Helsel and Hirsch, 1992). Summary statistics are grouped for all samples and for the larger-stream basins in the reservation on Bird Creek, Caney River, Hominy Creek, Salt Creek, and Sand Creek.

Analytical methods used for each sample are listed in table 11, at the back of this report. Surface-water-quality sites sampled, basin areas, and associated oil wells are listed in table 12, at the back of this report. Analytical results for each sample are reported in tables 13 and 14, at the back of this report.

Hypothesis testing for selected constituents was used to determine if statistical differences between the larger-stream basins existed. The Wilcoxon rank sum test (Wilcoxon, 1945; MathSoft Inc., 1999) was used because it is a nonparametric test requiring no assumptions about the data and is resistant to skewing by data outliers. The Wilcoxon rank sum tests the median of ranked data, instead of data values, to determine if two basin data sets were different. The test is appropriate for small and large data sets. The null hypothesis for the test was accepted if the two basin data sets being compared for a constituent had the same median and distribution. The null hypothesis was rejected if the probability (P-value) of the 2-sided test was less than or equal to 0.05 (95 percent confidence of relation). If the null hypothesis was rejected the alternate hypothesis was then true and the two basin data sets were significantly different for that constituent.

Stream discharge measurements (table 7) appear to be generally greater for Bird Creek and Caney River Basins than for Hominy Creek, Salt Creek, and Sand Creek Basins (fig. 8a), but because of the wide range of values in each of the larger-stream basins the statistical difference is not significant. Stream discharge measurements for Bird Creek Basin were significantly greater than those in Sand Creek Basin (table 7, fig. 8a). Hominy Creek Basin discharges were significantly less than those in Bird Creek, Caney River, and Sand Creek Basins.

Statistically significant differences between the larger basins for dissolved chloride are limited (table 8). Dissolved chloride concentrations were significantly greater in Hominy Creek Basin than in the other basins (fig. 8b). Dissolved chloride concentrations were significantly greater in Bird Creek Basin than in the Caney River Basin.

Dissolved chloride concentration exceeded the secondary drinking water standard of 250 milligrams per liter (U.S. Environmental Protection Agency, 1998) in four samples (fig. 8b). The National Primary Drinking Water Regulations and National Secondary Drinking Water Regulations are guidelines to evaluate health risks and drinking water quality (U.S. Environmental Protection Agency, 1998). These are referred to in this report as primary drinking water regulations and secondary drinking water standards. The primary drinking water regulations are enforceable for public water systems based on health risk; whereas the secondary drinking water standards are guidelines for the aesthetic quality of drinking water. Chloride in large concentrations, in combination with sodium and potassium, gives a salty taste to water and in large concentrations chloride increases the corrosiveness of water.

Chloride load is the rate at which dry weight of chloride passes a cross-section of a stream in any given time. Chloride load, reported in tons per day (table 9), was a product of the discharge measurement in cubic feet per second, dissolved chloride concentration in milligrams per liter, and a conversion factor of 0.00269. Chloride load for Bird Creek basin was significantly greater than the load for the Sand Creek Basin (table 9, fig. 8c). There were no significant differences in chloride load among the other basins.

Chloride yield, reported in tons per day per square mile (table 10), is the load divided by the basin area (table 12, at the back of this report) upstream of the sample site. There is no statistically significant difference between the larger basins for chloride yield (fig. 8d).

The National Atmospheric Deposition Program/National Trends Network is a nationwide network of precipitation monitoring sites. The purpose of the network is to collect data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends. The National Atmospheric Deposition Program/National Trends Network monitors indicate the mean annual chloride precipitation from the atmosphere is about 0.001 ton per day per square mile on the reservation (National Atmospheric Deposition Program/National Trends

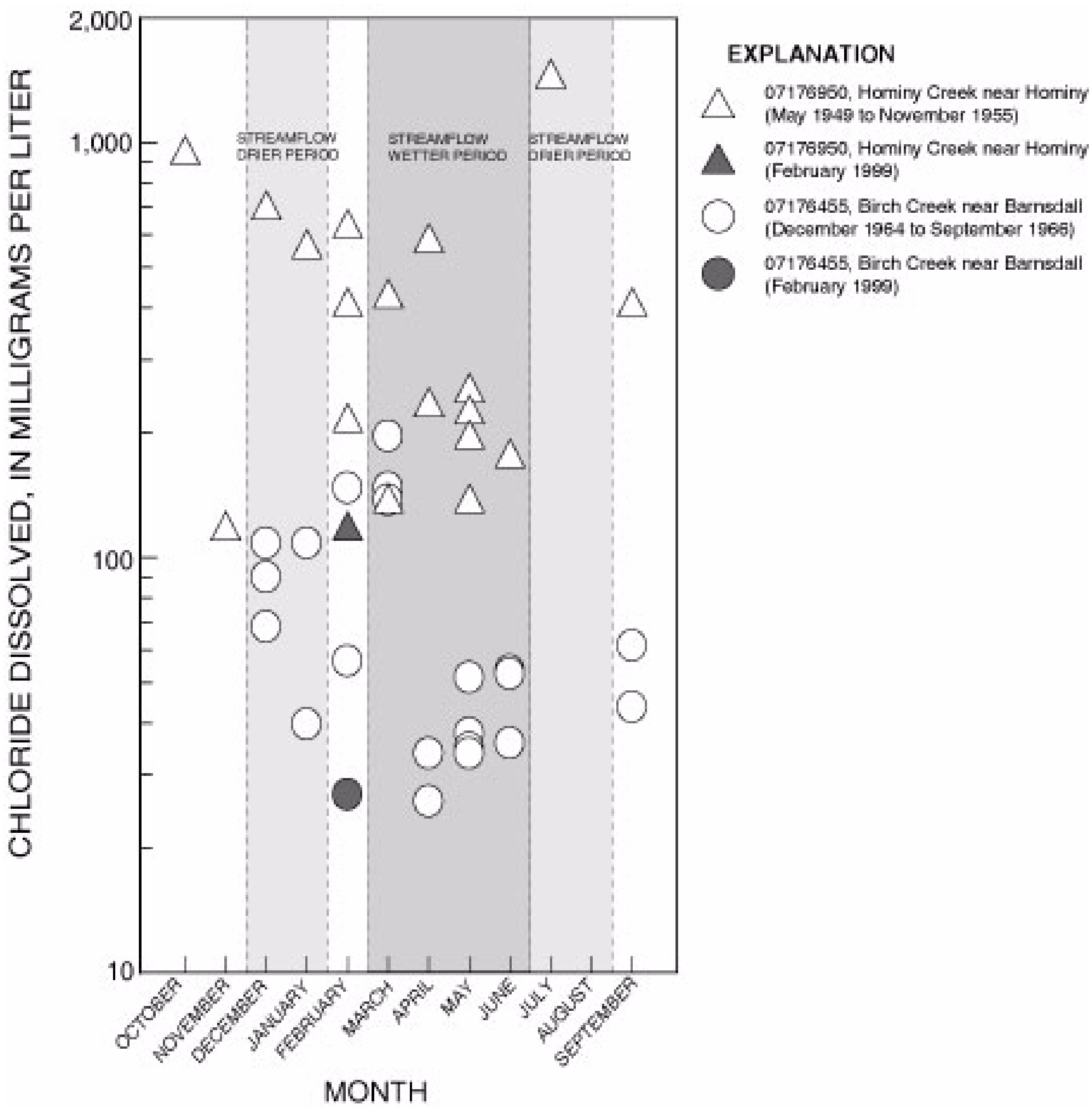


Figure 7. Dissolved chloride concentrations at two surface-water sites, historical and current water-quality data on the Osage Reservation, Oklahoma.

Table 7. Summary statistics of stream discharge measurements on the Osage Reservation, Oklahoma, 1999

[discharge measurements in cubic feet per second]

	Number of measurements	Mean	Minimum	Percentiles			Maximum
				25	50	75	
All samples	131	30	0.007	1.08	4.3	17	870
Bird Creek basin	24	72	0.056	5.8	19	69	870
Caney River basin	12	98	0.43	2.09	28	128	400
Hominy Creek basin	40	5.5	0.007	0.44	1.5	5.4	48
Salt Creek basin	15	18	0.04	0.41	12	26	81
Sand Creek basin	21	20	0.02	1.7	4.2	17	190

Table 8. Summary statistics of dissolved chloride concentrations in the Osage Reservation, Oklahoma, 1999

[chloride measurements in milligrams per liter]

	Number of measurements	Mean	Minimum	Percentiles			Maximum
				25	50	75	
All samples	140	63	2.0	13	27	51	1,100
Bird Creek basin	28	24	5.2	15	22	28	53
Caney River basin	12	23	2.6	4.1	12	19	130
Hominy Creek basin	41	130	7.8	27	52	130	1,100
Salt Creek basin	18	42	2.0	16	25	48	255
Sand Creek basin	21	28	4.0	9	19	37	110

Table 9. Summary statistics of chloride load in the Osage Reservation, Oklahoma, 1999

[chloride load in tons per day]

	Number of measurements	Mean	Minimum	Percentiles			Maximum
				25	50	75	
All samples	131	1.8	0.0002	0.08	0.3	1.4	42
Bird Creek basin	24	3.6	0.001	0.25	0.76	4.1	42
Caney River basin	12	3.2	0.0035	0.16	0.52	5.2	13
Hominy Creek basin	40	1.4	0.0018	0.04	0.21	1.0	15
Salt Creek basin	15	1.2	0.00021	0.03	0.22	1.7	5.2
Sand Creek basin	21	1.0	0.0016	0.08	0.11	0.86	7.7

Table 10. Summary statistics of chloride yield on the Osage Reservation, Oklahoma, 1999

[chloride yield in tons per day per square mile]

	Number of measurements	Mean	Minimum	Percentiles			Maximum
				25	50	75	
All samples	131	0.071	0.0000056	0.0071	0.020	0.067	1.6
Bird Creek basin	24	0.038	0.00021	0.014	0.026	0.048	0.14
Caney River basin	12	0.085	0.00026	0.013	0.039	0.076	0.44
Hominy Creek basin	40	0.055	0.00046	0.0057	0.015	0.069	0.56
Salt Creek basin	15	0.057	0.0000056	0.00021	0.019	0.10	0.20
Sand Creek basin	21	0.065	0.00026	0.0056	0.011	0.026	0.69

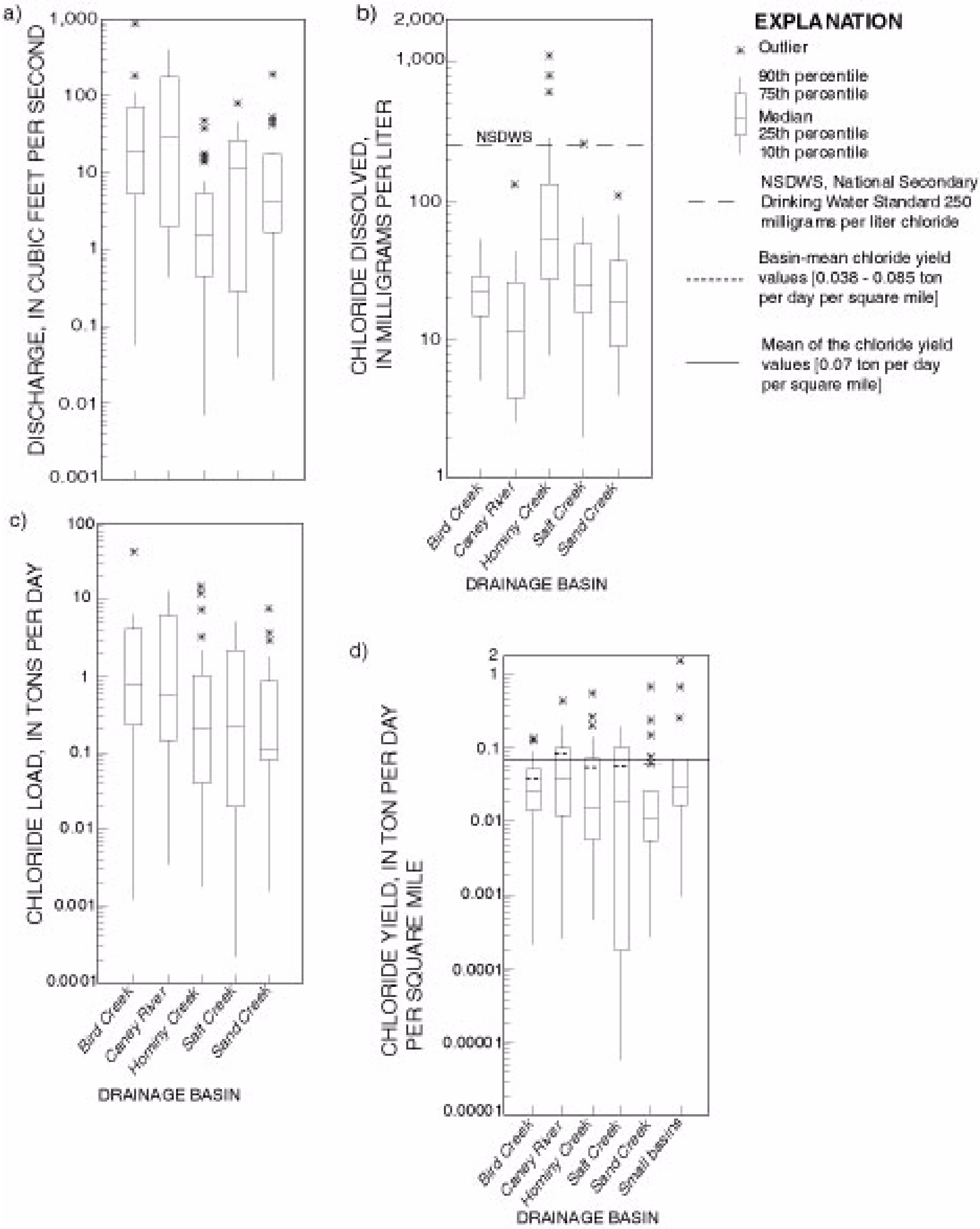


Figure 8. Stream discharge measurements at the time of sampling, grouped by major drainage basins; b) dissolved chloride concentration, grouped by major drainage basins; c) chloride load, grouped by major drainage basins; and d) chloride yield, grouped by major drainage basins.

Network, 2001). Yields greater than 0.001 ton per day per square mile may be attributed to the local environment and are affected by geologic conditions, surface and ground-water sources, and human activity.

The mean of the yields for chloride in the larger basins ranged from 0.038 to 0.085 ton per day per square mile (fig. 8d) and the mean of these basin-grouped-mean-chloride yields was 0.06 ton per day per square mile. The mean of the chloride yields for all the samples collected was 0.07 ton per day per square mile. Sample locations with yields greater than the regional values of 0.06 or 0.07 may indicate areas where additional monitoring and investigation may be useful (fig. 9). Many of these areas (fig. 9) are where dissolved chloride concentrations from surface-water samples were greater than 250 milligrams per liter in an earlier water-quality investigation (Rowe and others, 1982, p. 19-49).

Comparison of Surface-Water-Quality and Ground-Water-Quality Data

Thirty-three of the surface-water-quality samples were collected near domestic ground-water-supply wells (tables 16 and 17, at the back of this report) that were sampled in 1997 and the results were discussed in Abbott (2000). These samples included 18 of the 140 samples analyzed for dissolved chloride concentration and 15 of the 20 analyzed for the additional constituents. Most of the surface-water samples were collected 16 to 17 months after sampling the ground water.

There is no statistically significant difference between the dissolved chloride concentrations from the surface and nearby ground-water samples (fig. 10a). Chloride is one of the least reactive species in natural environments and tends to remain in solution. One of the surface-water samples, 07152505, (table 16, at the back of this report) exceeded the secondary drinking water standard for chloride of 250 milligrams per liter (U.S. Environmental Protection Agency, 1998) but the nearby ground-water sample was less than the secondary drinking water standard for chloride. Two surface-water samples, 07176929 and 07177420, (table 16, at the back of this report) were less than the secondary drinking water standard for chloride while the nearby ground-water samples exceeded the secondary drinking water standard for chloride.

The surface-water quality samples had significantly lesser concentrations of dissolved solids (fig. 10b), sulfate (fig. 10c), and nitrite plus nitrate as nitrogen (fig. 10d) than the ground-water samples. Dissolved solids, sulfate, and nitrite plus nitrate as nitrogen are more reactive than chloride in the natural environment. Only one surface-water sample, 07152505 and the nearby ground-water sample (table 16, at the back of this report) both exceeded the secondary drinking water standard for dissolved solids of 500 milligrams per liter (fig. 10b). Sulfate concentrations in two surface-water samples, 07176150 and 07174635, (table 16, at the back of this report) were 35 and 17 milligrams per liter, respectively, and the nearby ground-water samples exceeded the secondary drinking water standard of 250 milligrams per liter (fig. 10c). Nitrate concentrations in two surface-water samples, 07152460 and 07173005, (fig. 10d, table 16, at the back of this report) were 0.11 and 0.27 milligram per liter, respectively, and the two nearby

ground-water samples exceeded the primary drinking water regulation of 10 milligrams per liter. High nitrate concentrations in drinking water may cause methemoglobinemia, blue-baby syndrome (an often fatal disease in infants), and should not be consumed by infants, pregnant women, or nursing mothers.

Comparison of Surface-Water Quality and Oil Well Data

An investigation of possible relations between the surface-water-quality data and the oil-well data for the incremental basins was conducted. The surface-water-quality data also were compared to the oil-well data for wells within 1-mile radial distance upstream in the incremental basins. The 1-mile radial distance upstream in the incremental basin is only an arbitrary proximal zone near the sample site. The oil-well data included dates of first activity and dates of plugging, casing diameter, casing depth below land surface, and the type of treatment used to stimulate the well. No statistically significant relations were found between the surface-water-quality data and the oil-well data.

The oil-well data also were grouped by time periods of activity into pre-1930, 1930 to 1970, and post-1970. These groups attempt to account for differences in industry drilling and producing practices associated with various periods. For example, cable-tool drilling was used prior to 1930, but had limited use during the other two periods. Fracturing the producing formation in the wells to stimulate production has been practiced throughout each time period, but the methods of fracturing have changed from using explosives during the pre-1930 period to pressure and nitrogen-fracturing treatment during the post-1970 time period. Acid treatment of the formations became common practice in the mid-1950s. Acid-fracturing has been a common practice in the post-1970 period. No statistically significant relations were found between the surface-water-quality data and the oil-well data grouped by time for the incremental basins or for the 1-mile radial distance upstream the incremental basins.

Historical surface-water data indicate relatively large concentrations of chloride occurred on the reservation at least locally in the 1950s and 1960s (fig. 7) and a few surface-water samples had relatively large chloride concentrations in 1999 (figs. 8b, 10a-10c) but these conditions do not appear to be regionally prevalent. The management and disposal of produced brine water and the number of unplugged-abandoned wells in a basin may have an effect on water quality.

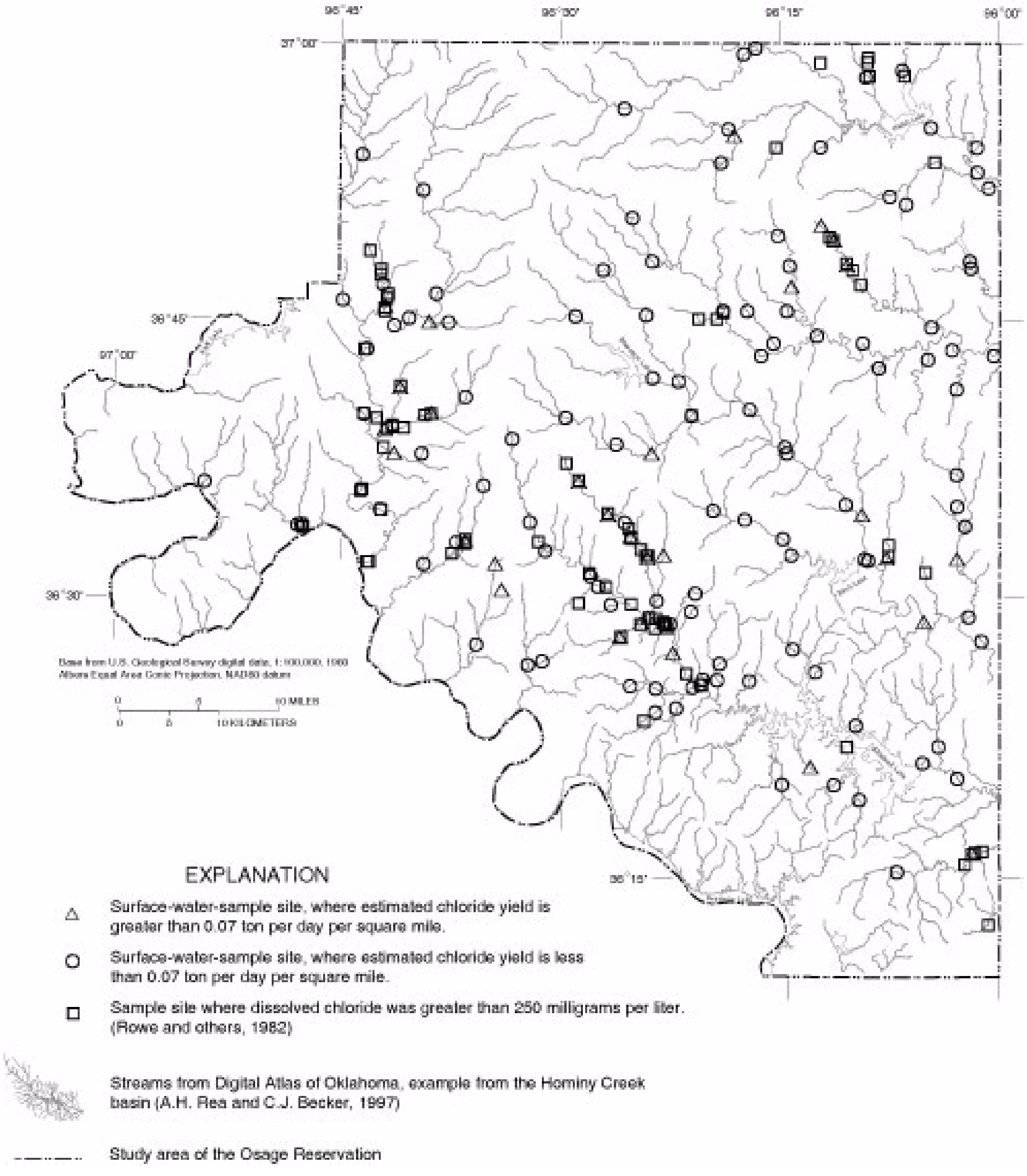


Figure 9. Surface-water sample sites where estimated chloride yield is greater than 0.07 ton per day per square mile on the Osage Reservation, Oklahoma.

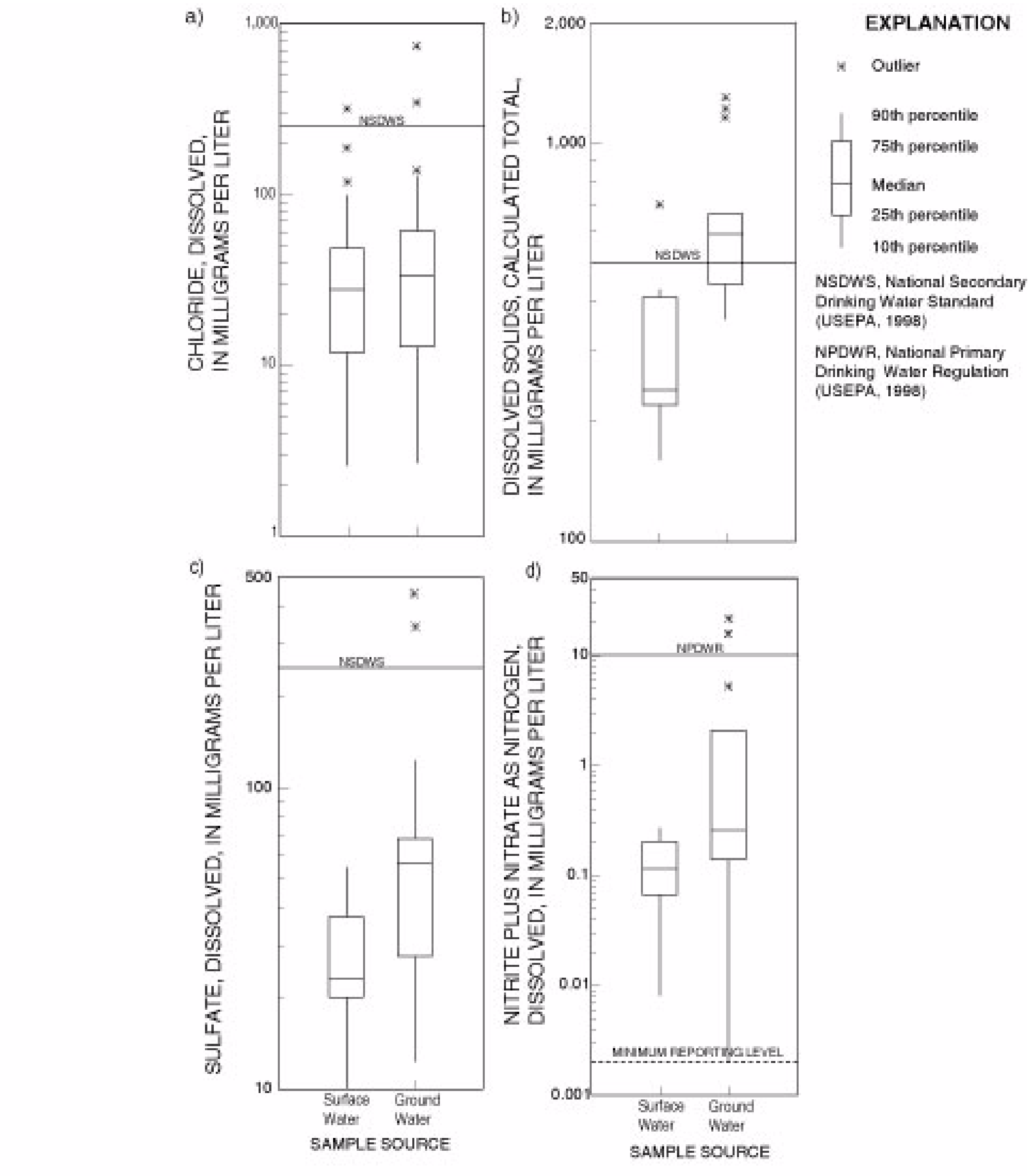


Figure 10. a) Dissolved chloride concentrations; b) dissolved solids concentration; c) dissolved sulfate concentration; and d) dissolved nitrite plus nitrate as nitrogen concentration in associated surface- and ground-water samples in the Osage Reservation, Oklahoma.

Summary

About 38,600 oil wells have been drilled on the Osage Reservation since drilling began in 1896. The term “oil well” in this report, is an industry well drilled to oil and gas production depths and includes oil and gas producers, nonproducing wells, injection wells, salt-water disposal wells, plugged wells, and abandoned wells. An early industry practice was to hold produced-brine water in surface pits. This was not allowed in the reservation after the late 1940s or early 1950s. Environmental problems with surface disposal of produced-brine water prompted a change to underground injection of the brine.

The Osage Reservation comprises three major drainage basins. The Caney River Basin is in the northeast, with the Sand Creek flowing into the river just south of Bartlesville. Lake Hulah is the major reservoir in the basin. The Bird Creek Basin is in the southeast, with Hominy Creek flowing into Bird Creek just south of Sperry. Bluestem Lake near Pawhuska, Birch Lake near Barnsdall, and Skiatook Lake near Skiatook are the major reservoirs in the Bird Creek Basin. The Salt Creek Basin in the west flows into the Arkansas River.

The streamflow characteristics in the study area were summarized by the seasonal distribution of streamflow, magnitude and frequency of floods, and annual low-flow frequency estimates. Variations in streamflow on the Osage Reservation during a year primarily result from variations in the quantity and frequency of rainfall, evapotranspiration, and reservoir operations. During some years, most streams do not flow during low rainfall periods in late summer, early fall, and in winter. Percent of mean annual discharge is largest during March through June, averaging 54 to 62 percent. Percent of mean annual discharge is smallest during December, January, July, and August, averaging only 14 to 21 percent.

Caney River near Hulah and Bird Creek near Sperry indicate the estimates of flood magnitude generally decrease with regulation. However, Bird Creek at Avant shows about the same flood magnitude before and after regulation and the documented extreme peak flow at Hulah is greater than before regulation.

Since small streams in the reservation do not flow during periods in late summer, early fall, and in winter when no rain falls, unregulated annual low-flow frequency estimates are zero or near zero for 1 to 10 consecutive days. Caney River near Hulah, Bird Creek at Avant, and Bird Creek near Sperry indicate that estimated annual low flows generally increase with regulation.

The drainage-basin data compiled include incremental basin area, basin area, number of oil wells in each incremental basin, number of oil wells in each basin, number of oil wells per square mile in each incremental basin, and number of oil wells per square mile in each basin. Incremental basin in this report refers to the surface-drainage areas between sample sites along a stream or the farthest upstream sample site.

The incremental basins range in size from 0.26 to 123 square miles with a median of 8.6 square miles. The basin areas of Caney River in the reservation (251 square miles), Salt Creek (273 square miles), and Sand Creek (227 square miles) are about the same, and there is no statistically significant difference in the sizes of the incremental basin areas within these larger basins. The basin areas of the Bird Creek Basin (418 square miles) and Hominy Creek Basin (383 square miles) are about the same but the incremental basin areas are statistically significantly different.

Total number of oil wells upgradient of the sample sites is 31,432 or 80 percent of the total in the reservation. The number of oil wells per incremental basin ranges from 5 to 2,311 wells. The total number of oil wells in the Caney River Basin in the reservation (2,975 wells), Salt Creek Basin (4,619 wells), and Sand Creek Basin (3,928 wells) are about the same, and there is no statistical difference in the distribution of the number of oil wells for the incremental basins for these streams. The total number of oil wells in the Bird Creek Basin (8,858 wells) and Hominy Creek Basin (7,842 wells) are about the same, but the distribution of the number of oil wells per incremental basins are statistically different. The number of oil wells per square mile in the incremental basins ranges from 0.86 to 154 wells. Some incremental basins in the Hominy, Salt, and Sand Creek Basins have oil well spacing less than 10 acres per well. The maximum number of 154 wells per square mile is from a small incremental basin in Hominy Creek Basin in Section 34-T22N-R10E.

Each of the 140 surface-water sites was sampled once during either February, March, or August 1999. Thirty-three of the samples were collected near domestic ground-water-supply wells to compare the surface and ground-water quality. Surface-water quality monitoring had been conducted previously at two sites included in this study. Hominy Creek near Hominy, 07176950, was monitored from May 1949 through November 1955. Birch Creek near Barnsdall, 07176455, was monitored from December 1964 through September 1966. Dissolved chloride concentrations for the two samples collected during 1999 were equaled or exceeded at both sites by the historical data. The dissolved chloride concentrations in 1999 may or may not indicate improved surface-water quality in the reservation.

Statistically significant differences between the larger basins for dissolved chloride are limited. Dissolved chloride concentrations were significantly greater in Hominy Creek Basin than in the other basins. Dissolved chloride concentration exceeded the secondary drinking water standards of 250 milligrams per liter in four samples.

Chloride load is the rate at which dry weight of chloride passes a cross-section of a stream in any given time. Chloride load for Bird Creek Basin was significantly greater than the load for the Sand Creek Basin. There were no significant differences in chloride load between the other basins.

Chloride yield, reported in tons per day per square mile, is the load divided by the basin area upstream of the sample site. There is no statistically significant difference between the larger basins for chloride yield. The mean of the yields for chloride in the larger basins ranged from 0.038 to 0.085 ton per day per square mile and the mean of these basin-grouped means

chloride yield was 0.06 ton per day per square mile. The mean of the chloride yields for all the samples collected was 0.07 ton per day per square mile. Sample locations with yields greater than the regional values of 0.06 or 0.07 may indicate areas where additional monitoring and investigation may be useful. Many of these areas are where dissolved chloride concentrations from surface-water samples were greater than 250 milligrams per liter in an earlier water-quality investigation.

There is no statistically significant difference between the dissolved chloride concentrations from the surface and nearby ground-water samples. The surface-water quality samples had significantly lesser concentrations of dissolved solids, sulfate, and nitrite plus nitrate as nitrogen than the ground-water samples.

An investigation of possible relations between the surface-water quality data and the oil-well data for the incremental basins was conducted. The surface-water-quality data also were compared to the oil-well data for wells within 1-mile radial distance upstream in the incremental basins. The oil-well data included dates of first activity and dates of plugging, casing diameter, casing depth below land surface, and the type of treatment used to stimulate the well. No statistically significant relations were found between the surface-water quality data and the oil-well data.

The oil-well data also were grouped by time periods of activity into pre-1930, 1930 to 1970, and post-1970. These groups attempt to account for differences in industry drilling and producing practices associated with various periods. No statistically significant relations were found between the surface-water-quality data and the oil-well data grouped by time for the incremental basins or for 1-mile upstream in the incremental basins

Historical surface-water data indicate relatively large concentrations of chloride occurred on the reservation at least locally in the 1950s and 1960s and a few surface-water samples had relatively large chloride concentrations in 1999 but these conditions do not appear to be regionally prevalent. The management and disposal of produced brine water and the number of unplugged-abandoned wells in a basin may have an effect on water quality.

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Supplemental Information

Delineation of basin boundaries

The drainage area boundaries for each water-quality-sample site (fig. 4) were used to determine the associated oil wells in each surface-water drainage basin. About 31,400 oil wells, 82 percent of the oil wells in the reservation (fig. 1), are upgradient of the 140 surface-water-quality-sample sites (figs. 2 and 4).

The drainage area for each surface-water site was determined from the National Elevation Dataset (NED-H) developed by the Earth Resources Observation System (EROS) Data Center. Based on 1:24,000-scale topographic maps, NED-H is a seamless, nationwide digital-elevation model with a resolution of one arc-second (about 30-meter pixel resolution). This digital-elevation model (fig. 5) is a grid array of elevation values, of the earth surface sampled by satellite along a regular interval. Information derived from NED-H data includes elevation, flow direction, flow accumulation, watershed boundaries, watershed areas, and synthetic streamline location data. Methods used for deriving these hydrologic features from the NED-H data are documented in Jenson and Domingue (1988). These data were processed using ARC/INFO 7.1, GRID software. Delineation of drainage basins is essentially a process of evaluating the local slope and direction of flow for every point in the digital-elevation data array. The upstream contributing drainage area for a point along a stream is determined by tracing all possible uphill paths from the grid cell containing the point until the drainage divide is reached. The watershed boundaries were checked for consistency with the topographic contours by overlaying the watershed boundaries on Digital Raster Graphics of 1:24,000 map sheets.

Oil-industry well data

Oil well locations (fig. 1) in the reservation used in this investigation were from the Natural Resources Information System (NRIS) data base (Geo Information Systems, 1999). Most oil wells in the data base have multiple entries for detailed well information of drilling, completion, work-overs, and plugging. Most multiple entries were identified and consolidated by searching for duplicate American Petroleum Institute identifier numbers or duplicate locations by the latitude and longitude. The American Petroleum Institute number is a unique-identifier number assigned to an oil well when intended drilling activity is initiated and is used to identify an oil well until it is plugged and abandoned. The data were consolidated to 38,599 well entries by two steps, but the exact number of oil wells in the reservation could not be determined from the NRIS data base. The exact number of boreholes is unknown because about 4,200 of the 38,599 oil-well sites are 118 feet or less from other sites. These locations are within a one-acre spacing and may or may not represent the same well. The actual number of wells drilled for oil and gas in the reservation is probably between 34,400 and 38,600. A site-by-site decision of the number of oil wells was beyond the scope of this study. For purposes of this report, there are an estimated 38,600 wells drilled for oil and gas in the reservation.

Water-quality sampling procedures

Each of the 140 surface-water sites was sampled once during either February, March, or August 1999. Thirty-three of the samples were collected near domestic ground-water-supply wells to compare the surface and ground-water quality. Sampling and related fieldwork were a three-step process: (1) streamflow measurement, (2) sampling and sample treatment, and (3) field measurements and analysis.

Most streamflow measurements for this investigation were wading measurements made using standard U.S. Geological Survey methods. Larger flow volumes were measured from bridges or were reported values from the U.S. Army Corps of Engineers from upstream reservoirs. Equipment and methods used are described in Buchanan and Somers (1969) and Rantz and others (1982). Streamflow measurements in cubic feet per second are listed in table 13.

A water-quality sample was collected at each site using the equal-width-increment technique. The samples at each station in the cross-section were composited in a churn splitter (Edwards and Glysson, 1988; Ward and Harr, 1990); resulting in a sample that represents water quality across the width of the stream at each sampling site. Samples collected for the analysis of dissolved-inorganic constituents were filtered through a 0.45-micron pore size disposable-cartridge filter and preserved with nitric acid.

Field analyses for stable water properties used standard U.S. Geological Survey methods. Specific conductance was measured using a portable conductivity meter with automatic temperature compensation. The conductivity meter was calibrated daily using standard conductivity solutions that bracketed the expected field values. Water temperature was measured to the nearest 0.1 degree Celsius using a calibrated electronic thermistor. pH values were measured using a portable pH meter, with automatic temperature compensation. The pH meters were calibrated daily before starting measurements using standard buffer solutions that bracketed the expected field pH values. Meter calibration was subsequently corroborated, using a third buffer solution. Alkalinity was measured by an incremental titration (Wells and others, 1990) of a filtered aliquot. Alkalinity was measured at the sample site or from a chilled sample at the end of each day.

Water-quality analyses

All surface-water-quality samples were analyzed for specific conductance and dissolved chloride concentration by the U.S. Geological Survey, Quality of Water Service Unit laboratory in Ocala, Florida, and the National Water Quality Laboratory in Lakewood, Colorado. Analytical methods used by the laboratories for the analyses of the water-quality samples are listed in table 11.

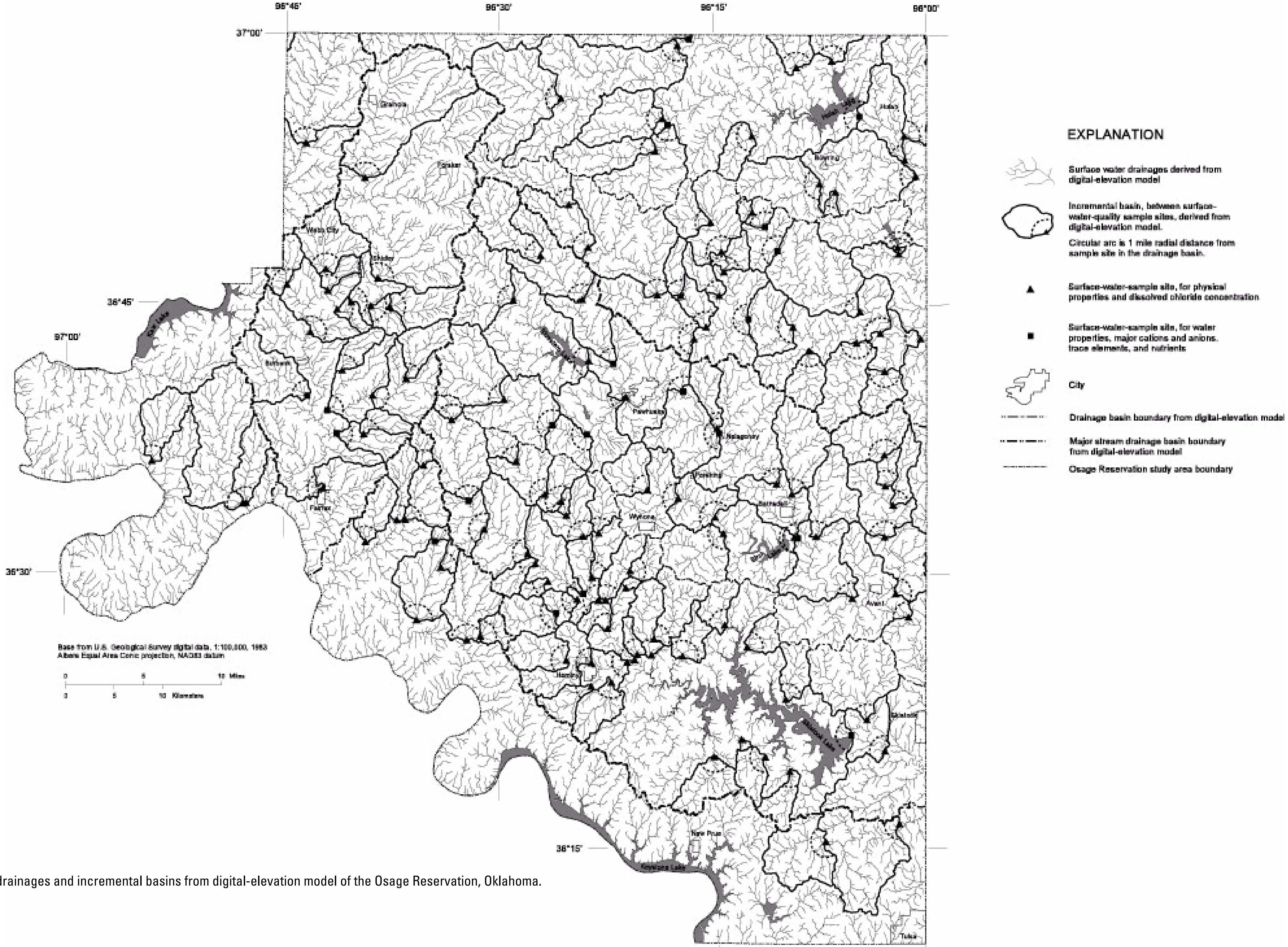

Figure 4. Surface drainages and incremental basins from digital-elevation model of the Osage Reservation, Oklahoma.

Figure 5. Digital-elevation model of the Osage Reservation, Oklahoma.

Brine constituents	Nutrient constituents	Staining constituents
Specific conductance	Nitrogen, nitrite plus nitrate,	Iron
pH	Nitrogen, ammonia	Manganese
Alkalinity, total	Nitrogen, ammonia plus organic	
Dissolved solids	Phosphorus, total	
Calcium	Phosphorus, orthophosphate	
Magnesium	Carbon organic, total	
Sodium		
Potassium		
Sulfate		
Chloride		
Fluoride		
Bromide		
Silica		
Arsenic		
Boron		
Lithium		
Strontium		
Carbon organic, total		

Water samples from 20 of these sites also were analyzed for the constituents that had been previously analyzed in a regional ground-water-quality survey in the reservation (Abbott, 2000), including water properties, major cations and anions, trace elements, and nutrients (table 11). The U.S. Geological Survey, Quality of Water Service Unit Laboratory in Ocala, Florida, performed the laboratory analyses. Analytical results are reported in tables 13 and 14. Water-quality constituents selected for analysis (listed above) were those associated with oil brines (Collins, 1975), nutrients associated with agriculture and domestic processes, and trace elements associated with staining.

Standard methods described in Fishman and Friedman (1989) and by U.S. Environmental Protection Agency protocols were used in the analyses (table 11).

Quality-control sampling

Twenty replicate samples were collected with the 140 chloride water-quality samples. Two replicate samples were collected with the 20 water-quality samples analyzed for the additional constituents. One equipment blank sample was processed. The analyses of the quality-control samples collected during the study are listed in tables 15a, and 15b. Replicate samples consist of two sets of samples collected from the same source during the same sampling event and analyzed in exactly the same manner. Replicate samples determine precision and reproducibility of sampling procedures and laboratory analytical methods. Relative percent difference between a water-quality sample and replicate sample is calculated, as follows:

$$RPD = \frac{|C_1 - C_2|}{\left(\frac{(C_1 + C_2)}{2}\right)} \times 100$$

where RPD is the relative percent difference, C1 is the concentration of the water-quality sample, and C2 is the concentration of the replicate sample. A small RPD, less than 10 percent, indicates consistency of sampling and analytical procedures. The relative percent difference for chloride was less than 10 percent for all the replicate samples. The relative percent difference for the additional constituents was less than 10 percent except for bromide, nitrogen as ammonia, nitrogen as ammonia plus organic, iron, and organic carbon. Differences in replicate sample concentrations for bromide, nitrogen as ammonia, nitrogen as ammonia plus organic, and iron were 0.1 milligram per liter or less, and for organic carbon was 0.5 milligram per liter. Larger RPD for small concentrations near the minimum reporting level (table 11) was expected.

Low concentrations, near the minimum reporting level, of some chemical constituents occurred in blank samples, possibly derived from the sampling equipment or from wind-blown particles. The equipment blank was prepared at the Oklahoma District office of the U.S. Geological Survey using standard U.S. Geological Survey procedures as described in Horowitz and others (1994). The equipment blank contained concentrations greater than the minimum reporting level (table 11) for alkalinity, calcium, silica, nitrite plus nitrate as nitrogen, boron, iron, and manganese. Water-quality sample values reported in table 13 are the results reported by the laboratories and are not corrected for the equipment blank values. Analyses for alkalinity, calcium, silica, boron, and manganese are considered to be valid, because the minimum value for the field water-quality samples is greater than the detected values in the equipment blanks. One field water-quality sample had a questionable iron value, less than the equipment blank. One field water-quality sample had a nitrite plus nitrate as nitrogen value less than the equipment blank.

The U.S. Geological Survey Quality of Water Service Unit Laboratory and the National Water Quality Laboratory maintain a blind sample program that tests the bias and variability of laboratory analytical procedures. Blind samples of known composition are analyzed as routine environmental samples and are subjected to identical laboratory handling, processing, and analytical procedures. Blind samples are submitted at a rate of 3-5 percent of the annual sample load for each analytical procedure. Standard reference sample water (Farrar and Long, 1997) is used to make the blind samples. The laboratory sets control limits at ± 2 standard deviations of the most-probable concentration. Precision and control charts are prepared to monitor the data quality and analytical results.

Table 11. Analytical methods used at the U.S. Geological Survey, Quality of Water Service Unit Laboratory, Ocala, Florida, and the National Water Quality Laboratory, Denver, Colorado

[mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; AE, atomic emission spectrophotometry; ICP, inductively coupled plasma spectrophotometry; AA, atomic absorption spectrophotometry; /T, trace; I- followed by numbers, a method code used by U.S. Geological Survey, Quality of Water Service Unit laboratory in Ocala, Florida and the National Water Quality Laboratory in Lakewood, Colorado; EPA- followed by numbers, a protocol described by the U.S. Environmental Protection Agency]

Constituents and reporting units	Method	Minimum reporting level
WATER PROPERTIES		
Specific conductance, field (µS/cm at 25°C)		1
pH, field, standard units		0.1
Water temperature (°C)		0.1
Alkalinity, total, field, (mg/L as calcium carbonate)	whole water, incremental titration	1
Dissolved solids, calculated sum (mg/L)		1
MAJOR CATIONS		
Calcium, dissolved (mg/L as calcium)	EPA-200.7, ICP/T	0.02
Magnesium, dissolved (mg/L as magnesium)	EPA-200.7, ICP/T	0.001
Sodium, dissolved (mg/L as sodium)	I-1735-85, AA, direct	0.1
Potassium, dissolved (mg/L as potassium)	I-1630-85, AA, direct	0.1
MAJOR ANIONS		
Sulfate, dissolved (mg/L as sulfate)	SM 426-C, Turbidimetry, auto, background corrected	0.2
Chloride, dissolved (mg/L as chloride)	I-2057-85, Colorimetry, thiocyanate, auto	0.1
Fluoride, dissolved (mg/L as fluoride)	I-2327-85, Ion selective electrode, auto	0.1
Bromide, dissolved (mg/L as bromide)	EPA-300.0, Colorimetry, fluorescein, auto	0.05
Silica, dissolved (mg/L as silica)	EPA-200.7, ICP/T	0.01
NUTRIENTS		
Nitrogen, nitrite plus nitrate, dissolved (mg/L as nitrogen)	EPA-353.2	0.002
Nitrogen, ammonia, dissolved (mg/L as nitrogen)	I-2522-85	0.002
Nitrogen, ammonia plus organic, dissolved (mg/L as nitrogen)	EPA-351.2	0.2
Phosphorus, total dissolved (mg/L as phosphorus)	I-4600-85	0.002
Phosphorus, orthophosphate dissolved (mg/L as phosphorus)	I-4601-85	0.001
Carbon organic, total dissolved (mg/L as carbon)	EPA-415.1	0.1
TRACE ELEMENTS		
Arsenic, dissolved (µg/L as arsenic)	EPA-206.2,AA, hydride, auto	1
Boron, dissolved (µg/L as boron)	EPA-200.7, ICP/T	3
Iron, dissolved (µg/L as iron)	EPA-200.7, ICP/T	1
Lithium, dissolved (µg/L as lithium)	I-1472-87, ICP	4
Manganese, dissolved (µg/L as manganese)	I-3456-85, AE, ICP	0.2
Strontium, dissolved (µg/L as strontium)	I-1472.87 AE, ICP	0.5

Table 12. Surface-water quality sites, basin areas, and associated oil wells on the Osage Reservation, Oklahoma

[basin, total surface drainage area upstream of sample site; oil well, any well drilled for oil and gas production purposes; --, first upstream sample site]

Station number[1]	Station name	Local identifier	Area of incremental basin[2], (square miles)	Number of oil wells in incremental basin[2]	Number of oil wells per square mile in incremental basin[2]	Area of basin, (square miles)	Number of oil wells in basin	Number of oil wells per square mile in basin
07148120	BEAVER CREEK SITE OS-122 NEAR GRAINOLA, OK	28N-05E-14 DDD 1	--	--	--	31.3	64	2.0
07152280	LITTLE DRUM CREEK SITE OS-203 NEAR PONCA CITY, OK	25N-04E-32 BCA 1	--	--	--	9.3	68	7.4
07152340	AOGA CREEK SITE OS-042 NEAR FAIRFAX, OK	24N-05E-17 BBA 1	--	--	--	28.5	156	5.5
07152345	CLEAR CREEK SITE OS-041 NEAR FAIRFAX, OK	24N-05E-08 CDD 1	--	--	--	7.5	53	7.0
07152355	SALT CREEK SITE OS-127 NEAR SHIDLER, OK	28N-06E-33 AAC 1	--	--	--	38.4	33	0.9
07152390	SALT CREEK SITE OS-110 NEAR SHIDLER, OK	27N-06E-34 BDB 1	73.7	219	3.0	112.1	252	2.2
07152410	ROCK CREEK SITE OS-091 NEAR SHIDLER, OK	26N-06E-11 BDD 1	--	--	--	9.0	25	2.8
07152415	ROCK CREEK SITE OS-090 NEAR SHIDLER, OK	26N-06E-10 BCD 1	3.5	96	27	12.6	121	9.6
07152417	SALT CREEK SITE OS-089 NEAR SHIDLER, OK	26N-06E-08 AAA 1	6.1	276	45	127.1	649	5.1
07152418	SALT CREEK SITE OS-088 NEAR SHIDLER, OK	26N-06E-08 CBB 1	2.4	160	67	133.1	809	6.1
07152419	HAY CREEK SITE OS-202 NEAR SHIDLER, OK	27N-06E-31 BAB 1	--	--	--	12.0	936	78
07152420	HAY CREEK SITE OS-087 NEAR SHIDLER, OK	26N-06E-06 BDD 1	3.0	249	84	15.0	1,185	79
07152423	MUD CREEK SITE OS-006 NEAR SHIDLER, OK	26N-05E-03 AAA 1	--	--	--	6.0	162	27
07152426	SALT CREEK SITE OS-086 NEAR BURBANK, OK	26N-05E-24 BAB 1	14.9	872	58	169.1	3,028	18
07152430	JIM CREEK SITE OS-070 NEAR BURBANK, OK	25N-05E-12 BBA 1	--	--	--	13.0	50	3.8
07152435	LITTLE CHIEF CREEK SITE OS-071 NEAR BURBANK, OK	25N-06E-01 ABB 1	--	--	--	7.2	26	3.6
07152440	LITTLE CHIEF CREEK SITE OS-074 NEAR BURBANK, OK	25N-06E-10 BAA 1	13.0	238	18	20.1	264	13
07152445	LOST MAN CREEK SITE OS-092 NEAR BURBANK, OK	26N-06E-32 BDD 1	--	--	--	4.4	211	48
07152450	LITTLE CHIEF CREEK SITE OS-073 NEAR BURBANK, OK	25N-06E-18 ABB 1	12.4	445	36	36.9	920	25
07152455	SOLOMAN CREEK TRIBUTARY SITE OS-072 NEAR FAIR-FAX, OK	25N-06E-21 DAA 1	--	--	--	3.8	159	42
07152460	SOLOMAN CREEK SITE OS-075 NEAR FAIFAX, OK	25N-06E-20 BCC 1	5.9	146	25	9.6	305	32
07152470	SALT CREEK SITE OS-043 AT FAIRFAX, OK	24N-06E-07 BAA 1	46.0	316	6.9	274.6	4,619	17

Table 12. Surface-water quality sites, basin areas, and associated oil wells on the Osage Reservation, Oklahoma—Continued

[basin, total surface drainage area upstream of sample site; oil well, any well drilled for oil and gas production purposes; --, first upstream sample site]

Station number[1]	Station name	Local identifier	Area of incremental basin[2], (square miles)	Number of oil wells in incremental basin[2]	Number of oil wells per square mile in incremental basin[2]	Area of basin, (square miles)	Number of oil wells in basin	Number of oil wells per square mile in basin
07152501	GRAY HORSE CREEK SITE OS-045 NEAR FAIRFAX, OK	24N-06E-24 BBA 1	--	--	--	5.8	91	16
07152502	LUCY CREEK SITE OS-077 NEAR FAIRFAX, OK	25N-07E-31 ADC 1	--	--	--	2.7	35	13
07152503	LUCY CREEK SITE OS-044 NEAR FAIRFAX, OK	24N-06E-13 DDC 1	8.3	264	32	11.0	299	27
07152504	GRAY HORSE CREEK TRIB. SITE OS-046 NEAR FAIRFAX, OK	24N-06E-27 BCA 1	--	--	--	6.4	39	6.1
07152505	SYCAMORE CREEK SITE OS-049 NEAR FAIRFAX, OK	24N-07E-29 ACA 1	--	--	--	1.0	43	43
07152506	SYCAMORE CREEK TRIBUTARY SITE OS-050 NEAR FAIRFAX, OK	24N-07E-33 CCD 1	--	--	--	1.6	88	54
07152507	SYCAMORE CREEK SITE OS-016 NEAR BLACKBURN, OK	23N-07E-19 ACC 1	13.5	104	7.7	16.2	235	14
07153040	BUG CREEK TRIBUTARY SITE OS-017 NEAR BLACKBURN, OK	23N-07E-26 ACA 1	--	--	--	3.2	78	24
07153060	BUG CREEK SITE OS-018 NEAR BLACKBURN, OK	23N-07E-27 DAB 1	16.3	193	12	19.5	271	14
07172050	CANEY RIVER SITE OS-140 NEAR ELGIN, KS	29N-09E-13 ABD 1	--	--	--	261.1	161	0.62
07172100	BUCK CREEK SITE OS-123 NEAR FORAKER, OK	28N-08E-03 ABB 1	--	--	--	26.4	71	2.7
07172300	BUCK CREEK SITE OS-137 NEAR ELGIN, KS	29N-09E-14 DBA 1	39.4	447	11	65.7	518	7.9
07172475	SOUTH FORK OF POND CREEK SITE OS-128 NEAR ELGIN, KS	28N-09E-22 ADB 1	--	--	--	10.8	123	11
07172480	POND CREEK SITE OS-126 NEAR ELGIN, KS	28N-09E-11 DBD 1	17.0	101	5.9	27.8	224	8.1
07172485	DRY CREEK SITE OS-125 NEAR ELGIN, KS	28N-09E-11 BDC 1	--	--	--	13.5	216	16
07172490	BIRCH CREEK SITE OS-130 NEAR BOWRING, OK	28N-10E-14 BCC 1	--	--	--	5.6	150	27
07172492	TURKEY CREEK SITE OS-131 NEAR HULAH, OK	29N-11E-30 AAB 1	--	--	--	13.7	111	8.1
07172494	HICKORY CREEK SITE OS-139 NEAR HULAH, OK	29N-11E-21 DAA 1	--	--	--	17.7	204	12
07173005	CANEY RIVER SITE OS-132 NEAR HULAH, OK	28N-11E-12 BCB 1	133.0	1,231	9.2	538.1	2,815	5.2
07173050	COON CREEK SITE OS-134 NEAR HULAH, OK	28N-12E-17 ADD 1	--	--	--	17.7	84	4.7
07173060	CANEY RIVER SITE OS-135 NEAR HULAH, OK	28N-12E-28 BBB 1	12.0	76	6.3	567.8	2,975	5.2

Table 12. Surface-water quality sites, basin areas, and associated oil wells on the Osage Reservation, Oklahoma—Continued

[basin, total surface drainage area upstream of sample site; oil well, any well drilled for oil and gas production purposes; --, first upstream sample site]

Station number[1]	Station name	Local identifier	Area of incremental basin[2], (square miles)	Number of oil wells in incremental basin[2]	Number of oil wells per square mile in incremental basin[2]	Area of basin, (square miles)	Number of oil wells in basin	Number of oil wells per square mile in basin
07173070	MISSION CREEK SITE OS-133 NEAR BOWRING, OK	28N-11E-33 ACC 1	--	--	--	15.8	260	16
07173080	MISSION CREEK TRIBUTARY SITE OS-119 NEAR BOWRING, OK	27N-11E-03 ABB 1	--	--	--	1.1	17	15
07173090	MISSION CREEK SITE OS-136 NEAR HULAH, OK	28N-12E-28 DDC 1	24.7	265	11	30.6	542	18
07174330	BUTLER CREEK SITE OS-121 NEAR BARTLESVILLE, OK	27N-12E-20 ACC 1	--	--	--	13.7	265	19
07174332	BUTLER CREEK SITE OS-120 NEAR BARTLESVILLE, OK	27N-12E-20 DCA 1	0.3	5	19	14.0	270	19
07174530	SAND CREEK SITE OS-111 NEAR FORAKER, OK	27N-08E-02 CCC 1	--	--	--	12.1	120	9.9
07174535	SAND CREEK SITE OS-113 NEAR PAWHUSKA, OK	27N-08E-24 CAA 1	9.8	54	5.5	21.9	174	8.0
07174545	SAND CREEK SITE OS-096 NEAR PAWHUSKA, OK	26N-09E-03 DAA 1	30.1	156	5.2	51.9	330	6.3
07174555	SAND CREEK SITE OS-097 NEAR PAWHUSKA, OK	26N-10E-19 BDB 1	17.8	82	4.6	69.7	412	5.9
07174558	CEDAR CREEK SITE OS-095 NEAR PAWHUSKA, OK	26N-09E-01 CAA 1	--	--	--	3.8	29	7.7
07174560	CEDAR CREEK SITE OS-102 NEAR PAWHUSKA, OK	26N-10E-17 CBB 1	4.5	79	17	8.3	108	13
07174562	ROCK CREEK SITE OS-129 NEAR HERD, OK	27N-10E-08 CDD 1	--	--	--	6.0	54	9.1
07174563	ROCK CREEK SITE OS-116 NEAR BOWRING, OK	27N-10E-21 CBB 1	13.4	241	18	19.4	295	15
07174565	ROCK CREEK SITE OS-118 NEAR OKESA, OK	27N-10E-33 BBA 1	3.9	53	14	23.3	348	15
07174568	ELM CREEK SITE OS-100 NEAR PAWHUSKA, OK	26N-10E-05 DAA 1	--	--	--	4.1	99	24
07174575	SAND CREEK SITE OS-101 NEAR OKESA, OK	26N-10E-15 AAA 1	18.4	278	15	123.8	1,245	10
07174585	SAND CREEK SITE OS-104 NEAR OKESA, OK	26N-11E-18 DBA 1	10.0	86	8.6	133.7	1,331	10
07174605	PAULA CREEK SITE OS-106 NEAR OKESA, OK	26N-11E-29 AAA 1	--	--	--	6.9	129	19
07174615	LITTLE ROCK CREEK SITE OS-105 NEAR OKESA, OK	26N-11E-23 DAA 1	--	--	--	14.0	275	20
07174620	BUCK CREEK SITE OS-114 NEAR BOWRING, OK	27N-10E-11 BCA 1	--	--	--	1.1	36	32
07174625	BUCK CREEK SITE OS-115 NEAR BOWRING, OK	27N-10E-14 AAD 1	2.5	175	70	3.6	211	58
07174635	BUCK CREEK SITE OS-117 NEAR BOWRING, OK	27N-10E-24 DDB 1	7.0	332	48	10.6	543	51

Table 12. Surface-water quality sites, basin areas, and associated oil wells on the Osage Reservation, Oklahoma—Continued

[basin, total surface drainage area upstream of sample site; oil well, any well drilled for oil and gas production purposes; --, first upstream sample site]

Station number[1]	Station name	Local identifier	Area of incremental basin[2], (square miles)	Number of oil wells in incremental basin[2]	Number of oil wells per square mile in incremental basin[2]	Area of basin, (square miles)	Number of oil wells in basin	Number of oil wells per square mile in basin
07174637	BUCK CREEK SITE OS-103 NEAR OKESA, OK	26N-11E-12 CBA 1	24.7	700	28	35.3	1243	35
07174640	SAND CREEK SITE OS-107 NEAR OKESA, OK	26N-12E-18 CDD 1	23.9	609	26	213.8	3,587	17
07174645	PANTHER CREEK SITE OS-109 NEAR BARTLESVILLE, OK	26N-12E-31 ACC 1	--	--	--	6.4	125	19
07174650	SAND CREEK SITE OS-108 NEAR BARTLESVILLE, OK	26N-12E-21 AAD 1	7.0	216	31	227.3	3,928	17
07176140	NORTH BIRD CREEK SITE OS-112 NEAR PEARSONIA, OK	27N-08E-28 BAC 1	--	--	--	13.3	204	15
07176145	NORTH BIRD CREEK SITE OS-098 NEAR PEARSONIA, OK	26N-08E-01 CCB 1	16.2	86	5.3	29.5	290	9.8
07176150	NORTH BIRD CREEK SITE OS-099 NEAR PAWHUSKA, OK	26N-09E-29 CCC 1	10.9	168	16	40.3	458	11
07176160	MIDDLE BIRD CREEK SITE OS-093 NEAR PAWHUSKA, OK	26N-08E-06 DCC 1	--	--	--	17.6	82	4.6
07176170	MIDDLE BIRD CREEK SITE OS-094 NEAR PAWHUSKA, OK	26N-08E-25 CDD 1	29.4	196	6.7	47.1	278	5.9
07176180	CLEAR CREEK SITE OS-076 NEAR PAWHUSKA, OK	25N-07E-12 ADA 1	--	--	--	17.2	54	3.1
07176220	CLEAR CREEK SITE OS-078 NEAR PAWHUSKA, OK	25N-08E-15 CAC 1	16.5	289	18	33.7	343	10
07176240	CLEAR CREEK SITE OS-079 NEAR PAWHUSKA, OK	25N-08E-24 BDD 1	6.5	158	24	40.3	501	12
07176300	CLEAR CREEK SITE OS-082 NEAR PAWHUSKA, OK	24N-09E-08 AAA 1	16.0	274	17	56.3	775	14
07176325	BIRD CREEK SITE OS-081 NEAR PAWHUSKA, OK	25N-09E-01 DBB 1	27.0	390	14	170.7	1,901	11
07176330	BIRD CREEK SITE OS-084 AT NELAGONEY, OK	25N-10E-20 ADD 1	16.6	424	26	187.3	2,325	12
07176335	BUFFALO CREEK SITE OS-083 NEAR NELAGONEY, OK	25N-10E-17 DDC 1	--	--	--	5.8	29	5.0
07176340	BIRD CREEK SITE OS-060 NEAR BARNSDALL, OK	24N-10E-01 DAA 1	29.9	382	13	223.1	2,736	12
07176345	CHOTEAU CREEK SITE OS-063 NEAR BARNSDALL, OK	24N-11E-08 BCC 1	--	--	--	14.4	617	43
07176425	BIRCH CREEK SITE OS-057 NEAR WYNONA, OK	24N-09E-03 DCC 1	--	--	--	7.3	259	35
07176440	BIRCH CREEK SITE OS-058 NEAR WYNONA, OK	24N-09E-12 ACC 1	13.8	295	21	21.2	554	26
07176455	BIRCH CREEK SITE OS-061 NEAR BARNSDALL, OK	24N-10E-17 DAA 1	9.5	457	48	30.6	1,011	33
07176457	FOUR MILE CREEK SITE OS-062 NEAR BARNSDALL, OK	24N-10E-21 DCB 1	--	--	--	13.4	450	33
07176470	BIRCH CREEK SITE OS-064 NEAR BARNSDALL, OK	24N-11E-20 CCC 1	20.1	489	24	64.2	1,950	30
07176475	BIRD CREEK SITE OS-065 NEAR BARNSDALL, OK	24N-11E-20 CDD 1	11.0	327	30	312.7	5,630	18

Table 12. Surface-water quality sites, basin areas, and associated oil wells on the Osage Reservation, Oklahoma—Continued

[basin, total surface drainage area upstream of sample site; oil well, any well drilled for oil and gas production purposes; --, first upstream sample site]

Station number[1]	Station name	Local identifier	Area of incremental basin[2], (square miles)	Number of oil wells in incremental basin[2]	Number of oil wells per square mile in incremental basin[2]	Area of basin, (square miles)	Number of oil wells in basin	Number of oil wells per square mile in basin
07176480	DOG THRESHER CREEK SITE OS-066 NEAR BARNSDALL, OK	24N-11E-21 CDD 1	--	--	--	12.4	479	39
07176490	BIRD CREEK SITE OS-038 NEAR AVANT, OK	23N-11E-11 DDB 1	16.7	391	23	341.8	6,500	19
07176695	CANDY CREEK SITE OS-085 NEAR WOLCO, OK	25N-12E-30 DBD 1	--	--	--	12.7	355	28
07176700	CANDY CREEK SITE OS-067 NEAR WOLCO, OK	24N-12E-05 CBB 1	2.5	28	11	15.2	383	25
07176750	LITTLE CANDY CREEK SITE OS-068 NEAR WOLCO, OK	24N-12E-08 DCC 1	--	--	--	4.9	199	41
07176800	CANDY CREEK SITE OS-069 NEAR WOLCO, OK	24N-12E-19 DDD 1	11.7	294	25	31.8	876	28
07176820	CANDY CREEK SITE OS-039 NEAR AVANT, OK	23N-12E-08 DBA 1	12.0	345	29	43.8	1,221	28
07176850	BIRD CREEK SITE OS-040 NEAR AVANT, OK	23N-12E-21 ABB 1	32.4	1,137	35	418.0	8,858	21
07176915	HOMINY CREEK SITE OS-201 NEAR FAIRFAX, OK	25N-07E-16 DBB 1	--	--	--	2.2	13	5.9
07176917	HOMINY CREEK SITE OS-047 NEAR FAIRFAX, OK	24N-07E-10 DDA 1	16.9	111	6.6	19.1	124	6.5
07176919	HOMINY CREEK SITE OS-048 NEAR FAIRFAX, OK	24N-07E-23 ADD 1	8.0	263	33	27.0	387	14
07176921	HOMINY CREEK SITE OS-055 NEAR HOMINY, OK	24N-08E-32 AAB 1	16.2	288	18	43.2	675	16
07176923	RAINBOW CREEK SITE OS-056 NEAR HOMINY, OK	24N-08E-33 CAC 1	--	--	--	3.8	169	45
07176925	HOMINY CREEK TRIBUTARY SITE OS-020 NEAR HOMINY, OK	23N-08E-03 CCB 1	--	--	--	1.6	111	67
07176927	HOMINY CREEK SITE OS-021 NEAR HOMINY, OK	23N-08E-12 CCC 1	11.1	318	28	59.8	1,273	21
07176929	NICICOLA CREEK SITE OS-023 NEAR HOMINY, OK	23N-08E-15 DCB 1	--	--	--	7.6	235	31
07176931	NICICOLA CREEK SITE OS-022 NEAR HOMINY, OK	23N-08E-12 DCB 1	3.2	65	20	10.8	300	28
07176933	LITTLE HOMINY CREEK SITE OS-080 NEAR WYNONA, OK	25N-08E-31 AAC 1	--	--	--	3.6	144	40
07176935	LITTLE HOMINY CREEK SITE OS-051 NEAR WYNONA, OK	24N-08E-09 ADA 1	9.2	151	16	12.8	295	23
07176937	LITTLE HOMINY CREEK SITE OS-052 NEAR WYNONA, OK	24N-08E-10 DAD 1	5.6	100	18	18.5	395	21
07176939	LITTLE HOMINY CREEK SITE OS-053 NEAR WYNONA, OK	24N-08E-14 CAC 1	0.9	33	35	19.4	428	22

Table 12. Surface-water quality sites, basin areas, and associated oil wells on the Osage Reservation, Oklahoma—Continued

[basin, total surface drainage area upstream of sample site; oil well, any well drilled for oil and gas production purposes; --, first upstream sample site]

Station number[1]	Station name	Local identifier	Area of incremental basin[2], (square miles)	Number of oil wells in incremental basin[2]	Number of oil wells per square mile in incremental basin[2]	Area of basin, (square miles)	Number of oil wells in basin	Number of oil wells per square mile in basin
07176941	LITTLE HOMINY CREEK SITE OS-054 NEAR WYNONA, OK	24N-08E-24 CDD 1	7.5	262	35	26.9	690	26
07176942	BITTER CREEK SITE OS-059 NEAR WYNONA, OK	24N-09E-19 CAD 1	--	--	--	5.2	75	14
07176944	BITTER CREEK SITE OS-019 NEAR HOMINY, OK	23N-08E-01 DCA 1	5.0	108	21	10.3	183	18
07176945	HOMINY CREEK SITE OS-028 NEAR HOMINY, OK	23N-09E-18 BAA 1	7.3	375	52	115.1	2,821	24
07176946	TWO MILE CREEK SITE OS-025 NEAR WYNONA, OK	23N-09E-04 BAA 1	--	--	--	4.0	59	15
07176947	TWO MILE CREEK SITE OS-027 NEAR HOMINY, OK	27N-09E-18 AAB 1	6.1	107	18	10.1	166	16
07176950	HOMINY CREEK SITE OS-029 NEAR HOMINY, OK	23N-09E-20 CCC 1	3.1	76	24	128.3	3,063	24
07176952	HOMINY CREEK TRIBUTARY SITE OS-026 NEAR WYNONA, OK	23N-09E-09 BBD 1	--	--	--	0.7	25	37
07176955	HOMINY CREEK SITE OS-032 NEAR HOMINY, OK	23N-09E-33 DAC 1	6.7	224	33	135.7	3,312	24
07176957	BULL CREEK TRIBUTARY SITE OS-033 NEAR HOMINY, OK	22N-08E-01 AAA 1	--	--	--	2.1	69	33
07176960	PENN CREEK SITE OS-024 NEAR HOMINY, OK	23N-08E-35 CDB 1	--	--	--	8.2	100	12
07176962	PENN CREEK SITE OS-004 NEAR HOMINY, OK	23N-09E-33 CDB 1	9.8	134	14	18.0	234	13
07176964	BLACKBIRD CREEK SITE OS-007 NEAR HOMINY, OK	22N-08E-12 ADD 1	--	--	--	4.8	76	16
07176966	MOSHETOMOIE CREEK SITE OS-005 NEAR HOMINY, OK	22N-09E-08 BAC 1	--	--	--	7.5	108	14
07176967	PENN CREEK SITE OS-031 NEAR HOMINY, OK	23N-09E-33 ADD 1	5.7	52	9.1	35.9	470	13
07176970	SUNSET CREEK SITE OS-030 NEAR HOMINY, OK	23N-09E-27 ADD 1	--	--	--	9.3	85	9.1
07176972	MAHALA CREEK SITE OS-034 NEAR HOMINY, OK	23N-09E-34 ADC 1	7.5	50	6.7	16.8	135	8.0
07176974	SAND CREEK SITE OS-035 NEAR HOMINY, OK	23N-09E-36 ADC 1	--	--	--	5.2	57	11
07176976	WILDHORSE CREEK SITE OS-010 NEAR NEW PRUE, OK	22N-10E-23 DDD 1	--	--	--	8.8	203	23
07176978	EAGLE CREEK SITE OS-008 NEAR NEW PRUE, OK	22N-10E-27 DCA 1	--	--	--	0.4	61	154
07176980	CEDAR CANYON SITE OS-036 NEAR BARNSDALL, OK	23N-10E-21 BDD 1	--	--	--	5.4	81	15
07176982	BULL CREEK TRIBUTARY SITE OS-037 NEAR AVANT, OK	23N-10E-26 CCA 1	--	--	--	3.9	159	40

Table 12. Surface-water quality sites, basin areas, and associated oil wells on the Osage Reservation, Oklahoma—Continued

[basin, total surface drainage area upstream of sample site; oil well, any well drilled for oil and gas production purposes; --, first upstream sample site]

Station number[1]	Station name	Local identifier	Area of incremental basin[2], (square miles)	Number of oil wells in incremental basin[2]	Number of oil wells per square mile in incremental basin[2]	Area of basin, (square miles)	Number of oil wells in basin	Number of oil wells per square mile in basin
07176984	TURKEY CREEK SITE OS-001 NEAR NEW PRUE, OK	21N-11E-06 DDD 1	--	--	--	5.1	70	14
07176986	TURKEY CREEK TRIBUTARY SITE OS-011 NEAR NEW PRUE, OK	22N-10E-36 CCD 1	--	--	--	5.5	168	31
07176988	LOST CREEK SITE OS-012 NEAR AVANT, OK	22N-11E-18 ABD 1	--	--	--	5.9	278	47
07177410	HOMINY CREEK SITE OS-014 NEAR SKIATOOK, OK	22N-11E-26 DA 1	122.8	2,311	19	353.5	7,374	21
07177420	QUAPAW CREEK SITE OS-013 NEAR SKIATOOK, OK	22N-11E-24 DAB 1	--	--	--	21.9	354	16
07177430	HOMINY CREEK SITE OS-015 NEAR SKIATOOK, OK	22N-12E-32 CBB 1	8.1	114	14	383.5	7,842	20
07177505	DELAWARE CREEK SITE OS-002 NEAR PRUE, OK	21N-11E-33 ADA 1	--	--	--	15.2	175	12
07177510	DELAWARE CREEK SITE OS-003 NEAR SPERRY, OK	21N-12E-29 AAD 1	24.4	947	39	39.7	1,122	28

[1]Station numbers are unique eight-digit numbers assigned in a downstream sequence. Station numbers become larger downstream within a drainage system.

[2]Incremental basin is the basin between two successive sites on the same stream.

Table 13. Specific conductance and chloride analyses of surface-water samples on the Osage Reservation, Oklahoma, 1999

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; specific conductance was measured in the field; mg/L, milligrams per liter; <, indicates concentration is less than the minimum reporting level; --, not available due to no flow; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida, and the National Water Quality Laboratory, Denver, Colorado]

Station number	Local identifier	Date sampled	Time	Stream discharge, (cubic feet per second)	Specific conductance, field (µS/cm)	Chloride, dissolved (mg/L as Cl)	Chloride load, (tons per day)	Chloride yield, (tons per day per square mile)
07148120	28N-05E-14 DDD 1	08/16/99	1630	0.99	510	11	0.029	0.00094
07152280	25N-04E-32 BCA 1	03/04/99	1300	3.5	670	17	0.16	0.017
07152340	24N-05E-17 BBA 1	03/01/99	1050	4.0	656	28	0.30	0.010
07152345	24N-05E-08 CDD 1	03/01/99	1030	1.1	410	5.1	0.15	0.020
07152355	28N-06E-33 AAC 1	08/16/99	1605	0.04	358	2.0	0.00022	0.0000056
07152390	27N-06E-34 BDB 1	08/16/99	1530	0.24	476	30	0.019	0.00017
07152410	26N-06E-11 BDD 1	02/17/99	0845	12	354	3.2	0.10	0.011
07152415	26N-06E-10 BCD 1	02/17/99	0930	26	334	17	1.2	0.094
07152417	26N-06E-08 AAA 1	08/16/99	1215	0.28	372	16	0.012	0.000092
07152418	26N-06E-08 CBB 1	08/16/99	1315	0.28	437	25	0.019	0.00014
07152419	27N-06E-31 BAB 1	08/16/99	1710	< 0.01	480	43	--	--
07152420	26N-06E-06 BDD 1	02/17/99	1245	26	460	31	2.2	0.14
07152423	26N-05E-03 AAA 1	08/16/99	1730	< 0.01	558	76	--	--
07152426	26N-05E-24 BAB 1	08/16/99	1355	0.54	422	25	0.036	0.00022
07152430	25N-05E-12 BBA 1	02/18/99	1505	12	356	5.9	0.19	0.015
07152435	25N-06E-01 ABB 1	02/16/99	1130	17	320	4.7	0.21	0.030
07152440	25N-06E-10 BAA 1	02/16/99	1018	46	522	21	2.6	0.13
07152445	26N-06E-32 BDD 1	02/17/99	1400	4.2	738	77	0.87	0.20
07152450	25N-06E-18 ABB 1	02/19/99	1005	29	632	49	3.82	0.10
07152455	25N-06E-21 DAA 1	08/16/99	1445	< 0.01	1,197	255	--	--
07152460	25N-06E-20 BCC 1	02/19/99	0915	6.7	730	53	0.96	0.10
07152470	24N-06E-07 BAA 1	03/01/99	1200	81	574	24	5.2	0.019
07152501	24N-06E-24 BBA 1	02/08/99	1320	5.4	292	14	0.20	0.035

Table 13. Specific conductance and chloride analyses of surface-water samples on the Osage Reservation, Oklahoma, 1999

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Station number	Local identifier	Date sampled	Time	Stream discharge, (cubic feet per second)	Specific conductance, field (µS/cm)	Chloride, dissolved (mg/L as Cl)	Chloride load, (tons per day)	Chloride yield, (tons per day per square mile)
07152502	25N-07E-31 ADC 1	02/16/99	1615	1.6	564	22	0.095	0.036
07152503	24N-06E-13 DDC 1	02/08/99	1245	11	602	95	2.8	0.26
07152504	24N-06E-27 BCA 1	02/08/99	1150	4.9	227	8.0	0.10	0.016
07152505	24N-07E-29 ACA 1	02/09/99	1345	1.8	1,280	320	1.56	1.6
07152506	24N-07E-33 CCD 1	02/08/99	1315	2.0	1,060	210	1.1	0.69
07152507	23N-07E-19 ACC 1	02/16/99	1250	5.0	742	83	1.1	0.069
07153040	23N-07E-26 ACA 1	02/16/99	1420	1.0	479	27	0.073	0.023
07153060	23N-07E-27 DAB 1	02/16/99	1345	7.0	579	42	0.79	0.040
07172050	29N-09E-13 ABD 1	03/02/99	1200	266	517	12	8.6	0.45
07172100	28N-08E-03 ABB 1	02/18/99	1100	27	449	3.3	0.24	0.0091
07172300	29N-09E-14 DBA 1	02/09/99	1200	82	297	4.4	0.97	0.015
07172475	28N-09E-22 ADB 1	02/10/99	0945	0.43	165	3.1	0.0036	0.00034
07172480	28N-09E-11 DBD 1	02/08/99	1400	36	230	4.3	4.2	0.15
07172485	28N-09E-11 BDC 1	02/10/99	1100	0.5	173	2.6	0.0035	0.00026
07172490	28N-10E-14 BCC 1	02/09/99	0815	3.7	155	11	0.11	0.020
07172492	29N-11E-30 AAB 1	03/03/99	1500	2.2	677	130	0.77	0.20
07172494	29N-11E-21 DAA 1	03/03/99	1235	1.6	409	40	0.17	0.046
07173005	28N-11E-12 BCB 1	03/02/99	0820	325	395	12	10	0.046
07173050	28N-12E-17 ADD 1	02/08/99	1115	30	112	5.0	0.40	0.032
07173060	28N-12E-28 BBB 1	03/03/99	0815	399	378	12	13	0.051
07173070	28N-11E-33 ACC 1	02/08/99	1345	21	152	7.9	0.45	0.028
07173080	27N-11E-03 ABB 1	02/08/99	1530	1.0	233	19	0.051	0.046
07173090	28N-12E-28 DDC 1	03/03/99	0925	4.5	311	22	0.27	0.0064

Table 13. Specific conductance and chloride analyses of surface-water samples on the Osage Reservation, Oklahoma, 1999

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; specific conductance was measured in the field; mg/L, milligrams per liter; <, indicates concentration is less than the minimum reporting level; --, not available due to no flow; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida, and the National Water Quality Laboratory, Denver, Colorado]

Station number	Local identifier	Date sampled	Time	Stream discharge, (cubic feet per second)	Specific conductance, field (µS/cm)	Chloride, dissolved (mg/L as Cl)	Chloride load, (tons per day)	Chloride yield, (tons per day per square mile)
07174330	27N-12E-20 ACC 1	02/08/99	1630	12	152	8.0	0.26	0.019
07174332	27N-12E-20 DCA 1	08/17/99	1445	< 0.01	373	17	--	--
07174530	27N-08E-02 CCC 1	03/01/99	1400	4.2	482	8.6	0.097	0.0080
07174535	27N-08E-24 CAA 1	03/04/99	0840	5.5	491	6.9	0.10	0.0047
07174545	26N-09E-03 DAA 1	02/18/99	0900	53	253	4.0	0.57	0.011
07174555	26N-10E-19 BDB 1	03/02/99	1610	17	417	8.3	0.38	0.0054
07174558	26N-09E-01 CAA 1	02/10/99	1300	1.7	156	7.1	0.032	0.0086
07174560	26N-10E-17 CBB 1	02/09/99	0800	4.4	112	9.2	0.11	0.013
07174562	27N-10E-08 CDD 1	08/17/99	1615	0.02	404	29	0.0016	0.00026
07174563	27N-10E-21 CBB 1	02/19/99	1200	0.50	518	25	0.034	0.0017
07174565	27N-10E-33 BBA 1	02/19/99	0930	18	319	37	1.8	0.077
07174568	26N-10E-05 DAA 1	02/09/99	1515	3.3	137	8.9	0.079	0.020
07174575	26N-10E-15 AAA 1	02/18/99	1000	190	292	15	7.7	0.062
07174585	26N-11E-18 DBA 1	08/18/99	0820	1.6	340	19	0.082	0.00061
07174605	26N-11E-29 AAA 1	02/09/99	1645	6.1	123	11	0.18	0.026
07174615	26N-11E-23 DAA 1	03/02/99	1000	2.0	201	14	0.075	0.0054
07174620	27N-10E-11 BCA 1	02/19/99	0830	2.6	565	110	0.77	0.68
07174625	27N-10E-14 AAD 1	02/09/99	0940	4.1	455	78	0.86	0.24
07174635	27N-10E-24 DDB 1	02/09/99	0800	12	408	48	1.6	0.15
07174637	26N-11E-12 CBA 1	08/17/99	0945	0.13	472	51	0.018	0.00051
07174640	26N-12E-18 CDD 1	03/02/99	1100	42	333	26	2.9	0.014
07174645	26N-12E-31 ACC 1	03/02/99	0845	0.49	460	43	0.057	0.0089
07174650	26N-12E-21 AAD 1	03/02/99	0745	47	348	29	3.7	0.016
07176140	27N-08E-28 BAC 1	08/17/99	1710	< 0.01	346	15	--	--

Table 13. Specific conductance and chloride analyses of surface-water samples on the Osage Reservation, Oklahoma, 1999

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Station number	Local identifier	Date sampled	Time	Stream discharge, (cubic feet per second)	Specific conductance, field (µS/cm)	Chloride, dissolved (mg/L as Cl)	Chloride load, (tons per day)	Chloride yield, (tons per day per square mile)
07176145	26N-08E-01 CCB 1	08/17/99	0900	< 0.01	527	18	--	--
07176150	26N-09E-29 CCC 1	03/03/99	1635	6.4	542	15	0.26	0.0064
07176160	26N-08E-06 DCC 1	02/17/99	1515	24	376	9.9	0.64	0.036
07176170	26N-08E-25 CDD 1	03/02/99	1300	11	267	6.0	0.18	0.0038
07176180	25N-07E-12 ADA 1	02/16/99	1330	34	403	5.2	0.48	0.028
07176220	25N-08E-15 CAC 1	02/10/99	1140	28	416	28	2.1	0.063
07176240	25N-08E-24 BDD 1	02/10/99	0938	41	470	47	5.2	0.13
07176300	24N-09E-08 AAA 1	03/02/99	1430	< 0.01	614	53	--	--
07176325	25N-09E-01 DBB 1	03/01/99	1500	81	426	21	4.6	0.027
07176330	25N-10E-20 ADD 1	03/04/99	0810	67	434	22	4.0	0.021
07176335	25N-10E-17 DDC 1	03/04/99	1035	0.06	542	8.0	0.0012	0.00021
07176340	24N-10E-01 DAA 1	02/09/99	1100	186	265	10	5.0	0.022
07176345	24N-11E-08 BCC 1	02/09/99	0800	14	185	27	1.0	0.071
07176425	24N-09E-03 DCC 1	02/19/99	0830	1.9	414	40	0.20	0.028
07176440	24N-09E-12 ACC 1	02/19/99	0935	4.0	404	49	0.53	0.025
07176455	24N-10E-17 DAA 1	02/10/99	0820	7.9	219	27	0.58	0.019
07176457	24N-10E-21 DCB 1	02/10/99	0950	9.1	185	21	0.51	0.038
07176470	24N-11E-20 CCC 1	02/09/99	0910	1.5	260	28	0.11	0.0034
07176475	24N-11E-20 CDD 1	03/03/99	1250	111	279	22	6.6	0.023
07176480	24N-11E-21 CDD 1	02/09/99	0950	11	210	29	0.86	0.069
07176490	23N-11E-11 DDB 1	02/09/99	1600	872	234	18	42	0.14
07176695	25N-12E-30 DBD 1	08/17/99	1213	< 0.01	327	28	--	--
07176700	24N-12E-05 CBB 1	03/02/99	1140	1.3	384	30	0.10	0.0069

Table 13. Specific conductance and chloride analyses of surface-water samples on the Osage Reservation, Oklahoma, 1999

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; specific conductance was measured in the field; mg/L, milligrams per liter; <, indicates concentration is less than the minimum reporting level; --, not available due to no flow; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida, and the National Water Quality Laboratory, Denver, Colorado]

Station number	Local identifier	Date sampled	Time	Stream discharge, (cubic feet per second)	Specific conductance, field (µS/cm)	Chloride, dissolved (mg/L as Cl)	Chloride load, (tons per day)	Chloride yield, (tons per day per square mile)
07176750	24N-12E-08 DCC 1	03/02/99	1050	0.55	444	47	0.070	0.014
07176800	24N-12E-19 DDD 1	02/09/99	1300	84	175	13	2.94	0.092
07176820	23N-12E-08 DBA 1	02/09/99	1500	47	267	15	1.90	0.043
07176850	23N-12E-21 ABB 1	03/02/99	0745	75	392	27	5.4	0.014
07176915	25N-07E-16 DBB 1	03/04/99	1250	0.20	563	11	0.0058	0.0026
07176917	24N-07E-10 DDA 1	02/09/99	1515	14	281	8.8	0.33	0.020
07176919	24N-07E-23 ADD 1	03/03/99	1545	1.6	794	79	0.34	0.014
07176921	24N-08E-32 AAB 1	03/03/99	1615	5.6	841	98	1.5	0.036
07176923	24N-08E-33 CAC 1	02/08/99	1735	0.86	453	22	0.051	0.014
07176925	23N-08E-03 CCB 1	03/04/99	1025	< 0.01	1,630	280	--	--
07176927	23N-08E-12 CCC 1	02/17/99	1030	48	810	120	16	0.27
07176929	23N-08E-15 DCB 1	02/17/99	1225	4.0	802	100	1.1	0.14
07176931	23N-08E-12 DCB 1	02/19/99	1045	3.0	900	150	1.2	0.11
07176933	25N-08E-31 AAC 1	02/16/99	1430	1.4	1,081	200	0.75	0.21
07176935	24N-08E-09 ADA 1	02/10/99	1400	7.7	527	49	1.0	0.079
07176937	24N-08E-10 DAD 1	03/04/99	1340	2.4	965	150	0.97	0.052
07176939	24N-08E-14 CAC 1	02/10/99	1305	15	553	52	2.1	0.11
07176941	24N-08E-24 CDD 1	03/03/99	1110	4.3	601	190	2.2	0.082
07176942	24N-09E-19 CAD 1	02/10/99	1115	5.1	319	38	0.52	0.099
07176944	23N-08E-01 DCA 1	03/03/99	1015	0.90	601	68	0.16	0.016
07176945	23N-09E-18 BAA 1	03/01/99	1540	16	1,010	170	7.3	0.065
07176946	23N-09E-04 BAA 1	03/01/99	1425	0.08	306	32	0.0069	0.0017
07176947	27N-09E-18 AAB 1	03/01/99	1642	0.45	452	55	0.067	0.0066

Table 13. Specific conductance and chloride analyses of surface-water samples on the Osage Reservation, Oklahoma, 1999

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; specific conductance was measured in the field; mg/L, milligrams per liter; <, indicates concentration is less than the minimum reporting level; --, not available due to no flow; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida, and the National Water Quality Laboratory, Denver, Colorado]

Station number	Local identifier	Date sampled	Time	Stream discharge, (cubic feet per second)	Specific conductance, field (µS/cm)	Chloride, dissolved (mg/L as Cl)	Chloride load, (tons per day)	Chloride yield, (tons per day per square mile)
07176950	23N-09E-20 CCC 1	02/18/99	1645	38	834	120	12	0.097
07176952	23N-09E-09 BBD 1	03/01/99	1500	0.01	465	74	0.0018	0.0026
07176955	23N-09E-33 DAC 1	03/04/99	0815	7.3	1,030	170	3.3	0.025
07176957	22N-08E-01 AAA 1	02/18/99	1315	3.7	446	27	0.019	0.0090
07176960	23N-08E-35 CDB 1	03/03/99	0915	0.97	536	50	0.13	0.016
07176962	23N-09E-33 CDB 1	02/18/99	1410	5.6	538	49	0.27	0.015
07176964	22N-08E-12 ADD 1	08/18/99	0950	0.07	2,890	790	0.15	0.031
07176966	22N-09E-08 BAC 1	02/16/99	1600	0.49	301	7.8	0.010	0.0014
07176967	23N-09E-33 ADD 1	02/18/99	1500	0.18	326	39	0.734	0.020
07176970	23N-09E-27 ADD 1	02/18/99	1120	1.4	201	10	0.038	0.0040
07176972	23N-09E-34 ADC 1	02/18/99	1545	2.1	176	8.4	0.45	0.027
07176974	23N-09E-36 ADC 1	02/18/99	1045	0.61	199	19	0.031	0.0060
07176976	22N-10E-23 DDD 1	02/18/99	1000	1.0	253	29	0.078	0.0089
07176978	22N-10E-27 DCA 1	02/17/99	1510	0.08	3,760	1,100	0.22	0.56
07176980	23N-10E-21 BDD 1	03/02/99	1445	0.33	384	37	0.033	0.0061
07176982	23N-10E-26 CCA 1	03/02/99	1335	0.02	747	130	0.0059	0.0015
07176984	21N-11E-06 DDD 1	02/17/99	1220	1.2	192	12	0.039	0.0076
07176986	22N-10E-36 CCD 1	02/17/99	1635	0.43	338	31	0.036	0.0066
07176988	22N-11E-18 ABD 1	03/03/99	0815	0.01	2,160	610	0.012	0.0020
07177410	22N-11E-26 DA 1	02/17/99	0810	2.3	224	25	0.16	0.00044
07177420	22N-11E-24 DAB 1	02/18/99	0835	5.3	336	14	0.20	0.0091
07177430	22N-12E-32 CBB 1	02/17/99	0750	18	281	22	1.1	0.0028
07177505	21N-11E-33 ADA 1	02/17/99	0950	2.6	297	16	0.11	0.0074
07177510	21N-12E-29 AAD 1	02/17/99	0850	7.6	640	140	2.9	0.072

Table 14. Chemical analyses of 20 surface-water samples for water properties, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma,1999

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; specific conductance, pH, and alkalinity were measured in the field and the laboratory; mg/L, milligrams per liter; µg/L, micrograms per liter;--, indicates no data available; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida]

Station number	Local identifier	Date sampled	Time	Nearby ground water-well-local identifier	Specific conductance, field (µS/cm)	pH, field, whole water (standard units)	Alkalinity, water dissolved, total incremental titration, field (mg/L as $CaCO_3$)
07152430	25N-05E-12 BBA 1	02/18/99	1505	25N-05E-12 BCA 1	356	7.8	169
07152450	25N-06E-18 ABB 1	02/19/99	1005	25N-06E-07 DBD 1	632	8.4	241
07152460	25N-06E-20 BCC 1	02/19/99	0915	25N-06E-20 DAC 1	730	8.4	272
07152505	24N-07E-29 ACA 1	02/09/99	1345	24N-07E-29 ACA 1	1280	7.8	148
07172050	29N-09E-13 ABD 1	03/02/99	1200	--	517	8.3	209
07172480	28N-09E-11 DBD 1	02/08/99	1400	--	230	7.7	94
07173005	28N-11E-12 BCB 1	03/02/99	0820	28N-11E-12 BDD 1	395	8.4	171
07174575	26N-10E-15 AAA 1	02/18/99	1000	--	292	7.7	110
07174625	27N-10E-14 AAD 1	02/09/99	0940	27N-10E-13 DBB 1	455	7.4	104
07174635	27N-10E-24 DDB 1	02/09/99	0800	27N-10E-24 DAD 1	408	7.8	127
07176150	26N-09E-29 CCC 1	03/03/99	1635	26N-09E-32 BBB 1	542	8.5	231
07176220	25N-08E-15 CAC 1	02/10/99	1140	25N-08E-22 BAB 1	416	7.6	151
07176240	25N-08E-24 BDD 1	02/10/99	0938	25N-08E-24 CAA 1	470	7.8	150
07176325	25N-09E-01 DBB 1	03/01/99	1500	25N-09E-01 ACC 1	426	8.2	168
07176330	25N-10E-20 ADD 1	03/04/99	0810	25N-10E-21 DBB 1	434	8.3	170
07176475	24N-11E-20 CDD 1	03/03/99	1250	--	279	8.5	87
07176917	24N-07E-10 DDA 1	02/09/99	1515	24N-07E-10 DDB 1	281	7.7	113
07176927	23N-08E-12 CCC 1	02/17/99	1030	23N-08E-11 AAA 1	810	8.1	184
07176929	23N-08E-15 DCB 1	02/17/99	1225	23N-08E-15 DBA 1	802	8.5	195
07177410	22N-11E-26 DAC 1	02/17/99	0810	--	224	7.8	58

Table 14. Chemical analyses of 20 surface-water samples for field parameters, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma, 1999—Continued

Station number	Local identifier	Nearby ground water-well-local identifier	Dissolved solids, calculated total (mg/L)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
07152430	25N-05E-12 BBA 1	25N-05E-12 BCA 1	190	54	6.5	12	1.9	10	5.9
07152450	25N-06E-18 ABB 1	25N-06E-07 DBD 1	350	78	11	40	1.3	20	49
07152460	25N-06E-20 BCC 1	25N-06E-20 DAC 1	410	82	14	55	1.4	40	53
07152505	24N-07E-29 ACA 1	24N-07E-29 ACA 1	700	100	18	120	1.9	46	320
07172050	29N-09E-13 ABD 1	--	260	70	12	12	1.4	27	12
07172480	28N-09E-11 DBD 1	--	120	35	4.5	5.7	1.6	12	4.3
07173005	28N-11E-12 BCB 1	28N-11E-12 BDD 1	220	58	8.3	11	2	22	12
07174575	26N-10E-15 AAA 1	--	160	37	6.7	13	1.8	16	15
07174625	27N-10E-14 AAD 1	27N-10E-13 DBB 1	240	41	6.9	39	1.3	14	78
07174635	27N-10E-24 DDB 1	27N-10E-24 DAD 1	220	47	7.5	25	1.5	17	48
07176150	26N-09E-29 CCC 1	26N-09E-32 BBB 1	300	77	13	18	1.3	35	15
07176220	25N-08E-15 CAC 1	25N-08E-22 BAB 1	220	53	7.6	19	1.8	22	28
07176240	25N-08E-24 BDD 1	25N-08E-24 CAA 1	250	56	7.7	26	1.8	20	47
07176325	25N-09E-01 DBB 1	25N-09E-01 ACC 1	230	56	8.6	16	2.5	23	21
07176330	25N-10E-20 ADD 1	25N-10E-21 DBB 1	210	37	8.1	15	1.9	24	22
07176475	24N-11E-20 CDD 1	--	150	30	6.4	14	2.3	17	22
07176917	24N-07E-10 DDA 1	24N-07E-10 DDB 1	160	37	6.8	13	2	26	8.8
07176927	23N-08E-12 CCC 1	23N-08E-11 AAA 1	420	73	16	64	1.9	37	120
07176929	23N-08E-15 DCB 1	23N-08E-15 DBA 1	430	71	22	57	1.9	54	100
07177410	22N-11E-26 DAC 1	--	110	20	5	15	2.5	10	25

Appendix 14. Chemical analyses of 20 surface-water samples for field parameters, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma, 1999—Continued

Station number	Local identifier	Nearby ground water-well-local identifier	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total dissolved (mg/L as N)
07152430	25N-05E-12 BBA 1	25N-05E-12 BCA 1	0.18	0.05	8.6	0.24	0.02	0.98
07152450	25N-06E-18 ABB 1	25N-06E-07 DBD 1	0.25	0.2	8	0.11	0.008	0.64
07152460	25N-06E-20 BCC 1	25N-06E-20 DAC 1	0.32	0.2	6.5	0.11	0.006	0.49
07152505	24N-07E-29 ACA 1	24N-07E-29 ACA 1	0.18	1	9.5	0.066	0.02	0.51
07172050	29N-09E-13 ABD 1	--	0.19	0.05	4.6	0.15	0.017	0.24
07172480	28N-09E-11 DBD 1	--	0.12	0.05	8.6	0.08	0.018	0.77
07173005	28N-11E-12 BCB 1	28N-11E-12 BDD 1	0.16	0.05	7.3	0.27	0.018	0.49
07174575	26N-10E-15 AAA 1	--	0.13	0.05	7.6	0.2	0.025	0.99
07174625	27N-10E-14 AAD 1	27N-10E-13 DBB 1	0.1	0.2	10	0.05	0.01	0.63
07174635	27N-10E-24 DDB 1	27N-10E-24 DAD 1	0.1	0.1	8.3	0.073	0.014	0.54
07176150	26N-09E-29 CCC 1	26N-09E-32 BBB 1	0.21	0.05	6.7	0.008	0.014	0.33
07176220	25N-08E-15 CAC 1	25N-08E-22 BAB 1	0.14	0.07	8.8	0.21	0.014	0.68
07176240	25N-08E-24 BDD 1	25N-08E-24 CAA 1	0.13	0.1	8.6	0.20	0.01	0.73
07176325	25N-09E-01 DBB 1	25N-09E-01 ACC 1	0.16	0.06	6.5	0.18	0.02	0.37
07176330	25N-10E-20 ADD 1	25N-10E-21 DBB 1	0.16	0.08	5.6	0.14	0.018	0.35
07176475	24N-11E-20 CDD 1	--	0.11	0.06	5.3	0.26	0.038	0.48
07176917	24N-07E-10 DDA 1	24N-07E-10 DDB 1	0.15	0.05	9.4	0.18	0.018	0.95
07176927	23N-08E-12 CCC 1	23N-08E-11 AAA 1	0.16	0.4	9.2	0.09	0.004	0.61
07176929	23N-08E-15 DCB 1	23N-08E-15 DBA 1	0.16	0.4	5.7	0.034	0.004	0.62
07177410	22N-11E-26 DAC 1	--	0.11	0.1	2.3	0.23	0.014	0.6

Table 14. Chemical analyses of 20 surface-water samples for field parameters, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma, 1999—Continued

Station number	Local identifier	Nearby ground water-well-local identifier	Phosphorus, total dissolved (mg/L as P)	Phosphorus, ortho phosphate dissolved (mg/L as P)	Arsenic, dissolved (μg/L as As)	Boron, dissolved (μg/L as B)	Iron, dissolved (μg/L as Fe)	Lithium, dissolved (μg/L as Li)
07152430	25N-05E-12 BBA 1	25N-05E-12 BCA 1	0.02	0.008	1	29	30	4
07152450	25N-06E-18 ABB 1	25N-06E-07 DBD 1	0.006	0.001	1	37	6.9	5
07152460	25N-06E-20 BCC 1	25N-06E-20 DAC 1	0.002	0.001	1	56	3.3	7
07152505	24N-07E-29 ACA 1	24N-07E-29 ACA 1	0.005	0.002	1	44	19	5
07172050	29N-09E-13 ABD 1	--	0.014	0.001	1	29	1	5
07172480	28N-09E-11 DBD 1	--	0.014	0.001	1	26	49	4
07173005	28N-11E-12 BCB 1	28N-11E-12 BDD 1	0.002	0.005	1	35	5.1	4
07174575	26N-10E-15 AAA 1	--	0.022	0.001	1	28	36	4
07174625	27N-10E-14 AAD 1	27N-10E-13 DBB 1	0.006	0.001	1	29	27	4
07174635	27N-10E-24 DDB 1	27N-10E-24 DAD 1	0.005	0.001	1	28	25	4
07176150	26N-09E-29 CCC 1	26N-09E-32 BBB 1	0.002	0.001	1	44	3.8	4
07176220	25N-08E-15 CAC 1	25N-08E-22 BAB 1	0.02	0.002	1	31	29	4
07176240	25N-08E-24 BDD 1	25N-08E-24 CAA 1	0.014	0.001	1	31	28	4
07176325	25N-09E-01 DBB 1	25N-09E-01 ACC 1	0.002	0.02	1	62	9.7	4
07176330	25N-10E-20 ADD 1	25N-10E-21 DBB 1	0.026	0.001	1	53	2.9	4
07176475	24N-11E-20 CDD 1	--	0.002	0.008	1	33	23	4
07176917	24N-07E-10 DDA 1	24N-07E-10 DDB 1	0.058	0.001	1	36	50	4
07176927	23N-08E-12 CCC 1	23N-08E-11 AAA 1	0.003	0.001	1	45	7.9	9
07176929	23N-08E-15 DCB 1	23N-08E-15 DBA 1	0.002	0.001	1	48	4.9	10
07177410	22N-11E-26 DAC 1	--	0.003	0.001	1	31	5.5	4

Table 14. Chemical analyses of 20 surface-water samples for field parameters, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma, 1999—Continued

Station number	Local identifier	Nearby groundwater-well-local identifier	Manganese, dissolved (mg/L as Mn)	Strontium, dissolved (mg/L as Sr)	Carbon organic, total dissolved (mg/L as C)
07152430	25N-05E-12 BBA 1	25N-05E-12 BCA 1	12	270	6.8
07152450	25N-06E-18 ABB 1	25N-06E-07 DBD 1	11	610	3.0
07152460	25N-06E-20 BCC 1	25N-06E-20 DAC 1	10	650	1.8
07152505	24N-07E-29 ACA 1	24N-07E-29 ACA 1	63	650	3.4
07172050	29N-09E-13 ABD 1	--	1.9	500	0.9
07172480	28N-09E-11 DBD 1	--	16	170	5.3
07173005	28N-11E-12 BCB 1	28N-11E-12 BDD 1	24	340	2.9
07174575	26N-10E-15 AAA 1	--	17	190	6.1
07174625	27N-10E-14 AAD 1	27N-10E-13 DBB 1	100	390	3.3
07174635	27N-10E-24 DDB 1	27N-10E-24 DAD 1	47	340	3.2
07176150	26N-09E-29 CCC 1	26N-09E-32 BBB 1	23	470	0.9
07176220	25N-08E-15 CAC 1	25N-08E-22 BAB 1	17	350	5.0
07176240	25N-08E-24 BDD 1	25N-08E-24 CAA 1	19	500	6.0
07176325	25N-09E-01 DBB 1	25N-09E-01 ACC 1	37	370	2.3
07176330	25N-10E-20 ADD 1	25N-10E-21 DBB 1	15	270	2.3
07176475	24N-11E-20 CDD 1	--	24	240	3.1
07176917	24N-07E-10 DDA 1	24N-07E-10 DDB 1	18	180	7.9
07176927	23N-08E-12 CCC 1	23N-08E-11 AAA 1	170	850	3.1
07176929	23N-08E-15 DCB 1	23N-08E-15 DBA 1	70	640	2.7
07177410	22N-11E-26 DAC 1	--	20	170	2.8

Table 15a. Chemical analyses of quality-control samples for chloride from surface water on the Osage Reservation, Oklahoma, 1999

[mg/L, milligrams per liter; --, indicates no data; <, indicates concentration is less than the minimum reporting level; “, as above; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida, and the National Water Quality Laboratory, Denver, Colorado]

Station number	Local identifier	Date	Time	Type sample	Chloride, dissolved (mg/L as CL)
07152417	26N-06E-08 AAA 1	08/16/99	1220	Replicate	15
07152420	26N-06E-06 BDD 1	02/17/99	1246	“	32
07152455	25N-06E-21 DAA 1	08/16/99	1450	“	252
07152503	24N-06E-13 DDC 1	02/08/99	1246	“	98
07172485	28N-09E-11 BDC 1	02/10/99	1101	“	2.6
07172492	29N-11E-30 AAB 1	03/03/99	1501	“	140
07172494	29N-11E-21 DAA 1	03/03/99	1236	“	41
07174545	26N-09E-03 DAA 1	02/18/99	0901	“	4
07174562	27N-10E-08 CDD 1	08/17/99	1620	“	28
07174620	27N-10E-11 BCA 1	02/19/99	0831	“	110
07174635	27N-10E-24 DDB 1	02/09/99	0801	“	48
07176140	27N-08E-28 BAC 1	08/17/99	1715	“	15
07176455	24N-10E-17 DAA 1	02/10/99	0821	“	27
07176480	24N-11E-21 CDD 1	02/09/99	0951	“	29
07176921	24N-08E-32 AAB 1	03/03/99	1616	“	97
07176927	23N-08E-12 CCC 1	02/17/99	1031	“	120
07176933	25N-08E-31 AAC 1	02/16/99	1431	“	200
07176960	23N-08E-35 CDB 1	03/03/99	0916	“	50
07176972	23N-09E-34 ADC 1	02/18/99	1546	“	9
07176978	22N-10E-27 DCA 1	0217/99	1511	“	1100
07176982	23N-10E-26 CCA 1	03/02/99	1336	“	130
07176986	22N-10E-36 CCD 1	02/12/99	1636	“	30
--	--	--	--	Blank	<0.1

Table 15b.Chemical analyses of quality-control samples for water properties, major cations and anions, trace elements, and nutrients from surface water on the Osage Reservation, Oklahoma, 1999

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, indicates no data; <, indicates concentration is less than the minimum reporting level; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida, and the National Water Quality Laboratory, Denver, Colorado]

Station number	Local identifier	Date	Time	Type sample	Specific conductance, lab (µS/cm)	pH, whole water, laboratory (standard units)	Alkalinity, water dissolved, laboratory (mg/L as $CaCO_3$)	Dissolved solids, calculated total (mg/L)
07174635	27N-10E-24 DDB 1	02/09/99	0801	Replicate	426	7.9	127	229
07176927	23N-08E-12 CCC 1	02/17/99	1031	Replicate	789	8.1	183	432
--	--	--	--	Blank	1.5	5.68	4.5	--

Table 15b. Chemical analyses of quality-control samples for water properties, major cations and anions, trace elements, and nutrients from surface water on the Osage Reservation, Oklahoma, 1999—Continued

Station number	Local identifier	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as CL)	Fluoride, dissolved (mg/L as F)
07174635	27N-10E-24 DDB 1	47	7.4	25	1.5	17	48	<0.1
07176927	23N-08E-12 CCC 1	73	16	63	1.9	37	120	0.16
--	--	0.1	.0	<0.1	<0.1	<0.2	<0.1	<0.1

Table 15b. Chemical analyses of quality-control samples for water properties, major cations and anions, trace elements, and nutrients from surface water on the Osage Reservation, Oklahoma, 1999—Continued

Station number	Local identifier	Bromide, dissolve (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, $NO_2 + NO_3$ dissolved (mg/L as N)	Nitrogen, Ammonia (mg/L as N)	Nitrogen, Ammonia + Organic (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho (mg/L as P)
07174635	27N-10E-24 DDB 1	0.2	8.3	0.072	0.012	0.53	0.005	<0.001
07176927	23N-08E-12 CCC 1	0.4	9.2	0.09	0.006	0.54	0.003	<0.001
--	--	<0.05	0.03	0.01	0.002	<0.2	<0.002	<0.001

Table 15b. Chemical analyses of quality-control samples for water properties, major cations and anions, trace elements, and nutrients from surface water on the Osage Reservation, Oklahoma, 1999—Continued

Station number	Local identifier	Arsenic, dissolved (μg/L as As)	Boron, dissolved (μg/L as B)	Iron, dissolved (μg/L as Fe)	Lithium, dissolved (μg/L as Li)	Manganese, dissolved (μg/L as Mn)	Strontium, dissolved (μg/L as Sr)	Carbon organic, total dissolved (mg/L as C)
07174635	27N-10E-24 DDB 1	<1	27	29	<4	47	340	3.1
07176927	23N-08E-12 CCC 1	<1	46	7.9	10	170	850	2.6
--	--	<1.	12.	2.4	<4.	0.3	<.5	<.1

Table 16. Comparison of surface-water and nearby ground-water samples on the Osage Reservation, Oklahoma

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; specific conductance, was measured in the field; mg/L, milligrams per liter; --, no data available; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida]

Surface-water samples						Nearby ground-water samples					
Station number	Local identifier	Date sampled	Time	Specific conductance, field (µS/cm)	Dissolved solids, calculated total (mg/L)	Site-identification number	Local identifier	Date sampled	Time	Specific conductance, field (µS/cm)	Dissolved solids, calculated total (mg/L)
07152426	26N-05E-24 BAB 1	08/16/99	1355	422	--	364300096432301	26N-05E-24 CBA 1	10/22/97	0830	627	--
07152430	25N-05E-12 BBA 1	02/18/99	1505	356	190	363943096431901	25N-05E-12 BCA 1	10/21/97	1200	741	439
07152450	25N-06E-18 ABB 1	02/19/99	1005	632	350	363920096414001	25N-06E-07 DBD 1	10/21/97	0820	815	481
07152460	25N-06E-20 BCC 1	02/19/99	0915	730	410	363735096403201	25N-06E-20 DAC 1	10/22/97	1000	1,050	653
07152505	24N-07E-29 ACA 1	02/09/99	1345	1,280	700	363155096342401	24N-07E-29 ACA 1	10/22/97	1000	756	587
07152507	23N-07E-19 ACC 1	02/16/99	1250	742	--	362731096352801	23N-07E-19 ACB 1	10/23/97	0915	1,180	--
07172100	28N-08E-03 ABB 1	02/18/99	1100	449	--	365623096252901	28N-08E-03 AAC 1	11/18/97	1130	1,180	--
07172475	28N-09E-22 ADB 1	02/10/99	0945	165	--	365350096183101	28N-09E-23 BAB 1	11/18/97	1700	507	--
07172485	28N-09E-11 BDC 1	02/10/99	1100	173	--	365522096183001	28N-09E-11 BAC 1	10/28/97	1215	982	--
07172490	28N-10E-14 BCC 1	02/09/99	0815	155	--	365420096120101	28N-10E-11 CDC 1	10/28/97	1400	813	--
07173005	28N-11E-12 BCB 1	03/02/99	0820	395	220	365514096041601	28N-11E-12 BDD 1	10/30/97	0930	821	499
07174545	26N-09E-03 DAA 1	02/18/99	0900	253	--	364515096183701	26N-09E-02 CCD 1	10/22/97	1030	864	--
07174560	26N-10E-17 CBB 1	02/09/99	0800	112	--	364328096152601	26N-10E-17 CCC 1	10/21/97	0915	648	--
07174563	27N-10E-21 CBB 1	02/19/99	1200	518	--	364752096141501	27N-10E-21 CDB 1	11/17/97	1415	218	--
07174565	27N-10E-33 BBA 1	02/19/99	0930	319	--	364640096142001	27N-10E-33 BCA 1	11/17/99	1300	712	--
07174625	27N-10E-14 AAD 1	02/09/99	0940	455	240	364901096104501	27N-10E-13 DBB 1	10/22/97	0930	1,080	614
07174635	27N-10E-24 DDB 1	02/09/99	0800	408	220	364805096102101	27N-10E-24 DAD 1	10/22/97	0900	1,830	1,210
07176150	26N-09E-29 CCC 1	03/03/99	1635	542	300	364140096215901	26N-09E-32 BBB 1	10/21/97	1430	1,680	1,150
07176220	25N-08E-15 CAC 1	02/10/99	1140	416	220	363807096255901	25N-08E-22 BAB 1	12/17/97	1145	724	410
07176240	25N-08E-24 BDD 1	02/10/99	0938	470	250	363745096234301	25N-08E-24 CAA 1	10/21/97	1230	1,150	660
07176325	25N-09E-01 DBB 1	03/01/99	1500	426	230	364023096170401	25N-09E-01 ACC 1	12/17/97	1030	626	358

Table 16. Comparison of surface-water and nearby ground-water samples on the Osage Reservation, Oklahoma—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; specific conductance, was measured in the field; mg/L, milligrams per liter; --, no data available; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida]

Surface-water samples						Nearby ground-water samples					
Station number	Local identifier	Date sampled	Time	Specific conductance, field (µS/cm)	Dissolved solids, calculated total (mg/L)	Site-identification number	Local identifier	Date sampled	Time	Specific conductance, field (µS/cm)	Dissolved solids, calculated total (mg/L)
07176330	25N-10E-20 ADD 1	03/04/99	0810	434	210	363744096135401	25N-10E-21 DBB 1	12/16/97	1330	745	399
07176425	24N-09E-03 DCC 1	02/19/99	0830	414	--	363419096195001	24N-09E-10 BCD 1	12/16/97	1045	383	--
07176440	24N-09E-12 ACC 1	02/19/99	0935	404	--	363421096171601	24N-09E-12 ACD 1	12/16/97	1125	899	--
07176917	24N-07E-10 DDA 1	02/09/99	1515	281	160	363406096320501	24N-07E-10 DDB 1	10/22/97	1230	748	459
07176923	24N-08E-33 CAC 1	02/08/99	1735	453	--	363033096272101	24N-08E-33 CDB 1	12/15/97	1700	745	--
07176927	23N-08E-12 CCC 1	02/17/99	1030	810	420	362926096242901	23N-08E-11 AAA 1	10/29/97	1140	1,060	622
07176929	23N-08E-15 DCB 1	02/17/99	1225	802	430	362809096254801	23N-08E-15 DBA 1	12/15/97	1630	2,540	1,290
07176935	24N-08E-09 ADA 1	02/10/99	1400	527	--	363453096264101	24N-08E-04 DDA 1	10/22/97	1500	644	--
07176941	24N-08E-24 CDD 1	03/03/99	1110	601	--	363216096234501	24N-08E-24 DCA 1	11/05/97	1145	830	--
07176946	23N-09E-04 BAA1	03/01/99	1425	306	--	363014096204601	23N-09E-04 BAD 1	12/16/97	1000	1,150	--
07176967	23N-09E-33 ADD 1	02/18/99	1500	326	--	362541096195701	23N-09E-34 BCC 1	10/29/97	1415	921	--
07177420	22N-11E-24 DAB 1	02/18/99	0835	336	--	362222096040101	22N-11E-24 AAD 1	10/23/97	0900	1,420	--

Table 16. Comparison of surface-water and nearby ground-water samples on the Osage Reservation, Oklahoma—Continued

Surface-water samples					Nearby ground-water samples				
Station number	**Local identifier**	**Sulfate, dissolved (mg/L as SO_4)**	**Chloride, dissolved, (mg/L as Cl)**	**Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)**	**Site-identification number**	**Local identifier**	**Sulfate, dissolved (mg/L as SO_4)**	**Chloride, dissolved, (mg/L as Cl)**	**Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)**
07152426	26N-05E-24 BAB 1	--	25	--	364300096432301	26N-05E-24 CBA 1	--	2.7	--
07152430	25N-05E-12 BBA 1	10	5.9	0.24	363943096431901	25N-05E-12 BCA 1	16	13	0.002
07152450	25N-06E-18 ABB 1	20	49	0.11	363920096414001	25N-06E-07 DBD 1	21	8.3	0.10
07152460	25N-06E-20 BCC 1	40	53	0.11	363735096403201	25N-06E-20 DAC 1	58	29	22
07152505	24N-07E-29 ACA 1	46	320	0.066	363155096342401	24N-07E-29 ACA 1	66	23	0.14
07152507	23N-07E-19 ACC 1	--	83	--	362731096352801	23N-07E-19 ACB 1	--	76	--
07172100	28N-08E-03 ABB 1	--	3.3	--	365623096252901	28N-08E-03 AAC 1	--	120	--
07172475	28N-09E-22 ADB 1	--	3.1	--	365350096183101	28N-09E-23 BAB 1	--	61	--
07172485	28N-09E-11 BDC 1	--	2.6	--	365522096183001	28N-09E-11 BAC 1	--	87	--
07172490	28N-10E-14 BCC 1	--	11	--	365420096120101	28N-10E-11 CDC 1	--	15	--
07173005	28N-11E-12 BCB 1	22	12	0.27	365514096041601	28N-11E-12 BDD 1	29	12	16
07174545	26N-09E-03 DAA 1	--	4.0	--	364515096183701	26N-09E-02 CCD 1	--	21	--
07174560	26N-10E-17 CBB 1	--	9.2	--	364328096152601	26N-10E-17 CCC 1	--	42	--
07174563	27N-10E-21 CBB 1	--	25	--	364752096141501	27N-10E-21 CDB 1	--	6.6	--
07174565	27N-10E-33 BBA 1	--	37	--	364640096142001	27N-10E-33 BCA 1	--	8.7	--
07174625	27N-10E-14 AAD 1	14	78	0.05	364901096104501	27N-10E-13 DBB 1	55	130	0.25
07174635	27N-10E-24 DDB 1	17	48	0.073	364805096102101	27N-10E-24 DAD 1	430	140	0.013
07176150	26N-09E-29 CCC 1	35	15	0.008	364140096215901	26N-09E-32 BBB 1	330	46	0.35
07176220	25N-08E-15 CAC 1	22	28	0.21	363807096255901	25N-08E-22 BAB 1	12	36	1.4
07176240	25N-08E-24 BDD 1	20	47	0.20	363745096234301	25N-08E-24 CAA 1	63	130	5.3
07176325	25N-09E-01 DBB 1	23	21	0.18	364023096170401	25N-09E-01 ACC 1	27	9.6	0.071
07176330	25N-10E-20 ADD 1	24	22	0.14	363744096135401	25N-10E-21 DBB 1	57	38	--

Table 16. Comparison of surface-water and nearby ground-water samples on the Osage Reservation, Oklahoma—Continued

Surface-water samples					Nearby ground-water samples				
Station number	Local identifier	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved, (mg/L as Cl)	Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	Site-identification number	Local identifier	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved, (mg/L as Cl)	Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)
07176425	24N-09E-03 DCC 1	--	40	--	363419096195001	24N-09E-10 BCD 1	--	13	--
07176440	24N-09E-12 ACC 1	--	49	--	363421096171601	24N-09E-12 ACD 1	--	14	--
07176917	24N-07E-10 DDA 1	26	8.8	0.18	363406096320501	24N-07E-10 DDB 1	43	30	0.26
07176923	24N-08E-33 CAC 1	--	22	--	363033096272101	24N-08E-33 CDB 1	--	34	--
07176927	23N-08E-12 CCC 1	37	120	0.09	362926096242901	23N-08E-11 AAA 1	120	63	0.22
07176929	23N-08E-15 DCB 1	54	100	0.034	362809096254801	23N-08E-15 DBA 1	27	750	2.1
07176935	24N-08E-09 ADA 1	--	49	--	363453096264101	24N-08E-04 DDA 1	--	6.9	--
07176941	24N-08E-24 CDD 1	--	190	--	363216096234501	24N-08E-24 DCA 1	--	62	--
07176946	23N-09E-04 BAA1	--	32	--	363014096204601	23N-09E-04 BAD 1	--	57	--
07176967	23N-09E-33 ADD 1	--	39	--	362541096195701	23N-09E-34 BCC 1	--	40	--
07177420	22N-11E-24 DAB 1	--	14	--	362222096040101	22N-11E-24 AAD 1	--	350	--

Table 17. Chemical analyses of ground-water samples from wells near surface-water sites for water properties, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma

[mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ^{O}C, degrees Celsius; specific conductance, pH, and alkalinity were measured in the field and the laboratory; --, indicates no data available; <, indicates concentration is less than the minimum reporting level; all samples were collected by the U.S. Geological Survey; laboratory analyses were done by the U.S. Geological Survey, Quality of Water Service Unit laboratory, Ocala, Florida]

Site-identification number	Local identifier	Date sampled	Time	Nearby surface-water station number	Specific conductance, field (µS/cm)	pH, field, whole water (standard units)	Temperature water (^{O}C)	Alkalinity, water dissolved, total incremental titration, field (mg/L as $CaCO_3$)
363943096431901	25N-05E-12 BCA 1	10/21/97	1200	07152430	741	6.9	--	378
363920096414001	25N-06E-07 DBD 1	10/21/97	0820	07152450	815	7.1	--	402
363735096403201	25N-06E-20 DAC 1	10/22/97	1000	07152460	1,050	6.8	--	398
363155096342401	24N-07E-29 ACA 1	10/22/97	1000	07152505	756	9.1	--	424
365514096041601	28N-11E-12 BDD 1	10/30/97	0930	07173005	821	6.9	16.5	221
364901096104501	27N-10E-13 DBB 1	10/22/97	0930	07174625	1,080	7.1	16.5	318
364805096102101	27N-10E-24 DAD 1	10/22/97	0900	07174635	1,830	7.1	16.0	388
364140096215901	26N-09E-32 BBB 1	10/21/97	1430	07176150	1,680	6.8	16.5	588
363807096255901	25N-08E-22 BAB 1	12/17/97	1145	07176220	724	7.2	15.0	320
363745096234301	25N-08E-24 CAA 1	10/21/97	1230	07176240	1,150	7.1	18.0	308
364023096170401	25N-09E-01 ACC 1	12/17/97	1030	07176325	626	8.0	11.0	295
363744096135401	25N-10E-21 DBB 1	12/16/97	1330	07176330	745	7.3	15.5	240
363406096320501	24N-07E-10 DDB 1	10/22/97	1230	07176917	748	7.5	--	328
362926096242901	23N-08E-11 AAA 1	10/29/97	1140	07176927	1,060	7.1	--	356
362809096254801	23N-08E-15 DBA 1	12/15/97	1630	07176929	2,540	6.0	16.5	50

Table 17. Chemical analyses of ground-water samples from wells near surface-water sites for water properties, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma—Continued

Site-identification number	Local identifier	Nearby surface-water station number	Dissolved solids, calculated total (mg/L)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
363943096431901	25N-05E-12 BCA 1	07152430	439	120	15	21	1.0	16	13
363920096414001	25N-06E-07 DBD 1	07152450	481	110	17	51	1.8	21	8.3
363735096403201	25N-06E-20 DAC 1	07152460	653	140	31	41	0.70	58	29
363155096342401	24N-07E-29 ACA 1	07152505	587	1.1	0.30	230	0.50	66	23
365514096041601	28N-11E-12 BDD 1	07173005	499	120	16	28	0.40	29	12
364901096104501	27N-10E-13 DBB 1	07174625	614	120	24	75	2.2	55	130
364805096102101	27N-10E-24 DAD 1	07174635	1,210	170	91	120	4.4	430	140
364140096215901	26N-09E-32 BBB 1	07176150	1,150	270	33	97	1.0	330	46
363807096255901	25N-08E-22 BAB 1	07176220	410	110	14	24	0.80	12	36
363745096234301	25N-08E-24 CAA 1	07176240	660	130	23	73	5.6	63	130
364023096170401	25N-09E-01 ACC 1	07176325	358	31	28	70	2.2	27	9.6
363744096135401	25N-10E-21 DBB 1	07176330	399	60	29	48	2.1	57	38
363406096320501	24N-07E-10 DDB 1	07176917	459	66	7.0	100	1.0	43	30
362926096242901	23N-08E-11 AAA 1	07176927	622	56	33	120	2.4	120	63
362809096254801	23N-08E-15 DBA 1	07176929	1,290	170	57	220	1.9	27	750

Table 17. Chemical analyses of ground-water samples from wells near surface-water sites for water properties, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma—Continued

Site-identification number	Local identifier	Nearby surface-water station number	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total dissolved (mg/L as N)
363943096431901	25N-05E-12 BCA 1	07152430	0.30	0.10	26	0.002	0.15	<0.20
363920096414001	25N-06E-07 DBD 1	07152450	0.40	0.10	14	0.10	0.047	0.94
363735096403201	25N-06E-20 DAC 1	07152460	0.30	<0.050	16	22.0	0.006	0.20
363155096342401	24N-07E-29 ACA 1	07152505	1.0	0.090	9.3	0.14	0.11	<0.20
365514096041601	28N-11E-12 BDD 1	07173005	0.20	<0.050	21	16.0	0.006	<0.20
364901096104501	27N-10E-13 DBB 1	07174625	0.30	0.30	15	0.252	0.009	<0.20
364805096102101	27N-10E-24 DAD 1	07174635	0.30	0.40	20	0.013	0.41	0.41
364140096215901	26N-09E-32 BBB 1	07176150	0.20	0.40	16	0.35	0.008	<0.20
363807096255901	25N-08E-22 BAB 1	07176220	0.17	0.20	14	1.4	<0.002	<0.20
363745096234301	25N-08E-24 CAA 1	07176240	0.20	0.50	26	5.3	0.005	<0.20
364023096170401	25N-09E-01 ACC 1	07176325	0.57	0.070	12	0.071	0.01	<0.20
363744096135401	25N-10E-21 DBB 1	07176330	0.18	0.20	20	--	--	--
363406096320501	24N-07E-10 DDB 1	07176917	0.40	0.10	14	0.26	0.028	<0.20
362926096242901	23N-08E-11 AAA 1	07176927	0.40	0.30	15	0.220	0.011	<0.20
362809096254801	23N-08E-15 DBA 1	07176929	<.10	2.6	22	2.1	0.009	<0.20

Table 17. Chemical analyses of ground-water samples from wells near surface-water sites for water properties, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma—Continued

Site-identification number	Local identifier	Nearby surface-water station number	Phosphorus, total dissolved (mg/L as P)	Phosphorus, ortho phosphate dissolved (mg/L as P)	Arsenic, dissolved (μg/L as As)	Boron, dissolved (μg/L as B)	Iron, dissolved (μg/L as Fe)	Lithium, dissolved (μg/L as Li)
363943096431901	25N-05E-12 BCA 1	07152430	0.10	0.008	1	67	1,900	5
363920096414001	25N-06E-07 DBD 1	07152450	0.010	0.010	<1	110	190	<4
363735096403201	25N-06E-20 DAC 1	07152460	0.030	0.030	<1	87	<1.0	7
363155096342401	24N-07E-29 ACA 1	07152505	0.010	0.010	<1	690	6.0	6
365514096041601	28N-11E-12 BDD 1	07173005	0.030	0.030	<1	85	7.0	9
364901096104501	27N-10E-13 DBB 1	07174625	0.003	<0.001	<1	400	30	10
364805096102101	27N-10E-24 DAD 1	07174635	0.002	<0.001	<1	390	510	20
364140096215901	26N-09E-32 BBB 1	07176150	0.010	<0.001	<1	180	460	<4
363807096255901	25N-08E-22 BAB 1	07176220	<0.002	<0.001	<1	37	<1.0	<4
363745096234301	25N-08E-24 CAA 1	07176240	0.040	0.050	<1	40	7.0	6
364023096170401	25N-09E-01 ACC 1	07176325	<0.002	<0.001	<1	370	1.0	20
363744096135401	25N-10E-21 DBB 1	07176330	--	--	<1	80	6.0	7
363406096320501	24N-07E-10 DDB 1	07176917	0.002	<0.001	<1	290	3.0	6
362926096242901	23N-08E-11 AAA 1	07176927	0.010	0.008	<1	340	10	10
362809096254801	23N-08E-15 DBA 1	07176929	0.010	0.001	<1	30	230	20

Table 17. Chemical analyses of ground-water samples from wells near surface-water sites for water properties, major cations and anions, trace elements, and nutrients on the Osage Reservation, Oklahoma—Continued

Site-identification number	Local identifier	Nearby surface-water station number	Manganese, dissolved (mg/L as Mn)	Strontium, dissolved (mg/L as Sr)	Carbon organic, total dissolved (mg/L as C)
363943096431901	25N-05E-12 BCA 1	07152430	240	670	0.80
363920096414001	25N-06E-07 DBD 1	07152450	15	720	2.8
363735096403201	25N-06E-20 DAC 1	07152460	0.60	1,100	0.80
363155096342401	24N-07E-29 ACA 1	07152505	1.0	52	<0.10
365514096041601	28N-11E-12 BDD 1	07173005	0.60	670	0.40
364901096104501	27N-10E-13 DBB 1	07174625	11	810	0.20
364805096102101	27N-10E-24 DAD 1	07174635	200	1,500	<0.10
364140096215901	26N-09E-32 BBB 1	07176150	1,400	1,100	0.60
363807096255901	25N-08E-22 BAB 1	07176220	0.30	770	0.50
363745096234301	25N-08E-24 CAA 1	07176240	1.5	930	0.90
364023096170401	25N-09E-01 ACC 1	07176325	3.9	270	0.50
363744096135401	25N-10E-21 DBB 1	07176330	53	460	--
363406096320501	24N-07E-10 DDB 1	07176917	2.2	400	<0.10
362926096242901	23N-08E-11 AAA 1	07176927	7.7	860	0.20
362809096254801	23N-08E-15 DBA 1	07176929	290	1,200	0.10