Freshwater Resources and Saline Water Near the Sac And Fox Nation Tribal Lands, Eastern Lincoln County, Oklahoma

By Marvin M. Abbott

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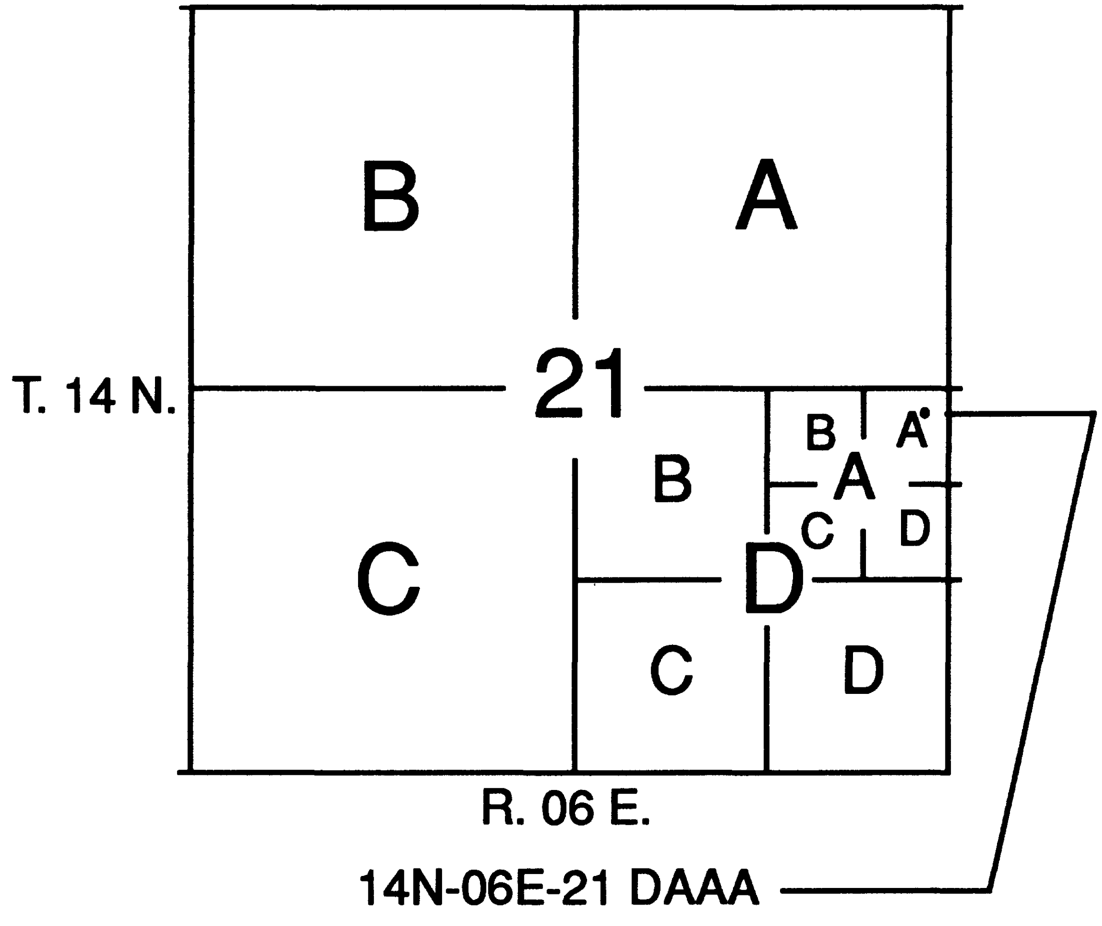
The locations of the sample-collection sites are identified by a site-id number and a local identifier number. The site-id number is composed of the latitude and longitude of the location to the nearest second plus a sequence number. The location of the dot in the figure is latitude 35°40'23" and longitude 96°39'48". A sequence number is added to make the local identifier unique in the U.S. Geological Survey data base. If the sequence number is 1, the complete site-id number is 354023096394801. The local identifier 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 U.S. 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 NE1/4 NE1/4 NE1/4 SE1/4 sec. 21, T. 14 N., R. 06 E., is denoted by the local identifier number 14N–06E–21 DAAA. If the sequence number is 1, the complete identifier number is 14N–06E–21 DAAA 1.



CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
foot squared per day (ft^2/d)	0.0929	meter squared per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch (in.)	2.540	centimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Temperature in degree Fahrenheit (°F) can be converted to degree Celsius (°C) as follows:

$$°C = (°F - 32)/1.8$$

Temperature in degree Celsius (°C) can be converted to degree Fahrenheit (°F) as follows:

$$°F = 1.8\ °C + 32$$

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.

Freshwater Resources and Saline Water Near the Sac and Fox Nation Tribal Land, Eastern Lincoln County, Oklahoma

By Marvin M. Abbott

Abstract

The purpose of this project was to evaluate the freshwater resources and possible sources of high-chloride and high-sulfate concentrations in parts of the aquifer near the Sac and Fox Nation tribal land in eastern Lincoln County, Oklahoma. Water-quality sampling and borehole geophysical data indicate the potential for fresh ground water on tribal land generally is greatest in the Vanoss Formation, in the SE1/4 sec. 21, T. 14 N., R. 06 E. and in the NE1/4 sec. 22, T. 14 N., R. 06 E. These locations avoid the flood-prone areas and borehole geophysical resistivity logs indicate the altitude of the base of fresh ground water is below 650 ft. The altitude of the base of fresh ground water is indicated to be generally near the surface under the W1/2 sec. 22, T. 14 N., R. 06 E., the SE1/4 sec. 22, SE1/4 SE1/4 NE1/4 sec. 21, and NE1/4 NW1/4 NW1/4 sec. 27.

Conditions are more favorable for placement of fresh ground-water wells in sec. 34, T. 14 N., R. 06 E., where the tribe has leased water rights, than on tribal land in secs. 15, 16, 21, and 22, T. 14 N., R. 06 E. Sandstones overlain by or enclosed in thick clay and shale sequences are likely to be somewhat isolated from the flow system and retain some of the residual brine. Borehole geophysical logs suggest that sandstones near CH1, CM1, and WT1 have more clay and shale content than the sandstones near L2. Greater amounts of clay in the sandstones will retard the flushing of residual brines from the sandstones and could result in a shallow base of fresh water near CH1, CM1, and WT1. For these reasons and because circulation of fresh ground water is limited by discharge to the Deep Fork, general water quality under tribal land would probably be poorer than in the area where the tribe has leased water rights.

Samples have chloride or sulfate concentrations greater than 250 milligrams per liter in the W1/2 sec. 22, T. 14 N., R. 06 E. Six cluster well samples from tribal land have chloride or sulfate concentrations above the suggested maximum contaminant levels set by U.S. Environmental Protection Agency.

Water-quality data indicate there may be more than one source for the salinity in the very saline and briny samples near the tribal land. Two possible sources for chloride and sulfate in water-quality samples are shallow brines and deep oil brines. Probable sources of shallow brines in the study area are: 1) solution of minerals by fresh water moving through the aquifer and 2) residual brines deposited with the sediment. There are no salt or gypsum beds in the Vanoss, Ada, or Vamoosa Formations, but there may be nodules and finely disseminated minerals present in the formations. Residual brines could remain in sandstones and shales that have low hydraulic conductivity and have not been diluted by freshwater recharge. Data suggest both sources have mixed with the fresh ground water from the Vanoss Formation. This is indicated by the relations of the bromide/chloride concentration ratio to chloride concentration, δD to $\delta^{18}O$, and by $\delta^{18}O$ to chloride molality relation.

INTRODUCTION

The Sac and Fox Nation tribal land consists of 960 acres located in eastern Lincoln County, Oklahoma. The location is 3.5 mi south of the town of Stroud, Oklahoma, and is bounded on three sides by the Deep Fork and an extensive wetlands area along the river flood plain (fig. 1). The Deep Fork is a tributary of the North Canadian River and flows from west to east across the study area. The river has an average altitude of 770 ft above sea level and has a vertical drop of approximately 20 ft along 8 mi in the study area. Low rolling hills from 40 to 120 ft high characterize the area. The mean annual precipitation is about 36 in. of rainfall and the average annual temperature is about 15 degrees °C.

Water from domestic supply wells in sec. 21, T. 14 N., R. 06 E. has become increasingly saline in recent years. The Sac and Fox consider the ground water unusable on the tribal land; and the tribe has leased water rights in sec. 34, T. 14 N., R. 06 E. Stratigraphically equivalent sandstones north and south of the tribal land produce potable water. Potential saline sources in the area are surface water from the Deep Fork, shallow brines, and brines from oil production at approximately 3,000 ft. The U.S. Geological Survey in cooperation with the Sac and Fox Nation initiated a study to evaluate shallow ground water as a drinking-water supply and potential sources of high saline water on and near the tribal land.

Purpose and Scope

The purpose of this report is to describe freshwater resources and evaluate possible sources of high-chloride and high-sulfate concentrations in parts of the aquifer. Data are interpreted to determine (1) whether ground water near the Sac and Fox Nation tribal land meets drinking-water standards and (2) where the ground water quality does not meet these standards, how large an area may be affected. The report discusses the general geohydrology of the freshwater aquifer and the probable sources of high-chloride and high-sulfate concentrations in the area.

Water-quality samples, well clusters, and borehole geophysical logs were used to investigate the area. Water-quality samples from a 40 mi^2 area included surface water from the Deep Fork, ground water, and produced oil-field brines. Well clusters were installed at four locations in the study area on and near tribal land. The well clusters were used to sample selected permeable zones in the aquifer. Borehole geophysical logs were used for subsurface mapping and for better definition of the lateral extent of the sandstone aquifers.

Regional Geologic Setting

The stratigraphy in the region has been discussed by several authors. Morton (1986) described the Ada–Vamoosa aquifer as a bedrock sequence of Pennsylvanian formations that are lithologically similar and hydrologically connected. These include in ascending order the Barnsdall, Tallant, Vamoosa, Ada, and Vanoss Formations (fig. 2). Fresh ground water in the study area is in rocks of the Vamoosa, Ada, and Vanoss Formations of the Virgilian Series. Masters (1958) described the geology of the Prague area, 12 mi south of the tribal land (fig. 1). Oakes and Branson (1956) described the stratigraphy along the Turner Turnpike, 5 mi north of the tribal headquarters, not shown on figure 1. Oakes (1959) described the geology of Creek County east of the study area. Ries (1954) described the geology of Okfuskee County, to the southeast.

Faults have been mapped in the area in a north-south en ´echelon band. The individual faults strike generally northwest at about 20° (D'Lugosz and others, 1986). The geologic map by Bingham and Moore (1975) indicates two such faults in the aquifer north of the Deep Fork. D'Lugosz and others (1986) reported these faults average about 2 mi in length and most are normal faults down thrown to the west. The faults usually have 50 ft of vertical displacement in the study area and rarely exceed 100 ft (D'Lugosz and others, 1986). The depth of influence of these faults in the study area is not known. In the Seminole oil field, 30 mi to the south, Levorsen (1929) noted the depth of such faults was limited to 600 ft and some were only 100 to 300 ft deep. His subsurface work suggests that the displacement on these faults decreases with depth.

History of Oil Production

Oil production began in the 1930's from the Prue sand at depths of 2,900 to 3,100 ft below land surface. The Prue sand is the upper informal subsurface unit of the Senora Formation (fig. 2). All the oil production in T. 14 N., R. 06 E., secs. 14, 15, 16, 21, 22, 23, 26, 27, and 28 is from the Prue sand. There have been 183 wells drilled for oil and gas in secs. 15, 16, 21, and 22 on which the tribal land is located.

There are other formations that produce oil in the township. These include the Simpson Group, the Viola Limestone, and the Bartlesville sand in secs. 12 and 35. The Hunton Group is productive in the NW1/4 sec. 10 and the SW1/4 sec. 3. These formations are older than the Prue sand and are approximately 4,000 ft below land surface in the area (Cole, 1958).

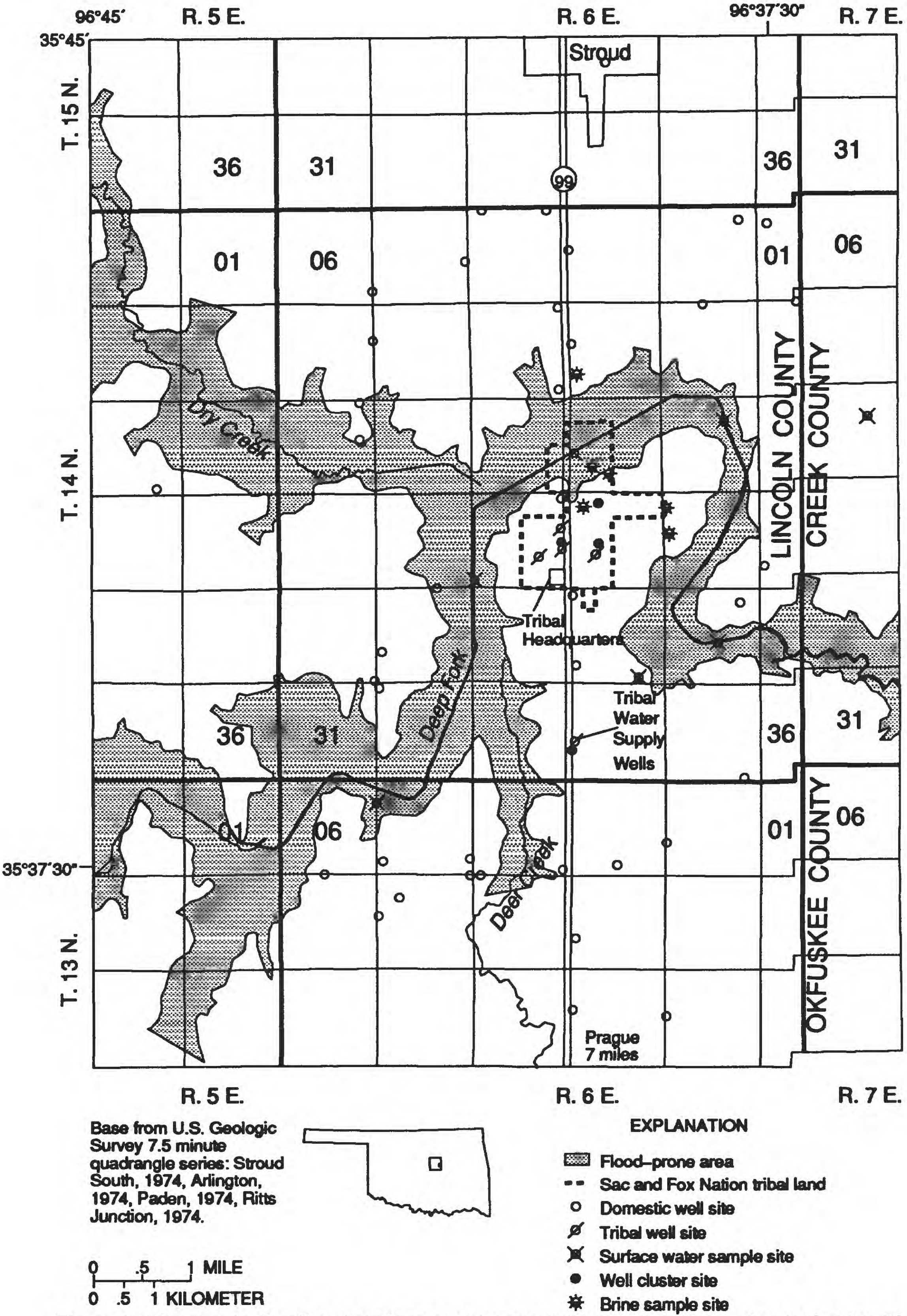


Figure 1. Map showing location of study area, water-chemistry sampling sites, and water-level well locations, eastern Lincoln County, Oklahoma.

System	Series	Group	Formation	Member	Informal subsurface unit
Pennsylvanian	Virgilian		Vanoss Formation		
			Ada Formation	Turkey Run Limestone	
				Lecompton Limestone	
			Vamoosa Formation		
	Missourian	Ochelata	Tallant Formation		
			Barnsdall Formation		
			Wann Formation		
			Iola Formation		
			Chanute Formation		
		Skiatook	Dewey Limestone		
			Nellie Bly Formation		
			Hogshooter Limestone		
			Coffeyville Formation		
			Checkerboard Limestone		
			Seminole Formation		
	Desmoinesian	Marmaton			
		Cabaniss	Senora Formation		Prue sand
			Stuart Shale		
			Thurman Sandstone		
		Krebs	Boggy Formation		Bartlesville sand
			Savanna Formation		
			McAlester Formation		
			Hartshorne Sandstone		
Undifferentiated rocks of Silurian, Devonian, Mississippian, and Early Pennsylvanian age in the subsurface					
Silurian		Hunton			
Ordovician			Sylvan Shale		
			Fernvale Limestone		
			Viola Limestone		
		Simpson			
		Arbuckle			

Figure 2. Major time-stratigraphic and selected geologic units in the study area (from Miser, 1954; Oklahoma Corporation Commission, written commun., 1995).

The Oklahoma Corporation Commission formed the Sac and Fox Prue Sand Unit in 1952 and the Southeast Sac and Fox Prue Sand Unit in 1954. These are areas where the oil production is derived from a common source of supply. Secondary recovery efforts by waterflooding of the producing formation began the year the units were formed. Waterflooding is the process of injecting water under pressure to drive the remaining oil to the producing wells. During waterflooding many of the producing wells were converted to injection wells. Information and data pertaining to oil-well locations, oil production, and waterflooding activities were obtained from documents from the Oklahoma Corporation Commission.

Acknowledgments

The author wishes to express his gratitude to the organizations and individuals who contributed and assisted in the project. Special thanks are given to Chief Elmer Manatowa and the members of the Sac and Fox Nation who were helpful and cooperative during the field work. Many area farmers assisted greatly by supplying information concerning construction of their wells and by allowing water samples to be collected from their wells. Robert Gordon Oil Company, the operator of the oil production at the time the wells were sampled, permitted sampling of their wells and supplied personnel to assist with well-head connections. Jack Lewis permitted two observation wells to be drilled on his property near the tribal water-supply wells.

METHODS OF DATA COLLECTION AND INTERPRETATION

This study first investigated the regional ground-water system within a 3-mi radius of tribal land (fig. 1) to evaluate the general water quality. Water levels were measured in 43 wells during this well inventory in 1990 (table 1). Fifty-eight water samples were collected from June 1990 through June 1993. Thirty of these samples were collected from domestic wells (fig. 1) and from four existing unused wells that were on tribal land (fig. 3). Eleven water-quality samples were taken from the three well clusters on tribal land and three from land where the tribe has leased water rights. Four surface-water samples from the Deep Fork and six deep oil-field brines samples also were collected.

The regional geohydrology was investigated using borehole geophysical logs. The geophysical logs provided information on the thickness and continuity of the aquifers. A map of the altitude of the base of fresh ground water was constructed from resistivity logs of wells drilled after 1950.

Sample Collection, Preparation, and Chemical Analysis

Specific conductance, dissolved oxygen, pH, and temperature were measured with portable field meters. Alkalinity was measured by an incremental titration (Wells and others, 1990) of a filtered aliquot. Water samples collected from wells were taken after consistent measurements of specific conductance, dissolved oxygen, pH, and temperature were obtained in a flow-through cell. Where sustained flow could not be obtained from a well, a sample was collected after the well had been purged of at least three borehole volumes of water.

All analyses were performed by the U.S. Geological Survey National Water Quality Laboratory in Arvada, Colorado. The analytical methods used in the analyses are listed in tables 2 and 3. Specific conductance, pH, major elements, and trace elements (table 2) were determined using standard methods described in Fishman and Friedman (1989). The radiochemical analyses (table 2) were determined using standard methods as described in Thatcher and others (1977). Stable isotopes (table 3) of hydrogen and oxygen were determined using mass spectrometry. The relative difference in the ratio of the heavy isotope to the more abundant lighter isotope was determined for each sample and compared to the ratio of a standard. The ratios are reported in parts per thousand (permil) difference from the standard. The results are reported relative to standard mean ocean water (SMOW). The reported values are designated by the Greek letter "δ" A complete discussion of stable isotope hydrology is given by Gat and Gonfiantini (1981).

The analytical results are summarized for ground water in appendix 1 and surface water in appendix 2. Samples collected during the investigation of the regional ground-water system in 1990 were not analyzed for trace metals, fluoride, silica, radium-226, radon-222, or stable isotopes. The remaining samples

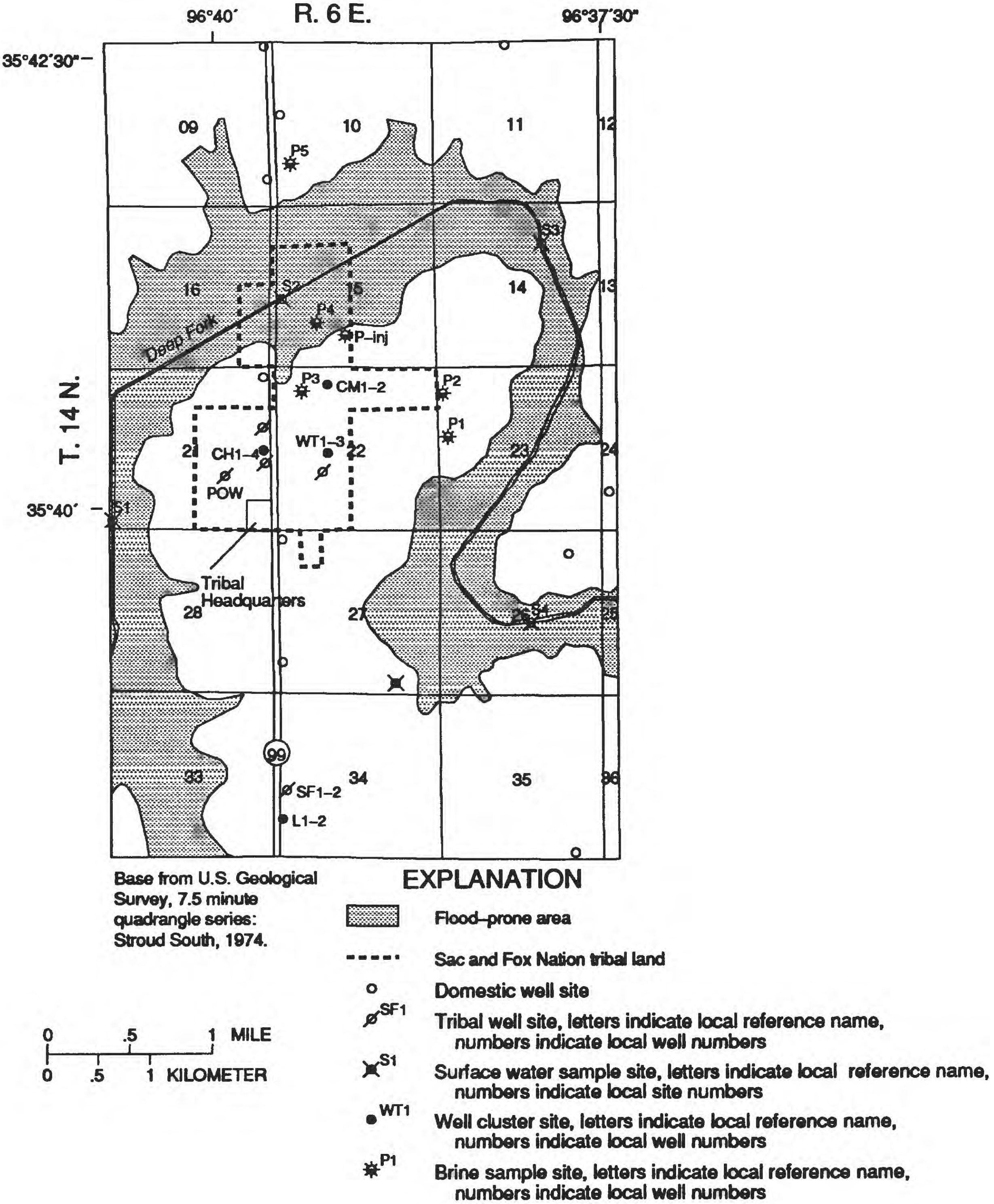
Table 1. Location and description of wells with water level measurements in the Ada-Vamoosa aquifer in the study area, on and near Sac and Fox Nation tribal land, eastern Lincoln County, Oklahoma

[Aquifer codes: 322VNSS, Vanoss Formation; 322ADA, Ada Formation]

Local well number	Site ID	Aquifer code	Altitude of land surface (feet above sea level)	Depth of well (feet below land surface)	Water level (date)	Water level (feet below land surface)	Water-level (altitude, feet above sea level)
13N–06E–02 CBC 1	353738096383901	322VNSS	905	40	03-21-90	2.0	903.0
13N-06E-03 CCB 1	353733096373101	322VNSS	870	84	03-16-90	35.79	834.21
13N-06E-03 CDD 1	353726096391201	322VNSS	890	185	03-20-90	78.60	811.40
13N-06E-04 DDD 1	353721096394501	322VNSS	860	162	03-16-90	39.52	820.48
13N-06E-05 CCC 1	353729096414801	322VNSS	825	171	03-20-90	50.63	774.37
13N-06E-08 AAA 2	353721096405001	322VNSS	850	121	03-20-90	63.70	786.30
13N-06E-08 BCC 1	353659096415101	322VNSS	895	216.4	04-04-90	117.28	777.72
13N-06E-08 BDB 1	353709096413701	322VNSS	880	174	03-20-90	80.00	800.00
13N-06E-09 BBB 1	353721096404301	322VNSS	825	68	03-20-90	37.0	788.0
13N-06E-10 CBC 1	353646096394301	322VNSS	815	45	04-03-90	12.0	803.0
13N-06E-14 BCC 1	353603096384001	322VNSS	890	180	03-28-90	106.0	784.0
14N-05E-14 DCD 1	354053096441701	322VNSS	860	108	04-04-90	68.75	791.25
14N-06E-02 AAB 1	354319096374901	322VNSS	875	95	03-21-90	77.50	797.50
14N-06E-03 BCC 1	354303096394201	322ADA	850	279	03-15-90	86.43	763.57
14N-06E-04 AAB 1	354325096395701	322VNSS	820	100	03-21-90	37.98	782.02
14N-06E-04 BBA 1	354325096404001	322VNSS	890	172	03-15-90	80.50	809.50
14N-06E-05 DAA 1	354257096405101	322VNSS	850	90.5	03-13-90	52.80	797.20
14N-06E-06 DAD 1	354253096425301	322VNSS	860	142.5	03-15-90	56.00	804.00
14N-06E-07 ADA 1	354241096415301	322VNSS	830	136	03-13-90	34.10	795.90
14N-06E-07 ADD 1	354214096415301	322VNSS	815	132	03-13-90	23.04	791.96
14N-06E-09 AAA 1	354233096394701	322VNSS	840	95.5	03-15-90	34.51	805.49
14N-06E-09 DDD 1	354150096394601	322ADA	806	142	03-20-90	45.73	760.27
14N-06E-10 BCC 1	354211096394301	322ADA	830	184	03-16-90	51.70	778.30
14N-06E-18 AAB 1	354140096420201	322VNSS	800	78.7	03-16-90	19.96	780.04
14N-06E-18 ADD 1	354120096420201	322VNSS	780	37	03-20-90	17.89	762.11
14N-06E-21 AAA 1	354008096404601	322VNSS	820	116	03-19-90	106.00	714.00
14N-06E-21 ADD 1	354030096394501	322VNSS	830	87.5	03-28-90	8.06	821.94
14N-06E-21 DAA 1	354019096394501	322VNSS	832	77	03-15-90	10.56	821.44
14N-06E-21 DAAA 2	354023096394804	322VNSS	832	140	09-21-92	38.26	793.74
14N-06E-21 DAAA 3	354023096394805	322VNSS	832	95	09-21-92	18.35	813.65

Table 1. Location and description of wells with water level measurements in the Ada–Vamoosa aquifer in the study area, on and near Sac and Fox Nation tribal land, eastern Lincoln County, Oklahoma —Continued

Local well number	Site ID	Aquifer code	Altitude of land surface (feet above sea level)	Depth of well (feet below land surface)	Water level (date)	Water level (feet below land surface)	Water-level (altitude, feet above sea level)
14N-06E-21 DAAA 4	354023096394804	322VNSS	832	28.0	09-21-92	13.2	818.8
14N-06E-21 DBD 1	354015096400301	322VNSS	839	133	03-19-90	61.39	777.61
14N-06E-22 BAC 2	354044096392301	322ADA	835	155	09-21-92	65.75	769.25
14N-06E-22 CAB 1	354022096392301	322ADA	887	230	09-21-92	54.52	832.50
14N-06E-22 CAB 2	354022096392302	322VNSS	887	130.0	09-21-92	105.0	782.0
14N-06E-22 CAB 3	354022096392303	322VNSS	887	56.0	09-21-92	33.2	853.8
14N-06E-22 CAC 1	354016096392501	322VNSS	860	47.0	03-19-90	21.4	838.6
14N-06E-24 CCB 1	354009096373301	322ADA	815	94.80	04-05-90	48.47	766.53
14N-06E-26 AAC 1	353949096374901	322ADA	810	115.50	04-05-90	81.37	728.63
14N-06E-27 BBB 1	353957096394201	322VNSS	840	133	03-15-90	23.87	816.13
14N-06E-29 ABA 1	353958096411101	322VNSS	780	87	04-03-90	17.45	762.55
14N-06E-29 CBC 1	353923096414801	322VNSS	842	169	03-21-90	36.13	805.87
14N-06E-30 DDD 1	353907096415301	322VNSS	820	148	03-21-90	43.70	776.30



Base from U.S. Geological Survey, 7.5 minute quadrangle series: Stroud South, 1974.

Figure 3. Map showing location of water-chemistry sampling sites on and adjacent to the Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma.

Table 2. Listing of analytical methods used at the National Water Quality Laboratory

[Parameter code, codes used to designate chemical constituents in the WATSTORE data base of the U.S. Geological Survey and in the STORET data base of the Environmental Protection Agency; g/mL, grams per milliliter; mg/L, milligrams per liter; µg/L, micrograms per liter; AE, atomic emission spectrophotometry; ICP, inductively coupled plasma spectrophotometry; AA, atomic absorption spectrophotometry; DCP, direct coupled plasma spectrophotometry; pCi/L, picocuries per liter]

Parameter code	Parameter name, phase, and units	Method	Minimum reporting level
		WATER PROPERTIES	
71820	Density, g/mL at 20 degrees Celsius	Gravimetry	0.99
70300	Solids, Residue on evaporation at 180 degrees Celsius (mg/L)	Gravimetry	1
		MAJOR CATIONS	
00915	Calcium, dissolved (mg/L as Ca)	AE, ICP, direct	0.02
00925	Magnesium, dissolved (mg/L as Mg)	AE, ICP, direct	0.01
00930	Sodium, dissolved (mg/L as Na)	AE, ICP, direct	0.2
00935	Potassium, dissolved (mg/L as K)	AA, direct	0.1
		MAJOR ANIONS	
71870	Bromide, dissolved (mg/L as Br)	Colorimetry, fluorescein, auto	0.01
00940	Chloride, dissolved (mg/L as Cl)	Colorimetry, thiocyanate, auto	0.1
00950	Fluoride, dissolved (mg/L as F)	Ion selective electrode, auto	0.1
71865	Iodide, dissolved (mg/L as I)	Colorimetry, ceric-arsenious oxide, auto	0.001
00955	Silica, dissolved (mg/L as Si)	AE, ICP, direct	0.01
00945	Sulfate, dissolved (mg/L as SO_4)	Turbidimetry, auto, background corrected	1
		TRACE ELEMENTS	
01000	Arsenic, dissolved (µg/L as As)	AA, hydride, auto	1
01005	Barium, dissolved (µg/L as Ba)	AE, ICP, direct	2
01010	Beryllium, dissolved (µg/L as Be)	AE, ICP, direct	0.5
01020	Boron, dissolved (µg/L as B)	AE, DCP, direct	10
01025	Cadmium, dissolved (µg/L as Cd)	AE, ICP, direct	1
01030	Chromium, dissolved (µg/L as Cr)	AE, ICP, direct	5

Table 2. Listing of analytical methods used at the National Water Quality Laboratory —Continued

Parameter code	Parameter name, phase, and units	Method	Minimum reporting level
01035	Cobalt, dissolved (µg/L as Co)	AE, ICP, direct	3
01040	Copper, dissolved (µg/L as Cu)	AE, ICP, direct	10
01046	Iron, dissolved (µg/L as Fe)	AE, ICP, direct	3
01049	Lead, dissolved (µg/L as Pb)	AE, ICP, direct	10
01130	Lithium, dissolved (µg/L as Li)	AE, ICP, direct	4
		AA, direct	10
01056	Manganese, dissolved (µg/L as Mn)	AE, ICP, direct	1
01060	Molybdenum, dissolved (µg/L as Mo)	AE, ICP, direct	10
01065	Nickel, dissolved (µg/L as Ni)	AE, ICP, direct	10
01145	Selenium, dissolved (µg/L as Se)	AA, hydride, auto	1
01075	Silver, dissolved (µg/L as Ag)	AE, ICP, direct	1
01080	Strontium, dissolved (µg/L as Sr)	AE, ICP, direct	0.5
		AA, direct	10
01085	Vanadium, dissolved (µg/L as V)	AE, ICP, direct	6
01090	Zinc, dissolved (µg/L as Zn)	AE, ICP, direct	3
	RADIONUCLIDES		
09511	Radium 226, dissolved (pCi/L as Ra-226)	Radon emanation	0.01
82303	Radon 222, total (pCi/L as Rn-222)	Liquid scintillation	80

Table 3. Listing of analytical methods used at the National Water Quality Laboratory for stable isotopes

[Parameter code, codes used to designate chemical constituents in the WATSTORE data base of the U.S. Geological Survey and in the STORET data base of the Environmental Protection Agency; permil, per thousand; SMOW, Standard Mean Ocean Water (Craig, 1961); H_2, hydrogen molecule; CO_2, carbon dioxide]

Parameter code	Parameter name, phase, and units	Method	Precision ±
		STABLE ISOTOPES	
82082	Hydrogen–2/hydrogen–1, in permil relative to SMOW	Conversion to H_2 by reaction with zinc metal, mass spectrometry	1.5
82085	Oxygen–18/oxygen–16, in permil relative to SMOW	Equilibration with CO_2, mass spectrometry	0.10

were collected during 1991 and 1992. These samples included stable isotopes and, if the specific conductance was not greater than 6,000 microsiemens per centimeter (µS/cm), the trace constituents. Appendixes 1 and 2 also list the quality-assurance samples collected during the study. Duplicate samples were taken for 10 percent of the samples from the well clusters. Three of the sites were resampled on different dates.

Eleven samples listed in appendixes 1 and 2 are analyses by the U.S. Geological Survey for other investigations. Ten samples dated in 1979 and 1980, are from Morton (1986) and were within the regional ground-water system investigation area of this report. One analysis, dated July 23, 1951, was from Laine and others (1951). It was from a Vamoosa Formation well in Stroud, SE 1/4 NW 1/4 SE 1/4 sec. 27, T. 15 N., R. 06 E., report as drilled to 500 ft below land surface (Smith, 1942). The well had been a city water-supply well but has been unused since the water quality degraded. Other regional geochemical investigations of ground water in the Ada-Vamoosa aquifer are Bingham and Moore (1975) and D'Lugosz and others (1986).

The suggested maximum contaminant levels set by U.S. Environmental Protection Agency (1989) for chloride (250 milligrams per liter [mg/L]) and sulfate (250 mg/L) were used to separate fresh and saline water analyses in appendixes 1 and 2. Discussions of salinity in this report will follow the classification by Robinove and others (1958) where salinization is based on changes in total dissolved solids (TDS) (table 4). Water-quality sample, 14N-06E-27 BBB 1, is listed with the saline ground water (appendix 1) because the TDS is 1,230 mg/L. Water-quality sample 14N-06E-21 DBD 1, dated March 29, 1990, has a TDS of 1,420 mg/L but is listed with the fresh ground water (appendix 1) because later sampling of the well is thought to be more representative of the aquifer water quality.

Table 4. Salinity classification based on TDS ranges, (Robinove and others, 1958)

Class	Total Dissolved Solids (milligrams per liter)		
Fresh	0	–	1,000
Slightly saline	1,000	–	3,000
Moderately saline	3,000	–	10,000
Very saline	10,000	–	35,000
Briny	greater than		35,000

Description of the Sampling Sites

The tribal land is bounded on three sides by approximately 8 mi of the river valley and associated wetlands (figs. 1 and 3). During periods of low flow, the principal component of surface-water flow is ground-water discharge to the surface-water system. The headwaters for the Deep Fork are 54 mi to the west of tribal land on Permian formations. Four samples were collected from the river during an extended period of no rainfall in August 1991. The sample at the upstream site, 14N–06E–21 CCC 1 (site S1, appendix 2), was collected west of the Sac and Fox headquarters building. The remaining three surface-water sites were selected at 2–mi intervals downstream.

An inventory of existing domestic wells was conducted in T. 13 and 14 N., R. 06 E. located 39 wells (fig. 1). The information available on the construction of these wells is limited. Many of the wells are screened at the bottom of the borehole and sand packed throughout much of the well depth to increase well yield.

Four well clusters were constructed for water-quality sampling and water-level observations. The first three well clusters were 14N–06E–21 DAAA 1, 2, 3, and 4; 14N–06E–22 BAC 1 and 2; and 14N–06E–22 CAB 1, 2, 3, and 4. For discussion purposes in this report sampled well clusters are named for a local geographical reference. The well number consists of the cluster name, a sequence number of the well in the cluster, and the formation from which the samples were collected. Wells in the first cluster in NE1/4 NE1/4 NE1/4 SE1/4 sec. 21, T. 14 N., R. 06 E., are near the tribal courthouse and will be referred to as CH1, CH2, CH3, and CH4. Wells in the second cluster in SW1/4 NE1/4 NW1/4 sec. 22, T. 14 N., R. 06 E., are near the tribal cemetery and will be referred to as CM1 and CM2. Wells in the third cluster, NW1/4 NE1/4 SW 1/4 sec. 22, T. 14 N., R. 06 E., are near the tribal watertower and will be referred to as WT1, WT2, and WT3. The formations are labeled Vanoss = VS, Ada = AD, Vamoosa = VM, and Vamoosa/Tallant = VM/T.

Each well cluster consists of 2-4 wells drilled approximately 10 ft apart and constructed to sample and observe selected zones. The locations of the clusters were selected to sample areas of suspected salt-water encroachment or areas where additional information was needed.

CH1 was first drilled to 41 ft and a water-quality sample from the shallowest water bearing sandstone in the Vanoss Formation (fig. 4) was taken through a submersible pump in the open borehole. CH1 was then drilled to 248 ft (fig. 4), deep enough to sample a saline-water-bearing horizon in the Vamoosa Formation. An inflatable packer and screen assembly were placed on the drill pipe and then lowered into the borehole. The bottom of the packer was placed at 230 ft. A submersible pump was lowered inside the drill pipe through which the water sample was collected. The water level above the packer and outside the drill pipe was monitored with an electrical water-level meter during sampling to assure the packer seal. After sampling, CH1 was plugged to 108 ft with cement grout and bentonite to seal off the saline-water-bearing horizon. The well was then drilled to 190 ft and was completed using polyvinyl chloride (PVC) plastic casing, screens, and sand pack but a water-quality sample from this zone was not possible because of cement problems.

CM1 was drilled to 262 ft (fig. 5), into stratigraphically equivalent sandstones as CH1 in the Vamoosa Formation (fig. 4). A water sample was collected with an inflatable packer and screen assembly through a submersible pump like CH1. The bottom of the packer was at 190 ft. CM1 was completely sealed, after sampling, with cement and not completed in a shallower freshwater zone.

WT1 was drilled to 302 ft (fig. 6), into stratigraphically equivalent sandstones as CH1 in the Vamoosa Formation (fig. 4). A water sample was collected with an inflatable packer and screen assembly through a submersible pump like CH1. The bottom of the packer was at 270 ft. WT1 was plugged, after sampling, with cement grout and bentonite to seal off the saline-water bearing horizon to 230 ft. The well was completed in a shallower single freshwater zone in the Ada Formation (fig. 6) using PVC casing, screens, and sand pack.

Subsequent wells in each well cluster were completed by isolating selected sandstones using PVC casing, screens, and sand pack. The sandstones were selected from natural gamma-ray borehole geophysical logs from the test well in each cluster. The annulus of all cluster wells were sealed above the sand pack with bentonite or cement to prevent invasion of the selected zone by water from shallower sandstones. The subsequent wells in each cluster were logged inside the PVC casing with natural gamma-ray logs to confirm the completion of these wells in the selected sandstones and to evaluate the extent of lateral change of the sandstone units. The wells in each cluster were drilled a minimum of 10 ft from the nearest well to ensure integrity between wells.

The two wells constructed on private land near where the tribe has leased water rights, 14N–06E–34 CBC 1 and 2, (referred to as L1 and L2) were drilled to 300 ft and 560 ft. The 300-ft well, in the Vamoosa Formation, was constructed for a water-level observation well and was not sampled. The 560-ft well, L2 (fig. 7), was drilled into the shallowest sandstones containing saline water and was screened from 500 to 560 ft. Two water-quality samples, a field and a replicate sample, were obtained from the well. The two sand-

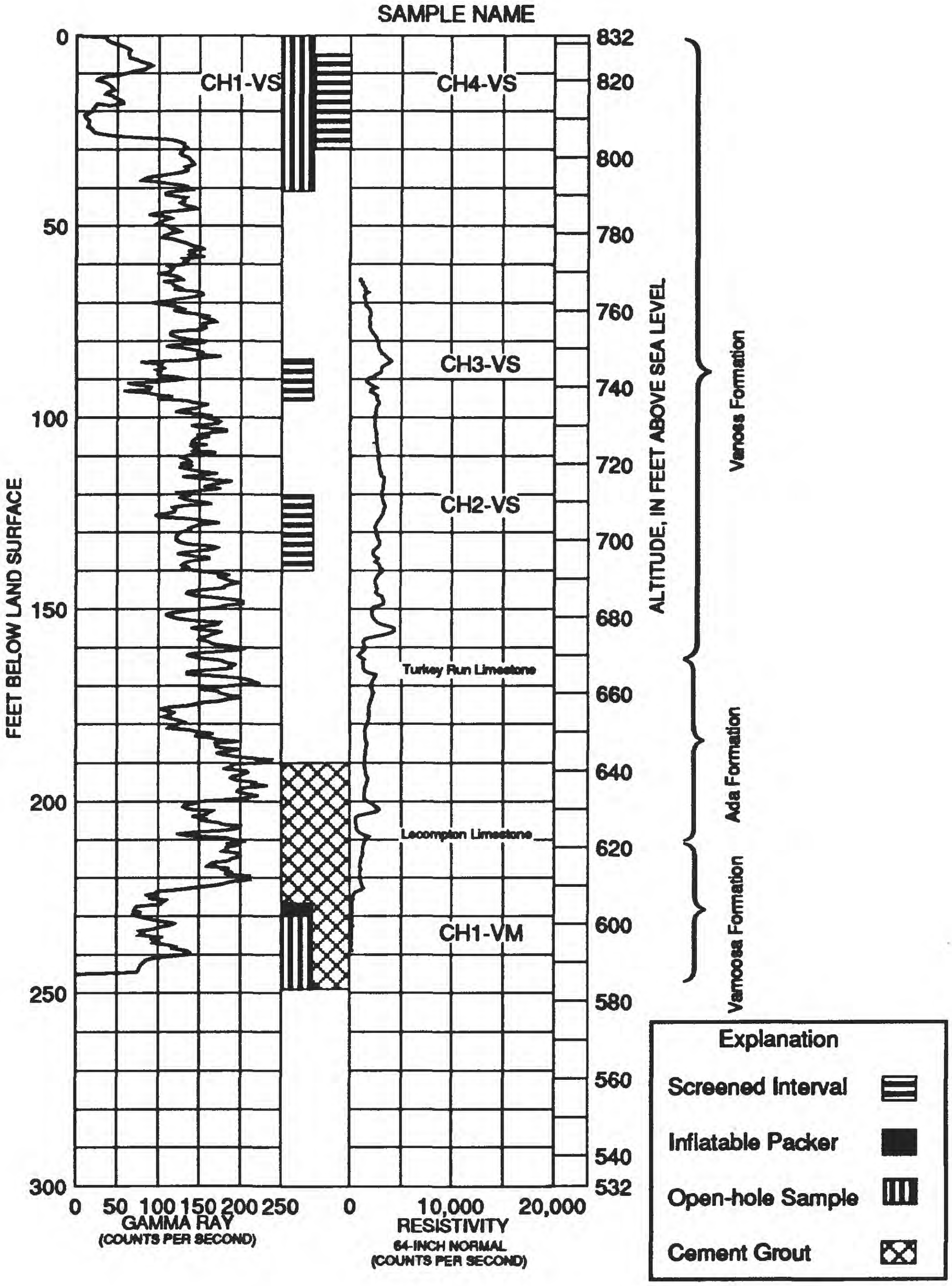


Figure 4. Geophysical logs from borehole CH1, sample interval for CH1-VS and CH1-VM, and screened interval for samples CH2-VS, CH3-VS, and CH4-VS, in boreholes CH2, CH3, and CH4; 14N-06E-21 DAAA; eastern Lincoln County, Oklahoma.

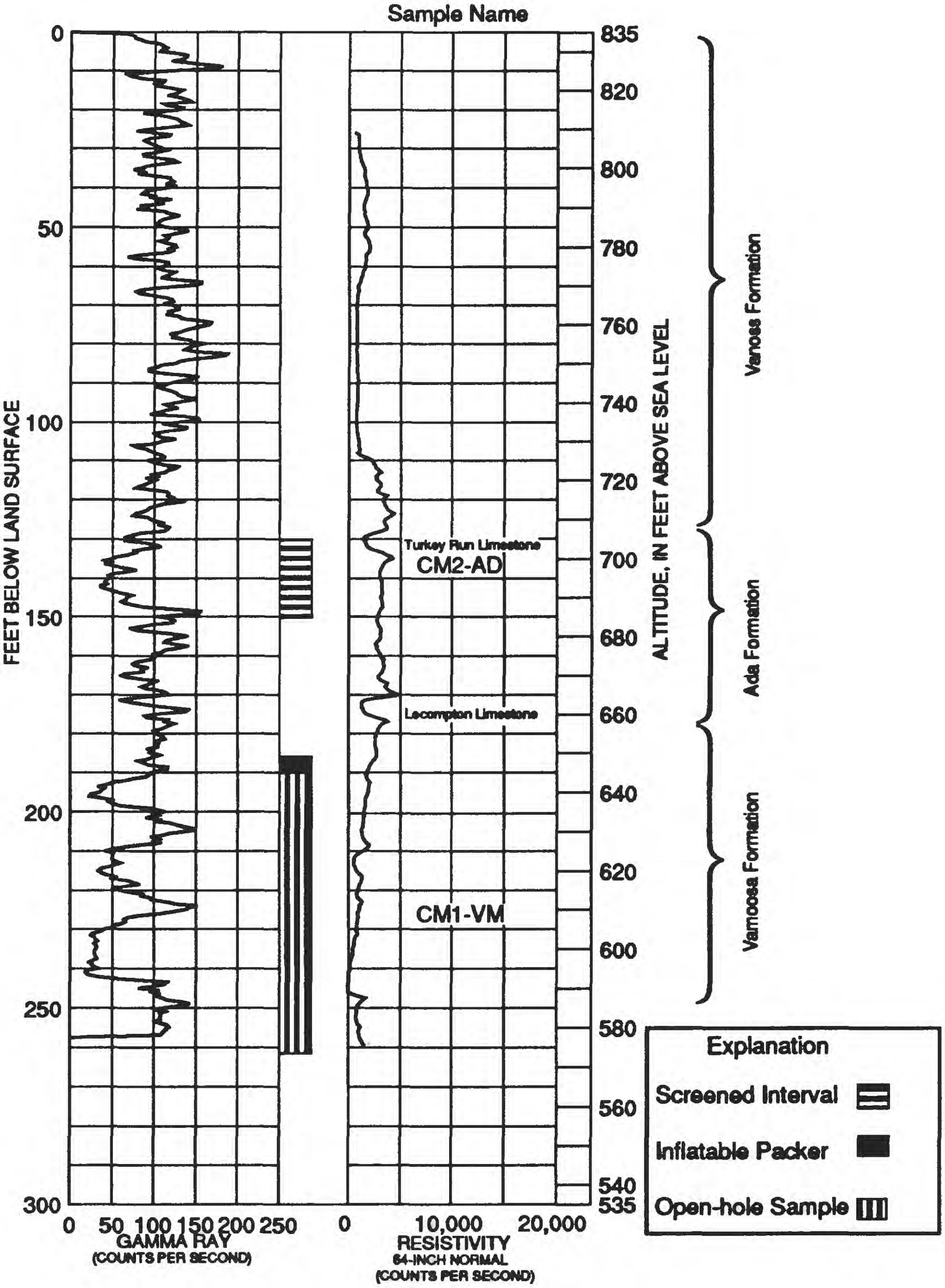


Figure 5. Geophysical logs from borehole CM1, sample interval for CM1-VM, and screened interval for sample CM2-AD, in borehole CM2; 14N-06E-22 BAC; eastern Lincoln County, Oklahoma.

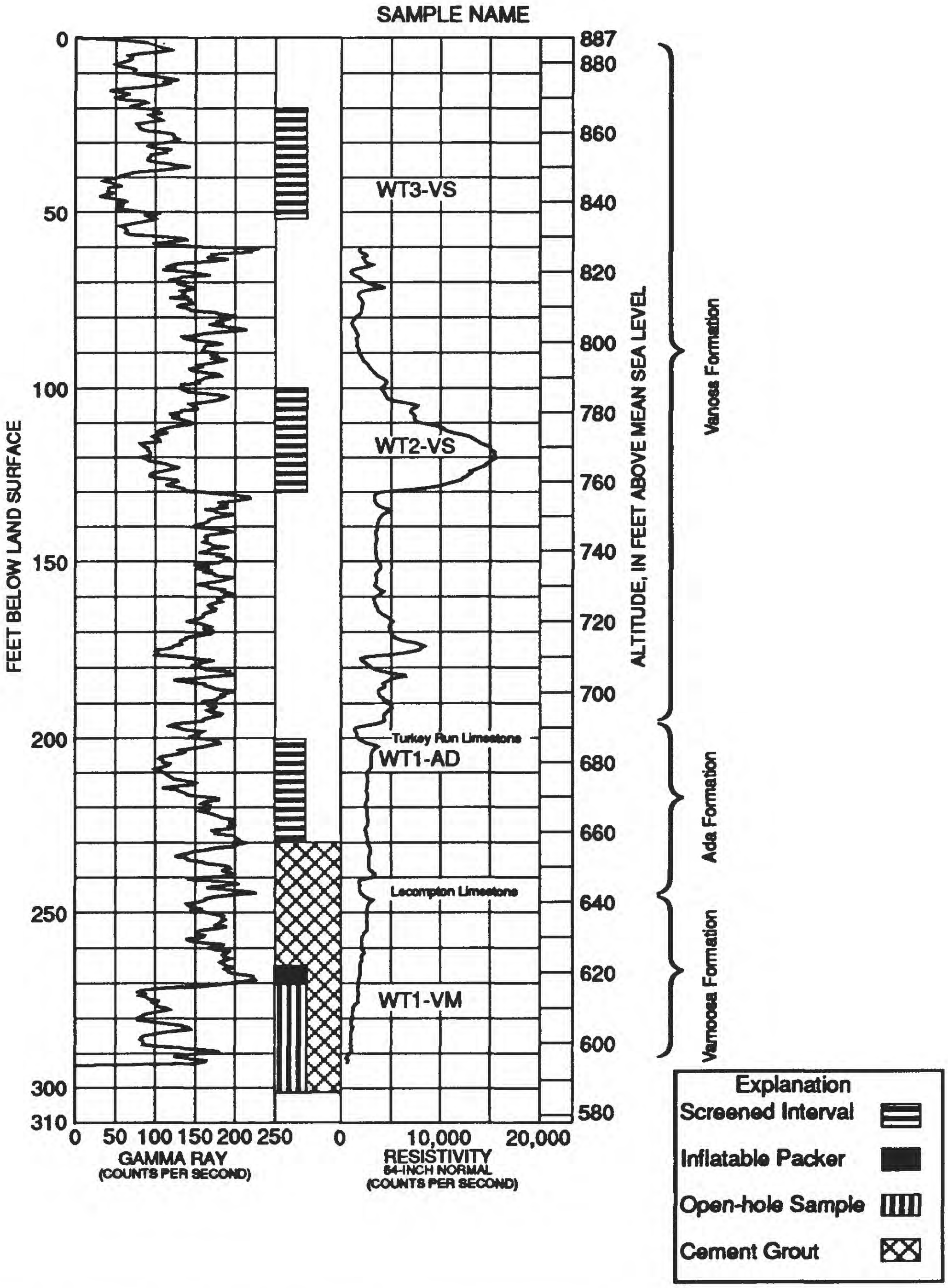


Figure 6. Geophysical logs from borehole WT1, screened and sample interval for WT1-AD and WT1-VM, and screened interval for samples WT2-VS and WT3-VS, in boreholes WT2 and WT3; 14N-06E-22 CAB; eastern Lincoln County, Oklahoma.

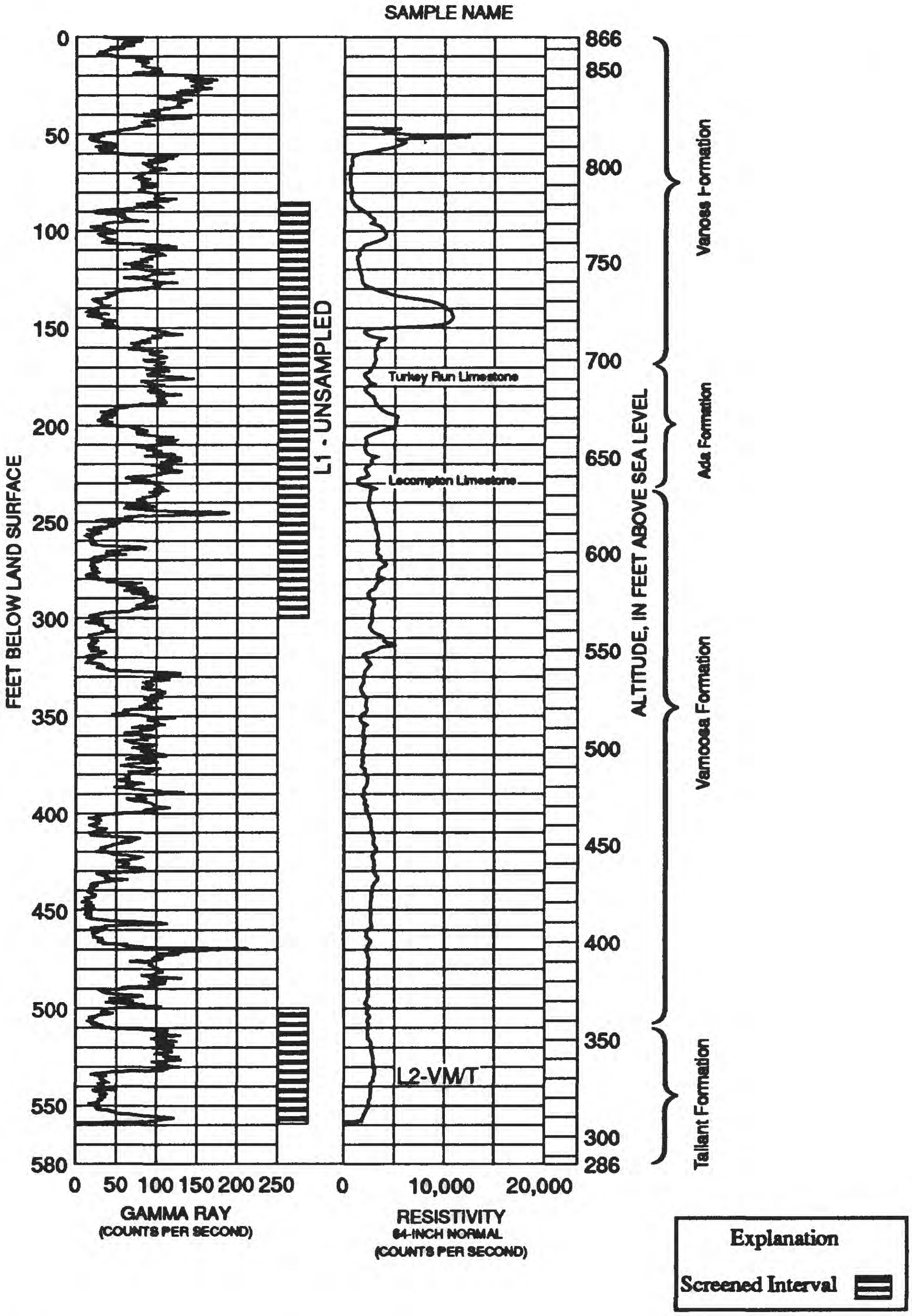


Figure 7. Geophysical logs from borehole L2, screened interval for L2–VM/T, and screened interval in borehole L1; 14N-06E-34 CBC; eastern Lincoln County, Oklahoma.

stone units supplying this well probably are the lowest sandstone of the Vamoosa Formation and the upper sandstone of the underlying Tallant Formation of the Missourian Series below the Vamoosa Formation (fig. 7). Borehole geophysical logs from oil wells were used to select the depth to drill in this well.

The tribal water-supply wells are 14N–06E–34 CBB 1 (north well) and 2 (south well). These wells were screened to 260 ft and 270 ft, respectively, in the Vamoosa Formation. The wells are 246 ft apart and 1,144 ft from L1. For discussion purposes these wells will be referred to as SF1 (north well) and SF2 (south well).

All oil production on the Sac and Fox Nation tribal land is from the Prue sand at approximately 3,000 ft below land surface. The Prue sand is an informal member of the Senora Formation of the Cabaniss Group of the Desmoinesian Series of the Pennsylvanian (fig. 2). Six brine samples from the oil production were collected in February 1992. Five samples were taken at well-head pumping units that were on or adjacent to tribal land. In this report these wells will be referred to as P1, P2, P3, P4, and P5 (fig. 3). One sample was collected from the waterflood injection system at the pressure pump on the Sac and Fox Prue Sand Waterflood Unit in NE1/2 SE1/4 SW1/4 sec. 15, T. 14 N., R. 06 E. and will be referred to as P-inj (fig. 3).

The five samples from the producing pumping units are water taken directly from the Prue sand and represent the present formation water. The injection-water sample, P-inj, represents the water composition that is injected back into the Prue sand by the waterflood operations. The injection water is composed of formation water from several producing wells, any make-up water needed for additional volume into the injection system, and chemicals that are added to the injection water to reduce problems from sulfate precipitates and paraffins. The volume of make-up water added to the injection system at the beginning of a waterflood is much larger than the volume needed later in the waterflood. The original Prue brine composition and its variance across secs. 15, 16, 21, and 22, T. 14 N., R. 06 E. are not known. Changes from the original brine composition would have occurred as the waterflood operations were injecting the largest amount of make-up water. No make-up water is being added currently to the injection systems. The make-up water was reportedly from the Tallant Formation (Canard, 1989). The lower sandstone in L2 (from 530 - 560 ft) is in the Tallant Formation.

Geohydrologic Investigation Methods

The well clusters were logged using U.S. Geological Survey borehole geophysical logging equipment. The logs were interpreted to correlate between the geologic units, to obtain a qualitative evaluation of the water resistivity in the units, and to evaluate the thickness and placement of the sandstones within the aquifer system. The borehole geophysical logs from the deepest wells in each cluster are shown in figures 4-7 and the well locations are noted on figures 1 and 3. Sampling intervals for each well in the cluster are indicated on the logs. U.S. Geological Survey logging equipment recordings were taken in counts per second (cps). Complete cores were taken from two test wells, CH1 and WT1, to correlate lithology with the geophysical logs.

The regional strike and dip were determined from cluster wells CH1, CM1, and WT1. The Turkey Run Limestone marker, at 167 ft in CH1, was used in the calculation. The strike was N 22° W and dip was 0.8° W. The strike of the faults in the region are generally N 20° W. Each of the domestic wells was evaluated using the regional strike and dip to determine if the well had penetrated the Ada Formation or had only been drilled into the Vanoss Formation (table 1).

The gamma-ray logs on figures 4-6 indicate the thickness and position of sandstones and shales in the test hole. Sandstones, such as 10-27 ft in CH1 (fig. 4), have 10-100 cps on the gamma-ray logs. Shales, 130-170 ft and 250-270 ft in WT1 (fig. 6), have 150-240 cps. Shaley sandstones and limestones have 100-150 cps on the gamma-ray logs.

FRESHWATER RESOURCES

Surface-Water Geochemistry in the Study Area

Surface-water samples (S1, S2, S3, and S4), in appendix 2, were collected in August 1991 during a period of low flow when the Deep Fork receives water from Lake Arcadia near Oklahoma City and from the lower Permian formations downstream from the lake and west of the study area. These samples contain approximately equal concentrations of sodium and calcium plus magnesium (appendix 2). The alkalinity (as calcium carbonate) from these surface-water samples is approximately twice the chloride concentration (appendix 2). They contain measurable dissolved-oxygen concentrations and have TDS less than 600 mg/L.

Fresh Ground-Water Geochemistry in the Study Area

Fresh ground water in the Vanoss Formation occurs in recharge areas where the water has not been in the ground-water system long and water-rock interaction is controlled by time. Shallow samples from the Vanoss Formation, such as CH1-VS, CH4-VS, WT2-VS, and WT3-VS, generally are composed of sodium bicarbonate or sodium-calcium-magnesium bicarbonate water. Water from the Vanoss Formation contains measurable dissolved-oxygen concentrations throughout the area, as shown by measurements made while sampling (appendix 1). Fresh ground water from the Ada and Vamoosa Formations has TDS less than 600 mg/L and is sodium bicarbonate or sodium-calcium-magnesium bicarbonate water. The one dissolved oxygen measurement for a sample from the Vamoosa Formation, SF2-VM, showed measurable dissolved oxygen.

Geology of the Freshwater Aquifers

The Vamoosa Formation is composed of lenticular sandstones and silty shales (Oakes, 1959). The sandstones are generally well-cemented and medium to fine grained. The base of the Formation in Creek County (fig. 1) is described by Oakes (1959) as a conglomerate. Oakes (1959) described a massive sandstone section in the lower half of the Vamoosa Formation in T. 14 N., R. 07 E. similar to the section seen on the log from 400 ft to 470 ft in borehole L2 (fig. 7). The upper sandstones of the Vamoosa Formation present in wells CH1, CM1, and WT1 (figs. 4-6) are in borehole L2 from 245 ft to 326 ft (fig. 7). The top of the formation is placed at the base of the Lecompton Limestone (figs. 4-7). The Vamoosa Formation is approximately 250 ft thick in the study area.

The Ada Formation as described by Oakes (1959) is approximately 40 ft thick and contains two limestone beds, the Lecompton Limestone at the base and the Turkey Run Limestone at the top. The presence of the Lecompton Limestone was confirmed in T. 13 N., R. 07 E. by Ries (1954), but he reported the Turkey Run Limestone is absent in Okfuskee County (fig. 1). The two limestones are tentatively identified in the study area by projecting the general regional dip (Oakes, 1959) of 70 ft per mile or 0.8° to the west from the Lecompton outcrops, secs. 19 and 31, T. 14 N., R. 07 E., to the cluster well WT1 (fig. 6). Two thin limestones were present in the well core at depths of 195 and 242 ft separated by 40 ft of shale and sandstone. Similar limestones also can be identified in the remaining well-cluster logs in figures 4, 5, and 7. A water-bearing sandstone is present at 195 ft between the Turkey Run and Lecompton Limestones (fig. 7) in borehole L2.

The Vanoss Formation overlies the Ada Formation and forms the hills above the Deep Fork valley on tribal land. Cores taken from the well clusters contained very fine- to fine-grained sandstones that were moderately to well cemented and were interbedded with red and gray shales. A complete stratigraphic section of the Vanoss Formation is not present on tribal land. Borehole WT1 penetrated 195 ft of the Vanoss Formation.

The gamma-ray logs indicate the sandstones in the Vanoss, Ada, and upper Vamoosa Formations, on the tribal land, are thinner than the shales. Hydraulic conductivity in shales is much less than in sandstones. Volumetric rate of ground-water movement is smaller through shales and is greater in sandstones.

Hydrology of the Freshwater Aquifers

Hydrologic data for the aquifers are published in Hart (1974), Bingham and Moore (1975), Bingham and Bergman (1980), D'Lugosz and others (1986), and Morton (1986). Recharge to the ground-water system occurs where sandstones outcrop on topographically higher areas. The Vanoss and Ada Formations are unconfined and semiconfined aquifers in the study area. The Vamoosa Formation is a confined aquifer in the study area but is at the surface in Creek County, 2 mi to the east of the Sac and Fox Nation (Oakes, 1959). Morton concluded the gradient of the water table in the unconfined areas of the aquifer was locally toward gaining streams (Morton, 1986, Plate 1, map A). He also stated that in the confined part of the aquifer the potentiometric surface followed the regional dip to the west. Therefore, recharge to the confined part of the aquifer is east of the tribal land.

Discharge from the ground-water system occurs where sandstones outcrop near gaining streams such as the Deep Fork (Morton, 1986) and its associated wetlands. Stream discharge measurements made at the time of sampling during a low-flow period indicated the river was gaining 1.5 cubic feet per second for each subsequent mile downstream.

Base of Fresh Ground Water

Fresh ground water is underlain by briny water because TDS and salinity generally increase with greater depths. The depth to the shallow brine varies because of local conditions such as the amount of precipitation, the thickness of the sandstones in the aquifers, the velocity and direction of ground-water movement, the length of the flow paths from the area of recharge to the discharge area, and the amount of ground water withdrawn by wells. Locally the shallow brine and the fresh ground-water lenses would eventually reach chemical and hydrologic equilibrium if recharge equals discharge and remains constant. In recharge areas and where the sandstone sequence is thick (Morton, 1986) the upper boundary of the shallow brine is deeper and the saturated thickness of fresh ground water above it is greater. Conversely, in discharge areas and where siltstone and shale sequences are thicker, the shallow brine is closer to the land surface and the fresh ground-water lens is not well developed.

The altitude of the base of fresh water was evaluated from borehole geophysical logs of oil wells. No data were available on many of the wells because of the deep surface casing or the well interval was not logged. Borehole geophysical logs are continuous recorded measurements of physical properties of the rocks through which the hole was drilled, the fluid in the rock, and the fluid in the borehole. Many of the oil wells on tribal land were drilled and producing before borehole geophysical logging became common practice. Log data used to evaluate the altitude of the base of fresh ground water are from oil wells drilled beginning in 1953 and 1954 on tribal land, after the waterflooding started in the Sac and Fox Prue Sand Units. Log data used in the evaluation and not on tribal land or in the Sac and Fox Prue Sand Units are from wells beginning in 1951. During this time 16 in. and 64 in. normal–resistivity and lateral–resistivity logging was common practice. The 16 in. (short normal) resistivity log only investigates near the borehole in the zone invaded by drilling mud. The 64 in. (long normal) and the lateral–resistivity logs investigate the invaded zone and the undisturbed formation (Keys, 1988).

Borehole geophysical logs are used to evaluate the economic potential of oil wells and so the potential producing zones are logged with the greatest care. Since the shallow freshwater zones are not of economic interest, many logs do not record the shallow zones. Most of the oil wells for which data are available are recorded from the base of the surface casing to the total depth of the well. The length of surface casing required in well construction is regulated by the Oklahoma Corporation Commission and the requirements have changed with time. The more recent wells have surface casing set to greater depths than do the older wells.

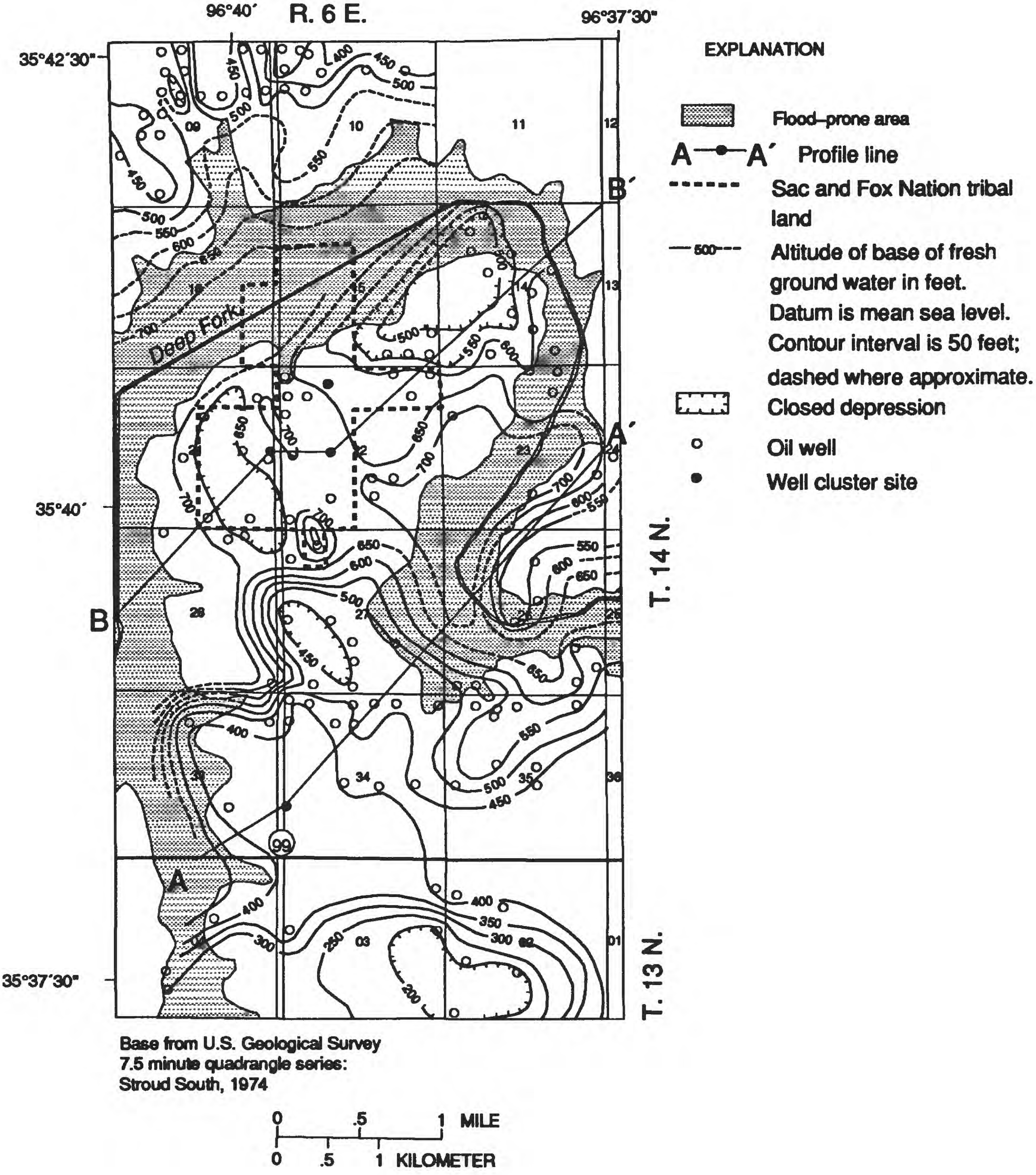
Drilling practices are fairly constant in central Oklahoma, where sodium bentonite is used as the drilling fluid and the lithologic sequence in the formations is regionally constant. The well clusters and the early oil wells were drilled with native mud that forms in the borehole in the saturated zone.

Since fresh water has a greater resistance to the flow of electrons than brine water, borehole resistivity logs will shift to higher values as the TDS in the water decrease. Logs, however, do not respond only to changes in water quality. Keys and MacCary (1973) pointed out that resistivity logs measure changes in formation fluid, borehole fluid, and formation lithology. Log response then is a crude measure of changes in water quality.

Figure 8 shows the altitude of the base of fresh ground water presented in feet above sea level. The map illustrates the lower surface of fresh ground water. The data for figure 8 are given in appendix 3. A minimum resistivity value of 10 ohm-meters in a sandstone was chosen to represent the change from fresh water to saline water. The resistivity value selected is an arbitrary selection only for mapping purposes.

Figure 9 shows sections from near the Deep Fork on the east, across a topographically high area to the river or the wetlands to the west. The sections show the land surface and the altitude of the base of fresh ground water in figure 8.

The altitude of the base of fresh water is nearer the land surface along the river and the wetlands than in the adjoining areas that are topographically higher



Base from U.S. Geological Survey
7.5 minute quadrangle series:
Stroud South, 1974

Figure 8. Map of the altitude of the base of fresh ground water, from wells drilled between 1951-95, eastern Lincoln County, Oklahoma.

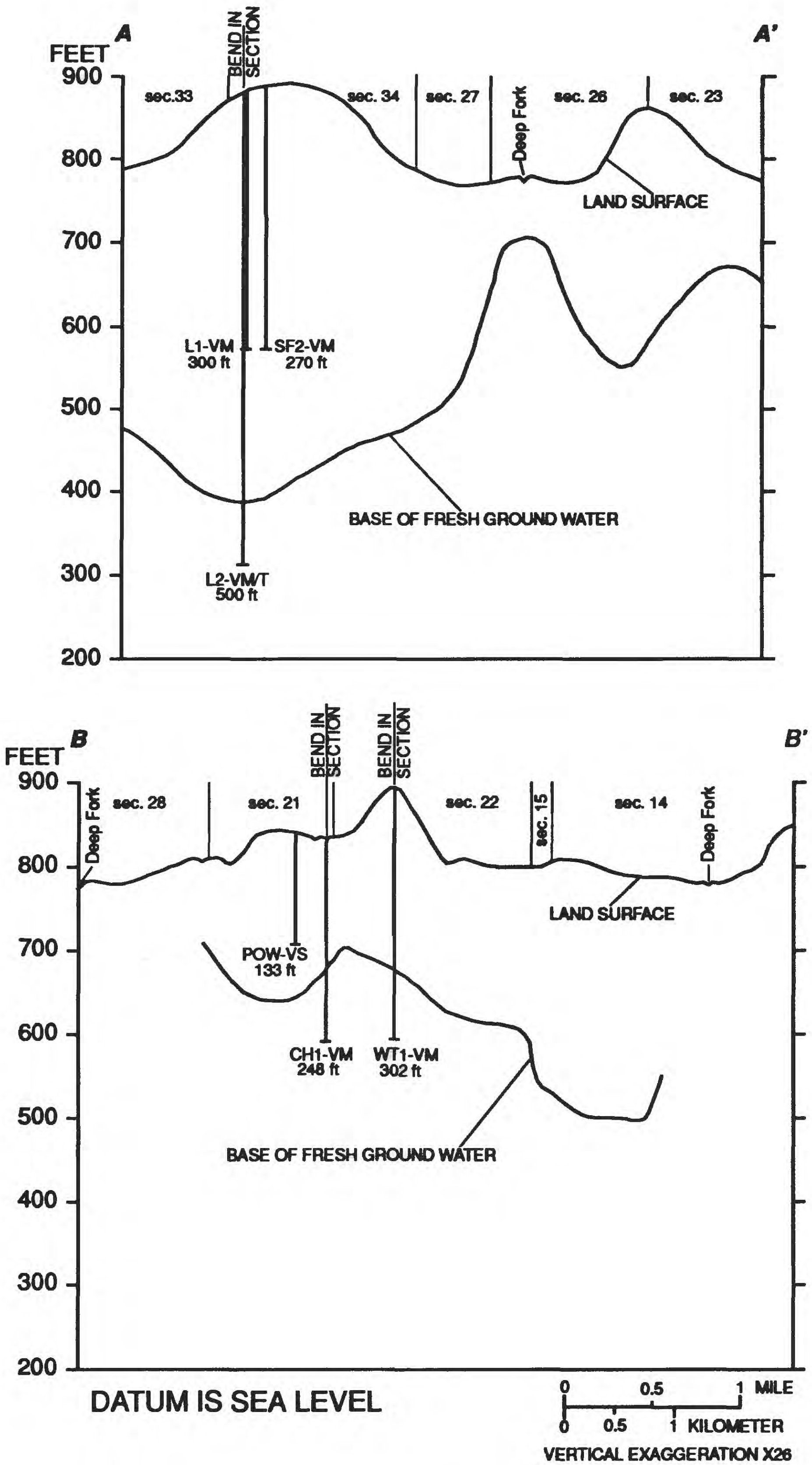


Figure 9. Generalized hydrologic sections A—A' and B—B' showing relation between land surface and base of fresh ground water in the Ada-Vamoosa aquifer, 1951-95, eastern Lincoln County, Oklahoma.

(figs. 8 and 9). In section A–A′, the altitude of the base of fresh ground water is generally low beneath the topographically high areas such as secs. 26 and 34, T. 14 N., R. 06 E. The altitude of the base of fresh ground water near the Deep Fork in section A–A′, is nearer the land surface at 700 ft. Sandstones are present throughout the Vanoss and Ada Formations in L2 (fig. 7) in sec. 34.

The altitude of the base of fresh ground water in section B–B′ (fig. 9) under the W1/2 sec. 22, T. 14 N.,R. 06 E. is generally near 700 ft, which is nearer the land surface beneath the topographically high area than on section A–A′. In figure 8 the area where the base of fresh ground water is near the land surface includes the SE1/4 sec. 22, T. 14 N., R. 06 E. and extends into the E1/2 NE1/4 sec. 21, T. 14 N., R. 06 E. and NE1/4 NW1/4 NW1/4 sec. 27, T. 14 N., R. 06 E. West of this area in the W1/2 E1/2 sec. 21, T. 14 N., R. 06 E. (fig. 8) the altitude of the base of fresh ground water is lower, as would be expected based on land surface. A lens of fresh ground water has developed in the W1/2 sec. 14, T. 14 N., R. 06 E., the SE1/4 sec. 15, T. 14 N., R. 06 E., and the NE1/4 sec. 22, T. 14 N., R. 06 E. Shales and siltstones dominate most of the Vanoss and Ada Formations in CH1, CM1, and WT1 (figs. 4-6).

The altitude of the base of fresh ground water (fig. 8) determined from borehole geophysical logs was generally comparable to the fresh and saline ground water samples from the well clusters (appendix 1). The difference in the altitude of the base of fresh ground water of the two methods ranged from 23 to 70 ft and is expected because the two methods are sensitive to different variables. The altitude of the base of fresh ground water from borehole geophysical logs (fig. 8) near the CH well cluster was about 680 ft. Freshwater samples (appendix 1) taken from the CH well cluster were CH1-VS and CH4-VS (fig. 4) at an altitude of 790 ft. Shallowest saline water sample (appendix 1) taken from the CH well cluster was moderately saline from CH3-VS at an altitude of 750 ft. The altitude of the base of fresh ground water determined by the water-quality samples in the CH well cluster was between 750 ft and 790 ft.

The altitude of the base of fresh ground water (fig. 8) near the CM well cluster was about 640 ft. Fresh water was not sampled in the CM well cluster (appendix 1). Slightly saline water was from CM2-AD (fig. 5). The altitude of the base of fresh ground water determined by the water-quality samples was above 705 ft.

The altitude of the base of fresh ground water (fig. 8) near the WT well cluster was about 680 ft. Freshwater samples (appendix 1) taken from the WT well cluster were WT1-AD, WT2-VS, and WT3-VS (fig. 6). Shallowest saline water sample taken from the WT well cluster was briny water (table 4) from WT1-VM. The altitude of the base of fresh ground water determined by the water-quality samples in the WT well cluster was between 657 ft and 618 ft.

Borehole geophysical logs and water-quality samples indicate the fresh ground water was better developed near sec. 34, T. 14 N., R. 06 E., where the tribe has leased water rights, than near the tribal land. The altitude of the base of fresh ground water near SF1 and SF2 in figure 8 was about 400 ft. Fresh water was sampled from SF1 and SF2 (appendix 1), which were screened in the same interval as L1 (fig. 7) to an altitude of about 570 ft. Briny water was sampled from L2 (fig. 7), which was screened to an altitude of about 385 ft. The altitude of the base of fresh ground water from the water-quality samples in sec. 34, T. 14 N., R. 06 E. was between 385 ft and 570 ft.

Water-quality sampling and borehole geophysical data indicate the potential for fresh ground water on tribal land generally is greatest in the Vanoss Formation, in the SE1/4 sec. 21, T. 14 N., R. 06 E. and in the NE1/4 sec. 22, T. 14 N., R. 06 E. These locations avoid the flood-prone areas and borehole geophysical resistivity logs indicate the altitude of the base of fresh ground water is below 650 ft (fig. 8). Fresh ground water samples were CH1-VS, CH4-VS, WT2-VS, WT3-VS, and WT1-AD. Domestic wells listed in appendix 1, which are on or near tribal land, that produce fresh ground water are completed in the Vanoss Formation.

Conditions are more favorable for placement of fresh ground water wells near SF1 and SF2 in section 34, where the tribe has leased water rights, than on tribal land in secs. 15, 16, 21, and 22, T. 14 N., R. 06 E. General water quality near the Deep Fork is poor because the gradient of the water table in the unconfined part of the aquifer is locally toward the river (Morton, 1986) and not circulating into the confined beds of the aquifer. Sandstones comprise only 6 percent of the stratigraphic section in borehole CH1 (fig. 4), 9 percent of CM1 (fig. 5), and 20 percent of WT1 (fig. 6). L2 (fig. 7) has 42 percent sandstone present in the fresh ground water interval from 45-330 ft. Thick shale beds in the Vanoss Formation at CH1, CM1, and WT1 (figs. 4-6) impede vertical recharge near these wells. Thin shale beds logged in L2 in the Vanoss and Ada Formations provide less impedance to vertical recharge near SF1 and SF2.

SALINE WATER

Ground water from the Ada and Vamoosa Formations, in the area where the altitude of the base of fresh ground water is near the surface, in the W1/2 sec. 22, T. 14 N., R. 06 E., have high sodium chloride (NaCl) and sodium sulfate (Na_2SO_4) concentrations on tribal land (appendix 1). Water-quality samples CH2-VS, CH3-VS, CM2-AD, CH1-VM, CM1-VM, WT1-VM, and L2-VM/T have chloride or sulfate concentrations greater than 250 mg/L.

Potential Sources of Brine

Two possible sources for sodium chloride and sodium sulfate are shallow brines and deep brines from oil production at 3,000 ft. The Deep Fork was not considered as a possible source of salinity because the water is sodium-calcium-magnesium bicarbonate and not concentrated enough to create the sodium chloride or sodium sulfate water in the Vanoss, Ada, and Vamoosa Formations. Shallow brines and the brines from oil production are discussed as potential sources of salinity by Morton (1986) and Richter and Kreitler (1991).

Shallow brine composition in the study area is unknown and may vary. CH1-VM, WT1-VM, and L2–VM/T may represent shallow brine compositions. Probable sources of shallow brine in the study area are: 1) solution of minerals as fresh water moves through the aquifer and 2) residual brine deposited with the sediment (Richter and Kreitler, 1991). There are no salt or gypsum beds in the Vanoss, Ada, or Vamoosa Formations. Salt and gypsum were not found in the cores from CM1 and WT1. Salt and gypsum may be present, however, as nodules and finely disseminated minerals in the formations that could create the sodium chloride and sodium sulfate in the water-quality samples.

It can be assumed that the regional aquifer that now contains fresh ground water once was filled with seawater at the time of deposition (Parkhurst and other, 1992; Richter and Kreitler, 1991). Over time, the freshwater flow system has flushed out or removed most of the brine. Residual brine can remain in sandstones and shales that have not been diluted by freshwater circulation. Sandstones overlain by or enclosed in thick clay and shale sequences are likely to be somewhat isolated from the flow system and retain some of the residual brine. The Vanoss Formation intersected by WT2 (fig. 6) has about 18 ft of shaley sandstone enclosed in 190 ft of clay and shale, and WT2-VS has a TDS of 774 mg/L. The Vanoss Formation intersected by CH3 (fig. 4) has about 5 ft of shaley sandstone enclosed in 200 ft of clay and shale and CH3-VS has a TDS of 3,840 mg/L. This suggests higher TDS values maybe expected from thin shaley sandstones. The Vanoss, Ada, and upper Vamoosa Formations intersected by L2 (fig. 7) have 4 sandstone units that total 55ft in 195 ft of clay and shale. Each of these sandstones are 10 to 20 ft thick. Sample SF2-VM is from the same sandstone interval, shown as L1-unsampled (fig. 7) and has a TDS of 254 mg/L. Multiple sandstones in the interval probably improve freshwater circulation. Borehole geophysical logs suggest the sandstones near CH1, CM1, and WT1 have more clay and shale content than the sandstones near L2. Greater amounts of clay in the sandstones will retard the flushing of residual brines from the sandstones and could result in a shallow base of fresh water near CH1, CM1, and WT1.

Fresh ground water and underlying shallow brines are separated by a mixing zone. The chemical make-up of water in the mixing zone will vary with the composition and percentages of the waters mixed. Discharge boundaries near the Deep Fork are areas of mixing of fresh ground water, shallow brines, and deep circulation brines. Complex mixing makes brine source determinations difficult in these areas. The mixing zone in a recharge area is produced from local water-rock interaction as fresh water moves through in the shallow ground-water environment and dilutes the shallow brines. The mixture should be relatively undisturbed by the circulation of deeper oil brines.

Prue sand oil-field brines are a potential source of salinity in shallow fresh ground water because of oil production operations, surface brine spills, and water-flooding activities. Before 1972 (Bruce Langhus, Oklahoma Corporation Commission, oral commun., 1996) brines generally were held in earth pits until the water evaporated or infiltrated the ground-water system. There is no evidence in the data for regional salinization from the surface but local areas may exist.

L2 was drilled to 560 ft in 14N-06E-34 CBC, near the tribal water-supply wells, to sample a shallow brine or a mixed water that was assumed to be undisturbed by deeper oil brines. A field sample and a duplicate were analyzed from L2–VM/T (appendix 1). Both analyses are presented in the following discussion, where they differ for bromide and deuterium.

Geochemistry of Saline Ground Water

Chemistry of the saline ground-water samples varies in composition and concentration on tribal land (appendix 1). CH2-VS, CH3-VS, and CM1-VM are sodium chloride and sodium sulfate water. These moderately saline to very saline (table 4) water samples have TDS of 8,890 mg/L, 3,840 mg/L, and 18,400 mg/L (appendix 1) respectively. CM2-AD is sodium sulfate water with a slightly saline TDS of 1,340 mg/L. CH1-VM, WT1-VM, and L2–VM/T are briny sodium chloride water (table 4). These samples have TDS of 58,500 mg/L, 78,300 mg/L, and 58,900 mg/L respectively. The water from the Prue sand is briny and dominated by sodium chloride. The TDS ranges from 88,200 to 147,000 mg/L.

Brine Detection and Identification Methods

Ground water can be characterized by several different physical parameters or chemical constituents such as dissolved ion concentrations, isotopic enrichment, TDS, or conductivity. Several methods of brine identification based on relations between constituent concentrations have been discussed by Chebotarev (1955), Rittenhouse (1967), Collins (1974, 1975), Whittemore and Pollock (1979), Whittemore (1984, 1988), Morton (1986), Knuth and others (1990), and Richter and Kreitler (1991).

Bromide to Chloride Ratios and Chloride Concentration

Dissolved ionic species of chloride and bromide were selected for characterization and comparison of the ground water in the study area. These dissolved species were chosen because they are probably the least reactive with other dissolved species in the ground water and with the solid minerals of the aquifer. The concentrations of these ions in a freshwater/brine mixture is affected only by the concentration of the brine, the concentration of the fresh water, and the relative volumes in the mixture. A plot of the ratio of bromide/chloride concentrations (×10,000) and chloride concentration for the water samples is shown in figure 10. At higher chloride concentrations the ratio is relatively constant ratio. A plot of the ratio of iodide/chloride and chloride concentration for the water samples produced similar results.

Morton (1986) reported a brine index threshold value of 400 mg/L for chloride. The index threshold value is the concentration at which Morton (1986) determined oil-associated brine degradation of fresh water could be identified. Water-quality samples from CH2-VS, CH3-VS, CH1-VM, CM1-VM, WT1-VM, and L2-VM/T have chloride values greater than 400 mg/L. For the seven samples from these six sites the bromide/chloride ratio ranged from 42.5 to 52.4. For the 45 samples having chloride concentrations below 400 mg/L the bromide/chloride ratio ranged from 8.3 to 200.0.

A mixing curve envelope was produced on the plot from selected end member samples by the relationship in equation 1.

$$C_{(\text{mixed water})} \times V_1 = (C_1 \times V_x) + (C_2 \times V_{(1\text{-}x)}) \quad (1)$$

where $C_{(\text{mixed water})}$, C_1, and C_2 are the concentrations (mg/L) of chloride and bromide for the mixed water and the two beginning waters, and V_1, V_x, and $V_{(1\text{-}x)}$ are the decimal percentage volume of each water. The bromide/chloride ratio for the mixing curve envelope is calculated from the $C_{(\text{mixed water})}$ values for chloride and bromide. Water samples from the Prue brine and fresh water were chosen as end members. Calculations for the upper mixing curve were made from samples from P1 and the well located at 14N–06E–09 AAA. The lower mixing curve was calculated from samples from P2 and the well located at 13N–06E–08 BCC. The calculated mixing curves for chloride concentrations of greater than 400 mg/L have a bromide/chloride ratio of approximately 35 to 75. Ground-water samples from tribal land with higher chloride concentrations plot within the mixing-curve envelope and have ratios between 40 and 50.

If a brine is the salinity source for a mixed-water sample that has a chloride concentration greater than 400 mg/L, the bromide/chloride ratio for the two waters would be equal. Dilution of the Prue brines from the waterfloods could produce the bromide and chloride values in the saline water from CH2-VS,

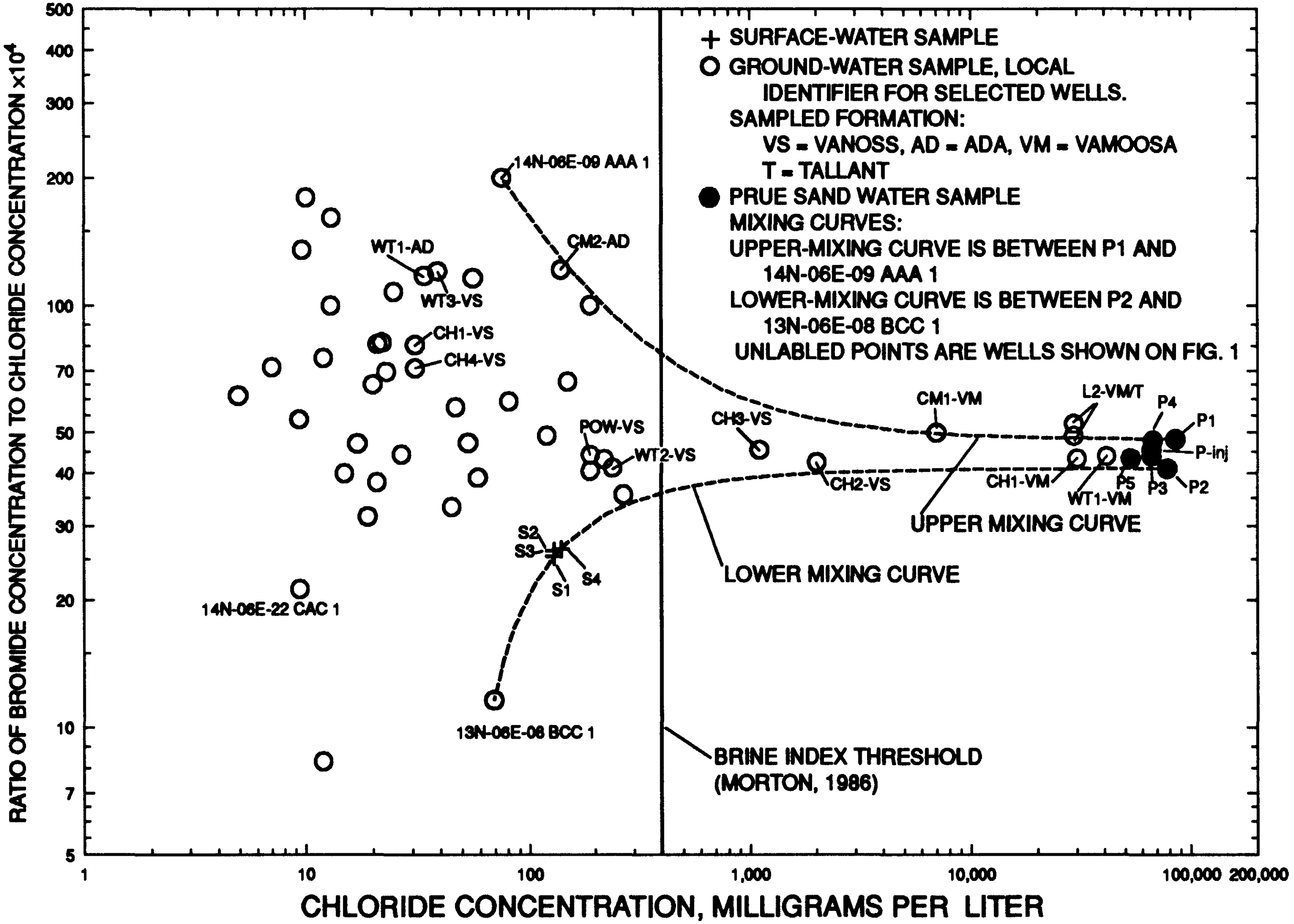


Figure 10. Relation between the ratio of bromide concentration to chloride concentration and chloride concentration in water samples, eastern Lincoln County, Oklahoma.

CH3-VS, CH1–VM, CM1–VM, WT1–VM, and L2–VM/T.

Parkhurst and Christenson (1987) presented chemical analyses of water from across Oklahoma. The statewide data indicate other formations, unsampled in the study area, may contain waterthat could produce the mixed-water samples. Therefore, dissolved ionic species cannot determine whether water from the Prue sand in the waterfloods is the only oil brine source for the saline water.

Stable Isotope Evaluation

Water molecules are composed of the elements of hydrogen and oxygen that have naturally occurring stable isotopes. Stable isotopes are conservative in characterizing the origin of the water molecule. The uses of stable isotopes were discussed in Gat and Gonfiantini (1981) and the application to saline formation water was described in Clayton and others (1966).

Isotopes are atoms of the same element that have different atomic masses, determined by the number of neutrons in the nucleus. Stable isotopes of hydrogen have atomic masses of 1 and 2. The more common or abundant form of hydrogen has a mass number of 1. The less abundant form has an atomic mass of 2 and is named deuterium. Oxygen has three naturally occurring stable isotopes of atomic masses 16, 17, and 18. The more abundant form has a mass of 16 and the less common form has a mass of 18. The natural abundance of the oxygen isotope of mass 17 is small and was not considered in the analyses.

Atmospheric moisture originates from ocean water that can be considered constant in its isotopic composition (Ferronsky and Polyakov, 1982). As fresh ground water originates as precipitation, an understanding of the distribution of the isotopic species in rain water is important. On a global scale, the natural abundance of deuterium (δD) and oxygen-18 ($\delta^{18}O$) have been related to equation 2 (Craig, 1961).

$$\delta D(‰) = 8\delta^{18}O(‰) + 10 \qquad (2)$$

The isotopes are measured as a ratio of (δ) of the isotope concentration in the sample to the concentration in standard mean ocean water and reported in parts per thousand (‰) or permil. On a plot of δD versus $\delta^{18}O$, equation 2 plots as a line and is known as the global meteoric water line (Craig, 1961). Several factors affect the distribution of the isotopic species in local rainfall and thus modify equation 2 for local conditions.

The work by Parkhurst and others (1992) on the data from the Central Oklahoma aquifer defined a local meteoric water line for the sandstone aquifers overlying the Vanoss Formation, west of the tribal land. Data from Parkhurst and others (1992) plot along the line in the lower left corner of figure 11, with δD values from -30 to -45 and $\delta^{18}O$ values from -5 to -7. The equation for the meteoric water line for the Central Oklahoma aquifer is given in equation 3 (Parkhurst and others, 1992).

$$\delta D(‰) = 8\delta^{18}O(‰) + 12 \qquad (3)$$

The low specific conductance samples from well clusters in the Vanoss Formation and the tribal water-supply well, SF2-VM, are closely associated with the data from the Central Oklahoma aquifer (fig. 11). The precision of the analysis for δD is 1.5(‰) and for $\delta^{18}O$ is 0.1(‰) as is shown by the box in figure 11 (Carol Kendall, U.S. Geological Survey, written commun. 1993).

Interaction of ground water with minerals, liquids, and gases in shallow aquifers and deep formations will change the isotopic distribution. The water-rock interaction has a great effect on the isotopic composition of ground water (Kharaka and Thordsen, 1992). If the flow-path conditions are maintained for a very long time, as in deeper formations or in rocks with poor circulation, ground water will eventually approach an equilibrium with the aquifer and have a distinct distribution of δD and $\delta^{18}O$. Mixing is the only important process controlling the distribution of δD and $\delta^{18}O$ in ground water for short term reaction times, such as decades.

The samples with high specific conductance from the oil wells, CH1–VM, WT1–VM, and L2–VM/T are not on the local meteoric water line. A linear regression through these samples plots along a line with a slope of 4.0. The precision of the analysis is shown in figure 11 for each of the ground-water samples with $\delta^{18}O$ values greater than -5.

The isotopic composition of varying mixtures of two waters will plot along a straight line connecting the two end-member waters on a plot of δD versus $\delta^{18}O$ (Arad and others, 1975; Gat, 1981; and Panichi and Gonfiantini, 1981). Several mixing possibilities can be seen in figure 11.

The original, pre-waterflood, isotopic composition of the Prue water is not known. The Prue brine

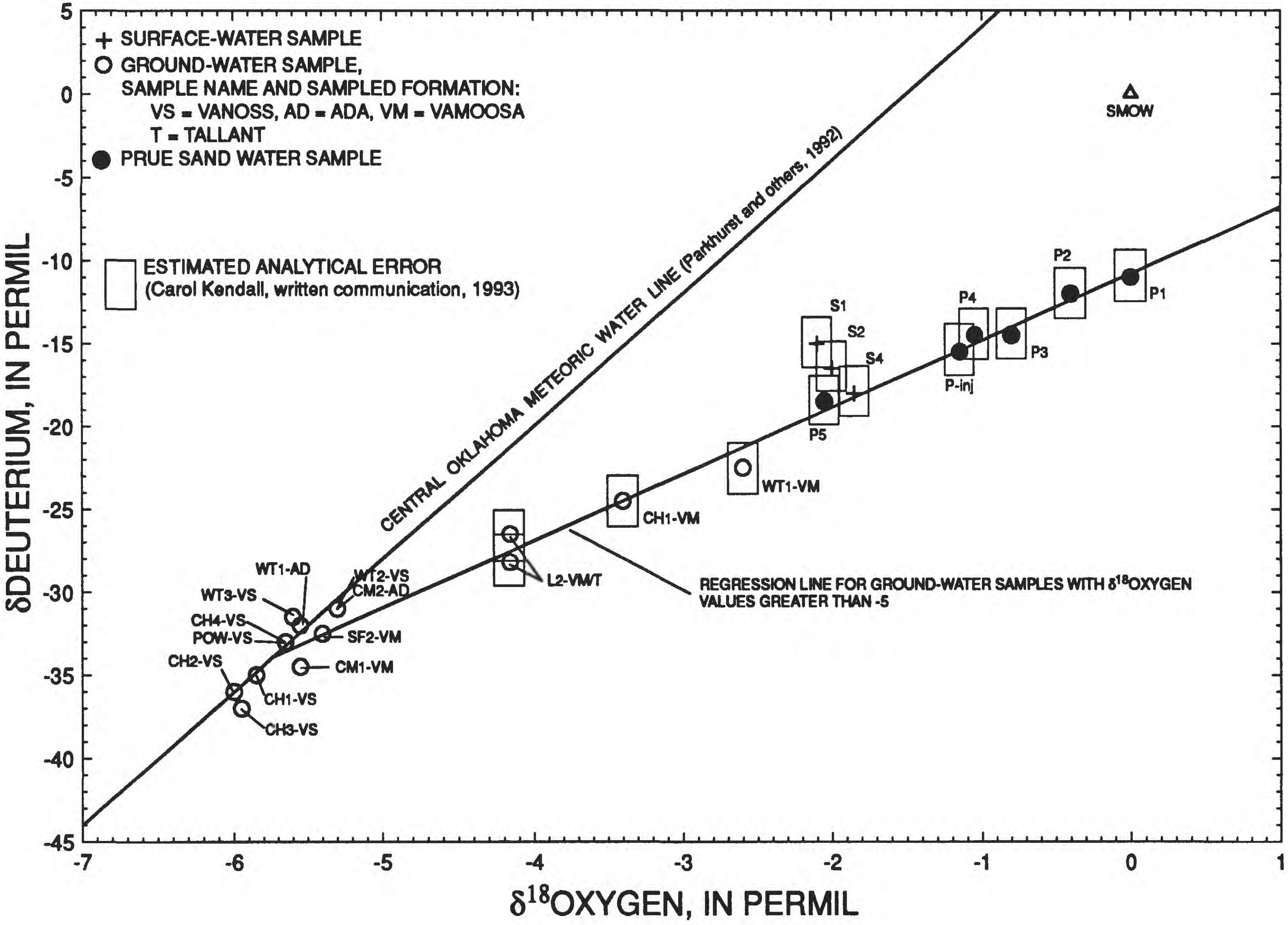


Figure 11. Relation between δDeuterium and δ^{18}Oxygen (relative to standard mean ocean water [SMOW]), in eastern Lincoln County, Oklahoma.

sample P1 has the highest specific conductance, chloride concentration, and TDS. The sample also is farthest from the fresh ground water on the isotope plot (fig. 11). The sample is probably least affected by the waterflooding activity and is probably closest to the original Prue water composition.

Waterflooding of the Prue sand on the tribal land has continued since 1952. Make-up water for the Sac and Fox Prue Sand Unit was reportedly obtained from water-supply wells located in secs. 15 and 16, T. 14 N., R. 06 E. that were 500 to 600 ft deep (Canard, 1989). Borehole geophysical log correlations indicate the lowest sandstone in L2 (fig. 7) is one of the zones completed in the water-supply wells in secs. 15 and 16. L2–VM/T plots on the regression line with the Prue brines and could have been supplying the make-up water in the waterflood. Fresh ground water also may have been used in the waterfloods and could have produced water compositions along the regression line.

The high-chloride samples CH1–VM, WT1–VM, and L2-VM/T could result from mixing of the Prue brine from the waterflood with any of the fresher ground water on the regression line. The less saline samples from CH2-VS, CH3-VS, and CM1–VM are composed predominately of fresh ground water (fig. 11) and could have a small percentage of brine water. Additional isotope data from other oil producing formations in the area near the tribal land would be needed to determine if the Prue brine has a distinct isotopic composition.

Relation of δ^{18}Oxygen to Chloride

Gat (1981) and Craig (1966) discuss the use of plots combining salinity and stable isotopes. A plot of salinity (TDS) in units of mg/L and a stable isotope will produce a curved mixing line (Gat, 1981). Craig (1966) proposed a change from units of concentration (mg/L) to molality (moles/kilogram of water) that would produce a straight mixing line between two end members. Figure 12 is a plot of the chloride molality and δ^{18}O. Chloride was selected, instead of TDS, because it is conservative and independent of the other species in the ground-water solution and of the lithologies of the aquifers. The concentration of chloride in a freshwater/brine mixture is affected only by the freshwater chloride concentration, the brine chloride concentration, and the relative volumes in the mixture. The molality values were calculated by WATEQF of the NETPATH input program (Plummer and others, 1991).

A linear regression through samples P1, P2, P3, P4, P5, and P-inj plots along a line with a slope of 5.08 (fig. 12). The straight line mixing suggested by Craig (1966) is along the regression line. The briny water (table 4) from CH1–VM, and WT1–VM (appendix 1) are on the mixing line with the waterflood samples and could have resulted from mixing of the Prue brine with fresh ground water.

The briny water from L2–VM/T and the very saline water from CM1–VM (fig. 3) are slightly more depleted in the δ^{18}O isotope and are not on the mixing line of the first group. A second possible mixing line along a linear regression through moderately saline CH2-VS and slightly saline CH3-VS, CM1-VM, and L2-VM/T plots along a line with a slope of 6.04. CM1–VM and L2-VM/T could be mixtures of the Vanoss Formation fresh ground water and a Prue brine near P1 composition or mixtures of the Vanoss Formation fresh ground water and a residual brine of unknown composition. Residual brines may be found in shallow sandstones and shales that have low hydraulic conductivity and recharge such as CM1 (fig. 5) or in deeper sandstones that have not been diluted by freshwater recharge such as L2 (fig. 7). If the briny water from L2–VM/T was used in the initial waterflooding in the Prue sand, the relationship is not as apparent in figure 12 as it is suggested in figure 11.

Water-quality data indicate there may be more than one source for the salinity in the very saline and briny samples near the tribal land (fig. 12). The data suggest both sources have mixed with the fresh ground water from the Vanoss Formation.

SUMMARY AND CONCLUSIONS

Water-quality sampling and borehole geophysical data indicate the potential for fresh ground water on tribal land generally is greatest in the Vanoss Formation, in the SE1/4 sec. 21, T. 14 N., R. 06 E. and in the NE1/4 sec. 22, T. 14 N., R. 06 E. These locations avoid the flood-prone areas and borehole geophysical resistivity logs indicate the altitude of the base of fresh ground water is below 650 ft. Borehole geophysical logs indicate the altitude of the base of fresh ground water is generally near the surface under the W1/2 sec. 22, T. 14 N., R. 06 E., the SE1/4 section 22, SE1/4

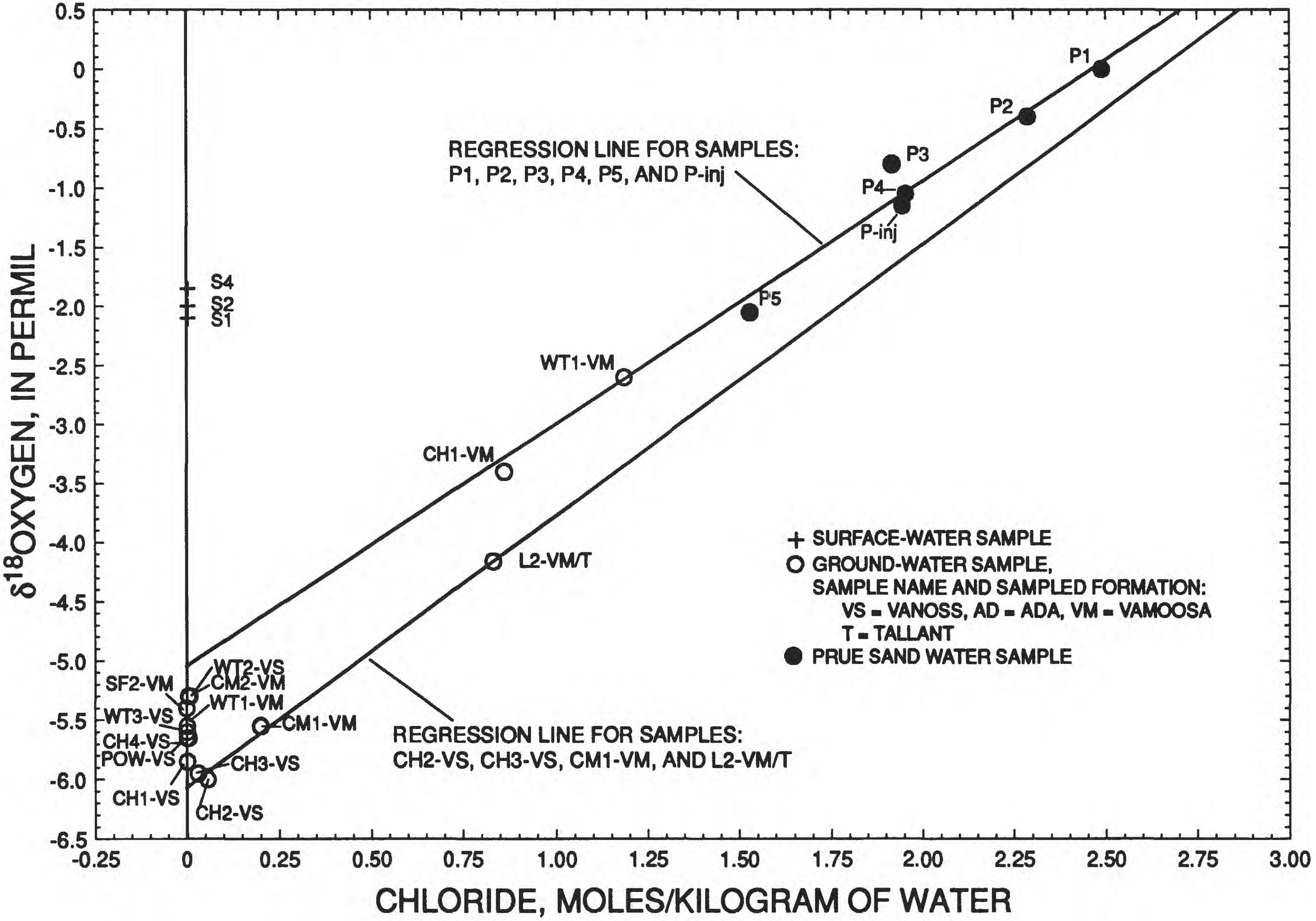


Figure 12. Relation between δ^{18}Oxygen (relative to standard mean ocean water) and chloride molality, in eastern Lincoln County, Oklahoma.

SE1/4 NE1/4 section 21, and NE1/4 NW1/4 NW1/4 section 27.

Conditions are more favorable for placement of fresh ground-water wells near SF1 and SF2 in section 34, where the tribe has leased water rights, than on tribal land in secs. 15, 16, 21, and 22, T. 14 N., R. 06 E. Sandstones overlain by or enclosed in thick clay and shale sequences are likely to be somewhat isolated from the flow system and retain some of the residual brine. Borehole geophysical logs suggest that sandstones near CH1, CM1, and WT1 have more clay and shale content than the sandstones near L2. Greater amounts of clay in the sandstones will retard the flushing of residual brines from the sandstones and could result in a shallow base of fresh water near CH1, CM1, and WT1. For these reasons and because circulation of fresh ground water is limited by discharge to the Deep Fork, general water quality under tribal land would probably be poorer than in the area where the tribe has leased water rights near SF1 and SF2.

Ground water from the Ada and Vamoosa Formations, from the area where the altitude of the base of fresh ground water is near the surface, have high sodium chloride and high sodium sulfate concentrations on tribal land. Water-quality samples CH2-VS, CH3-VS, CM2-AD, CH1-VM, CM1-VM, WT1-VM, and L2-VM/T have chloride or sulfate concentrations greater than 250 mg/L. Two possible sources for chloride and sulfate in water-quality samples are shallow brines and deep brines from oil production at 3,000 ft. Probable sources of shallow brine in the study area are: 1) solution of minerals as fresh water moves through the aquifer and 2) residual brine deposited with the sediment. There are no salt or gypsum beds in the Vanoss, Ada, or Vamoosa Formations, but there may be nodules and finely disseminated minerals present in the formations. Residual brine could remain in sandstones and shales that have low hydraulic conductivity and have not been diluted by freshwater recharge.

If a brine is the salinity source for a mixed-water sample the bromide/chloride ratio for the two waters will be equal. Dilution of the Prue brines from the waterfloods could produce the bromide and chloride values in the saline water from CH2-VS, CH3-VS, CH1–VM, CM1–VM, WT1–VM, and L2–VM/T. The statewide data indicate other formations, unsampled in the study area, may contain water that could produce the mixed-water samples.

The isotopic composition of varying mixtures of two waters will plot along a straight line connecting the two end-member waters on a plot of δD versus $\delta^{18}O$. L2–VM/T plots on the regression line with the Prue brines and could have been supplying the make-up water in the waterflood. Fresh ground water also may have been used in the waterfloods and could have produced water compositions along the regression line. The high-chloride samples CH1–VM, WT1–VM, and L2-VM/T could result from mixing of the Prue brine from the waterflood with any of the fresher ground water on the regression line. Additional isotope data from other oil producing formations in the area near the tribal land would be needed to determine if the Prue brine has a distinct isotopic composition.

A mixture of two waters plot along a straight line on a plot of chloride molality and a stable isotope ($\delta^{18}O$). A linear regression through samples P1, P2, P3, P4, P5, and P-inj plots along a line with a slope of 5.08. The briny water from CH1–VM, and WT1–VM are on the mixing line with the waterflood samples. The briny water from L2–VM/T and the very saline water from CM1–VM are slightly more depleted in the $\delta^{18}O$ isotope and are not on the mixing line of the first group. A second possible mixing line along a linear regression through moderately saline CH2-VS and slightly saline CH3-VS, CM1-VM, and L2-VM/T plots along a line with a slope of 6.04. If the briny water from L2–VM/T was used in the initial waterflooding in the Prue sand, the relationship is not as apparent on a plot of chloride molality and $\delta^{18}O$ isotope. Water-quality data indicate there may be more than one source for the salinity in the very saline and briny samples near the tribal land. Data suggest both sources have mixed with the fresh ground water from the Vanoss Formation.

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APPENDIXES

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma

[°C, degrees Celsius; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; g/mL; grams per milliliter; µg/L, micrograms per liter; pCi/L, picocuries per liter; permil, per thousand; --, no analysis or no sample name]

Local identifier	Station number	Date	Depth of well, total (feet) (72008)	Sample name	Temperature water (°C) (00010)	Specific conductance (µS/cm) (00095)	pH, water whole field (standard units) (00400)	Oxygen, dissolved (mg/L) (00300)	Alkalinity, water dissolved, total incremental titration, field (mg/L as $CaCO_3$) (39086)	Solids, residue at 180°C dissolved (mg/L) (70300)
FRESH WATER[1]—Vanoss Formation										
13N-06E-03 CCB 1	353733096373101	03-27-90	84	--	17.0	676	7.6	--	345	400
13N-06E-03 CDD 1	353726096391201	03-27-90	185	--	17.5	509	7.5	--	242	289
13N-06E-08 AAA 2	353721096405001	03-27-90	121	--	17.5	956	7.6	--	358	617
13N-06E-08 BCC 1	353659096415101	04-05-90	216.4	--	18.5	1,230	8.3	--	392	801
13N-06E-08 BDB 1	353709096413701	04-04-90	174	--	17.5	556	7.7	--	251	315
13N-06E-14 BCC 1	353603096384001	03-28-90	180	--	17.5	670	8.8	<0.1	240	405
13N-06E-15 BCC 1	353607096394201	07-25-79	170	--	--	773	7.1	--	240	510
14N-05E-14 DCD 1	354053096441701	04-05-90	108	--	17.5	670	7.6	--	288	406
14N-06E-02 AAB 1	354319096374901	04-05-90	95	--	17.5	643	7.5	--	331	394
14N-06E-04 BBA 1	354325096404001	04-05-90	172	--	17.5	491	7.5	--	270	340
14N-06E-05 DAA 1	354257096405101	04-03-90	90.5	--	17.5	507	7.7	--	296	362
14N-06E-06 DAD 1	354253096425301	03-29-90	142.5	--	17.5	1,450	8.0	--	446	831
14N-06E-18 AAB 1	354140096420201	04-03-90	78.7	--	16.5	340	7.1	--	235	252
14N-06E-18 ADD 1	354120096420201	03-29-90	37	--	15.5	1,030	6.9	--	392	634
14N-06E-21 AAA 1	354008096404601	04-03-90	116	--	18.0	840	7.1	--	326	475
14N-06E-21 ADD 1	354030096394501	03-28-90	87.5	--	17.0	920	8.3	--	402	614
14N-06E-21 DAAA 1	354023096394801	05-23-91	41	CH1–VS	17.5	548	7.0	7.6	224	336
14N-06E-21 DAAA 4	354023096394806	09-10-91	28	CH4–VS	21.5	602	7.0	8.8	228	321
14N-06E-21 DBD 1	354015096400301	03-29-90	133	POW–VS	17.0	2,400	8.0	--	--	[2]1,420
		06-29-92	133	POW–VS	18.0	1,480	8.1	0.1	362	848

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Density, (g/mL at 20°C) (71820)	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Strontium, dissolved (µg/L as Sr) (01080)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870)
FRESH WATER[1]—Vanoss Formation—Continued										
13N-06E-03 CCB 1	--	60	37	28	--	390	10	10	--	0.18
13N-06E-03 CDD 1	--	47	23	25	--	300	7.4	15	--	0.060
13N-06E-08 AAA 2	--	32	16	150	--	320	140	13	--	0.13
13N-06E-08 BCC 1	--	9.3	3.9	270	--	160	130	69	--	0.080
13N-06E-08 BDB 1	--	29	16	70	--	120	16	23	--	0.16
13N-06E-14 BCC 1	--	4.4	1.9	150	--	63	99	7.0	--	0.050
13N-06E-15 BCC 1	--	30	16	140	2.9	640	45	100	1.6	0.60
14N-05E-14 DCD 1	--	46	32	58	--	340	31	13	--	0.21
14N-06E-02 AAB 1	--	48	33	51	--	2,300	59	21	--	0.080
14N-06E-04 BBA 1	--	40	20	60	--	560	20	22	--	0.18
14N-06E-05 DAA 1	--	32	23	82	--	700	26	27	--	0.12
14N-06E-06 DAD 1	--	13	15	270	--	320	240	59	--	0.23
14N-06E-18 AAB 1	--	27	12	60	--	140	12	9.6	--	0.13
14N-06E-18 ADD 1	--	40	24	150	--	290	53	81	--	0.48
14N-06E-21 AAA 1	--	60	28	78	--	880	53	47	--	0.27
14N-06E-21 ADD 1	--	55	37	99	--	1,100	120	21	--	0.17
14N-06E-21 DAAA 1	--	43	25	45	1.0	200	34	31	0.20	0.25
14N-06E-21 DAAA 4	--	46	26	49	1.5	240	29	31	0.40	0.22
14N-06E-21 DBD 1	--	20	5.6	490	--	1,100	220	420	--	0.49
	--	11	3.1	310	2.7	540	110	190	1.8	0.84

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local Identifier	Silica, dissolved (mg/L as SiO_2) (00955)	Arsenic, dissolved (µg/L as As) (01000)	Barium, dissolved (µg/L as Ba) (01005)	Beryllium, dissolved (µg/L as Be) (01010)	Boron, dissolved (µg/L as B) (01020)	Cadmium, dissolved (µg/L as Cd) (01025)	Chromium, dissolved (µg/L as Cr) (01030)	Cobalt, dissolved (µg/L as Co) (01035)	Copper, dissolved (µg/L as Cu) (01040)
FRESH WATER[1]—Vanoss Formation—Continued									
13N-06E-03 CCB 1	--	--	--	--	--	--	--	--	--
13N-06E-03 CDD 1	--	--	--	--	--	--	--	--	--
13N-06E-08 AAA 2	--	--	--	--	--	--	--	--	--
13N-06E-08 BCC 1	--	--	--	--	--	--	--	--	--
13N-06E-08 BDB 1	--	--	--	--	--	--	--	--	--
13N-06E-14 BCC 1	--	--	--	--	--	--	--	--	--
13N-06E-15 BCC 1	12	--	--	--	--	--	--	--	--
14N-05E-14 DCD 1	--	--	--	--	--	--	--	--	--
14N-06E-02 AAB 1	--	--	--	--	--	--	--	--	--
14N-06E-04 BBA 1	--	--	--	--	--	--	--	--	--
14N-06E-05 DAA 1	--	--	--	--	--	--	--	--	--
14N-06E-06 DAD 1	--	--	--	--	--	--	--	--	--
14N-06E-18 AAB 1	--	--	--	--	--	--	--	--	--
14N-06E-18 ADD 1	--	--	--	--	--	--	--	--	--
14N-06E-21 AAA 1	--	--	--	--	--	--	--	--	--
14N-06E-21 ADD 1	--	--	--	--	--	--	--	--	--
14N-06E-21 DAAA 1	20	--	130	<0.5	80	<1.0	<5	<3	<10
14N-06E-21 DAAA 4	19	<1	160	<0.5	120	<1.0	<5	<3	<10
14N-06E-21 DBD 1	--	--	--	--	--	--	--	--	--
	9.8	2	52	<0.5	4,300	<1.0	<5	<3	<10

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Iron, dissolved (µg/L as Fe) (01046)	Iodide, dissolved (mg/L as I) (71865)	Lead, dissolved (µg/L as Pb) (01049)	Lithium, dissolved (µg/L as Li) (01130)	Manganese, dissolved (µg/L as Mn) (01056)	Molybdenum, dissolved (µg/L as Mo) (01060)	Nickel, dissolved (µg/L as Ni) (01065)	Selenium, dissolved (µg/L as Se) (01145)	Silver, dissolved (µg/L as Ag) (01075)
FRESH WATER[1]—Vanoss Formation—Continued									
13N-06E-03 CCB 1	--	0.005	--	13	--	--	--	--	--
13N-06E-03 CDD 1	--	0.002	--	11	--	--	--	--	--
13N-06E-08 AAA 2	--	0.013	--	20	--	--	--	--	--
13N-06E-08 BCC 1	--	0.012	--	15	--	--	--	--	--
13N-06E-08 BDB 1	--	0.008	--	9	--	--	--	--	--
13N-06E-14 BCC 1	--	0.009	--	8	--	--	--	--	--
13N-06E-15 BCC 1	--	--	--	<10	--	--	--	--	--
14N-05E-14 DCD 1	--	0.025	--	9	--	--	--	--	--
14N-06E-02 AAB 1	--	0.012	--	16	--	--	--	--	--
14N-06E-04 BBA 1	--	0.009	--	18	--	--	--	--	--
14N-06E-05 DAA 1	--	0.006	--	22	--	--	--	--	--
14N-06E-06 DAD 1	--	0.011	--	12	--	--	--	--	--
14N-06E-18 AAB 1	--	0.011	--	6	--	--	--	--	--
14N-06E-18 ADD 1	--	0.020	--	11	--	--	--	--	--
14N-06E-21 AAA 1	--	0.007	--	20	--	--	--	--	--
14N-06E-21 ADD 1	--	0.170	--	9	--	--	--	--	--
14N-06E-21 DAAA 1	47	0.002	<10	11	28	<10	<10	--	<1.0
14N-06E-21 DAAA 4	47	0.003	<10	11	5	<10	<10	<1	<1.0
14N-06E-21 DBD 1	--	0.037	--	30	--	--	--	--	--
	19	0.021	<10	16	2	<10	<10	<1	<1.0

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Vanadium, dissolved (µg/L as V) (01085)	Zinc, dissolved (µg/L as Zn) (01090)	Radium–226, dissolved, radon method (pCi/L) (09511)	Radium–226, 2 sigma water, dissolved, (pCi/L) (76001)	Radon–222, 2 sigma total (pCi/L) (82303)	Radon–222, stable water, whole, total, (pCi/L) (76002)	H-2/H-1, stable isotope ratio (permil) (82082)	O-18/O-16, isotope ratio (permil) (82085)
FRESH WATER[1]—Vanoss Formation—Continued								
13N-06E-03 CCB 1	--	--	--	--	--	--	--	--
13N-06E-03 CDD 1	--	--	--	--	--	--	--	--
13N-06E-08 AAA 2	--	--	--	--	--	--	--	--
13N-06E-08 BCC 1	--	--	--	--	--	--	--	--
13N-06E-08 BDB 1	--	--	--	--	--	--	--	--
13N-06E-14 BCC 1	--	--	--	--	--	--	--	--
13N-06E-15 BCC 1	--	--	--	--	--	--	--	--
14N-05E-14 DCD 1	--	--	--	--	--	--	--	--
14N-06E-02 AAB 1	--	--	--	--	--	--	--	--
14N-06E-04 BBA 1	--	--	--	--	--	--	--	--
14N-06E-05 DAA 1	--	--	--	--	--	--	--	--
14N-06E-06 DAD 1	--	--	--	--	--	--	--	--
14N-06E-18 AAB 1	--	--	--	--	--	--	--	--
14N-06E-18 ADD 1	--	--	--	--	--	--	--	--
14N-06E-21 AAA 1	--	--	--	--	--	--	--	--
14N-06E-21 ADD 1	--	--	--	--	--	--	--	--
14N-06E-21 DAAA 1	<6	250	0.13	0.030	220	23	-35.0	-5.85
14N-06E-21 DAAA 4	<6	42	0.27	0.050	230	30	-33.0	-5.65
14N-06E-21 DBD 1	--	--	--	--	--	--	--	--
	<6	<3	0.66	0.110	760	28	-33.0	-5.65

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Station number	Date	Depth of well, total (feet) (72008)	Sample name	Temperature water (°C) (00010)	Specific conductance (µS/cm) (00095)	pH, water whole field (standard units) (00400)	Oxygen, dissolved (mg/L) (00300)	Alkalinity, water dissolved, total incremental titration, field (mg/L as $CaCO_3$) (39086)	Solids, residue at 180°C dissolved (mg/L) (70300)
FRESH WATER[1]—Vanoss Formation—Continued										
14N-06E-21 DBD 1		06-29-92	133	POW-VS	18.0	--	8.1	--	--	858
14N-06E-22 CAB 2	354022096392302	09-02-92	130	WT2–VS	--	1,380	8.4	--	272	774
		09-02-92	130	WT2–VS	--	--	--	--	--	--
14N-06E-22 CAB 3	354022096392303	02-19-92	56	WT3–VS	--	799	7.4	--	364	654
14N-06E-22 CAC 1	354016096392501	03-27-90	47.25	--	14.0	350	8.0	8.4	156	208
14N-06E-27 CCB 1	353915096394101	07-26-79	125	--	24.5	520	6.9	--	190	326
14N-06E-29 ABA 1	353958096411101	04-03-90	87	--	16.5	1,100	7.6	--	239	629
14N-06E-29 CBC 1	353923096414801	04-03-90	169	--	17.0	370	7.3	--	386	475
14N-06E-30 DDD 1	353907096415301	04-03-90	148	--	17.5	1,080	7.6	--	312	623
14N-06E-32 BBB 1	353903096415001	04-03-90	120	--	17.0	1,410	6.8	--	334	872
14N-06E-35 DDC 1	353813096374701	07-26-79	118	--	25.5	644	7.5	--	280	400
FRESH WATER[1]—Ada-Vamoosa Formation										
14N-06E-03 BCC 1	354303096394201	04-04-90	279	--	18.5	770	7.2	--	340	470
14N-06E-10 BCC 1	354211096394301	04-04-90	184	--	17.5	900	8.0	--	330	562
14N-06E-11 BAA 1	354233096381301	02-28-80	68.65	--	23.0	982	7.2	--	290	561
14N-06E-12 AAA 1	354234096371101	02-27-80	260	--	22.0	690	7.5	--	280	356
14N-06E-22 CAB 1	354022096392301	06-18-92	230	WT1–AD	20.0	1,400	7.1	--	402	470
		06-18-92	230	WT1–AD	20.0	1,400	7.1	--	402	489
14N-06E-24 CCB 1	354009096373301	04-05-90	94.80	--	16.0	365	6.1	--	52	238
14N-06E-26 AAC 1	353949096374901	04-05-90	115.50	--	17.0	610	7.2	--	306	339
14N-06E-34 CBB 1	353838096391001	03-29-90	260	SF1–VM	17.5	420	7.8	--	188	256
14N-06E-34 CBB 2	353837096391001	03-31-92	270	SF2–VM	17.0	431	7.6	6.2	209	254

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Density, (g/mL at 20°C) (71820)	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Strontium, dissolved (µg/L as Sr) (01080)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870)
FRESH WATER[1]—Vanoss Formation—Continued										
14N-06E-21 DBD 1	--	11	3.0	310	2.7	540	120	220	2.1	[2]0.060
14N-06E-22 CAB 2	--	25	7.1	250	5.3	1,000	70	240	0.70	0.99
	--	--	--	--	--	--	--	--	--	--
14N-06E-22 CAB 3	--	91	67	35	1.1	240	48	39	0.40	0.47
14N-06E-22 CAC 1	--	40	11	20	--	220	18	9.4	--	0.020
14N-06E-27 CCB 1	--	41	20	39	1.3	170	26	35	0.40	0.40
14N-06E-29 ABA 1	--	36	17	170	--	550	56	190	--	0.77
14N-06E-29 CBC 1	--	55	29	77	--	420	19	56	--	0.65
14N-06E-30 DDD 1	--	27	13	190	--	220	30	150	--	0.99
14N-06E-32 BBB 1	--	94	51	130	--	580	64	190	--	1.9
14N-06E-35 DDC 1	--	51	27	54	3.1	520	24	48	0.50	0.80
FRESH WATER[1]—Ada-Vamoosa Formation—Continued										
14N-06E-03 BCC 1	--	54	24	85	--	700	62	20	--	0.13
14N-06E-10 BCC 1	--	11	3.2	190	--	370	120	12	--	<0.010
14N-06E-11 BAA 1	--	67	43	63	3.3	490	110	69	0.40	0.20
14N-06E-12 AAA 1	--	47	28	45	2.7	410	13	36	0.20	0.20
14N-06E-22 CAB 1	--	77	43	44	2.5	480	43	34	0.40	0.40
	--	77	43	45	2.5	480	43	34	0.40	0.40
14N-06E-24 CCB 1	--	26	9.8	25	--	120	15	45	--	0.15
14N-06E-26 AAC 1	--	66	31	21	--	170	11	25	--	0.27
14N-06E-34 CBB 1	--	32	14	40	--	390	11	19	--	0.060
14N-06E-34 CBB 2	--	35	16	37	2.8	360	6.9	17	0.30	0.080

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Silica, dissolved (mg/L as SiO_2) (00955)	Arsenic, dissolved (µg/L as As) (01000)	Barium, dissolved (µg/L as Ba) (01005)	Beryllium, dissolved (µg/L as Be) (01010)	Boron, dissolved (µg/L as B) (01020)	Cadmium, dissolved (µg/L as Cd) (01025)	Chromium, dissolved (µg/L as Cr) (01030)	Cobalt, dissolved (µg/L as Co) (01035)	Copper, dissolved (µg/L as Cu) (01040)
FRESH WATER[1]—Vanoss Formation —Continued									
14N-06E-21 DBD 1	9.9	2	54	<0.5	4,300	<1.0	<5	<3	<10
14N-06E-22 CAB 2	16	<1	140	<0.5	2,200	<1.0	<5	<3	<10
	--	--	--	--	--	--	--	--	--
14N-06E-22 CAB 3	15	<1	260	<0.5	80	<1.0	<5	<3	<10
14N-06E-22 CAC 1	--	--	--	--	--	--	--	--	--
14N-06E-27 CCB 1	15	--	--	--	--	--	--	--	--
14N-06E-29 ABA 1	--	--	--	--	--	--	--	--	--
14N-06E-29 CBC 1	--	--	--	--	--	--	--	--	--
14N-06E-30 DDD 1	--	--	--	--	--	--	--	--	--
14N-06E-32 BBB 1	--	--	--	--	--	--	--	--	--
14N-06E-35 DDC 1	17	--	--	--	--	--	--	--	--
FRESH WATER[1]—Ada-Vamoosa Formation—Continued									
14N-06E-03 BCC 1	--	--	--	--	--	--	--	--	--
14N-06E-10 BCC 1	--	--	--	--	--	--	--	--	--
14N-06E-11 BAA 1	12	--	--	--	--	--	--	--	--
14N-06E-12 AAA 1	17	--	--	--	--	--	--	--	--
14N-06E-22 CAB 1	15	<1	250	<0.5		<1.0	<5	<3	10
	15	1	250	<0.5	500	<1.0	<5	<3	10
14N-06E-24 CCB 1	--	--	--	--	--	--	--	--	--
14N-06E-26 AAC 1	--	--	--	--	--	--	--	--	--
14N-06E-34 CBB 1	--	--	--	--	--	--	--	--	--
14N-06E-34 CBB 2	20	<1	420	<0.5	500	<1.0	<5	<3	<10

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Iron, dissolved (µg/L as Fe) (01046)	Iodide, dissolved (mg/L as I) (71865)	Lead, dissolved (µg/L as Pb) (01049)	Lithium, dissolved (µg/L as Li) (01130)	Manganese, dissolved (µg/L as Mn) (01056)	Molybdenum, dissolved (µg/L as Mo) (01060)	Nickel, dissolved (µg/L as Ni) (01065)	Selenium, dissolved (µg/L as Se) (01145)	Silver, dissolved (µg/L as Ag) (01075)
FRESH WATER[1]—Vanoss Formation—Continued									
14N-06E-21 DBD 1	21	0.021	<10	16	2	<10	<10	<1	1.0
14N-06E-22 CAB 2	9	0.022	<10	29	10	<10	<10	<1	1.0
	--	--	--	--	--	--	--	--	--
14N-06E-22 CAB 3	30	0.002	<10	11	3	<10	<10	<1	<1.0
14N-06E-22 CAC 1	--	0.004	--	10	--	--	--	--	--
14N-06E-27 CCB 1	--	--	--	8	--	--	--	--	--
14N-06E-29 ABA 1	--	0.029	--	22	--	--	--	--	--
14N-06E-29 CBC 1	--	0.032	--	20	--	--	--	--	--
14N-06E-30 DDD 1	--	0.012	--	24	--	--	--	--	--
14N-06E-32 BBB 1	--	0.020	--	22	--	--	--	--	--
14N-06E-35 DDC 1	--	--	--	20	--	--	--	--	--
FRESH WATER[1]—Ada-Vamoosa Formation—Continued									
14N-06E-03 BCC 1	--	0.002	--	18	--	--	--	--	--
14N-06E-10 BCC 1	--	0.053	--	14	--	--	--	--	--
14N-06E-11 BAA 1	--	<0.002	--	40	--	--	--	--	--
14N-06E-12 AAA 1	--	--	--	20	--	--	--	--	--
14N-06E-22 CAB 1	3	0.003	10	12	74	<10	10	<1	<1.0
	5	0.003	<10	12	77	<10	20	<1	<1.0
14N-06E-24 CCB 1	--	0.002	--	11	--	--	--	--	--
14N-06E-26 AAC 1	--	0.002	--	15	--	--	--	--	--
14N-06E-34 CBB 1	--	0.002	--	12	--	--	--	--	--
14N-06E-34 CBB 2	<3	0.002	<10	12	<1	<10	<10	1	1.0

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Vanadium, dissolved (µg/L as V) (01085)	Zinc, dissolved (µg/L as Zn) (01090)	Radium-226, dissolved, radon method (pCi/L) (09511)	Radium-226, 2 sigma water, dissolved, (pCi/L) (76001)	Radon-222, 2 sigma total (pCi/L) (82303)	Radon-222, stable water, whole, total, (pCi/L) (76002)	H-2/H-1, stable isotope ratio (permil) (82082)	O-18/O-16, isotope ratio (permil) (82085)
FRESH WATER[1]—Vanoss Formation—Continued								
14N-06E-21 DBD 1	<6	<3	0.57	0.090	750	27	-32.5	-5.65
14N-06E-22 CAB 2	10	<3	0.39	0.070	280	27	-31.0	-5.30
	--	--	--	--	--	--	-30.0	-5.30
14N-06E-22 CAB 3	<6	350	0.30	0.050	<80	<0	-31.5	-5.60
14N-06E-22 CAC 1	--	--	--	--	--	--	--	--
14N-06E-27 CCB 1	--	--	--	--	--	--	--	--
14N-06E-29 ABA 1	--	--	--	--	--	--	--	--
14N-06E-29 CBC 1	--	--	--	--	--	--	--	--
14N-06E-30 DDD 1	--	--	--	--	--	--	--	--
14N-06E-32 BBB 1	--	--	--	--	--	--	--	--
14N-06E-35 DDC 1	--	--	--	--	--	--	--	--
FRESH WATER[1]—Ada-Vamoosa Formation—Continued								
14N-06E-03 BCC 1	--	--	--	--	--	--	--	--
14N-06E-10 BCC 1	--	--	--	--	--	--	--	--
14N-06E-11 BAA 1	--	--	--	--	--	--	--	--
14N-06E-12 AAA 1	--	--	--	--	--	--	--	--
14N-06E-22 CAB 1	<6	1,800	0.52	0.090	250	25	-32.0	-5.55
	<6	1,800	0.53	0.090	260	25	-31.0	-5.55
14N-06E-24 CCB 1	--	--	--	--	--	--	--	--
14N-06E-26 AAC 1	--	--	--	--	--	--	--	--
14N-06E-34 CBB 1	--	--	--	--	--	--	--	--
14N-06E-34 CBB 2	10	63	0.47	0.080	160	24	-32.5	-5.40

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Station number	Date	Depth of well, total (feet) (72008)	Sample name	Temperature water (°C) (00010)	Specific conductance (μS/cm) (00095)	pH, water whole field (standard units) (00400)	Oxygen, dissolved (mg/L) (00300)	Alkalinity, water dissolved, total incremental titration, field (mg/L as $CaCO_3$) (39086)	Solids, residue at 180°C dissolved (mg/L) (70300)
SALINE[1]—Vanoss Formation										
13N-06E-04 DDD 1	353721096394501	03-28-90	162	--	17.5	1620	7.9	<0.1	<147	1,150
13N-06E-05 CCC 1	353729096414801	04-04-90	171	--	17.5	3,320	8.0	--	395	2,230
13N-06E-07 BAA 1	353722096422701	07-25-79	161	--	28.5	1,320	7.6	--	420	1,040
14N-06E-04 AAB 1	354325096395701	04-05-90	100	--	17.0	1,950	7.6	--	189	1,440
14N-06E-07 ADD 1	354214096415301	03-29-90	132	--	16.5	1,470	7.9	--	344	1,120
14N-06E-09 AAA 1	354233096394701	03-29-90	95.5	--	17.0	1,840	7.0	--	465	1,150
14N-06E-09 DDD 1	354150096394601	04-04-90	142	--	17.5	2,850	7.2	--	229	2,380
14N-06E-21 DAA 1	354019096394501	03-27-90	77	--	17.5	2,520	7.3	--	1030	1,740
14N-06E-21 DAAA 2	354023096394804	08-14-91	140	CH2–VS	21.0	11,400	7.6	--	148	8,890
14N-06E-21 DAAA 3	354023096394805	11-12-91	95	CH3–VS	--	6,080	8.9	--	148	3,840
14N-06E-27 BBB 1	353957096394201	03-29-90	133	--	16.5	1,870	7.1	--	396	1,230
SALINE[1]—Ada-Vamoosa Formations										
14N-06E-21 DAAA 1	354023096394802	06-06-91	248	CH1–VM	17.5	75,600	7.0	0.3	150	58,500
		06-06-91	248	CH1–VM	17.5	74,900	6.9	0.3	--	56,700
14N-06E-22 BAC 1	354044096392401	10-02-91	262	CM1–VM	18.5	26,100	7.3	0.2	128	18,400
14N-06E-22 BAC 2	354044096392301	08-10-92	155	CM2–AD	--	1,920	8.1	--	180	1,340
		08-10-92	155	CM2–AD	--	1,920	8.1	--	180	
14N-06E-22 CAB 1	354022096392300	07-11-91	302	WT1–VM	18.5	95,800	6.9	0.2	108	78,300
14N-06E-34 CBC 2	353827096394202	06-14-93	560	L2–VM/T	20.0	72,000	5.7	--	122	58,900
		06-14-93	560	L2–VM/T	20.0	72,000	5.7	--	122	58,700
SALINE[1]—Prue sand										
14N-06E-10 CBC 1	354155096393701	02-13-92	3,205	P5	--	110,000	6.3	--	360	88,200
14N-06E-15 CAC 1	354104096392701	02-07-92	3,131	P4	--	125,000	5.5	--	308	112,000
14N-06E-15 CDA 1	354100096391601	02-07-92	3,037	P-inj	--	133,000	5.5	--	334	108,000
14N-06E-22 BBD 1	354042096393301	02-13-92	3,091	P3	--	139,000	3.6	--	288	119,000
14N-06E-23 BBC 1	354041096383801	02-20-92	3,000	P2	--	153,000	5.3	--	284	137,000
14N-06E-23 BCC 1	354027096383601	02-20-92	3,035	P1	--	162,000	5.3	--	180	147,000

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Density, (g/mL at 20°C) (71820)	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Strontium, dissolved (µg/L as Sr) (01080)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870)
SALINE[1]—Vanoss Formation —Continued										
13N-06E-04 DDD 1	--	50	17	290	--	1,700	630	4.9	--	0.030
13N-06E-05 CCC 1	--	16	6.5	710	--	440	880	270	--	0.96
13N-06E-07 BAA 1	--	11	5.9	350	3.0	450	360	26	4.6	0.20
14N-06E-04 AAB 1	--	87	19	330	--	2,300	800	9.3	--	0.050
14N-06E-07 ADD 1	--	12	4.6	340	--	11,000	490	12	--	0.090
14N-06E-09 AAA 1	--	98	75	190	--	370	370	75	--	1.5
14N-06E-09 DDD 1	--	200	19	420	--	5,300	1,300	53	--	0.25
14N-06E-21 DAA 1	--	71	52	520	--	700	300	120	--	0.59
14N-06E-21 DAAA 2	--	460	90	2,300	19	7,700	3,400	2,000	2.4	8.5
14N-06E-21 DAAA 3	1.001	93	38	1,100	17	7,100	1,300	1,100	1.8	5.0
14N-06E-27 BBB 1	--	120	50	210	--	370	160	220	--	0.95
SALINE[1]—Ada-Vamoosa Formation—Continued										
14N-06E-21 DAAA 1	1.042	1,600	650	19,000	66	38,000	2,900	30,000	2.1	130
	--	1,500	560	17,000	53	52,000	3,100	32,000	[3]0.50	[3]10
14N-06E-22 BAC 1	1.011	740	160	5,300	29	14,000	3,700	7,000	2.8	35
14N-06E-22 BAC 2	--	36	10	400	3.7	1,000	600	140	0.90	1.7
	--	--	--	--	--	--	--	--	--	--
14N-06E-22 CAB 1	--	2,200	850	23,000	76	34,000	4,300	41,000	1.9	180
14N-06E-34 CBC 2	1.035	2,000	670	18,000	70	49,000	3,000	29,000	2.4	140
	1.035	2,200	710	18,000	69	50,000	3,100	29,000	2.4	150
SALINE[1]—Prue sand—Continued										
14N-06E-10 CBC 1	1.058	3,000	860	25,000	91	360,000	110	53,000	2.2	230
14N-06E-15 CAC 1	1.074	4,000	1,200	30,000	130	350,000	150	67,000	2.5	320
14N-06E-15 CDA 1	1.071	4,000	1,200	33,000	120	350,000	160	66,000	5.0	300
14N-06E-22 BBD 1	1.078	4,600	1,400	36,000	120	390,000	100	66,000	2.0	290
14N-06E-23 BBC 1	1.090	5,200	1,600	42,000	65	330,000	98	78,000	1.9	320
14N-06E-23 BCC 1	1.098	6,800	2,000	42,000	17	350,000	89	85,000	4.9	410

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Silica, dissolved (mg/L as SiO_2) (00955)	Arsenic, dissolved (µg/L as As) (01000)	Barium, dissolved (µg/L as Ba) (01005)	Beryllium, dissolved (µg/L as Be) (01010)	Boron, dissolved (µg/L as B) (01020)	Cadmium, dissolved (µg/L as Cd) (01025)	Chromium, dissolved (µg/L as Cr) (01030)	Cobalt, dissolved (µg/L as Co) (01035)	Copper, dissolved (µg/L as Cu) (01040)
SALINE[1]—Vanoss Formation —Continued									
13N-06E-04 DDD 1	--	--	--	--	--	--	--	--	--
13N-06E-05 CCC 1	--	--	--	--	--	--	--	--	--
13N-06E-07 BAA 1	7.6	--	--	--	--	--	--	--	--
14N-06E-04 AAB 1	--	--	--	--	--	--	--	--	--
14N-06E-07 ADD 1	--	--	--	--	--	--	--	--	--
14N-06E-09 AAA 1	--	--	--	--	--	--	--	--	--
14N-06E-09 DDD 1	--	--	--	--	--	--	--	--	--
14N-06E-21 DAA 1	--	--	--	--	--	--	--	--	--
14N-06E-21 DAAA 2	8.0	1	<100	<10	11,000	<1.0	<2	2	29
14N-06E-21 DAAA 3	6.2	--	--	--	8,800	--	--	--	--
14N-06E-27 BBB 1	--	--	-	--	--	--	--	--	--
SALINE[1]—Ada-Vamoosa Formation—Continued									
14N-06E-21 DAAA 1	6.7	--	--	--	11,000	--	--	--	--
	6.4	--	--	--	11,000	--	--	--	--
14N-06E-22 BAC 1	7.6	--	--	--	11,000	--	--	--	--
14N-06E-22 BAC 2	3.9	2	47	<0.5	3,800	<1.0	<5	<3	<10
	--	--	--	--	--	--	--	--	--
14N-06E-22 CAB 1	5.6	--	--	--	14,000	--	--	--	--
14N-06E-34 CBC 2	7.0	--	--	--	11,000	--	--	--	--
	7.0	--	--	--	11,000	--	--	--	--
SALINE[1]—Prue sand—Continued									
14N-06E-10 CBC 1	12	--	--	--	4,600	--	--	--	--
14N-06E-15 CAC 1	7.7	--	--	--	4,300	--	--	--	--
14N-06E-15 CDA 1	8.1	--	--	--	4,600	--	--	--	--
14N-06E-22 BBD 1	11	--	--	--	4,800	--	--	--	--
14N-06E-23 BBC 1	10	--	--	--	4,600	--	--	--	--
14N-06E-23 BCC 1	9.8	--	--	--	6,600	--	--	--	--

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Iron, dissolved (µg/L as Fe) (01046)	Iodide, dissolved (mg/L as I) (71865)	Lead, dissolved (µg/L as Pb) (01049)	Lithium, dissolved (µg/L as Li) (01130)	Manganese, dissolved (µg/L as Mn) (01056)	Molybdenum, dissolved (µg/L as Mo) (01060)	Nickel, dissolved (µg/L as Ni) (01065)	Selenium, dissolved (µg/L as Se) (01145)	Silver, dissolved (µg/L as Ag) (01075)
SALINE[1]—Vanoss Formation—Continued									
13N-06E-04 DDD 1	--	0.007	--	20	--	--	--	--	--
13N-06E-05 CCC 1	--	0.032	--	30	--	--	--	--	--
13N-06E-07 BAA 1	--	0.010	--	20	--	--	--	--	--
14N-06E-04 AAB 1	--	0.006	--	28	--	--	--	--	--
14N-06E-07 ADD 1	--	0.008	--	18	--	--	--	--	--
14N-06E-09 AAA 1	--	0.041	--	15	--	--	--	--	--
14N-06E-09 DDD 1	--	0.010	--	30	--	--	--	--	--
14N-06E-21 DAA 1	--	0.011	--	20	--	--	--	--	--
14N-06E-21 DAAA 2	150	0.190	<1	110	150	3	2	<1	<1.0
14N-06E-21 DAAA 3	--	0.080	--	70	--	--	--	--	--
14N-06E-27 BBB 1	--	0.029	--	23	--	--	--	--	--
SALINE[1]—Ada-Vamoosa Formation—Continued									
14N-06E-21 DAAA 1	--	2.3	--	260	--	--	--	--	--
	--	2.2	--	300	--	--	--	--	--
14N-06E-22 BAC 1	--	0.670	--	180	--	--	--	--	--
14N-06E-22 BAC 2	46	0.014	<10	31	260	10	<10	<1	<1.0
	--	--	--	--	--	--	--	--	--
14N-06E-22 CAB 1	--	3.1	--	300	--	--	--	--	--
14N-06E-34 CBC 2	--	2.4	--	250	--	--	--	--	--
	--	2.5	--	250	--	--	--	--	--
SALINE[1]—Prue sand—Continued									
14N-06E-10 CBC 1	--	--	--	670	--	--	--	--	--
14N-06E-15 CAC 1	--	7.1	--	720	--	--	--	--	--
14N-06E-15 CDA 1	--	6.6	--	700	--	--	--	--	--
14N-06E-22 BBD 1	--	5.6	--	760	--	--	--	--	--
14N-06E-23 BBC 1	--	5.1	--	720	--	--	--	--	--
14N-06E-23 BCC 1	--	5.9	--	680	--	--	--	--	--

Appendix 1. Chemical analyses of ground water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Vanadium, dissolved (µg/L as V) (01085)	Zinc, dissolved (µg/L as Zn) (01090)	Radium-226, dissolved, radon method (pCi/L) (09511)	Radium-226, 2 sigma water, dissolved, (pCi/L) (76001)	Radon-222, 2 sigma total (pCi/L) (82303)	Radon-222, stable water, whole, total, (pCi/L) (76002)	H-2/H-1, stable isotope ratio (permil) (82082)	O-18/O-16, isotope ratio (permil) (82085)
SALINE[1]—Vanoss Formation—Continued								
13N-06E-04 DDD 1	--	--	--	--	--	--	--	--
13N-06E-05 CCC 1	--	--	--	--	--	--	--	--
13N-06E-07 BAA 1	--	--	--	--	--	--	--	--
14N-06E-04 AAB 1	--	--	--	--	--	--	--	--
14N-06E-07 ADD 1	--	--	--	--	--	--	--	--
14N-06E-09 AAA 1	--	--	--	--	--	--	--	--
14N-06E-09 DDD 1	--	--	--	--	--	--	--	--
14N-06E-21 DAA 1	--	--	--	--	--	--	--	--
14N-06E-21 DAAA 2	43	2,900	1.5	0.260	340	26	-36.0	-6.00
14N-06E-21 DAAA 3	--	--	0.82	0.140	200	25	-37.0	-5.95
14N-06E-27 BBB 1	--	--	--	--	--	--	--	--
SALINE[1]—Ada-Vamoosa Formation—Continued								
14N-06E-21 DAAA 1	--	--	--	--	440	42	-24.5	-3.40
	--	--	--	--	440	42	-24.5	-3.40
14N-06E-22 BAC 1	--	--	5.8	1.00	230	25	-34.5	-5.55
14N-06E-22 BAC 2	<6	11	0.13	0.030	<80	24	-31.0	-5.30
	--	--	--	--	--	--	-30.5	-5.25
14N-06E-22 CAB 1	--	--	--	--	300	41	-22.5	-2.60
14N-06E-34 CBC 2	--	--	--	--	230	24	-28.2	-4.16
	--	--	--	--	230	25	-26.5	-4.16
SALINE[1]—Prue sand—Continued								
14N-06E-10 CBC 1	--	--	--	--	340	27	-18.5	-2.05
14N-06E-15 CAC 1	--	--	--	--	--	--	-14.5	-1.05
14N-06E-15 CDA 1	--	--	--	--	--	--	-15.5	-1.15
14N-06E-22 BBD 1	--	--	--	--	1,300	31	-14.5	-0.8
14N-06E-23 BBC 1	--	--	--	--	350	34	-12.0	-0.4
14N-06E-23 BCC 1	--	--	--	--	250	24	-11.0	0.0

1. The suggested maximum contaminant levels set by U.S. Environmental Protection Agency (1989) for chloride (250 mg/L) and sulfate (250 mg/L) were used to separate fresh and saline water analyses in table 4.
2. Listed with the fresh ground water because later sampling of the well is thought to be more representative of the aquifer water quality.
3. Associated field-replicate sample results did not meet quality-control acceptance.

Appendix 2. Chemical analyses of surface water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma

[°C, degrees Celsius; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; g/mL; grams per milliliter; µg/L, micrograms per liter; pCi/L, picocuries per liter; permil, per thousand; --, no analysis or no sample name]

Local identifier	Station number	Date	Sample name	Temperature water (°C) (00010)	Specific conductance (µS/cm) (00095)	pH, water whole field (standard units) (00400)	Oxygen, dissolved (mg/L) (00300)	Alkalinity, water dissolved, total incremental titration, field (mg/L as $CaCO_3$) (39086)	Solids, residue at 180°C dissolved (mg/L) (70300)
FRESH[1]— Surface water									
Deep Fork near Arlington, OK 14N–06E–21 CCC 1	07242850	08-27-91	S1	26.0	969	8.9	8.3	266	564
Deep Fork near Stroud, OK 14N–06E–15 CBB 1	07242900	09-14-79	S2	21.5	900	8.1	--	180	549
		08-27-91	S2	25.0	1,000	8.8	7.1	284	586
Robinson Creek nr Arlington, OK 13N–06E–06 AAD 1	07242930	07-25-79	--	30.0	774	8.4	--	170	517
Deep Fork blw Dry Ck nr Stroud, OK 14N–06E–14 ABD 1	07243050	08-28-91	S3	28.0	986	8.8	10.0	295	584
Deep Fork abv Barby Ck nr Stroud, OK 14N–06E–26 DBB 1	07243070	08-28-91	S4	28.0	985	8.8	7.7	308	592
SALINE[1] —Surface water									
Todd Lake Trib nr Stroud, OK 14N–06E–27 DCD 1	07243080	02-27-80	--	22.0	6,200	7.5	--	300	3750
Deep Fork Trib nr Stroud, OK 14N–07E–18 ACA 1	07243100	03-04-80	--	9.0	3,710	7.9	--	210	2060

Appendix 2. Chemical analyses of surface water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Density, (g/mL at 20°C) (71820)	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Strontium, dissolved (µg/L as Sr) (01080)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870)
FRESH[1]— Surface water—Continued										
Deep Fork near Arlington, OK 14N–06E–21 CCC 1	--	50	40	110	4.4	570	48	130	0.40	0.34
Deep Fork near Stroud, OK 14N–06E–15 CBB 1	--	51	25	100	7.4	850	69	160	0.50	0.90
	--	51	41	110	4.5	590	46	130	0.40	0.33
Robinson Creek nr Arlington, OK 13N–06E–06 AAD 1	--	43	30	65	6.6	520	61	150	0.40	1.1
Deep Fork blw Dry Ck nr Stroud, OK 14N–06E–14 ABD 1	--	49	39	110	4.5	570	51	140	0.50	0.37
Deep Fork abv Barby Ck nr Stroud, OK 14N–06E–26 DBB 1	--	50	41	110	4.7	580	51	140	0.40	0.37
SALINE[1]— Surface water—Continued										
Todd Lake Trib nr Stroud, OK 14N–06E–27 DCD 1	--	330	180	750	5.3	3,400	18	2,100	0.20	19
Deep Fork Trib nr Stroud, OK 14N–07E–18 ACA 1	--	200	96	390	5.2	1,900	50	1,000	0.20	4.0

Appendix 2. Chemical analyses of surface water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Silica, dissolved (mg/L as SiO_2) (00955)	Arsenic, dissolved (µg/L as As) (01000)	Barium, dissolved (µg/L as Ba) (01005)	Beryllium, dissolved (µg/L as Be) (01010)	Boron, dissolved (µg/L as B) (01020)	Cadmium, dissolved (µg/L as Cd) (01025)	Chromium, dissolved (µg/L as Cr) (01030)	Cobalt, dissolved (µg/L as Co) (01035)	Copper, dissolved (µg/L as Cu) (01040)
FRESH[1] —Surface water—Continued									
Deep Fork near Arlington, OK 14N–06E–21 CCC 1	8.4	7	190	1	370	<1.0	<5	<3	<10
Deep Fork near Stroud, OK 14N–06E–15 CBB 1	5.3	--	--	--	--	--	--	--	--
	8.6	13	200	1	380	<1.0	<5	<3	<10
Robinson Creek nr Arlington, OK 13N–06E–06 AAD 1	2.7	--	--	--	--	--	--	--	--
Deep Fork blw Dry Ck nr Stroud, OK 14N–06E–14 ABD 1	7.8	9	190	<0.5	380	<1.0	<5	<3	<10
Deep Fork abv Barby Ck nr Stroud, OK 14N–06E–26 DBB 1	8.0	8	200	1	380	1.0	<5	<3	<10
SALINE[1] —Surface water—Continued									
Todd Lake Trib nr Stroud, OK 14N–06E–27 DCD 1	13	--	--	--	--	--	--	--	--
Deep Fork Trib nr Stroud, OK 14N–07E–18 ACA 1	12	--	--	--	--	--	--	--	--

Appendix 2. Chemical analyses of surface water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Iron, dissolved (µg/L as Fe) (01046)	Iodide, dissolved (mg/L as I) (71865)	Lead, dissolved (µg/L as Pb) (01049)	Lithium, dissolved (µg/L as Li) (01130)	Manganese, dissolved (µg/L as Mn) (01056)	Molybdenum, dissolved (µg/L as Mo) (01060)	Nickel, dissolved (µg/L as Ni) (01065)	Selenium, dissolved (µg/L as Se) (01145)	Silver, dissolved (µg/L as Ag) (01075)
FRESH[1] —Surface water—Continued									
Deep Fork near Arlington, OK 14N–06E–21 CCC 1	4	0.056	<10	9	2	<10	<10	<1	<1.0
Deep Fork near Stroud, OK 14N–06E–15 CBB 1	--	0.070	--	20	--	--	--	--	--
	5	0.056	<10	9	1	<10	<10	<1	<1.0
Robinson Creek nr Arlington, OK 13N–06E–06 AAD 1	--	--	--	5	--	--	--	--	--
Deep Fork blw Dry Ck nr Stroud, OK 14N–06E–14 ABD 1	<3	0.057	<10	9	<1	10	<10	<1	<1.0
Deep Fork abv Barby Ck nr Stroud, OK 14N–06E–26 DBB 1	5	0.060	<10	9	2	10	<10	<1	1.0
SALINE[1]— Surface water—Continued									
Todd Lake Trib nr Stroud, OK 14N–06E–27 DCD 1	--	0.030	--	10	--	--	--	--	--
Deep Fork Trib nr Stroud, OK 14N–07E–18 ACA 1	--	0.040	--	20	--	--	--	--	--

Appendix 2. Chemical analyses of surface water samples, on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma—Continued

Local identifier	Vanadium, dissolved (µg/L as V) (01085)	Zinc, dissolved (µg/L as Zn) (01090)	Radium–226, dissolved, radon method (pCi/L) (09511)	Radium–226, 2 sigma water, dissolved, (pCi/L) (76001)	Radon–222, 2 sigma total (pCi/L) (82303)	Radon–222, stable water, whole, total, (pCi/L) (76002)	H-2/H-1, stable isotope ratio (permil) (82082)	O-18/O-16, isotope ratio (permil) (82085)
FRESH[1] —Surface water—Continued								
Deep Fork near Arlington, OK 14N–06E–21 CCC 1	19	3	0.09	0.020	<80	24	-15.0	-2.10
Deep Fork near Stroud, OK 14N–06E–15 CBB 1	--	--	--	--	--	--	--	--
	17	<3	0.12	0.020	<80	24	-16.5	-2.00
Robinson Creek nr Arlington, OK 13N–06E–06 AAD 1	--	--	--	--	--	--	--	--
Deep Fork blw Dry Ck nr Stroud, OK 14N–06E–14 ABD 1	20	5	0.10	0.020	<80	27	--	--
Deep Fork abv Barby Ck nr Stroud, OK 14N–06E–26 DBB 1	19	<3	0.14	0.030	<80	22	-18.0	-1.85
SALINE[1] —Surface water—Continued								
Todd Lake Trib nr Stroud, OK 14N–06E–27 DCD 1	--	--	--	--	--	--	--	--
Deep Fork Trib nr Stroud, OK 14N–07E–18 ACA 1	--	--	--	--	--	--	--	--

[1] The suggested maximum contaminant levels set by U.S. Environmental Protection Agency (1989) for chloride (250 mg/L) and sulfate (250 mg/L) were used to separate fresh and saline water analyses in table 5.

Appendix 3. Depth to and altitude of base of fresh ground water in wells on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma

Local identifier	Date well logged	Elevation of datum (feet above sea level)	Base of fresh water (feet below land surface)	Altitude of base of fresh water (feet above sea level)
13N-06E-02 BBC	12-15-65	896	485	411
13N-06E-02 BDB	02-14-58	861	470	391
13N-06E-02 CB	04-28-83	865	655	210
13N-06E-02 CCC	07-23-69	868	690	178
13N-06E-03 AAD	02-06-54	876	460	416
13N-06E-03 ADD	07-02-67	916	715	201
13N-06E-03 BCC	06-20-84	862	500	362
13N-06E-03 DCD	12-24-51	905	675	230
13N-06E-04 AC	07-19-51	810	390	420
13N-06E-04 CAC	01-28-83	792	460	332
13N-06E-04 CDB	10-07-52	795	492	303
14N-06E-09 AAA	07-21-51	828	365	463
14N-06E-09 AAB	06-30-55	820	300	520
14N-06E-09 ABA	06-11-55	879	450	429
14N-06E-09 ACA	03-02-55	819	386	433
14N-06E-09 ACB	04-13-55	848	400	448
14N-06E-09 ADA	10-22-51	821	360	461
14N-06E-09 ADB	05-08-55	792	330	462
14N-06E-09 BAA	04-02-55	862	345	517
14N-06E-09 BAB	05-05-55	823	330	493
14N-06E-09 BAC	04-23-55	823	350	473
14N-06E-09 BAD	03-19-55	847	340	507
14N-06E-09 BCD	06-15-55	789	380	409
14N-06E-09 BDA	05-17-55	830	385	445
14N-06E-09 BDB	06-05-55	812	320	492
14N-06E-09 BDC	06-23-55	787	310	477
14N-06E-09 CAB	05-27-55	787	320	467
14N-06E-09 CBA	04-05-55	831	375	456
14N-06E-09 CBC	10-17-82	865	390	475
14N-06E-09 CDC	03-19-82	845	400	445

Appendix 3. Depth to and altitude of base of fresh ground water in wells on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma —Continued

Local identifier	Date well logged	Elevation of datum (feet above sea level)	Base of fresh water (feet below land surface)	Altitude of base of fresh water (feet above sea level)
14N-06E-10 AAC	04-14-57	790	340	450
14N-06E-10 ABC	08-14-51	802	295	507
14N-06E-10 BAC	11-02-51	868	454	414
14N-06E-10 BBC	01-08-52	844	460	384
14N-06E-10 BBA	02-04-52	845	450	395
14N-06E-10 BBB	06-07-51	880	490	390
14N-06E-10 BCA	12-14-51	865	395	470
14N-06E-10 BCB	09-24-51	856	360	496
14N-06E-14 ACD	11-18-64	779	170	609
14N-06E-14 BAB	05-14-62	780	292	488
14N-06E-14 BBD	06-12-63	779	290	489
14N-06E-14 BCA	06-18-63	778	300	478
14N-06E-14 BDA	04-13-62	778	245	533
14N-06E-14 BDC	08-06-62	788	330	458
14N-06E-14 CAD	01-16-63	797	258	539
14N-06E-14 CDC	05-15-53	796	170	626
14N-06E-14 DBB	08-21-62	786	180	606
14N-06E-14 DCD	11-14-53	779	140	639
14N-06E-15 DCD	05-25-53	804	270	534
14N-06E-15 DDC	05-03-53	786	220	566
14N-06E-15 DDD	05-14-53	797	270	527
14N-06E-21 AAD	01-01-53	792	90	702
14N-06E-21 ACB	03-13-53	810	160	650
14N-06E-21 ACC	01-01-52	826	160	666
14N-06E-21 CBA	02-24-53	827	150	677
14N-06E-21 DAA	02-12-53	838	170	668
14N-06E-21 DAB	02-24-53	827	170	657
14N-06E-21 DCC	03-18-71	815	130	685
14N-06E-21 DDC	04-18-70	835	190	645
14N-06E-22 AAC	03-17-53	799	170	629

Appendix 3. Depth to and altitude of base of fresh ground water in wells on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma —Continued

Local identifier	Date well logged	Elevation of datum (feet above sea level)	Base of fresh water (feet below land surface)	Altitude of base of fresh water (feet above sea level)
14N-06E-22 AAA	09-12-70	790	176	614
14N-06E-22 ABA	03-13-53	808	175	633
14N-06E-22 DBC	03-04-54	850	140	710
14N-06E-22 BBC	04-26-53	822	135	687
14N-06E-22 BCB	01-12-53	844	170	674
14N-06E-22 CBB	02-08-53	843	145	698
14N-06E-22 CCC	02-07-71	838	173	665
14N-06E-22 CDB	09-30-53	850	170	680
14N-06E-22 DBD	11-02-54	803	110	693
14N-06E-22 DCB	02-06-54	882	175	707
14N-06E-23 AAC	07-17-55	775	160	615
14N-06E-23 ABA	10-11-53	779	155	624
14N-06E-23 ABB	08-10-53	778	180	598
14N-06E-23 ABD	03-12-53	824	185	639
14N-06E-26 ABC	11-21-51	838	280	558
14N-06E-26 ACC	07-14-64	781	215	566
14N-06E-26 CAA	04-03-54	783	260	523
14N-06E-26 CCC	02-24-54	772	270	502
14N-06E-26 CCD	03-10-54	770	240	530
14N-06E-26 DDA	10-28-71	812	260	552
14N-06E-26 DDC	01-31-78	820	190	630
14N-06E-27 BBA	09-23-92	875	72	803
14N-06E-27 CAB	01-23-85	864	395	469
14N-06E-27 CAD	06-29-82	859	385	474
14N-06E-27 CDA	12-10-53	833	360	473
14N-06E-27 CBB	01-13-85	856	420	436
14N-06E-27 CCD	12-04-53	841	353	488
14N-06E-27 CDD	11-17-53	795	335	460
14N-06E-27 DBD	11-06-53	773	290	483
14N-06E-28 AAB	06-08-53	842	190	652

Appendix 3. Depth to and altitude of base of fresh ground water in wells on and near Sac and Fox Nation tribal lands, eastern Lincoln County, Oklahoma —Continued

Local identifier	Date well logged	Elevation of datum (feet above sea level)	Base of fresh water (feet below land surface)	Altitude of base of fresh water (feet above sea level)
14N-06E-28 ABA	05-13-71	828	165	663
14N-06E-33 AAD	03-03-54	868	440	428
14N-06E-33 DBD	05-01-51	822	453	369
14N-06E-34 BAA	10-07-53	851	400	451
14N-06E-34 AAA	12-22-53	785	297	488
14N-06E-34 ABA	11-29-53	791	330	461
14N-06E-34 ABB	11-21-51	800	330	470
14N-06E-34 BAC	09-16-53	864	450	414
14N-06E-34 BAD	10-07-53	857	395	462
14N-06E-34 BBA	09-22-53	863	450	413
14N-06E-34 BBB	09-02-53	841	425	416
14N-06E-34 BBC	08-13-53	872	460	412
14N-06E-34 CA	04-24-82	870	455	415
14N-06E-34 DAB	01-21-55	809	350	459
14N-06E-34 DBB	10-23-53	863	425	438
14N-06E-35 AAB	01-05-54	816	260	556
14N-06E-35 BAA	12-29-53	849	260	589
14N-06E-35 BA	12-19-77	800	230	570
14N-06E-35 BAB	03-20-54	795	240	555
14N-06E-35 BBA	04-23-54	802	260	542
14N-06E-35 BDC	11-16-55	834	265	569
14N-06E-35 CBB	10-27-53	834	330	504