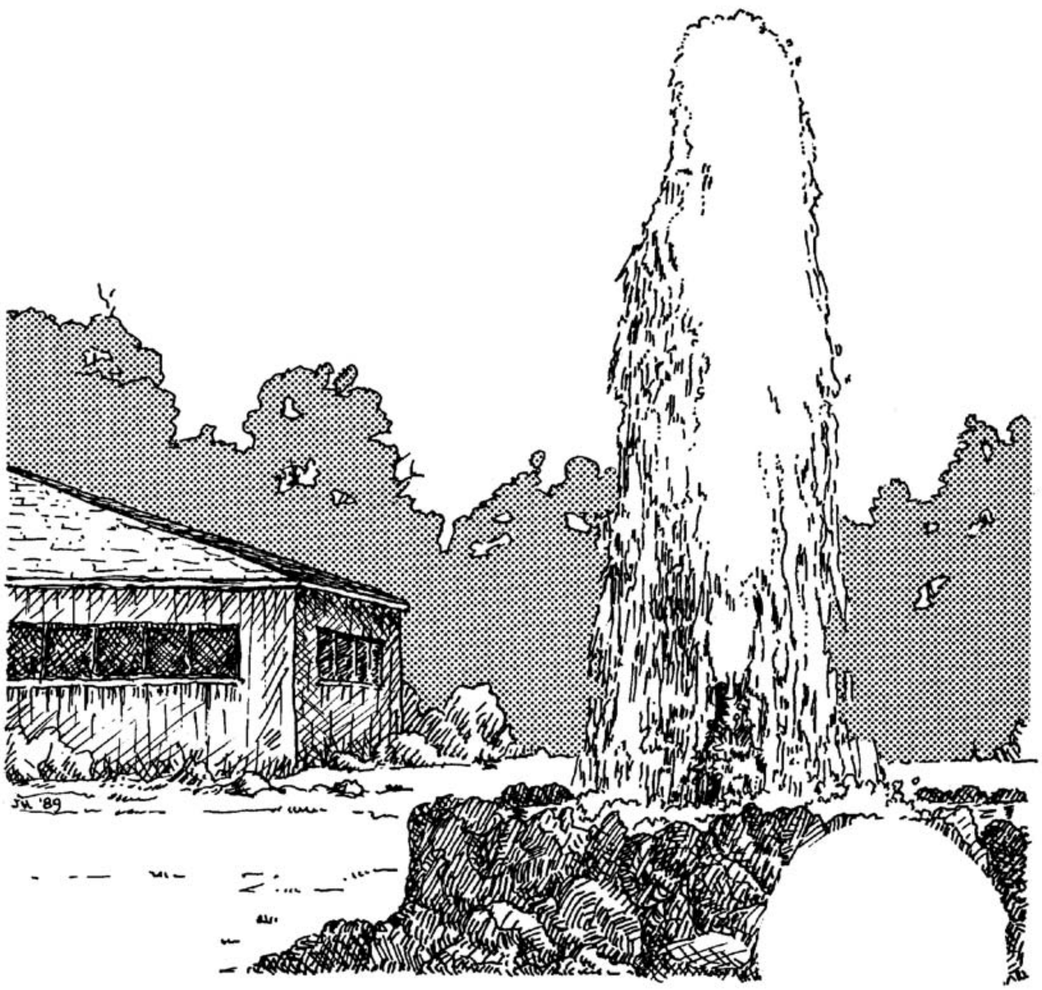
Prepared in cooperation with the
NATIONAL PARK SERVICE

Hydrogeology of the Chickasaw National Recreation Area, Murray County, Oklahoma

Water-Resources Investigations Report 94–4102



U.S. Department of the Interior
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Cover credit: Sketch of Vendome Well in the Chickasaw National Recreation Area, by John Havens, U.S. Geological Survey, from a photograph taken in the early 1930's.

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Hydrogeology of the Chickasaw National Recreation Area, Murray County, Oklahoma

By RONALD L. HANSON and STEVEN W. CATES

Prepared in cooperation with the National Park Service

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

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PLATES

[Plates are in pocket at back of the paper copy of the report. Plates are not included in the electronic version of report.]

FIGURES

TABLES

Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square mile (mi^2)	259.0	hectare (ha)
	Flow rate	
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter (L/s/m)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

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

°C = (°F - 32) / 1.8

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

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

REPORT TERMINOLOGY

In referring to specific areas of this study the following designations are used (fig. 1):

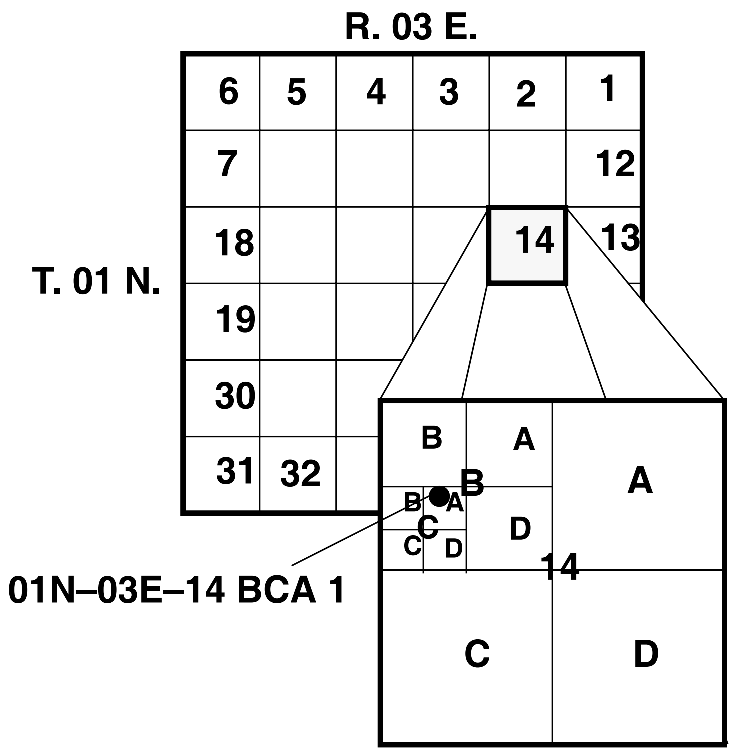
Park—The Travertine District, which contains 1.33 mi^2 and includes Veterans Lake, Vendome Well, and the original Platt National Park area.

CNRA—Chickasaw National Recreation Area, which contains a total area of 15 mi^2 and includes Travertine District and Lake of the Arbuckles.

Study Area—An area encompassing R. 2 E. to R. 5 E. and T. 2 N. to T. 2 S. (fig.1), including most of Murray County and parts of Garvin, Pontotoc, Johnston, and Carter Counties.

SITE-NUMBERING SYSTEM

The method used in this report to assign a number to a data-collection site is based on its Local Identifier, which is its public land-survey location as described by a particular township, range, and quarter-quarter-quarter section. As shown below, the fractional parts of a section are given from larger to smaller areas of the section; the final digit is the sequential number of a site within the smallest fractional subdivision (10 acres, in the example shown).



The location of each well also is described by a site identification number that, in most instances, corresponds to the latitude and longitude of the site. This identification number is used to locate the site in the USGS computer data files. Thus, well 01N–03E–14 BCA 1, which is located at latitude 34°33′35″ and longitude 096°57′46″, has a site identification number of 343335096574601. The last two digits (01) in the identification number are a sequence number referring to a specific well within the smallest subdivision of latitude and longitude.

Hydrogeology of the Chickasaw National Recreation Area, Murray County, Oklahoma

By Ronald L. Hanson and Steven W. Cates

Abstract

The Travertine District (Park) of the Chickasaw National Recreation Area, operated and maintained by the National Park Service, is near the City of Sulphur in south-central Oklahoma. The Park was established in 1902 because of its unique hydrologic setting, which includes Rock Creek, Travertine Creek, numerous mineralized and freshwater springs, and a dense cover of riparian vegetation. Since the turn of the century several flowing artesian wells have been drilled within and adjacent to the Park. Discharge from many of these springs and the numbers of flowing wells have declined substantially during the past 86 years. To determine the cause of these declines, a better understanding of the hydrologic system must be obtained. The U.S. Geological Survey, in cooperation with the National Park Service, has appraised hydrologic information obtained for the Park from several studies conducted during 1902–87.

The principal geologic units referred to in this report are the Arbuckle Group and the overlying Simpson Group. These rocks are of Upper Cambrian to Middle Ordovician age and are composed of dolomitic limestone, with some sandstones and shales in the Simpson Group. Surface geologic maps give a general understanding of the regional subsurface geology, but information about the subsurface geology within the Park is poor.

The Simpson and Arbuckle aquifers are the principal aquifers in the study area. The two aquifers are not differentiated readily in some parts of the study area because of the similarity of the Simpson and Arbuckle rocks; thus, both water-bearing units are referred to frequently as the Arbuckle-Simpson aquifer. The aquifers are confined under the Park, but are unconfined east and south of the Park. Precipitation on the outcrop area of the Arbuckle aquifer northeast and east of the Park recharges the freshwater springs (Antelope and Buffalo Springs) near the east boundary of the Park. The source of water from mineralized springs located in the central part of the Park, and flowing wells within and north of the Park, is believed to be a mix of waters from rocks of the Arbuckle and Simpson Groups. The source of water from two highly mineralized springs, Bromide and Medicine, that ceased to flow in the early 1970's is believed to be from the Simpson Group. Water-quality characteristics reflect the sources of ground water in the study area. The highly mineralized springs near the western end of the Park are a sodium chloride type with dissolved solids greater than 4,500 mg/L. The freshwater springs near the eastern end of the Park are a calcium bicarbonate type with total dissolved solids of less than 400 mg/L.

Flow from the artesian wells has declined substantially during the past 86 years and the wells are estimated to currently discharge only about 10 percent of the total flow reported in 1939. The depletion is believed to be caused by a gradual lowering of the hydraulic head within the aquifer. The influence on the hydrologic system of local municipal and industrial pumping from the Arbuckle-Simpson aquifer is difficult to discern because the system is much more sensitive to precipitation than to pumpage. Ground-water levels and spring flows in this region respond rapidly to precipitation. The effects of withdrawals from the City of Sulphur and Oklahoma Gas and Electric Company power-plant water-well fields are not discernible at wells and springs. The hydrologic system may be influenced by pumping, particularly during extended dry periods of several years, but the impact of pumping on the system cannot be determined without further investigation.

Introduction

The Travertine District (referred to as "Park" in this report) of the Chickasaw National Recreation Area (CNRA), is located in the south-central part of Oklahoma in Murray County near Sulphur, Oklahoma (fig. 1). The Park, which is administered by the National Park Service, was established initially by the United States Congress in 1902, named Sulphur Springs Reservation, and contained about 640 acres. By 1906 the Park had increased to 856 acres and on June 16, 1906, was renamed Platt National Park. During 1976, a small area encompassing the Vendome flowing well (plate 2) and Platt National Park was renamed Travertine District. At this time, Lake of the Arbuckles was combined with the Park and the total area of about 15 mi^2 was named Chickasaw National Recreation Area. In August 1983, the size of the CNRA was increased when the City of Sulphur donated to the National Park Service 345–acre Veterans Lake (plate 2) located on Wilson Creek near its confluence with Rock Creek. The Lake is considered part of the Travertine District.

The Park was established to preserve the numerous freshwater and mineral springs that discharge into Rock Creek and its principal tributary, Travertine Creek, both of

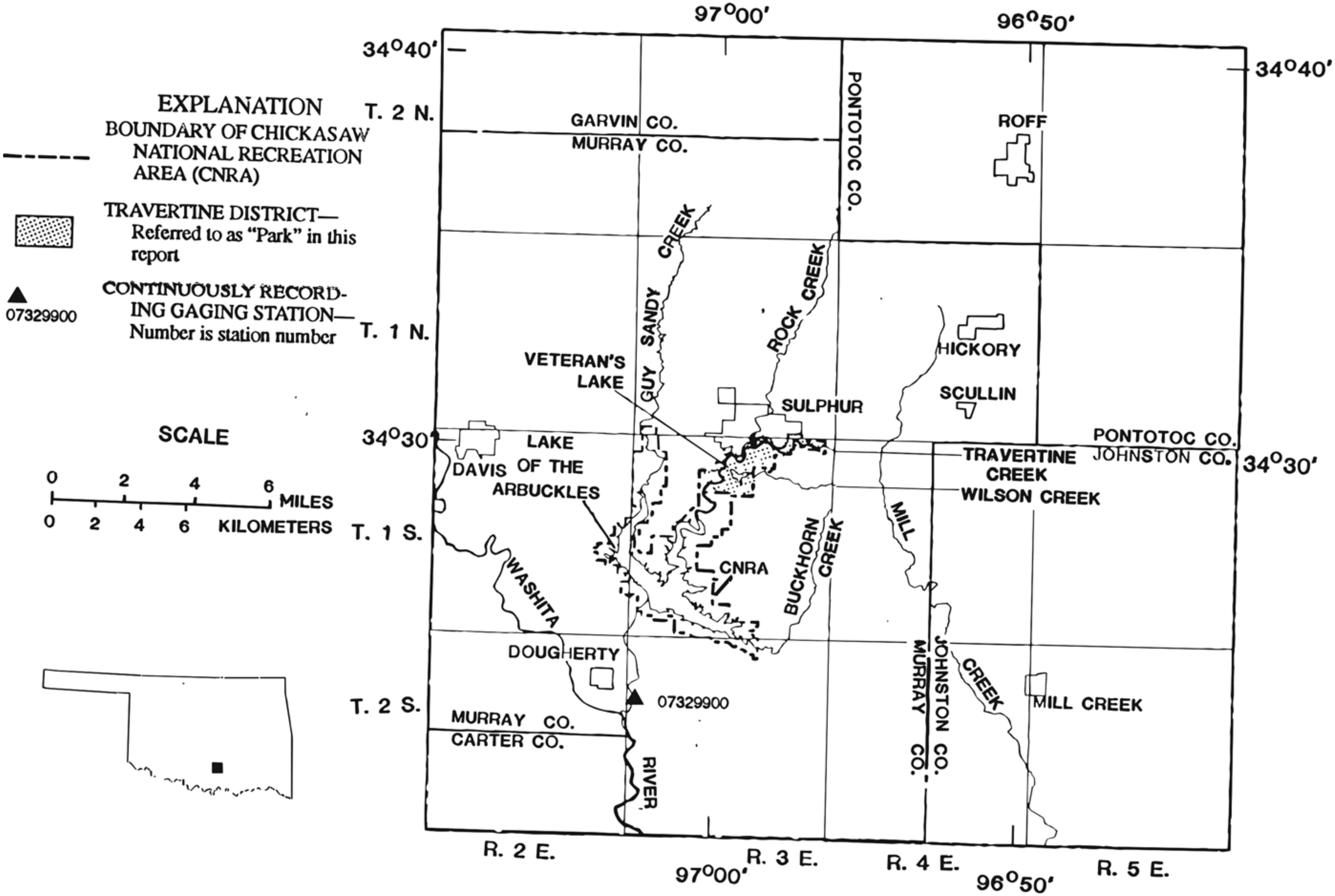


Figure 1. Location of study area showing Chickasaw National Recreation Area, Travertine District (Park), Veteran's Lake, Lake of the Arbuckles.

which flow through the Park. In July 1906 Gould (1906) documented 33 springs within the Park boundaries and classified them into eight separate "groups." Numerous flowing wells were drilled in the general vicinity during the 1920's and 1930's. The mineral waters flowing from some of the springs and wells have been used extensively for recreational and medicinal purposes; but over the years discharge from many of the springs and wells has declined significantly. A number of the springs have ceased to flow and others, such as seven individual springs in the Pavilion Group, have been combined into one spring. In 1987 only two freshwater springs (Antelope Spring and Buffalo Spring) and about five mineral springs (Hillside Spring and the Beach, Pavilion, and Ravine Groups, plate 2) within the Park flowed. Spring flow is intermittent in Antelope and Buffalo Springs, and the Ravine Group. Beach and Pavilion Groups, and Hillside Spring generally flow continuously, even during prolonged droughts.

Because of the apparent continued decline in the spring flows and possible future stresses on the hydrologic system by ground-water pumping, the U.S. Geological Survey (USGS), in cooperation with the National Park Service, conducted a study to compile and appraise information about the hydrogeology of the CNRA and adjoining areas.

The historical significance of the Park is based on its water resources. To assure that these critical water resources are available for future generations in keeping with National Park Service mandate, an extensive understanding of the study area hydrogeology is needed.

Purpose and Scope

The purpose of this report is to summarize and evaluate information pertaining to the hydrology of the CNRA. The scope of the study includes an evaluation of the quantity and quality of streamflow, spring flows, and artesian well flows. The study also evaluates the effect of local ground-water pumping on the hydrologic system. Although the study area covers 576 mi^2 and encompasses the CNRA (fig. 1), most of the information about streams, springs, artesian wells, and ground-water pumpage is limited to about a 20–mi^2 area in and immediately adjacent to the Park (plate 2). Selected geologic, hydrologic, and water-quality data are summarized for 1902–87.

Acknowledgments

Numerous individuals within the National Park Service, including personnel at the CNRA and in Ft. Collins, Colorado, have provided information for this study. The authors thank, in particular, Mr. Tom Taylor of the CNRA for his repeated prompt and comprehensive responses to requests for historic information about the Park and for his dedicated assistance in collecting field data.

The authors also appreciate the cooperation and support of many individuals from the City of Sulphur, including local residents, the staff with the City of Sulphur Water Department, and staff members of the Sulphur newspaper, the Times-Democrat, who have provided information and permitted access to their files. Finally, the authors recognize the cooperation of Oklahoma Gas and Electric Company (OG&E) personnel at their Sulphur plant and in their Oklahoma City office for providing pumpage and well data from the OG&E power plant.

Geography and Geology

The geographic and geologic setting with the CNRA must be characterized in order to evaluate adequately the hydrology of the area. This section discusses available information on the study-area landforms, soils, vegetation, precipitation, and geology.

Landforms

The Park lies within a region of Oklahoma that was subjected to extensive geologic activity. Complex faulting, folding, and deformation of rocks combined with erosion to form a land surface characterized by gently rolling hills dissected by streams and ravines. The Park encompasses a 2–1/2–mi reach of Rock Creek and all but the headwaters of Travertine Creek and is bounded on the south and southeast by northwest-trending low ridges incised by numerous small streams.

Within a 3–mi radius of the Park, the elevation ranges from a maximum of about 1,240 ft above sea level southeast of the Park to a minimum elevation of about 850 ft above sea level in Rock Creek at the southwest corner of the Park. Throughout most of the study area, however, local topographic relief varies by less than 150 ft. The most dominate physical feature within the Park is a vertical bluff, wooded at the top, that rises 140 ft above Rock Creek in the southwest corner of sec. 3, T. 1 S., R. 3 E.

Soils

Soil types within the study area have been classified by Watterson and others (1984). The most common soils in the uplands are cobbly loam and clay (Rayford series), which have a land-surface slope of between 5 and 20 percent, are relatively shallow (2 to 2.5 ft), and generally are used for rangeland. These soils are well drained but have a low water capacity and a shallow root zone due to a shallow contact with bedrock of indurated limestone. Soils in the stream valleys are generally of a silty-clay-loam type (Garvin and Elandco series). These soils are commonly 10 to 14 ft deep, well drained, and provide for a deep, well-established root growth. Because these lowland areas frequently are inundated by flood waters, land use is restricted to pasture where trees have been removed. Within the Park about six different soil types exist. All of these soils, however, have characteristics similar to the Rayford and Garvin/Elandco series soils.

Vegetation

Vegetative cover in the study area includes both the western steppe-type tall prairie grasses and the eastern-type broadleaf forests. The types of vegetative cover, particularly within the Park, have changed with time because of man's activities. Before the turn of the century, uncontrolled fires, started either by humans or lightning, prevented the establishment of dense tree growth, particularly in areas of shallow soils. However, more recent control of rangeland fires have allowed some trees to become established in the upland areas.

Prior to the 1920's, cattle overgrazing reduced grass cover. However, during the 1920's, cattle grazing and farming were discontinued permanently in the Park and the area was restored to its native grasses and oak-hickory forest. In 1933 the Civilian Conservation Corps made many improvements to the Park, including the establishment of 800,000 plants. This program involved the planting of 60 native tree species. One tree now common to the area is the eastern red cedar (juniper) that was introduced in the 1930's (Barker and Jameson, 1975).

Currently the valley floor along Travertine and Rock Creeks within the Park contains a diverse and dense cover of deciduous trees including oak, hickory, cottonwood, sycamore, and willow. The upland areas within the Park are characterized by various bunch grasses, cacti, and other xerophytes that can withstand both droughts and extreme temperatures.

The National Park Service Branch of Forestry, conducted a vegetation survey of the Park during 1937–39. They found the stream bottom was occupied by heavy woodland growth composed of oaks, elms, hickories, and other hardwoods. Away from the streams on flat or slightly rolling terrain was a mixed grassland dispersed with some large persimmon trees. An unpublished vegetation map prepared by G.M. Merrill (written commun., 1939) at a scale of 1 inch (in.) to 250 ft showed the following types and areas of cover:

Type of Cover	Acres
Barren	8.1
Grassland (80 percent herbaceous vegetation)	252.3
Cultivated residential	4.9
Chaparral (20 percent or more shrubs, excluding trees)	7.1
Woodland-Chaparral-Grass (80 percent or more broadleaf trees, grass, and herbaceous vegetation)	319.3
Woodland (80 percent or more broadleaf trees)	256.6
Total	848.3

An unpublished report on the vegetation and micro-environments of the Park in 1959 was prepared by E.E. Dale, Jr. (written commun., 1964). He delineated forested areas based on 15 transects within the Park. Dale's tree-ring data indicated the oldest living trees in the Park were a 96–year-old oak, an 88–year-old American elm, and an 81–year-old American elm. These data suggest that the Park may have had a major fire during the mid or late 1860's; however, no references have been found to document that such a fire occurred. Boeger (1987) refers to several fires in and adjacent to the Park during the past 80 years, but only one fire, in April 1946, is known to have burned an extensive area (16 acres) of the Park.

Insects and pests are considered to have been as destructive in the Park as fires—particularly Dutch elm disease (Boeger, 1987). Drought also has taken its toll on trees. In fact, 1956 was "one of the four driest years on record—loss of trees and shrub cover to the sustained drought was the worst anyone could remember" (Boeger, 1987).

Because plants, particularly riparian vegetation, are the largest users of soil moisture and shallow ground water, significant increases in the plant cover may be expected to cause corresponding decreases in discharge from those springs that are derived from shallow ground-water sources. Evapotranspiration from the general region of the study area is estimated by Fairchild, Hanson, and Davis (1990) to average about 31 in. per year or 80 percent of the average annual precipitation. The Park has had a significant increase in vegetative cover following the tree-planting program in the mid–1930's. The resulting increased water use by evapotranspiration and the effect on spring discharges is not documented; however, correlation of estimates of vegetative cover obtained from the early vegetative surveys and historical aerial photographs with corresponding measured spring flows may provide an indication of the influence that changes in vegetative cover have had on spring flows in the Park.

Precipitation

Rainfall first was measured by the National Park Service in the Park in February 1917. On August 9, 1918, the National Weather Service established an official weather station in the Park and began measuring daily temperatures and rainfall. Since then, the station has been moved several times. The current weather station is located in 01S–03E–03 ACA (plate 2) at an elevation of 995 ft above sea level. The station has been located at this site since November 1984 and is designated as Chickasaw NRA.

Previous National Weather Service designations for the station are: (1) Sulphur, Murray County (February 1917 to December 1950), and (2) Sulphur, Platt National Park (January 1951 to October 1984). The station now is classified as a "fire weather" site, which collects data used to determine the daily forest fire danger. Other climatic data collected at the station include monthly temperature extremes, freeze data, monthly and seasonal cooling degree days, and daily snowfall.

Monthly precipitation data have been published by the National Weather Service for selected months during February 1917 to January 1919. Continuous daily and monthly precipitation values have been published by the National Weather Service from January 1919 to the present. National Park Service personnel at the Park reviewed the precipitation data for the period 1919–87, including the monthly and annual totals. These revised data are available in computer files at both the Park and the USGS in Oklahoma City.

A plot of the annual precipitation for the period of record (January 1919 to December 1987) is shown in figure 2. The mean annual precipitation for this period is 38.29 in. Annual precipitation for the period of record ranges from a minimum of 19.54 in. for 1963 to a maximum of 60.86 in. for 1957. Monthly precipitation extremes were 16.43 in. during October 1970 and 16.26 in. during October 1981. Boeger (1987) indicates that major flooding occurred in the Park on January 21, 1916, but no record of rainfall is available. The maximum daily precipitation measured was 11.61 in. on October 8, 1970; the resulting flood is considered to have surpassed the January 21, 1916, flood (Boeger, 1987). Extended wet periods when annual precipitation was above normal for 3 or more consecutive years were:

Period	Duration
1926–29	4 years
1940–42	3 years
1944–46	3 years
1981–85	5 years

The records show that the decade of the 1940's was the wettest since records have been collected at this site.

Monthly precipitation totaling less than 0.1 in. has occurred on numerous occasions and zero monthly precipitation has occurred on six occasions during the 69–year period. Extended dry periods when annual precipitation was below normal for 3 or more consecutive years were:

Period	Duration
1920–22	3 years
1950–56	7 years
1961–66	6 years
1975–80	6 years

Even though the well-known drought of the 1930's did not have 3 consecutive years with precipitation below normal, 6 of the years during 1930 through 1939 were substantially below normal (fig. 2). Boeger (1987) indicates that January through June 1955 was the driest 6 months in the preceding 25 years.

Geology

Although no detailed geologic studies have been made within the Travertine District, a considerable number of regional geologic studies have been conducted adjacent to the Park (Decker and Merritt, 1931; Decker, 1941; Ham, 1955, 1969, 1973; Ham, McKinley, and others, 1954; Ham and others, 1964; Johnson and others, 1984). The first published geologic map that included the Park was in a report by Taff (1903). His map was prepared at a small scale (approximately 1:360,000) and provided a broad evaluation of the areal geology. A revision of Taff's 1903 geologic map was included in a report by Decker and Merritt (1931). The revised map (at a scale of about 1:84,000) was prepared by Decker, Cooper, and McGehee (1931) and shows the surface geology immediately east and south of the Park. Hazlett (1935) discusses the geological formations, the location of known major faults, and the geologic history. An update of the geology and water conditions in the Park was published by Gould and Schoff (1939) based on their visit to the area November 10–15, 1939. In a review of previous studies made of the Park, Dunn (1953) includes an aerial photograph (scale of 1:20,300) showing outcrops of the approximate contact of the Simpson Group of Ordovician age with the Vanoss Formation (Pontotoc Group) of Pennsylvanian age. Ham, McKinley, and others (1954) published an updated version of Decker, Cooper, and McGehee's 1931 geologic map at a scale of 1:72,000. This map includes some detail on the location of known (and assumed) faults in the study area.

The Arbuckle Group, of Upper Cambrian to Middle Ordovician age, is the oldest strata discussed in this report (plate 1). The Arbuckle, consisting of extensively folded and faulted dolomitic limestone and some sandstone, is present beneath several hundred square miles of south-central Oklahoma. These fractured rocks are widely exposed northeast and southeast of the Park where precipitation recharges them. The upper part of the Arbuckle Group varies in thickness because its upper contact is an erosional surface; however, this group has not been fully penetrated by drilling within the study area and therefore its thickness is unknown. Regionally, the Arbuckle is massive with a thickness of as much as 4,000 ft (Barthel, 1985). In some areas, no surface erosion has occurred and the Arbuckle is undeformed.

The Simpson Group, of Middle and Upper Ordovician age, is composed of sandstone, limestones, and shales. The Simpson Group crops out over large areas east and south of the Park (plate 1). Total thickness of the Simpson Group beneath the Park is unknown but within the study area it is estimated to be as much as 1,600 ft thick (Barthel, 1985).

The Simpson and Arbuckle Groups provide water to wells and springs in the study area and, because of the similarity of the rocks comprising these two Groups, the water-bearing rocks commonly are referred to as the Arbuckle-Simpson aquifer. Both the Simpson and Arbuckle Groups are completely covered by limestone conglomerate of the Vanoss Formation within the Park, thus obscuring the geologic structure of these groups beneath the Park. The structure is believed to be a northwest plunging graben (Gould, 1939) and units within the graben have been folded into a syncline (Sulphur Syncline, plate 1). This graben is bounded by the Sulphur Fault on the north and by an unnamed fault (sometimes referred to as the South Sulphur Fault) about 2 mi south of the Sulphur Fault (plate 1).

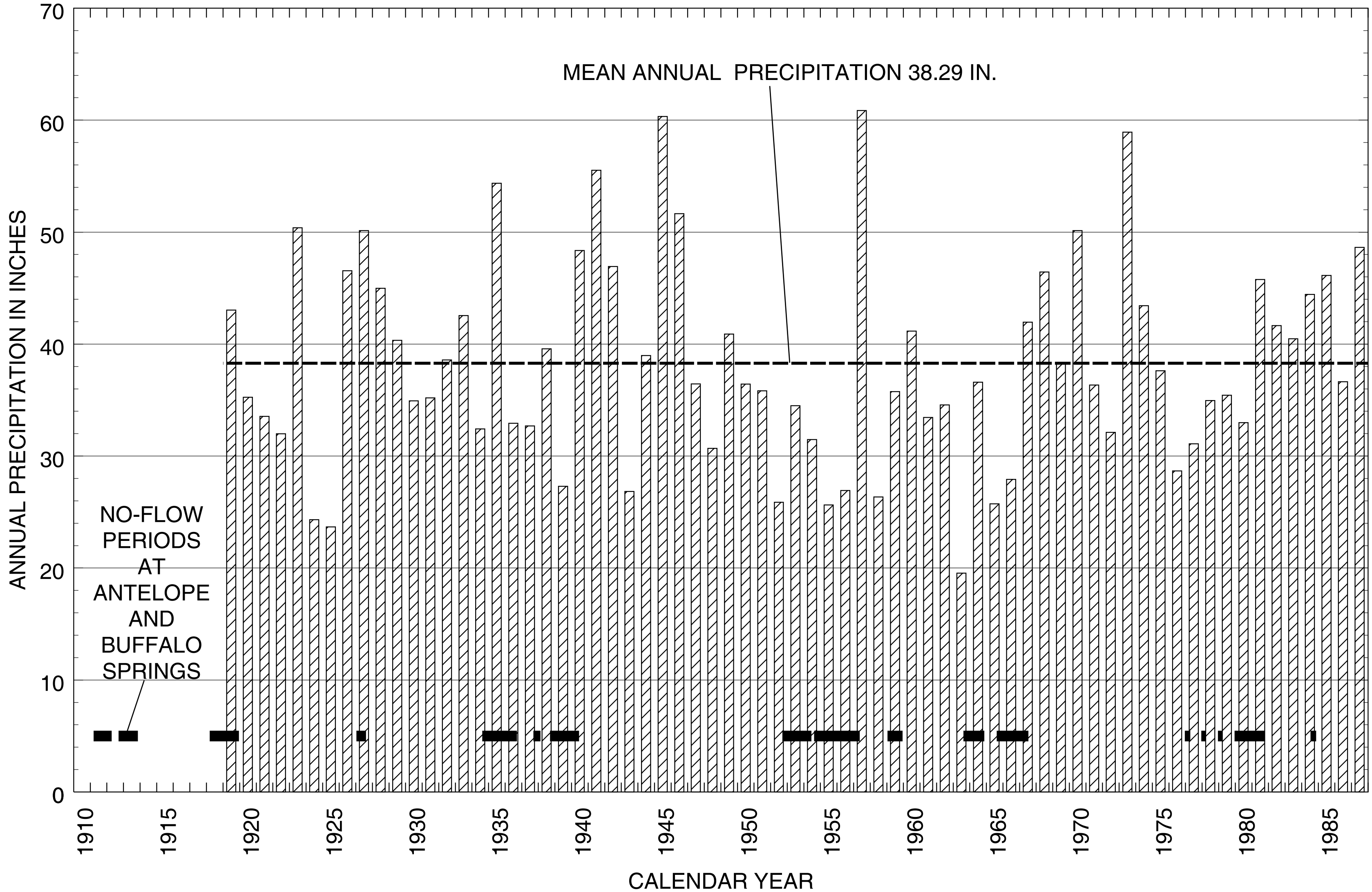


Figure 2. Annual precipitation at Chickasaw National Recreation Area, 1919–87 (data from National Park Service) and periods of no-flow at Antelope.

The only rock unit exposed in the Park is the Vanoss Formation of Pennsylvanian age. D.L. Hart, Jr. (written commun., 1972) in an unpublished study of the "Hydrology of the Platt National Park area, Murray County, Oklahoma," indicated that the thickness of this formation within the Park is unknown, but in some areas outside the Park it is believed to be as much as 1,600 ft. The Vanoss consists of a tightly cemented limestone conglomerate, a shale member, and minor sandstone lentils. This formation acts as a confining layer over the underlying Arbuckle-Simpson aquifer and wells that pass through the Vanoss and into the aquifer commonly provide artesian flow.

Numerous faults and folds have been mapped in the outcrop of the Simpson and Arbuckle Groups in the study area. Extreme variations in geometry exist between strike-slip, dip-slip, and overthrust faults. Left-lateral strike-slip faulting is considered to have been the dominant mechanism of deformation (Ham, 1956, 1969; Ham, Denison, and Merritt, 1964; Ham, McKinley, and others, 1954; Wickham and Denison, 1978; Carter, 1979; Booth, 1981; and Hass, 1981). Other than the graben under the Park, most of the northwest-trending regional faults are strike-slip. Shorter faults of various orientations were probably the result of forces associated with the major strike-slip fault deformation. These shorter faults are strike-slip, dip-slip, overthrust, or combinations of these fault types.

The Sulphur Fault (plate 1) has a relatively straight northwest-trending trace exposed at the surface from about 8 mi southeast of Sulphur to a point about 1 1/4 mi east of the Park. West of this point, the fault is covered by conglomerate of the Vanoss Formation, but the fault may underlie Antelope and Buffalo Springs. Location of the fault where buried under the Vanoss Formation is conjectural, and the extent to which the fault controls ground-water movement in the area also is conjectural (D.L. Hart, Jr., written commun., 1972).

The northwest-trending unnamed fault southeast of and roughly parallel to the Sulphur Fault is first observable on the surface about 2 1/2 mi southeast of the Park (plate 1). The location of this fault where buried under the Vanoss Formation also is uncertain.

Drillers' logs for three water wells at the OG&E power plant (plate 2), located 1 mi north of Sulphur, indicate the possible existence of a fault between well G2 and wells G1 and G3. The geometry of the fault and the exact vertical offset are not known, but about 173 ft of the Simpson Group section shown in the log for well G2 is missing in the logs for wells G1 and G3.

Geologic maps indicate that deformation in the study area is extensive. Oil-well logs from wells several miles west of the Park substantiate this complexity, but interpretation of the structural geometry beneath the Vanoss Formation in the Park area is impossible with existing stratigraphic data.

Barthel's (1985) examination of lineament orientations east of the CNRA indicates more extensive fracturing of the Arbuckle rocks than the Simpson rocks. He indicates a correlation between lineament orientations and general fault trends. His analysis also cites the preferred orientation of lineaments nearly identical to the intermittent stream directions at some locations. Barthel's study indicates that the Sulphur Fault may trend westerly under the Vanoss Formation toward Travertine Creek.

Hydrology

One of the principal objectives of this study is to evaluate the hydrologic characteristics of the CNRA. This section evaluated available information about the surface water (lakes and streams), the springs, and the ground water. Included in this section is a discussion of the water-quality characteristics of the surface water, springs, and ground water.

Surface Water

There are two major lakes within the study area, Veterans Lake (fig. 1 and plate 2) and Lake of the Arbuckles (fig. 1). Only Veterans Lake has a direct effect on the surface- or ground-water flow characteristics within the Travertine District.

Veterans Lake, which was constructed by the Works Progress Administration (WPA) in the 1930's, and adjoining land were acquired by the National Park Service from Sulphur in August 1983 (Boeger, 1987). The lake, formed by an earthen dam, has a surface area of 64 acres, a capacity of 600 acre-feet (acre-ft), and is located in the southwestern part of the Travertine District (fig. 2). Principal inflow to the lake is from Wilson Creek, which has a drainage area of 4.2 mi^2. Primary use of Veterans Lake is fishing, swimming, and boating.

Lake of the Arbuckles, which was constructed by the U.S. Bureau of Reclamation, occupies most of the southern half of the CNRA (fig. 1). An earthen dam is located on Rock Creek, 4 mi upstream from the mouth of the Creek. The reservoir began filling in April 1966 and reached capacity in 1 year (Boeger, 1987). The reservoir provides recreation and flood control for the general area, and is a water supply for the communities of Dougherty and Davis (fig. 1), and Wynnewood and Ardmore outside the study area. Operation of the reservoir was transferred to the Arbuckle Master Conservancy District in 1968. The principal streams contributing to the reservoir are Rock Creek, Guy Sandy Creek, and Buckhorn Creek and the total drainage area of these streams contributing to the reservoir is 126 mi^2. Capacity of the reservoir at spillway crest is 108,800 acre-ft and the water-surface area at spillway crest is 3,130 acres (Oklahoma Water Resources Board, 1990). A water-quality study of the reservoir (Streebin and Harp, 1977) indicates significant eutrophication in both the lake and inflow tributaries.

Some investigators have suggested that declining artesian well flows and spring flows in and near the Park could be restored if pumpage from the Arbuckle-Simpson aquifer were reduced. It has been proposed to discontinue the City of Sulphur's wells (plate 2), which withdraw ground water from the aquifer immediately north of the Park, and replace this supply with water piped to Sulphur from the Lake of the Arbuckles. The effect that these changes would have on the local ground-water levels, artesian-well flows, and spring flows is unknown, however.

There are five principal streams that flow into the CNRA and form Lake of the Arbuckles, as shown on figure 1. The largest stream in the study area is Rock Creek, which begins 10 mi north of the Park and flows south through the Park and into Lake of the Arbuckles before discharging into the Washita River near Dougherty, Oklahoma (fig. 1). Dry-weather flow in Rock Creek at the Park is derived from several springs and uncontrolled flowing artesian wells in the basin. Overflow from Sulphur's sewer system during heavy rainstorms also contributes flow to Rock Creek.

Periodic discharge measurements were obtained at Rock Creek at Dougherty (station number 07329900 in figure 1) from 1950 to 1956 and a continuous record of streamflow was collected at the gage site from March 1956 to June 1967. This gage was located 1 mi upstream from its confluence with the Washita River and included a drainage area of 138 mi^2. The gage was discontinued June 30, 1967, following completion of the Arbuckle Reservoir dam located 3 mi upstream from the gage. A hydrograph of the periodic and mean monthly discharges at this site for the period of record (water years 1950–67) is shown in figure 3. Discharges have been affected since October 1961 by several small floodwater-retarding structures, and after April 1966 by upstream regulation when the Lake of the Arbuckles reservoir began to fill. The hydrograph shows that base flows during the winter months (November-February) ranged between 8 and 15 ft^3/s and late summer (August-October) base flows commonly dropped to between 3 and 6 ft^3/s, with a minimum flow of 0.37 ft^3/s measured on September 20, 1955. Prior to regulation, Rock Creek was particularly low for several months in 1955, 1959, 1963, 1964, and 1965.

Travertine Creek begins immediately to the east of the Park (fig. 1 and plate 2) and flows westerly through the Park before discharging into Rock Creek. Dry-weather flow is supplied by numerous springs, including Antelope and Buffalo Springs near the Creek's headwaters. Other flows contributing to Travertine Creek include artesian-well flows from some of the Sulphur municipal wells and Vendome Well.

Wilson Creek begins southeast of the Park (fig. 1 and plate 2) and flows west. The creek is the principal surface-water source for Veterans Lake. Dry-weather flow is supplied by springs in the basin; however, the creek commonly goes dry during the summer months. No records are available of discharge from the lake, but water flows over the spillway during the wet season and discharges into Rock Creek, located about 0.3 river mi west of the Veterans Lake spillway.

Buckhorn Creek begins about 3 mi southeast of the Park (fig. 1) at a cluster of springs referred to as Lowrance Springs (plate 1) and flows south about 2 mi before turning back to the west-northwest and then discharges into the easternmost arm of Lake of the Arbuckles. The springs are the principal source of dry-weather flow for Buckhorn Creek.

Guy Sandy Creek begins about 10 mi north of the City of Sulphur (fig. 1), flows south, passing 2 mi west of the city, and discharges into the western arm of Lake of the Arbuckles. Wet-season streamflow is influenced by some upstream regulation from several small floodwater-retarding structures. Dry-weather flow probably is derived from numerous small intermittent springs and seepage from the retarding structures and several other small ponds in the basin.

The drainage area of each creek, percent of drainage area within the CNRA, and approximate number of small surface-water retention ponds within the drainage area are summarized in the following table:

Creek name	Drainage area		Approximate number of small ponds within drainage area
	Total (mi^2)	Percent in CNRA	
Rock Creek at confluence with Travertine Creek	38.4	1	300
Wilson Creek at confluence with Rock Creek below Veterans Lake	4.20	16	23
Travertine Creek at confluence with Rock Creek	3.87	61.7	25
Buckhorn Creek at confluence with Rock Creek	27.0	<1	Several hundred
Guy Sandy Creek at confluence with Rock Creek	44.0	23	Unknown

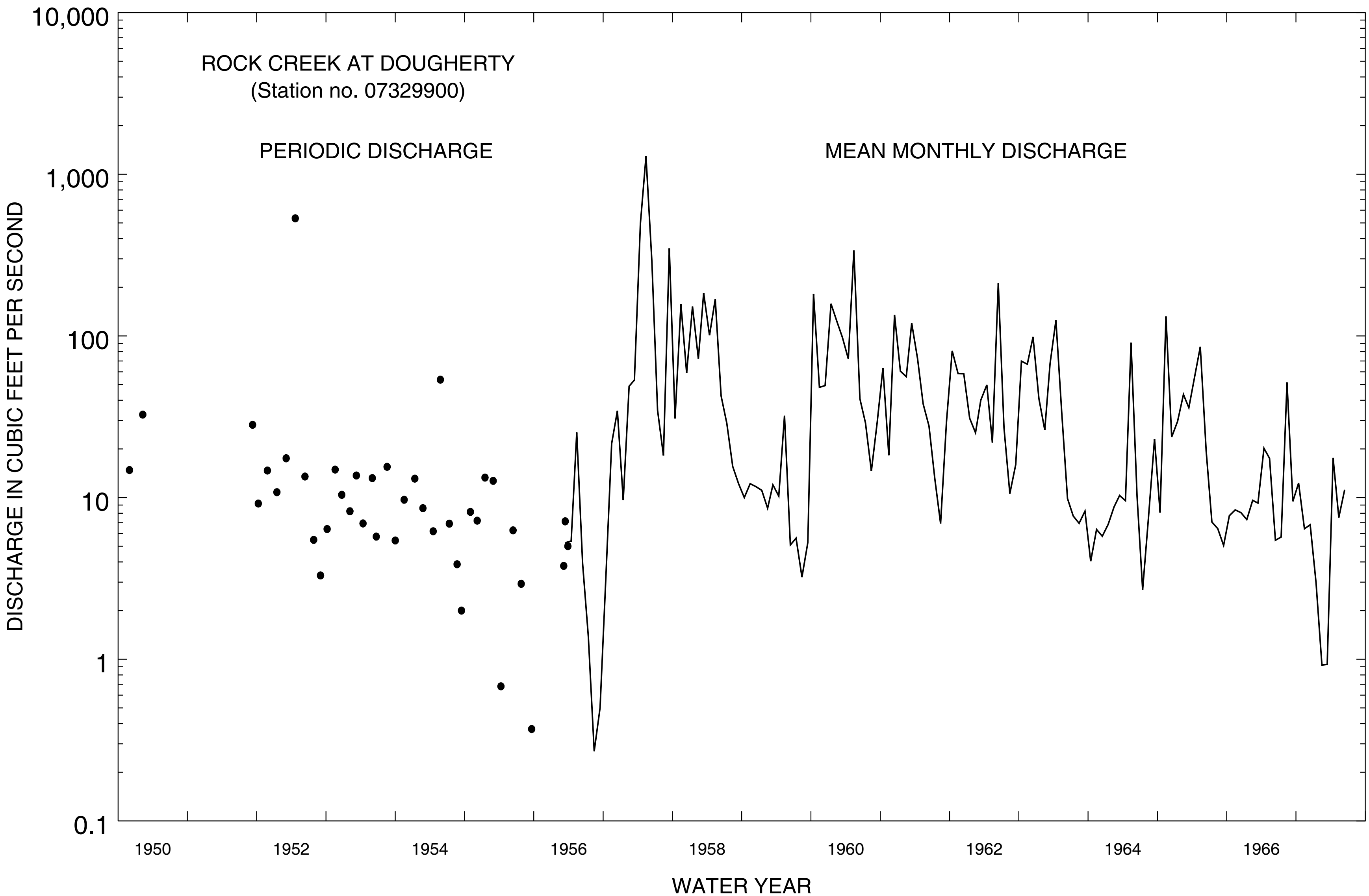


Figure 3. Periodic discharge (1950–56) and mean monthly discharge (1956–67) for Rock Creek at Dougherty, Oklahoma.

Several miscellaneous discharge measurements have been obtained on these five streams during the past 40 years by various State and Federal agencies. Table 1 (at back of report) summarizes the results of these measurements.

Springs

The first comprehensive evaluation of the Park springs was made by Gould (1906). During July 1906, he conducted a field survey of 33 springs, in which he documented the approximate location and estimated the flow of each spring. No detailed maps were available at the time of Gould's survey and some uncertainty exists as to the exact location of many of the springs.

Gould indicated that 6 of the springs were freshwater and 27 were mineralized. Total discharge from these 33 springs was estimated to be 3,741 gal/min or 8.33 ft^3/s. Table 2 lists these discharges for the two principal freshwater springs, Antelope Spring located in 01S–03E–01 ABB, and Buffalo Spring located in 01S–03E–01 ABD (plate 2). The other four freshwater springs observed by Gould in 1906 are within a group of seven springs in the southeastern corner of the Park referred to as the "Churchill Park Group." Total flow from these four freshwater springs was not measured, but two of the freshwater springs were estimated to discharge 3 gal/min each. Table 3 (at back of report) lists the springs visited by Gould in 1906 in downstream order, and gives the arbitrary site numbers of each spring and group names assigned by Gould. Included in Gould's reconnaissance was a statement about the general chemical character of the water and the physical condition of each spring.

The next estimates of flow from the Park springs were made in 1911 by Park Superintendent Col. William French in his annual report to the Secretary of the Interior. He indicated that Antelope and Buffalo Springs discharged about the same amount as in 1906, but Pavilion, Hillside, and Beach (renamed Black Sulphur Spring in 1926) Springs were all discharging higher flows than in 1906.

During 1934, the Civilian Conservation Corps constructed a circular, 25–ft diameter rock wall around an opening of Buffalo Spring to create a pool. Construction occurred during a dry period and, as a result, the wall retains only a small part of the total water discharging from a cluster of several small springs in the immediate vicinity. The pool created by this retaining wall is referred to as Buffalo Spring Pool. The pool discharges into a natural channel and, approximately 100 ft downstream from the pool, the channel discharges into an unnamed tributary of Travertine Creek. Numerous small springs occur along this channel; total flow from the pool and these small springs is referred to in this report as "Buffalo Spring Outflow."

During November 10–12, 1939, Gould and Schoff (1939) made the next estimates of spring flow, but only 19 of the original 33 springs could be located. They indicated that Antelope and Buffalo Springs had been dry since September 1938 and discharge of the mineral springs in the Bromide Springs Group (table 3) was diverted into tanks making it impossible to measure their flows. No mention was made of the four small freshwater springs in the Churchill Park Group, suggesting that these springs also had ceased flowing. The total spring discharge estimated by Gould and Schoff was about 20 percent of the discharge estimated in 1906. They made several recommendations that might ensure preservation of the water resources of the area, including controlling the discharge from existing flowing wells, limiting pumping from the city wells, and avoiding drilling new wells in the immediate vicinity of the Park.

Spring flows were estimated by Dunn (1953) during August 1953. His observations indicated that Antelope and Buffalo Springs were nearly dry, while discharge from the mineralized springs in the central area of the Park were about the same as Gould and Schoff observed in 1939. Dunn stated, however, that "* * * the flow of mineral springs fluctuates and some flows have stopped entirely in the past score of years. * * * part of the present low flow is due to climatic conditions." He also stated that several flowing artesian wells had been drilled in the vicinity since 1920, and believed the wells contributed to the decline in flow. Antelope and Buffalo Springs' flow was estimated again by the National Park Service on May 27, 1957, and measured on July 10, 1957, and on April 15, 1958, by the U.S. Bureau of Reclamation. These measurements indicate that the discharges from the two freshwater springs had returned to rates similar to those observed in 1906 and 1911.

On June 26, 1968, the National Park Service installed a brass pin in the bottom of Buffalo Spring Pool and began recording periodic measurements of the height of water above the top of the submerged pin. (See pin readings in table 2.) The pin was vandalized during a dry period from January 1980 to November 1981, but another pin was installed on November 5, 1981. Survey levels run June 26, 1968, and June 18, 1987, by the USGS indicate that the pin was reset 0.16 ft lower in 1981.

On July 18, 1968, the National Park Service installed a similar brass pin in the streambed at Antelope Spring about 8 ft downstream from where the spring discharges from the base of the rock cliff. This pin is believed to have been disturbed on several occasions during dry periods (William Werrell, written commun., November 26, 1985). The pin was reset by the National Park Service but the date is uncertain, and is assumed to be on or prior to January 8, 1982, when the first water-level record was obtained following a prolonged dry period of nearly 2 years. Survey levels run June 26, 1968, and June 18, 1987, by the USGS indicate that this pin is presently 0.01 ft lower than in 1968.

Table 2. Pin readings, gage heights, and estimated and measured discharges at Antelope Spring, Buffalo Spring Pool, and Buffalo Spring Outflow, 1906–87

[Discharge measured by U.S. Geological Survey except as footnoted; ft^3/s, cubic feet per second; **e**, estimated value; --, no data]

Date	Antelope Spring			Buffalo Spring Pool		Buffalo Spring Outflow
	Pin reading[1] (ft)	Gage height (ft)	Discharge (ft^3/s)	Pin reading[2] (ft)	Discharge (ft^3/s)	Discharge (ft^3/s)
07–12–06	--	--	[3] **e** 4.50	--	--	[3] **e** 3.50
09–12–11	--	--	[4,5] **e** 8.	--	--	[6] --
05–27–57	--	--	[4,5] **e** 6.	--	--	[5] --
07–10–57	--	--	[6] 4.74	--	--	[6] 5.05
04–15–58	--	--	[6] 3.96	--	--	[6] 4.84
	--					
06–26–68	.95	--	4.76	2.08	--	6.15
08–19–68	.95	--	4.04	2.00	--	4.48
10–28–68	--	--		1.98	--	3.33
10–29–68	.91	--	2.57	--	--	--
12–03–68	.91	--	3.10	2.00	--	3.24
01–07–69	.96	--	3.58	2.07	--	3.33
02–10–69	.93	--	3.54	2.03	--	3.26
03–14–69	.98	--	4.48	2.04	--	4.78
04–08–69	.99	--	5.63	2.04	--	4.81
05–12–69	1.03	--	5.93	2.08	--	5.32
06–13–69	.99	--	6.24	2.03	--	5.31
07–14–69	.92	--	4.71	2.02	--	4.75
09–24–69	.87	--	2.70		--	2.91
10–30–69	.88	--	2.85	1.96	--	2.68
11–21–69	**e** .88	--	2.44	**e** 2.95	--	2.15
07–03–75	**e** 1.19	--	5.7	--	--	--
11–18–85	.89	.60	2.84	2.19	.52	3.67
12–02–85	**e** .89	--	2.84	--	--	--
01–23–86	**e** .91	.63	5.10	2.21	--	4.07
01–29–86	.93	.63	4.85	2.21		
03–06–86	**e** .90	.60	3.85	**e** 2.16	.71	5.05
04–17–86	.86	.57	2.73	**e** 2.14	.28	3.63
06–03–86	--	--	--	**e** 2.18	.46	4.36
06–06–86	**e** .90	.60	4.26	--	--	--
07–09–86	**e** .88	.60	4.83	2.19	.45	5.55
08–21–86	.84	.55	3.73	--	.24	3.60
10–16–86	**e** .84	.55	2.52	--	.29	3.07
12–12–86	.87	.58	3.57	--	.40	3.86
01–29–87	.93	.63	4.85	**e** 2.22	.61	4.97
03–06–87	.98	.69	5.00	2.25	1.04	5.95

Table 2. Pin readings, gage heights, and estimated and measured discharges at Antelope Spring, Buffalo Spring Pool, and Buffalo Spring Outflow, 1906–87—Continued

[Discharge measured by U.S. Geological Survey except as footnoted; ft^3/s, cubic feet per second; **e**, estimated value; --, no data]

Date	Antelope Spring			Buffalo Spring Pool		Buffalo Spring Outflow
	Pin reading[1] (ft)	Gage height (ft)	Discharge (ft^3/s)	Pin reading[2] (ft)	Discharge (ft^3/s)	Discharge (ft^3/s)
04–16–87	1.00	.73	4.50	2.25	1.68	6.52
05–21–87	.96	.65	4.25	2.20	.82	--
07–15–87	.96	.63	3.70	2.10	.86	--
08–21–87	.86	.59	3.32	2.16	.45	--
10–08–87	--	.59	2.35	2.12	.31	--
11–05–87	.92	.57	3.69	2.12	.27	--
12– 17–87	--	--	--	2.18	.42	--

[1]Height of water above top of submerged brass pin in Antelope Spring. Datum of top of pin 1078.58 ft above sea level from July 18, 1968, to about December 1972. Datum 1978.57 ft above sea level after about January 8, 1982.

[2]Height of water above top of submerged brass pin in Buffalo Spring Pool. Datum of top of pin 1077.72 ft above sea level from June 26, 1968, to about January 1980. Datum 1077.56 ft above sea level after November 5, 1981.

[3]Discharge estimated by Gould, 1906.

[4]Discharge estimated by National Park Service.

[5]Discharge is combined flow of Antelope and Buffalo Springs.

[6]Discharge measured by U.S. Bureau of Reclamation.

Following are the known altitudes of the top of the submerged pins in Buffalo Spring Pool and Antelope Spring, based on these surveys:

Date	Pin altitude in feet above sea level	Comments
Buffalo Spring Pool		
June 26, 1968	1077.72	Pin installed by National Park Service
January 1980–October 1981	Unknown	Pin disturbed during this period—date unknown
November 5, 1981	1077.56	Pin reset by National Park Service 0.16 ft lower
Antelope Spring		
July 18, 1968	1078.31	Pin installed by National Park Service
December 1972–December 1982	Unknown	Pin disturbed during this period—date unknown
January 8, 1982	1078.30	Pin reset by National Park Service 0.01 ft lower

Except during extended droughts, measurements of the height of the water above the top of the submerged pins (see pin readings in table 2) have been obtained by the National Park Service at these sites at intervals varying from a few days to several weeks. A plot of these readings, expressed as altitude above the sea level, is included in figure $4A_2$. These graphs indicate that Antelope Spring discharges at an altitude about 0.5 ft lower than Buffalo Spring.

Periodic stage records in the pool at Hillside Spring were obtained by the National Park Service from June 26, 1968, through May 25, 1969. Periodic miscellaneous discharge measurements were obtained by the USGS at Hillside Spring from June 26, 1968, to November 21, 1969. During a bacterial contamination study of Hillside Spring in 1967 by Cumiford and others (1968), numerous spring-flow estimates were obtained from January 28, 1967, to May 22, 1967 (table 3). The method used to obtain these flows is not discussed in their report, but the discharge values do appear reasonable and indicate the spring maintained a steady discharge during dry periods.

Schornick, Harp, and Laguros (1976) present stage hydrographs for Antelope Spring and Buffalo Spring Pool for April 1973 to November 1974. They also give estimates of flow from Bromide Spring (about 1 gal/min) and Medicine Spring (less than 1 gal/min), but do not indicate the date of the estimates. Their method of determining the flow is not discussed; however, they state, "* * * accurate flow measurements have not been obtained."

Harp and others (1985) give monthly discharges for Antelope Spring and Buffalo Spring Pool for the period June 1969 to December 1984 and June 1972 to December 1984, respectively, derived by applying periodic pin readings collected by the National Park Service to a generalized weir equation for each spring. A comparison of these estimated discharges with measured discharges obtained by the USGS for the same stage indicates that the estimated discharges for Antelope Spring are 25 to 50 percent less than the measured discharges, while the estimated discharges from Buffalo Spring Pool are 75 to 150 percent greater than the measured values. Harp and others (1985) did not provide estimates of total discharge from the Buffalo Spring Outflow.

During 1985 the National Park Service installed a streamgaging station (07329849) at Antelope Spring and, on November 20, 1985, the USGS began collecting continuous records of stage and periodic (5– to 6–week interval) measurements of spring discharge. The daily mean discharges of Antelope Spring for the period of record, November 20, 1985–December 31, 1987, are presented in table 4 and shown in figure 5.

Periodic measurements of total discharge from Buffalo Spring Outflow (which includes the pool discharge) began November 18, 1985. The estimated and measured discharges for the period of record (1906–87) at Antelope Spring, Buffalo Spring Pool, and Buffalo Spring Outflow are given in table 2. The maximum discharges measured at each spring were 6.24 ft^3/s at Antelope Spring on June 13, 1969, and 6.52 ft^3/s at Buffalo Spring Outflow on April 16, 1987.

Periods when Antelope and Buffalo Springs have been dry are listed in table 5 and shown in figure 2. Personal interviews with local residents conducted by previous investigators revealed possible dry periods occurred in 1888, 1891, and 1896 at Antelope and Buffalo Springs; however, no data are available to verify these possible dry periods. Table 5 shows that, during the past 80 to 100 years, a particularly long dry period of 33 months occurred from August 1954 to May 1957. The springs also were dry for extended periods from August 1934 to September 1936, but the duration of these no-flow periods is not documented.

D.L. Hart, Jr. (written commun., 1972) indicates that during 1968–69 only 5 of the original 27 mineral springs could be located. However, these 5 springs actually include Hillside, Bromide, Medicine, the combined flows of 7 springs in the Pavilion Group, and the combined flows of 3 springs in the Beach (Black Sulphur) Group. He believed that only two of these, Bromide and Medicine, could be classified as true mineral springs because of high dissolved-solids and chloride content. Hart considered the other three spring groups—Pavilion, Beach, and Hillside—as mixed waters from rocks of the Arbuckle and Simpson Groups. Bromide and Medicine Springs are believed to have quit flowing in about 1973 (Boeger, 1987), but no documentation is available to confirm an exact date.

Ground Water

The ground-water system in the CNRA is complex and an understanding of this system requires knowledge of the hydraulic characteristics of the primary aquifers and the occurrence and movement of water through the aquifers. Included in this section are discussions of ground-water-level fluctuations, withdrawals by pumping and flow from artesian wells, and recharge to the system from precipitation.

Principal Aquifers

The sources of ground water for the springs and artesian wells in and adjacent to the Park are believed to be from rocks of the Simpson and Arbuckle Groups.

The Simpson aquifer of sandstone, limestone, and shale is widely exposed over large areas east and south of the Park (plate 1). Many investigators suggest that the Simpson aquifer is the source of the highly mineralized spring and artesian well flows in the study area.

The Arbuckle aquifer of dolomitic limestone is widely exposed east, southeast, and northeast of the Park (plate 1). The Arbuckle is considered the source of freshwater spring flow in the Park and, in particular, the source for Antelope and Buffalo Springs that discharge near the east boundary of the Park. Recharge to the Simpson and Arbuckle aquifers is from precipitation on outcrops of these two rock groups. The aquifers are confined by overlying conglomerate of the Vanoss Formation west of these outcrops (plate 1).

Table 4. Daily mean discharges for Antelope Spring at Sulphur, Oklahoma (station number 07329849, plate 2), for period of record Nov. 20, 1985–Dec. 31, 1987 (in cubic feet per second)

Day	1985		1986											
	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	---	4.0	5.8	5.2	4.3	2.4	4.0	4.3	4.7	3.0	2.4	2.4	1.9	3.6
2	---	4.3	5.8	5.2	4.3	2.7	3.6	4.3	4.7	3.0	2.4	2.4	1.7	3.6
3	---	4.7	5.8	5.2	4.3	2.7	3.6	4.3	4.7	3.0	2.4	2.4	1.7	3.6
4	---	4.7	5.8	5.8	4.3	2.7	3.6	4.3	4.7	3.0	2.7	2.4	1.9	3.6
5	---	4.7	5.8	5.8	4.3	2.7	4.0	4.3	4.7	3.0	3.0	2.4	1.9	3.6
6	---	4.7	5.8	5.8	4.0	2.4	4.0	4.3	4.7	3.0	3.0	2.4	2.1	3.3
7	---	5.2	5.8	5.8	4.3	2.4	4.0	4.3	4.7	3.0	3.0	2.4	2.1	3.3
8	---	5.2	5.8	5.8	4.7	2.4	4.0	4.3	4.7	3.0	3.3	2.4	2.1	3.3
9	---	5.2	5.8	5.8	4.3	2.4	4.0	4.3	4.7	3.0	3.3	2.4	2.1	3.3
10	---	5.2	5.8	5.8	4.3	2.4	4.0	4.3	4.7	3.3	3.3	2.4	2.1	3.3
11	---	5.2	5.8	5.8	4.3	2.4	4.0	4.3	4.7	3.6	3.0	2.4	2.1	3.6
12	---	5.2	5.8	5.8	4.3	2.4	4.0	4.3	4.3	3.6	3.0	2.4	2.1	3.6
13	---	5.2	5.8	5.8	4.3	2.4	4.0	4.3	4.3	3.6	3.0	2.4	2.1	3.6
14	---	5.2	5.8	5.8	4.3	2.4	4.0	4.3	4.0	3.6	3.0	2.7	2.4	3.6
15	---	5.2	5.8	5.8	4.3	2.4	4.0	4.3	4.0	3.6	3.0	2.4	2.4	4.0
16	---	5.2	5.8	5.8	4.3	2.7	4.3	4.3	3.6	3.6	3.0	2.4	2.4	4.0
17	---	5.2	5.8	5.2	4.3	2.7	4.7	4.3	3.6	3.6	3.0	2.1	2.4	4.0
18	---	5.2	5.8	5.8	4.3	3.6	4.7	4.3	3.6	3.6	3.0	1.7	2.4	4.0
19	---	5.2	5.2	5.8	4.3	3.6	5.2	4.3	3.6	3.6	3.0	1.7	2.4	4.0
20	3.3	5.2	5.2	5.8	4.3	3.6	5.8	4.3	4.0	3.6	3.0	1.4	2.4	4.0
21	3.6	5.2	5.2	5.8	5.2	3.3	5.8	4.3	4.0	3.6	3.0	1.4	2.4	3.6
22	3.6	5.2	5.2	5.8	4.3	3.3	5.8	4.7	4.0	3.0	3.0	1.4	2.4	3.6
23	3.6	5.2	4.7	4.7	4.0	3.3	6.4	4.7	4.0	2.7	3.0	1.3	2.4	4.0
24	3.6	5.8	4.7	4.7	3.0	3.6	6.4	4.7	4.0	2.7	3.0	1.3	2.4	4.0
25	3.6	5.8	4.7	4.7	3.0	3.6	5.8	4.7	4.0	3.0	2.7	1.3	2.4	4.0
26	4.0	5.8	4.7	4.7	3.0	3.6	4.7	4.7	3.6	3.0	2.7	1.3	2.4	4.0
27	4.0	5.8	4.3	4.3	2.7	3.6	4.3	4.7	3.3	2.7	2.7	1.3	2.4	4.0
28	4.0	5.8	4.7	4.3	2.4	3.6	4.3	4.7	3.3	2.7	2.7	1.3	2.7	4.0
29	4.0	5.8	4.7	---	2.4	4.0	4.3	4.7	3.3	2.4	2.7	1.3	3.3	4.0
30	4.0	5.8	4.7	---	2.4	4.0	4.3	4.7	3.0	2.4	2.7	1.7	3.6	4.0
31	---	5.8	4.7	---	2.4	---	4.3	---	3.0	2.4	---	1.9	---	4.0
Mean	--	5.22	5.39	5.45	3.90	2.98	4.51	4.42	4.07	3.13	2.90	1.97	2.30	3.75

Table 4. Mean daily discharges for Antelope Springs at Sulphur, Oklahoma for period of record Nov. 20, 1985–Dec. 31, 1987 (in cubic feet per second)—**Continued**

Day	1987											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	4.0	4.7	4.3	4.7	3.3	4.7	4.3	3.6	3.3	2.7	4.0	4.3
2	4.3	4.7	4.7	4.7	3.0	4.7	4.3	3.6	3.0	2.7	4.0	4.3
3	4.3	4.7	5.2	4.7	3.3	4.7	4.3	4.0	3.0	2.7	4.0	4.3
4	4.3	4.7	5.2	4.7	3.3	4.7	4.3	3.6	3.0	2.7	4.0	4.7
5	4.3	4.7	5.2	4.7	3.3	5.2	4.3	3.3	3.0	2.7	3.6	4.7
6	4.3	4.7	5.2	5.2	3.3	5.2	4.3	3.3	3.0	2.7	3.6	4.7
7	4.3	4.0	5.2	5.2	3.6	5.2	4.3	3.3	3.0	2.7	3.6	4.7
8	4.3	4.0	5.2	5.2	3.6	5.2	4.3	3.3	3.0	2.4	3.6	4.3
9	4.3	4.0	5.2	4.7	3.6	5.2	4.0	3.3	3.0	2.7	3.6	4.3
10	4.0	4.0	5.2	4.7	3.6	5.2	4.0	3.3	3.0	2.7	3.6	4.3
11	4.0	4.0	5.2	4.7	4.0	5.2	4.0	3.3	3.3	3.0	3.6	4.0
12	4.0	4.0	5.2	4.7	4.0	5.2	4.0	3.3	3.3	3.0	3.3	4.0
13	4.3	4.0	4.7	4.7	4.0	5.2	4.0	3.6	3.3	3.0	3.3	4.0
14	4.3	4.0	4.7	4.7	4.0	5.2	4.0	3.6	2.7	3.0	3.3	4.0
15	4.3	4.0	5.2	4.7	4.6	5.8	4.0	3.6	3.0	3.0	3.3	3.6
16	4.3	4.0	5.2	4.3	4.0	5.8	4.0	3.6	3.0	3.3	3.6	3.6
17	4.3	4.0	5.2	4.7	4.0	5.8	4.0	3.6	3.0	3.0	4.0	3.6
18	4.3	4.0	5.2	4.0	4.3	5.8	4.0	3.6	3.0	3.0	4.0	4.0
19	4.7	4.0	4.7	3.3	4.3	5.8	3.6	3.6	3.0	3.0	4.0	4.3
20	4.7	4.3	4.7	3.0	4.3	5.8	3.6	3.6	3.0	3.3	4.0	4.7
21	4.7	4.0	4.7	3.3	4.3	5.8	3.6	3.0	3.0	3.3	4.0	5.2
22	4.7	4.0	4.7	3.3	4.3	5.8	3.6	3.3	3.0	3.6	4.3	4.7
23	4.7	4.0	4.7	2.7	4.3	5.2	3.6	3.0	3.0	3.6	4.3	5.2
24	5.2	4.3	4.7	2.6	4.3	4.7	3.6	2.7	3.0	3.6	4.3	5.2
25	5.2	4.3	4.7	3.0	4.3	4.7	3.6	2.7	3.0	4.0	4.3	5.8
26	4.7	4.3	4.3	3.0	4.3	4.7	3.6	2.7	2.7	3.6	4.3	5.8
27	5.2	.0	4.7	2.7	4.3	4.7	3.6	3.0	2.7	3.6	4.0	6.4
28	4.7	4.0	4.7	3.0	4.3	4.7	3.6	3.0	2.7	3.6	4.0	7.0
29	4.7	--	4.7	3.0	4.3	4.3	3.6	3.3	2.7	3.6	4.0	7.6
30	5.2	--	4.7	3.3	4.7	4.3	3.6	3.0	2.7	4.0	4.0	7.0
31	4.7	--	5.2	---	4.7	--	3.6	3.3	---	4.0	---	7.0
Mean	4.49	4.19	4.92	4.04	3.95	5.15	3.91	3.32	2.98	3.15	3.85	4.88

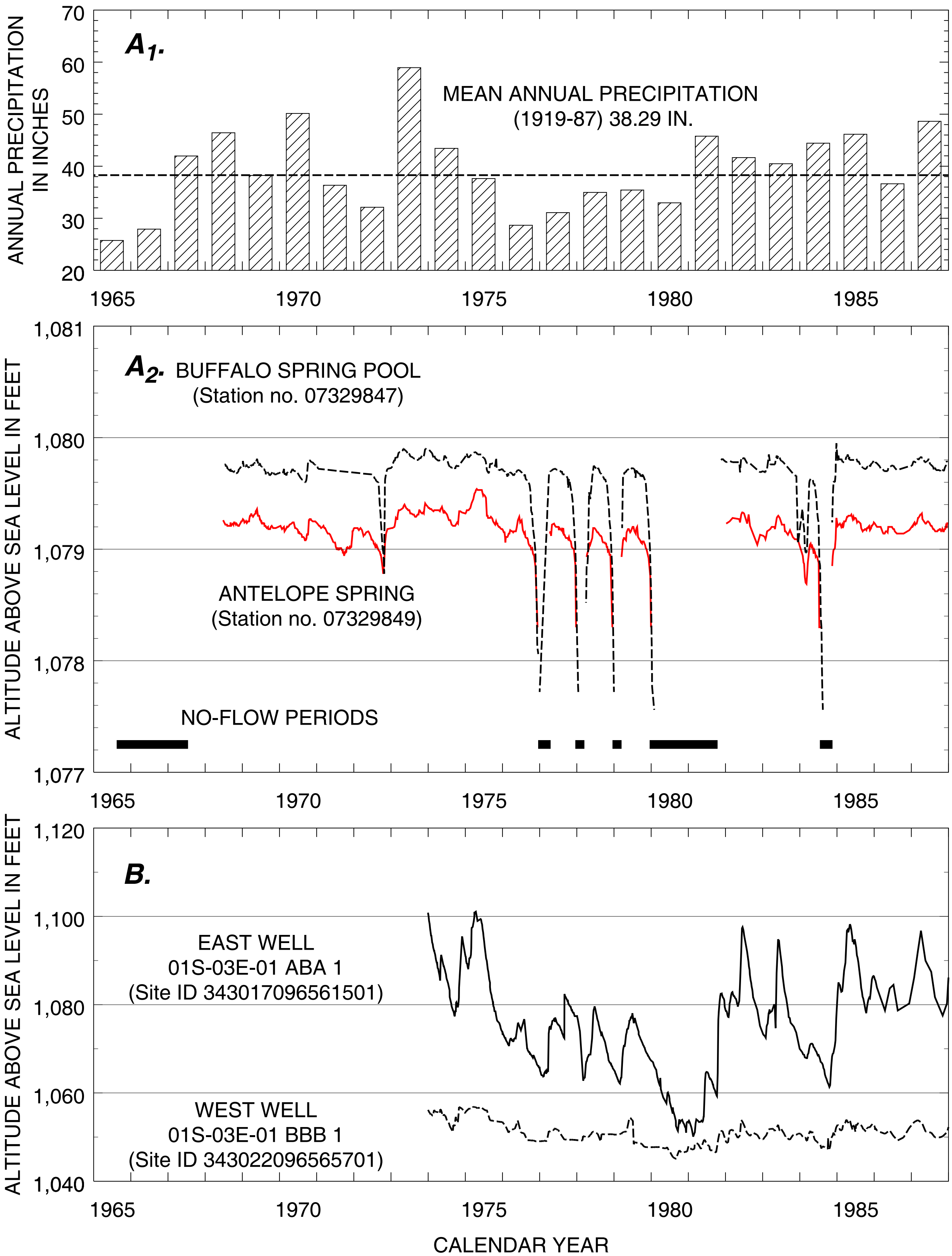


Figure 4. (A_1) Annual precipitation at the Chickasaw National Recreation Area (1965–87), (A_2) altitudes of water surface for Antelope Spring and Buffalo Spring Pool (1968–87), and periods of no flow at the springs, and (B) altitude of ground-water levels in East and West Wells (1974–87).

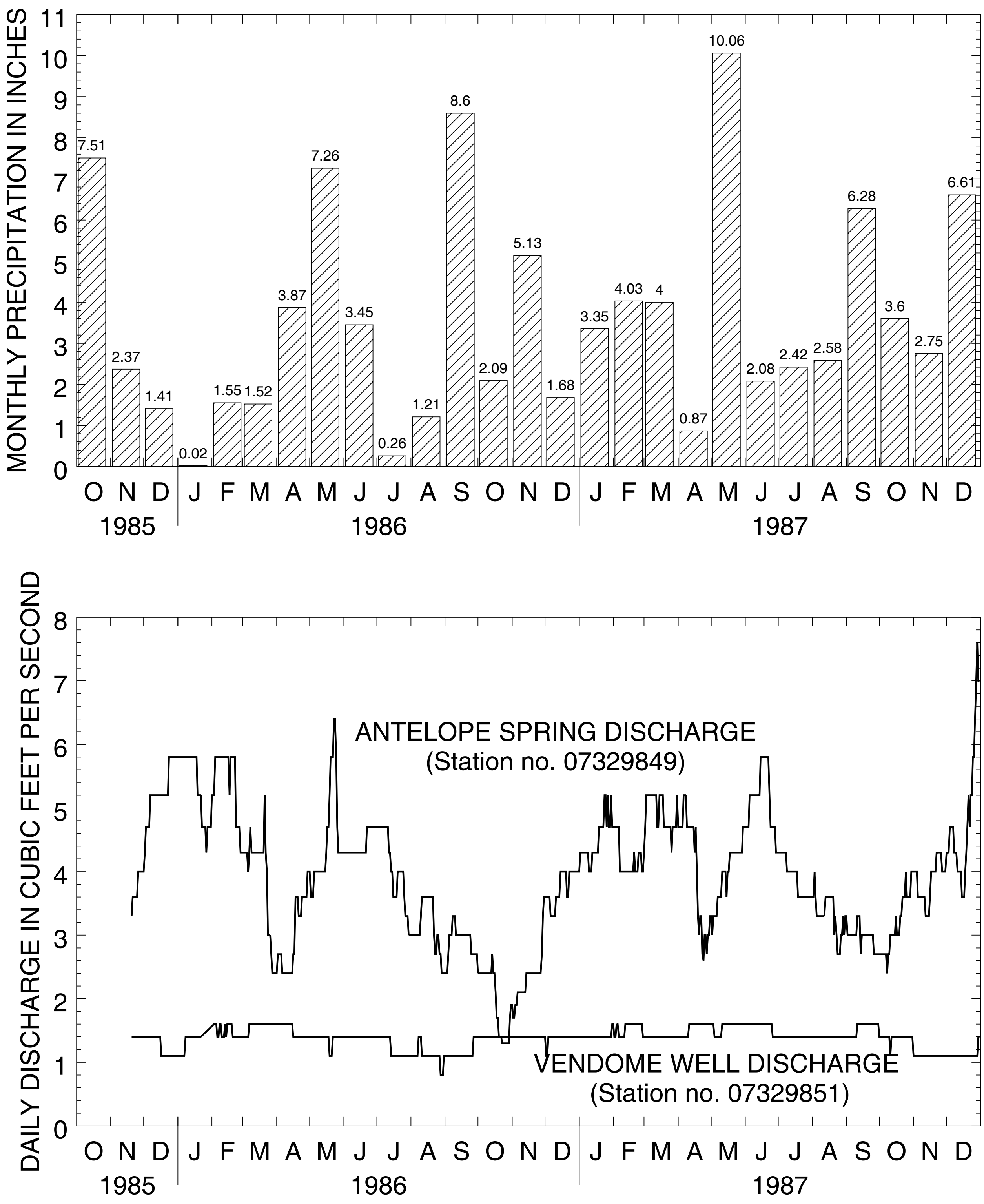


Figure 5. (A) Monthly precipitation at Chickasaw National Recreation Area, October 1985 through December 1987 (data from National Park Service) and (B) daily discharges for Antelope and Vendome Well, November 1985 through December 1987.

Table 5. Periods when both Antelope and Buffalo Springs have been dry, 1888–1984

[Dates from National Park Service files except as noted. Duration assumes flow ceased and resumed at mid-month]

Date flow ceased	Date flow resumed	Duration in months	Remarks
Month/year	Month/year		
1888	1888	Unknown	Dunn, 1953
1891	1891	Unknown	Boeger, 1987
1896	1896	Unknown	Gould, 1939
3/1911	4/1912	13	Buffalo Spring flow ceased 6/1911; Dunn, 1953
9/1912	11/1913	14	
3/1918	12/1919	21	Boeger, 1987
4/1927	8/1927	4	
8/1934	9/1936	25	Probable intermittent flow during this period; Boeger, 1987
9/1937	2/1938	5	Boeger, 1987
9/1938	6/1940	22	
12/1951	4/1952	4	Buffalo Spring flow ceased 2/1952; Boeger, 1987
9/1952	6/1954	21	
8/1954	5/1957	33	
1/1959	12/1959	11	
8/1963	11/1964	15	Boeger, 1987
8/1965	7/1967	23	
12/1976	4/1977	4	Buffalo Spring flow ceased 1/1977
12/1977	3/1978	3	Buffalo Spring flow ceased 1/1978
12/1978	3/1979	3	
12/1979	10/1981	22	Buffalo Spring flow ceased 1/1980
7/1984	11/1984	4	Buffalo Spring flow ceased 8/1984

Occurrence and Movement

Several investigators have conjectured about the direction of ground-water movement and the source of the ground water contributing to the flow of the springs. Gould (1906) states that flow from four artesian wells, about 450 to 500 ft deep, in Sulphur is derived from the upper part of the Simpson sandstone and “it is very probable that the water of the springs is derived from the same source.” Gould and Schoff (1939) believed that the spring waters originate in sandstone of the Simpson Group, and discharge to the surface through joints or fissures in the overlying Vanoss Formation, which they referred to as the Pontotoc conglomerate. They also speculated that the freshwater in Antelope and Buffalo Springs and the water in the Sulphur wells originates from recharge to conglomerate of the Vanoss Formation, immediately south and east of the Park.

Dunn (1953) states that freshwater is in the aquifer between 500 and 700 ft above sea level and mineral waters are in the aquifer between 100 and 400 ft above sea level. He states further that none of the mineral wells are cased or sealed to prevent “mixing” of the fresh and mineral waters. Apparently few, if any, of the casings in the wells producing mineral water extend to a depth of more than 300 ft below land surface (700 ft above sea level).

D.L. Hart, Jr. (written commun., 1972) collected ground-water-level, spring-discharge, and water-quality data at selected wells and springs in the study area and used this information along with the known geology to describe the relation between the geology and the regional ground-water flow system. Hart emphasized that no test drilling has been conducted to confirm the hydrologic and geologic factors controlling the flow characteristics in the area. He believed, however, that the Sulphur Fault (plate 1), is probably the principal control of freshwater flow to the Park. He indicates that water discharging from Antelope and Buffalo Springs is derived from the limestone and dolomite of the Arbuckle aquifer and not from the overlying

Vanoss Formation as suggested by Gould and Schoff (1939). The Arbuckle Group dips, in general, northwest and water levels in wells in the outcrop area are 100 to 200 ft higher than the springs in the Park. Hart assumes that water from the Arbuckle aquifer reaches the springs by moving upward under this hydraulic head through fractures and solution openings in the overlying, tightly cemented conglomerate of the Vanoss Formation. He also shows that a close correlation exists between seasonal ground-water levels in wells in the Arbuckle aquifer and seasonal discharge from Antelope and Buffalo Springs.

D.L. Hart, Jr. (written commun., 1972) indicates that water from the mineralized springs and flowing wells in the western part of the Park is probably from the sandstone of the Simpson aquifer that crops out east and south of the Park and dips generally northwest. Water levels in wells south of the Park in the Simpson aquifer are generally 50 to 100 ft higher than the mineral springs. He states that a zone of mixing occurs between the waters of the Arbuckle and Simpson aquifers in the central part of the Park as water moves up through fractures in these two aquifers and the overlying Vanoss Formation. These interpretations of the origin of the fresh and mineralized spring waters are based on the similarity between the water quality of the springs and the water quality of ground water in up-gradient wells for both the freshwater Arbuckle aquifer and mineralized Simpson aquifer.

Fairchild, Hanson, and Davis (1990) describe the regional ground-water flow system east of the Park based on ground-water levels measured in about 125 wells during the winters of 1976–77 and 1977–78. Even though the ground-water-level information is sparse in the vicinity of the Park, a potentiometric-surface map indicates potentiometric highs 4–5 mi east and 1–2 mi south of the Park, with ground-water movement in a westerly and northwesterly direction toward the Park.

A generalized potentiometric map of the Arbuckle-Simpson aquifer for the outcrop area east and south of the Park is shown in figure 6. The water-level contour lines were drawn assuming that the fault system shown in plate 1 does not affect the potentiometric surface. Most of the water-level data used to define this map are from data collected by Fairchild, Hanson, and Davis (1990) during the winters of 1976–77 and 1977–78. However, because of sparse water-level data for the winters, June 1977 measurements also were used to define the potentiometric surface northeast of the Park in the vicinity of Hickory. The map indicates that ground-water movement in the Arbuckle-Simpson aquifer in the vicinity of the Park is generally to the northwest. Unfortunately, no ground-water-level data are available within the immediate Park vicinity or in the confined part of the aquifer north and west of the Park to adequately define ground-water movement in these areas.

Barthel (1985) also developed a generalized potentiometric map of the Arbuckle-Simpson aquifer in the study area. It was based on ground-water levels for the winter of 1985 from 36 wells distributed over a 60 mi^2 area north, south, and east of the Park. This map indicates that ground-water movement is generally to the west. Limited ground-water-level data were available north of the Park and no data were obtained west of the Park to prepare this map.

Ground-Water-Level and Flow-Discharge Fluctuations

Fluctuation of the potentiometic surface is the result of water added (usually from recharge by precipitation) or withdrawn (by springs, wells, or evapotranspiration) from storage. Ground-water levels have been measured intermittently since 1938 at about 400 wells within the study area. Figure 7 shows the location of selected wells where ground-water levels have been measured.

The earliest recorded ground-water-level measurement within the study area was made in January 1938 at well 01N–02E–14 ADD 1 about 3.5 mi northwest of the Park. Available records suggest that no additional wells were measured again until the 1950’s. The first continuous water-level recorder in the area was at a 2,500–ft deep well, 01N–05E–27 DCC 1, drilled into the outcrop of the Arbuckle Group about 10 mi east of the Park. A hydrograph showing the water levels in this well, which operated from January 15, 1960, to February 10, 1968, and from October 20, 1976, to July 25, 1979, is shown in figure 8. This record is representative of the ground-water-level trends in the outcrop area of the Arbuckle Group and probably represents ground-water-level trends in the recharge area contributing to the Park springs. Figure 8 shows that the water-level altitude varied a maximum of about 58 ft during the approximate 10–year period of record. The first inventory of ground-water levels in and adjacent to the Park was by the USGS (Goemaat and Willard, 1983) during the fall and winter of 1968, when depth to water was measured in about 40 wells within the study area.

In 1972 the National Park Service drilled two wells, East Well and West Well, on the north boundary of the Park (plate 2) to determine if localized pumping affected regional ground-water levels. These wells also were established to observe the relation between ground-water levels and discharge from nearby Antelope and Buffalo Springs.

East Well, 01S–03E–01 ABA 1, is located in the northeast corner of the Park (plate 2), 1,000 ft northeast of Buffalo Spring and 1,000 ft east of Antelope Spring. The well is 238 ft deep, the top 25 ft is cased, and the remaining hole is uncased and penetrates the Arbuckle aquifer.

The East Well was drilled in August 1972 and continuous records of ground-water levels have been collected since December 28, 1973. There is natural asphalt throughout the lower 134 ft in East Well, which interferes with the movement of the recorder float in the well, resulting in erroneous water-level records during some periods. In July 1979, the well was cleaned to remove the naturally occurring asphalt. Periodic measurements of depth to water have been obtained by the National Park Service during June 1980 to October 1981 and February 1984 to January 1987 to check the continuous record. Selected water-level measurements at 5–day intervals from the continuous record are stored in the USGS National Water Information System computer file. For periods when the record is

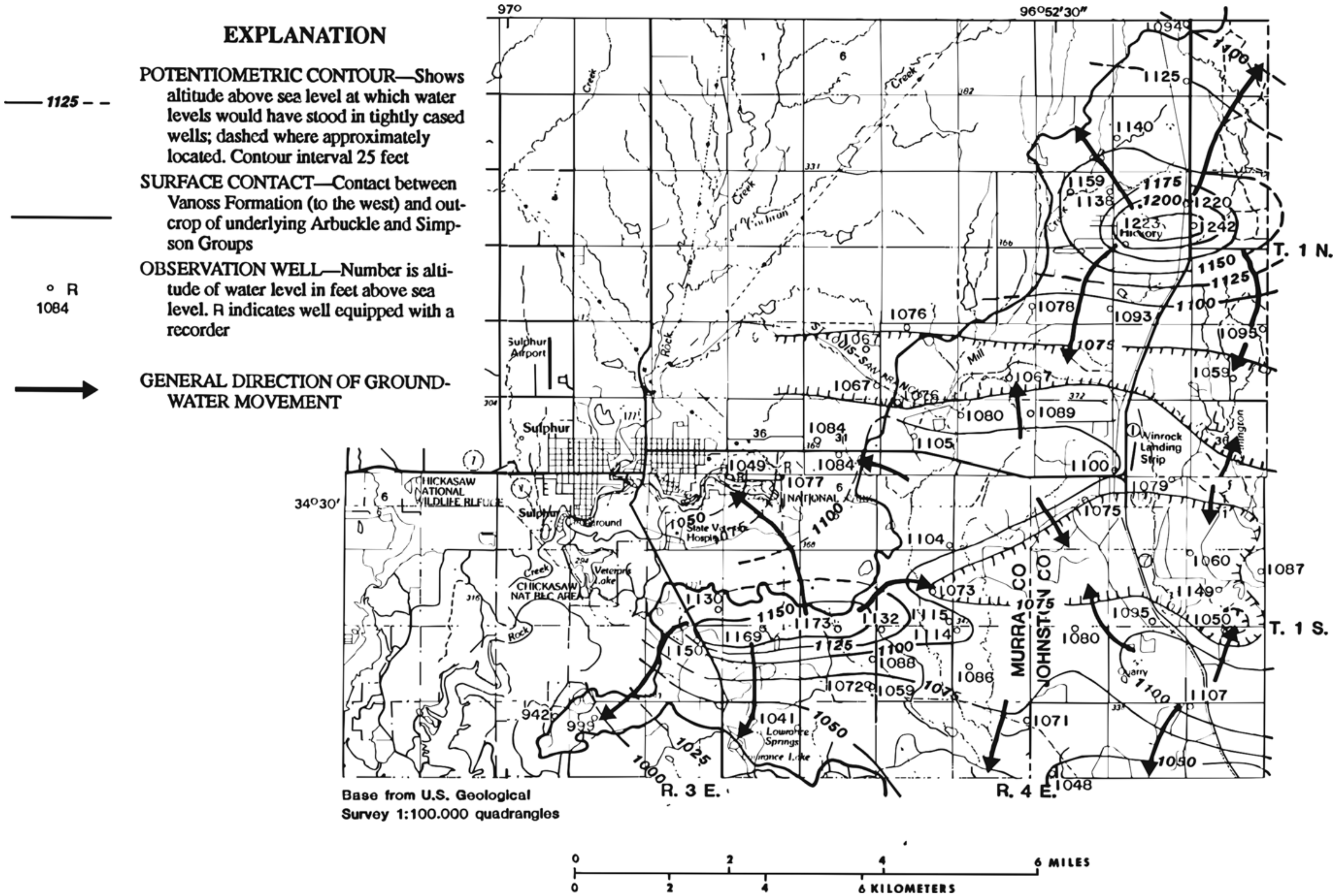


Figure 6. Locations of well, generalized potentiometric surface, and generalized direction of ground-water movement in the Arbuckle-Simpson aquifer.

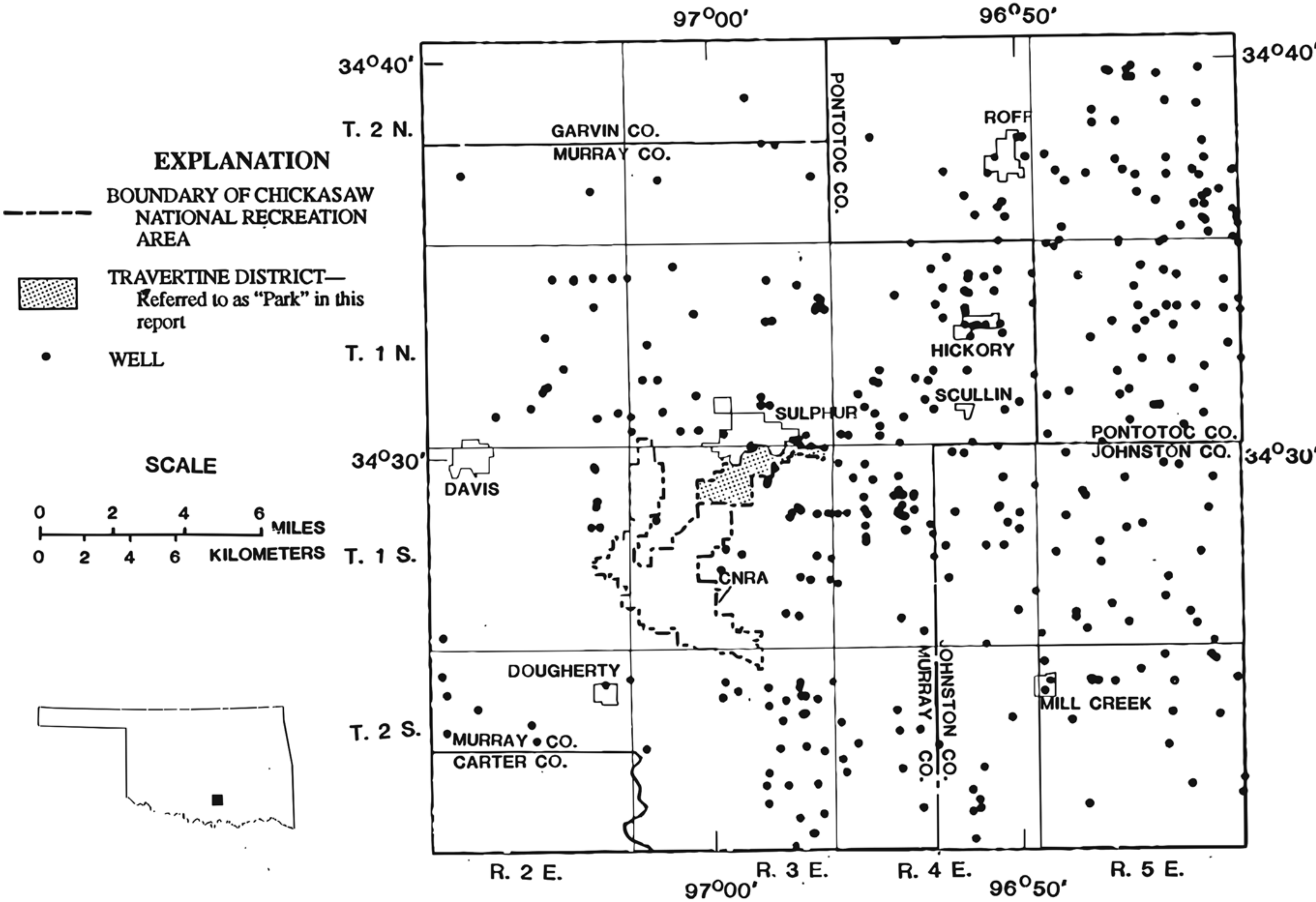


Figure 7. Locations of selected ground-water observation wells in the study area.

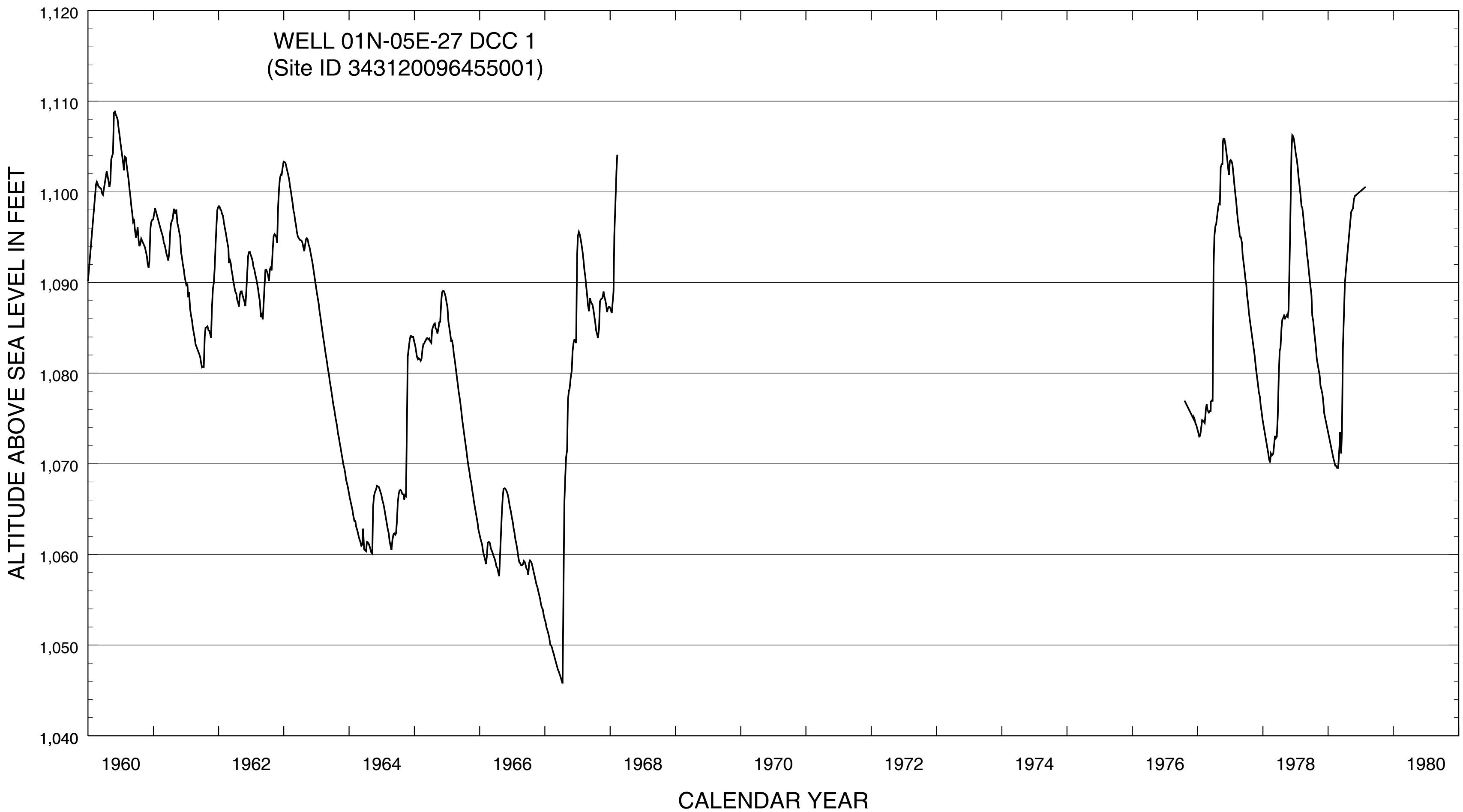


Figure 8. Water-level altitude in well 01N–05E–27 DCC 1, located 10 miles east of Park, 1960–80.

considered unreliable due to build-up of asphalt throughout the lower 134 ft in the well, only the periodic water-level measurements made by the National Park Service have been stored in the National Water Information System. Figure 4B shows a plot of the altitude of the water level in the East Well for the period of continuous record 1974–87.

Depth to water below land surface in the East Well has fluctuated between a minimum of 38.26 ft on December 28, 1973, which is the reading at the start of record, and a maximum of 89 ft on February 17, 1981.

The recorder trace for this well shows daily and monthly changes in water level of as much as 5 ft per month. Some of this fluctuation may be caused by pumping from the City of Sulphur wells located about 4,000 ft northwest of the East Well. On June 5, 1980, Sulphur began pumping Well S8 (plate 2), also referred to as Horseman Well, a 675–ft deep well located 1,900 ft west of the East Well; this pumping, however, does not appear to have caused a corresponding water-level decline at the East Well.

On October 26, 1978, the USGS obtained caliper and natural gamma logs of the East Well to a depth of 96 ft below land surface. The caliper log shows that the hole diameter averages 6.5 to 7 in. in the upper 60 ft, but is as wide as 15 in. in the lower 36 ft of the logged interval. The natural gamma log shows marked increases in naturally occurring gamma radiation at depths of 15 to 30 ft and 60 to 80 ft below land surface, suggesting that clay lenses may exist in these zones.

West Well, 01S–03E–01 BBB 1, is located about 2,700 ft west of Antelope Spring and 800 ft southeast of the City of Sulphur well field (plate 2). The well is 436 ft deep and open to the Arbuckle aquifer. Caliper logs indicate that the well may be cased to a depth of 23 ft below land surface.

The West Well was drilled in August 1972 and continuous water-level records have been collected at this site since December 28, 1973. Periodic measurements of depth to water also have been obtained by the National Park Service from December 1973 to January 1986. Selected water-level measurements at 5–day intervals are stored in the USGS National Water Information System computer files. For periods when the record is considered unreliable because of buildup of naturally occurring asphalt in the well, only the periodic water-level measurements made by the National Park Service are stored in the National Water Information System. Figure 4B shows a plot of the altitude of the water level in the West Well for the 1974–87 period of record.

Depth to water below land surface in the West Well has varied between 23.10 ft on March 20, 1975, and 34.93 ft on September 1, 1980. The recorder chart indicates many days of missing or questionable data and frequent inconsistencies between the recorded depth and measured depth to water. A slug test performed in the well on August 12, 1984, indicated a slow recovery in response to sudden changes in water level. These problems are attributed to naturally occurring asphalt, which collects in the well throughout the uncased part of the well. Accumulated asphalt was removed from the West Well during July 1979, but asphalt continued to accumulate in the well, and, on June 24, 1985, the well was redrilled to a depth of 426 ft.

On August 24, 1978, the USGS obtained conductivity, gamma-ray, temperature, caliper, and flow-direction log data to a depth of 70 ft, where an obstruction in the well was encountered. These data are insufficient to adequately define the lithologic characteristics of the formations penetrated by the well.

Fairchild, Hanson, and Davis (1990), monitored water levels in 15 wells in the study area from December 1976 to May 1979. Three of these wells, including the East and West Wells, were equipped with continuous ground-water-level recorders and the remaining 12 wells were measured monthly.

Another inventory of ground-water levels in Murray County was made by the USGS in 1981 (Goemaat and Willard, 1983). A total of 101 wells (including several flowing wells) were visited within about a 5–mi radius of the Park. Drillers' logs indicate that a few of these wells are completed in the Vanoss Formation, but most are believed to have been drilled into the Arbuckle-Simpson aquifer. Depth to water in the nonflowing wells ranged from near land surface at several wells to 440 ft below land surface at well 01N–03E–33 CBB 1.

As indicated previously, the tightly cemented Vanoss Formation in the Park vicinity acts as a confining layer over the underlying Arbuckle-Simpson aquifer. Water levels in the aquifer recharge area east of the Park are 100 to 200 ft higher than the land surface in the Park, and wells that pass through the Vanoss and tap the aquifer commonly flow. National Park Service files indicate that one of the first flowing artesian wells in the Sulphur area was the Bridgeman Well (no. 3, table 6, at back of report), drilled in about 1889. Since that time, references have been made to approximately 43 flowing wells, but some duplication of sites may exist because different names apparently refer to the same well. No documentation is available about the location of three of these wells. Table 6 lists the flowing wells, in several of which the discharge is unknown or which no longer flow. Plate 2 shows 40 wells with known locations.

Total discharge was estimated to be 20,500 gal/min from 16 flowing wells in the Sulphur area during 1937 (Gould and Schoff, 1939). Assuming a recharge rate of 1 foot per year (ft/yr), they calculated that the recharge area required to produce this discharge would be 51.5 mi^2. They also assumed that all of the flowing wells discharge only from the Simpson aquifer and that the Simpson has an estimated recharge area of 15 mi^2 to the east and south of the Park. Therefore, they concluded that approximately three times more water is being discharged annually from the artesian wells than is being recharged.

Only eight of the wells reported by Gould and Schoff flowed in 1987; however, an additional eight flowing wells within the area shown in figure 2 currently are discharging water. Table 6 lists the discharges estimated at each well as reported in various National Park Service files, memoranda, and reports as of December 1987. A preliminary estimate of the discharges from the flowing wells as of 1987 indicates the total flow is probably only about 10 percent of the flows reported in the 1930's.

The most prominent flowing well in the study area is the Vendome Well (no. 36 in plate 2 and table 6) located at the north edge of the Park. This well was drilled in 1922 to a depth of 365 ft and, until about 1975, the well supplied water to a public swimming pool. The well flows continuously from a 6–in. diameter well casing into an octagonal rock basin. Water discharges through an opening at the east side of the basin and flows southeasterly about 1,250 ft to Travertine Creek.

Comments written on a photograph of the well (circa 1930) state that the Vendome Well is the "largest flowing mineral well in the world" and discharges "3,500 gallons per minute" (National Park Service files). The discharge estimates given in table 6, however, suggest that the Vendome Well discharge may not have exceeded about 2,500 gal/min. Harp and others (1985) estimate that the flow from the well averaged about 2 ft^3/s (900 gal/min) during their study. Their estimates were obtained by measuring the height of the flow above the vertical well casing.

Geophysical logs indicate casing damage in the Vendome Well. The USGS ran caliper and natural gamma-ray logs of the well on March 2, 1978, to a depth of 245 ft. The caliper log indicates that the well diameter ranges between 4 1/2 and 6 in. throughout most of this depth, but widens to 8 to 9 in. for short intervals of less than 1 ft of depth at about 95 ft and 240 ft. On April 6, 1978, the USGS logged the well with temperature, resistivity, flow-direction, and spontaneous-potential and gamma-gamma tools to a depth of 245 ft. Both the gamma-gamma log and the resistivity log indicate that lenses of clay or shale occur at several intervals throughout the logged depth. The flow-direction log indicates that water may enter the well at depths of 40, 80, and 128 ft. On August 20, 1980, the National Park Service lowered a television camera into the well and obtained a visual log to a depth of 324 ft. Harp and others (1985) report that the well was cased to a depth of 300 ft with an inner diameter of 6 in., that the casing is "extremely corroded at depths between 250 and 300 ft", and that the television log shows that "a large cavity, 3 ft in thickness, was observed between 320 and 323 ft."

Flow from the Vendome Well has been monitored since November 20, 1985, when a weir was installed in the concrete channel 70 ft downstream from the well, and a continuous recording water-level recorder was placed in operation on the right bank of the channel. This site is assigned gaging-station number 07329851 (plate 2). Discharge measurements have been obtained by the USGS at approximately 5– to 6–week intervals since the gage began operation. Maximum discharge recorded since the station was established in 1985 was 1.6 ft^3/s (718 gal/min) during many days. Maximum discharge measured was 1.64 ft^3/sec (736 gal/min) on January 23, 1986. Minimum discharge recorded during the period of record was 0.8 ft^3/s (359 gal/min) during August 28–30, 1986. Average discharge during the period of record is about 1.4 ft^3/s (629 gal/min). A plot of the daily average discharges is shown in figure 6B. Fluctuations in discharge correspond with the fluctuations in regional ground-water levels as seen in figure 4B. Table 7 lists the daily mean discharges for Vendome Well for the period 1985–87.

Ground-Water Withdrawals

Relatively small amounts of water are pumped for domestic use from many wells completed in the Arbuckle-Simpson aquifer in the study area. However, the largest withdrawals of water from the aquifer by pumping within the study area are from the State Veterans Hospital well and from two well fields: City of Sulphur wells (9 wells) and OG&E power plant (3 wells).

National Park Service files indicate that five artesian wells (not shown in figure 2 or listed in table 6) had been drilled within 3/4 mi of the original Sulphur Post Office by April 1906 for water-supply purposes. The location of the Post Office at that time was in T. 1 S., R. 3 E., sec. 34, SW 1/4, on lot 9, block 176 between Muskogee and Davis Avenues. Water supply from these wells apparently either dwindled or became insufficient to meet the town's needs, and in 1922, six City wells were drilled east of town adjacent to the northeast boundary of the Park (wells S1–S6, plate 2 and table 10). The wells are from 450 to 725 ft deep and initially four of the six wells flowed at the surface (Gould and Schoff, 1939). With time, the hydraulic head declined significantly in all of the wells and by 1939 pumps had to be installed at the wells to pump water into storage tanks.

Gould and Schoff (1939) state that the wells probably take water from the Pontotoc conglomerate, now called the Vanoss Formation, because the water is "much less mineralized than that from the (underlying) Simpson." He theorized that most of the well water originates from recharge to the east in the Arbuckle outcrop and migrates down gradient into the Vanoss Formation.

A seventh City well (well S7 in plate 2 and table 6) was drilled about 200 ft east of the City's waterworks plant after the first six wells had been completed. The date this well was completed is unknown but it is believed to have been drilled prior to 1955. The well probably discharged freely at the land surface when completed, but the amount is unknown (Ralph Watson, Sulphur Public Works Director, personal commun., 1991).

On August 7, 1955, the City completed an eighth well (well S8 in plate 2 and table 6) on the Horseman property about 2,200 ft southeast of the waterworks plant. The purpose of this well was to pump water into Travertine Creek below Antelope and Buffalo Springs, which were dry because of a persistent drought (Boeger, 1987). National Park Service records indicate that well S8 began pumping on June 5, 1980, and continued pumping intermittently until about November 13, 1985, when the well was reported to be "free flowing." In 1983 a well (City Well S9 in plate 2 and table 6) was drilled 1,500 ft northeast of the water plant near State Highway 7, which also discharged freely at the land surface after completion.

Poe and Associates (1987) reported that the City of Sulphur wells "have flowed 20 million gallons per month during the wet months." By 1987, only five wells were used to supply

Table 7. Daily mean discharges for Vendome Well at Sulphur, Oklahoma (station no. 07329851, plate 2) for period of record Nov. 20, 1985–Dec. 31, 1987 (in cubic feet per second)

Day	1985		1986											
	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	---	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.4
2	---	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.1
3	---	1.4	1.1	1.6	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.1
4	---	1.4	1.1	1.6	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.4
5	---	1.4	1.1	1.6	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.4
6	---	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.4
7	---	1.4	1.1	1.4	1.6	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.4
8	---	1.4	1.4	1.6	1.6	1.6	1.4	1.4	1.4	1.4	1.1	1.4	1.4	1.4
9	---	1.4	1.4	1.6	1.6	1.6	1.4	1.4	1.4	1.4	1.1	1.4	1.4	1.4
10	---	1.4	1.4	1.4	1.6	1.6	1.4	1.4	1.4	1.4	1.1	1.4	1.4	1.4
11	---	1.4	1.4	1.4	1.6	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.4
12	---	1.4	1.4	1.4	1.6	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.4
13	---	1.4	1.4	1.6	1.6	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.4
14	---	1.4	1.4	1.4	1.6	1.6	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
15	---	1.4	1.4	1.6	1.6	1.6	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
16	---	1.4	1.4	1.6	1.6	1.4	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
17	---	1.1	1.4	1.6	1.6	1.4	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
18	---	1.1	1.4	1.6	1.6	1.4	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
19	---	1.1	1.4	1.6	1.6	1.4	1.1	1.4	1.1	1.1	1.1	1.4	1.4	1.4
20	1.4	1.1	1.4	1.4	1.6	1.4	1.1	1.4	1.1	1.1	1.1	1.4	1.4	1.4
21	1.4	1.1	1.4	1.4	1.6	1.4	1.1	1.4	1.1	1.1	1.1	1.4	1.4	1.4
22	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
23	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
24	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
25	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
26	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.1	1.4	1.4	1.4
27	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	1.1	1.4	1.4	1.4	1.4
28	1.4	1.1	1.4	1.4	1.6	1.4	1.4	1.4	1.1	.80	1.4	1.4	1.4	1.4
29	1.4	1.1	1.4	---	1.6	1.4	1.4	1.4	1.1	.80	1.4	1.4	1.4	1.4
30	1.4	1.1	1.4	---	1.6	1.4	1.4	1.4	1.1	.80	1.4	1.4	1.4	1.4
31	---	1.1	1.4	---	1.6	---	1.4	---	1.1	1.1	---	1.4	---	1.4
Mean	---	1.25	1.33	1.48	1.56	1.50	1.37	1.40	1.23	1.10	1.14	1.40	1.40	1.38

Table 7. Daily mean discharges for Vendome Well at Sulphur, Oklahoma (station no. 07329851, plate 2) for period of record Nov. 20, 1985–Dec. 31, 1987 (in cubic feet per second)—**Continued**

Day	1987											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	1.4	1.6	1.4	1.4	1.6	1.6	1.4	1.4	1.4	1.4	1.1	1.1
2	1.4	1.4	1.4	1.4	1.6	1.6	1.4	1.4	1.4	1.4	1.1	1.1
3	1.4	1.4	1.4	1.4	1.6	1.6	1.4	1.4	1.4	1.4	1.1	1.1
4	1.4	1.6	1.4	1.4	1.4	1.6	1.4	1.4	1.4	1.4	1.1	1.1
5	1.4	1.6	1.4	1.4	1.4	1.6	1.4	1.4	1.4	1.4	1.1	1.1
6	1.4	1.4	1.4	1.4	1.4	1.6	1.4	1.4	1.4	1.4	1.1	1.1
7	1.4	1.4	1.4	1.4	1.4	1.6	1.4	1.4	1.4	1.4	1.1	1.1
8	1.4	1.4	1.4	1.4	1.4	1.6	1.4	1.4	1.4	1.4	1.1	1.1
9	1.4	1.4	1.4	1.4	1.4	1.6	1.4	1.4	1.4	1.4	1.1	1.1
10	1.4	1.4	1.4	1.4	1.4	1.6	1.4	1.4	1.4	1.4	1.1	1.1
11	1.4	1.4	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.1	1.1	1.1
12	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
13	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
14	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
15	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
16	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
17	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
18	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
19	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
20	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
21	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
22	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
23	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
24	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
25	1.4	1.6	1.4	1.6	1.6	1.6	1.4	1.4	1.6	1.4	1.1	1.1
26	1.4	1.6	1.4	1.6	1.6	1.4	1.4	1.4	1.6	1.4	1.1	1.1
27	1.4	1.6	1.4	1.6	1.6	1.4	1.4	1.4	1.6	1.4	1.1	1.1
28	1.4	1.4	1.4	1.6	1.6	1.4	1.4	1.4	1.6	1.4	1.1	1.1
29	1.4	---	1.4	1.6	1.6	1.4	1.4	1.4	1.6	1.4	1.1	1.1
30	1.4	---	1.4	1.6	1.6	1.4	1.4	1.4	1.6	1.4	1.1	1.4
31	1.6	---	1.4	---	1.6	---	1.4	1.4	---	1.4	---	1.4
Mean	1.41	1.54	1.40	1.53	1.55	1.57	1.40	1.40	1.53	1.39	1.10	1.12

Table 8. Monthly and annual pumpage data for City of Sulphur wells S1–S9 (plate 2), 1965-87

[In 1,000 gallons; --, missing data; data from City of Sulphur]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1965	13,832	12,495	14,338	14,797	15,315	17,738	27,013	20,812	18,750	15,322	14,685	15,675	200,772
1966	16,890	16,035	16,822	17,910	17,955	19,583	21,649	18,948	16,597	17,047	15,045	16,365	210,846
1967	16,100	14,287	17,836	17,400	17,872	19,726	20,898	24,958	16,867	17,743	16,742	17,250	217,679
1968	18,259	16,336	17,692	16,750	17,122	18,997	20,187	21,760	17,449	15,825	14,662	14,925	209,964
1969	15,652	13,290	15,105	15,877	17,340	19,312	27,335	24,370	17,144	15,045	15,217	16,112	211,799
1970	16,950	15,187	15,867	16,710	19,439	19,260	27,021	28,540	18,682	16,678	16,372	16,920	227,626
1971	16,950	15,470	17,568	19,328	20,497	21,905	19,128	21,982	21,592	18,292	16,732	16,957	226,401
1972	18,675	17,940	19,870	21,468	23,335	27,232	31,080	28,941	24,600	22,005	19,770	22,462	277,378
1973	21,095	17,096	18,565	18,550	21,817	20,962	27,687	28,022	20,175	18,965	18,060	19,440	250,434
1974	19,687	17,085	19,740	20,145	23,580	22,281	31,694	26,780	20,782	--	19,305	21,652	--
1975	21,607	20,537	21,030	20,467	21,482	23,033	29,167	30,432	26,422	21,615	18,690	20,454	274,936
1976	21,202	19,972	20,270	20,497	21,330	25,322	29,440	34,746	32,656	28,250	20,680	20,385	294,750
1977	21,080	19,475	21,695	21,520	22,870	23,025	38,766	--	--	37,138	34,533	--	--
1978	30,500	30,835	35,117	--	35,796	35,743	--	--	37,584	38,559	36,819	--	--
1979	36,473	32,466	36,179	43,889	43,388	43,352	43,446	43,452	41,576	41,732	--	24,914	--
1980	24,611	22,393	23,545	25,924	26,676	15,302	45,958	44,388	35,413	26,880	23,586	23,008	337,684
1981	13,154	11,816	13,082	12,661	13,082	12,660	21,579	35,466	32,444	32,877	30,218	31,521	260,560
1982	33,402	31,383	33,119	32,207	34,252	34,575	35,743	35,743	34,590	35,743	34,590	--	--
1983	27,520	27,320	29,025	29,943	33,159	30,780	31,806	31,806	30,780	30,808	26,220	29,781	358,948
1984	37,824	27,909	29,105	--	28,519	32,871	34,875	34,875	33,750	33,750	33,750	34,935	--
1985	35,866	33,894	36,105	37,258	39,531	40,168	47,633	34,875	35,375	30,342	27,607	31,068	429,722
1986	29,801	24,678	28,094	28,369	29,913	33,532	52,615	48,337	35,718	32,093	31,022	31,568	405,740
1987	32,456	27,534	33,122	45,720	41,235	39,346	44,289	44,873	--	--	--	--	--

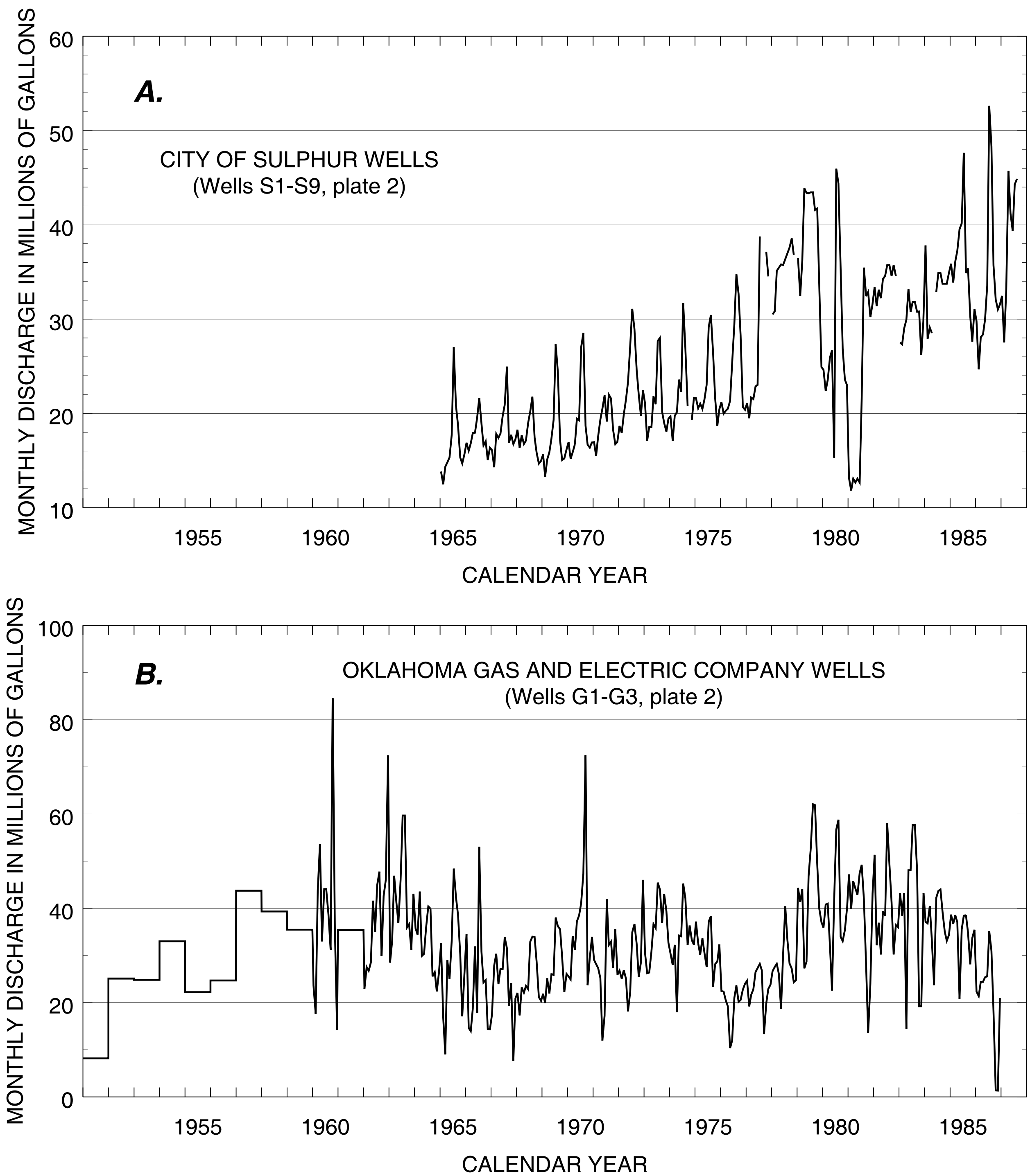


Figure 9. (A) Total monthly discharge of City of Sulphur waterworks wells (1965–87) (data from City of Sulphur), and (B) annual average discharge (1951–59, 1961) and total monthly discharge (1960, 1962–86) of Oklahoma Gas and Electric Company power-plant wells (data from Oklahoma Gas and Electric Company).

water to the City of Sulphur; well S1 is no longer operational and wells S4, S5, and S8 are open with artesian flow that discharges into Travertine Creek. Total daily pumpage from the City of Sulphur wells was recorded by the City for the period January 1, 1965–August 31, 1987. Table 8 shows the total monthly and annual pumpage values, and figure 9A shows a plot of these monthly values for that period. Table 8 shows that no data are available for several months during the period of record.

Lowest pumpage rates are during the winter months and highest rates are during the summer months, when water demands are high (fig. 9A). A moderate increase in pumpage occurred from 1965 to 1976 and a marked increase occurred from mid–1977 to late 1979. Annual pumpage, however, was relatively constant during the last 6 years of record (1982–87). The maximum water usage occurred in 1979 when the pumpage exceeded 40 million gallons per month from April through October. The reason for the unusually low pumpage during early 1981 is unknown, but precipitation was above normal for the first time since 1974.

During 1951 and 1952 three water-supply wells were drilled into the Arbuckle-Simpson aquifer by OG&E. These wells are located about three-quarters of a mile north of the City of Sulphur along Rock Creek (plate 2). Upon completion of drilling, the surface flow of each well was: 68 gal/min (G1); 1,560 gal/min (G2); and 2,000 gal/min (G3). An analysis of the drill cuttings made by the Oklahoma Geological Survey (memo from M.E. McKinley to OG&E dated July 23, 1953) indicates that a “considerable amount of structural relief” exists in the area. The top of the Arbuckle is more than 221 ft lower at well G2 than at well G3, and more than 191 ft lower than at well G1. They concluded that “flow in the Arbuckle dolomite sequence is apparently controlled by fractures rather than by permeable beds.”

The USGS, in an August 4, 1953, letter to OG&E, speculates that the well water may come from the Arbuckle aquifer, but there is no indication that one zone is more permeable than another. The letter also states that water may enter the wells from fractures and solution openings in the rock.

Annual pumpage rates for 1952–59, 1961, and monthly rates for January to December 1960 and January 1962 to December 1986 are available in the USGS National Water Information System computer files. Table 9 lists these annual and monthly pumpages and figure 9B shows a plot of these values for the period of record. Maximum annual pumpage by the OG&E plant was nearly 536 million gallons in 1979. Maximum monthly pumpage was 84.6 million gallons per month in October 1960. Minimum monthly pumpage was 1.4 million gallons per month during October and November 1986 prior to the plant’s closing in December 1986.

The State Veterans Hospital well (01S–03E–02 CAB 1) is located on the Hospital grounds approximately 80 ft east of the southeastern boundary of the Park (plate 2). There is no information on the date the well was established, its physical characteristics, or the formations penetrated. Daily pumpage records for 1987 obtained from the hospital indicated that pumping rates ranged from 11,000 gallons per day (gal/d) on February 8, 1987 to 72,000 gal/d on May 11, 1987.

Schornick, Harp, and Laguros (1976) investigated the “deprivation effects” that pumping and flowing wells have on discharge from Antelope and Buffalo Springs. In their investigation the regional aquifer system was assumed to be homogeneous and isotropic. Because no aquifer tests were performed, a range of possible “radius of influence” values of drawdown for each well were assumed. Their investigation suggests that the Vendome flowing well has the greatest influence on the freshwater springs, followed by the City of Sulphur wells and the OG&E wells.

Information on all of the wells discussed in this report have been entered into the USGS National Water Information system computer files. These files include, if known, the following types of information:

- Site identification number, legal description, and latitude and longitude
- Date drilled
- Availability of geophysical or lithologic logs
- Well diameter and total depth
- Depth to water below land surface (water level) and period of water-level record
- Altitude of land surface at well site to the nearest 5 ft
- Aquifer type (hydrologic unit)
- Date well was sampled if water-quality data have been collected

Table 10 (at back of report) lists the well sites in the study area and includes some of the information described above. In a few instances, the site identification number shown for a given well in the table does not agree with the true latitude and longitude for the well. These instances are footnoted in the table and the correct location of the well can be determined by the public land-survey number (local identifier) as described in the explanation following the table of contents.

Hydraulic Characteristics

The hydraulic characteristics of an aquifer describe its ability to store and transmit water. The more common characteristics as defined by Lohman (1972) include:

- Effective porosity (dimensionless)—the amount of interconnected pore space available for fluid transmission. It is expressed as a percentage of the total volume occupied by the interconnecting interstices.
- Hydraulic conductivity, *K*, (ft/d)—the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area of porous medium measured at right angles to the direction of flow.

Table 9. Monthly and annual pumpage data from Oklahoma Gas and Electric Company power-plant wells G1–G3 (plate 2), 1952-86

[In 1,000 gallons]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1952													301,086
1953													297,828
1954													395,909
1955													266,872
1956													296,524
1957													524,620
1958													471,832
1959													425,561
1960	23,669	17,603	43,615	53,681	33,004	44,064	44,064	38,781	31,157	84,578	35,589	14,207	464,012
1961													424,910
1962	22,912	27,542	26,731	28,515	41,634	35,018	44,911	47,791	29,816	42,601	46,059	72,437	465,967
1963	28,500	32,989	46,926	41,299	36,899	46,055	59,701	59,701	35,972	36,621	31,160	43,056	498,878
1964	35,747	34,403	43,584	29,894	30,320	35,903	40,393	39,943	25,570	26,469	22,382	26,413	391,021
1965	32,574	16,796	9,036	29,010	24,993	33,167	48,427	42,353	38,616	30,258	17,093	26,264	348,586
1966	34,610	14,629	13,915	18,727	31,918	17,883	53,027	30,882	24,283	24,778	14,396	14,338	293,386
1967	17,461	27,876	30,381	23,925	27,175	27,174	33,897	31,542	19,275	24,132	7,639	20,913	291,391
1968	22,055	17,295	23,224	22,100	23,538	22,844	32,911	34,008	33,957	28,600	21,159	20,354	302,046
1969	21,862	19,900	25,185	21,934	26,039	25,869	38,051	36,205	35,580	29,691	22,223	26,097	328,636
1970	25,535	24,910	34,135	31,182	37,219	38,500	41,096	47,379	72,493	23,676	29,551	33,922	439,598
1971	29,064	28,159	27,333	25,216	11,924	17,208	41,922	32,224	32,937	27,442	35,525	25,886	334,841
1972	26,791	25,069	26,890	25,095	18,149	22,336	34,936	36,662	32,468	25,453	28,495	46,052	348,396
1973	30,569	26,249	26,383	30,881	36,666	35,788	45,457	44,002	36,900	43,026	39,408	32,714	428,043
1974	30,438	28,012	32,262	17,964	34,215	34,080	45,224	42,063	32,234	36,378	33,222	32,264	398,356
1975	37,156	32,585	30,156	33,640	30,563	27,528	37,162	38,367	23,330	28,180	28,715	32,350	379,733
1976	22,452	22,345	20,574	19,193	10,321	11,934	20,996	23,619	20,168	20,571	22,722	24,007	238,901

Table 9. Monthly and annual pumpage data from Oklahoma Gas and Electric Company power-plant wells G1–G3 (plate 2), 1952-86—Continued

[In 1,000 gallons]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	24,630	19,207	21,624	22,821	26,504	27,315	28,235	26,838	13,339	19,835	22,904	23,814	277,065
1978	26,667	27,567	28,255	26,106	18,664	30,140	40,434	33,504	28,336	27,186	24,330	24,747	335,934
1979	44,332	41,346	44,058	27,262	28,669	46,762	52,779	62,091	61,910	49,457	39,977	37,070	535,713
1980	35,909	40,791	40,990	32,056	22,554	42,009	56,710	58,786	33,976	33,046	35,387	40,168	472,383
1981	47,206	39,891	45,763	44,185	42,866	47,486	49,217	41,924	27,798	13,575	23,970	43,117	466,997
1982	51,366	32,164	36,964	30,244	39,365	38,405	58,087	49,446	41,285	30,244	36,484	36,004	480,057
1983	43,279	38,470	43,279	14,426	48,088	48,088	57,706	57,706	48,088	19,235	19,235	43,279	480,879
1984	37,176	36,808	40,486	33,218	23,649	42,220	43,652	44,007	39,285	35,057	33,098	34,381	443,038
1985	38,666	36,687	38,579	37,019	20,753	35,528	38,423	38,523	34,816	28,086	33,696	35,464	416,240
1986	22,330	21,346	24,434	24,392	25,365	25,584	35,194	30,960	18,207	1,384	1,339	20,982	251,517

- Intrinsic permeability, k, (ft^2)—a measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.
- Specific capacity (ft^2/sec)—the rate of discharge of water from the well divided by the drawdown of water level within the well.
- Specific yield, Sy, (dimensionless)—the ratio of (1) the volume of water which the rock or soil, after being saturated, will yield by gravity to (2) the volume of the rock or soil. This definition implies that gravity drainage is complete.
- Storage coefficient, S, (dimensionless)—the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
- Transmissivity, T, (ft^2/d)—the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Several accepted analytical techniques have been used in past studies to estimate the hydraulic characteristics of the Arbuckle-Simpson aquifer. These techniques involve the evaluation of ground-water-level data and, in some instances, spring discharge. The techniques assume certain limiting constraints such as a homogeneous and isotropic aquifer of infinite areal extent. The techniques also assume that ground-water levels represent levels in a well that fully penetrates the saturated thickness of the aquifer. Unfortunately, none of the wells in the study area fully meet these criteria and rocks of the Simpson and Arbuckle Groups cannot be characterized as homogeneous because their porosity results primarily from irregularly distributed jointing, fractures, and solution channels (Fairchild, Hanson, and Davis, 1990).

Even though the Arbuckle-Simpson aquifer does not satisfy many of the assumptions required to apply these analytical techniques, some of the techniques may give approximate estimates of the hydraulic characteristics of the aquifer on a regional scale—particularly if the fractures and solution channels can be considered interconnected throughout the aquifer.

The techniques used in past studies to determine selected hydraulic characteristics for the study area include the following approaches:

1. Aquifer tests where one well is pumped for several hours or days at a constant discharge rate and corresponding changes in the ground-water level are measured in one or more nearby observation wells.
2. Short-term recovery tests where a well is pumped for several hours at a constant discharge and the rate of recovery of the water level in the well is recorded after the pump is shut off.
3. Slug tests where a known volume of water is either suddenly injected or removed from the well and the rate of recovery of the water level in the well is recorded.
4. Evaluation of the seasonal ground-water-level recession rate at selected wells.
5. Evaluation of the relation between spring discharge and slope of the ground-water potentiometric surface upgradient from the spring outlet.

Fairchild, Hanson, and Davis (1990) discuss the hydraulic characteristics of the Arbuckle-Simpson aquifer based on the results of selected aquifer tests conducted prior to and during their study. Their report indicates that the specific capacity of wells ranges from 0.17 to 104 gallons per minute per foot (gal/min/ft) of drawdown. Deep wells generally have higher specific capacity because they penetrate more fractures and solution channels than wells that penetrate only the upper part of the aquifer. Drillers and landowners report that the upper few hundred feet of the Arbuckle Group has a much lower permeability than the lower part. This reported increase in specific capacity and permeability with depth may reflect the complex geologic and structural nature of the rocks that make up the Arbuckle-Simpson aquifer. In places, however, wells as deep as 250 ft below land surface yield less than 1 gal/min. Such wells probably were drilled in relatively impermeable rocks and do not penetrate interconnected fractures or solution channels. Table 11 summarizes the specific capacity of selected wells in the Arbuckle-Simpson aquifer given by Fairchild, Hanson, and Davis (1990).

Fairchild, Hanson, and Davis (1990) also used streamflow and ground-water-level hydrographs to determine the hydraulic characteristics of the Arbuckle-Simpson aquifer on a regional basis. They estimated that the storage coefficient averages about 0.008, the specific yield averages about 0.011and the transmissivity averages about 15,000 ft^2/d.

Barthel (1985) also investigated the hydraulic characteristics of the Arbuckle and Simpson Groups. His analysis of selected rock specimens using a “helium porosimeter” indicates that the “effective porosity ranges from 7.4 to 10.4 percent for the Arbuckle Group and from 2.3 to 11.4 percent for the Simpson Group.”

Barthel (1985) performed a slug test in an abandoned petroleum exploration well located in 01N–04E–31 DDA, 1.25 mi northeast of Buffalo Springs, and calculated a hydraulic conductivity of 1.6 ft/d in a depth range of 158 to 237 ft below land surface. He also attempted to slug test the Park’s two observation wells, East Well (01S–03E–01 ABA), and West Well (01S–03E–01 BBB) shown in figure 2, to obtain hydraulic conductivity values but found that naturally occurring asphalt in the wells caused very slow water-level recoveries and unreliable test results.

The Prickett-Lonnquist (1971) ground-water digital model was applied by Barthel (1985) to interpret drawdown data from an aquifer test conducted in the City of Sulphur well S9 (plate 2). Pumpage and drawdown information were obtained by the drilling company following completion of the well in March 1983. Total depth of the well is 750 ft with an open hole below the 240 ft level. After completion the well had an artesian flow of about 150 gal/min. The drilling company pumped the well at a reported rate of 537 gal/min for 24 hours and recorded a total

Table 11. Summary of hydraulic characteristics at selected wells in the Arbuckle-Simpson aquifer

[ft, foot; (gal/min)/ft, gallons per minute per foot of drawdown; ft^2/d, square foot per day; hr, hour; --, no data. Modified from Fairchild, Hanson, and Davis (1990), except as noted in remarks]

Local identifier	Well depth (ft)	Depth below land surface of perforated interval or open hole		Yield (gal/min)	Draw-down (ft)	Duration of test (hr)	Specific capacity ([gal/min]/ft)	Trans-missivity *T* (ft^2/d)	Date of test	Geologic unit	Remarks
		Top (ft)	Bottom (ft)								
						JOHNSTON COUNTY					
02S-05E-08 ABB 1	110	45	105	--	--	24	--	1,740	07-06-77	Simpson Group	Aquifer test-observation well; Rural Water District well no. 1
02S-05E-08 ABB 2	107	75	105	153	34.8	24	4.4	--	07-06-77	Simpson Group	Aquifer test-pumped well; Rural Water District well no. 2
02S-05E-08 ABB 3	167	83	164	--	--	24	--	1,450	07-06-77	Simpson Group	Aquifer test-observation well; Rural Water District well no. 3
						MURRAY COUNTY					
01N-03E-36 CBD 1	750	240	750	537	85	24	6.3	--	04-01-83	--	Sulphur well S9; Barthel, 1985
01N-03E-26 CCC 1	511	414	511	185	121	6	1.5	--	08-31-51	Simpson Group	OG&E well G1; well cased to bottom and per-forated
01N-04E-15 BDA 1	133	--	--	53	35.7	1	1.5	125	12-19-78	Simpson Group	Recovery data analyzed
01N-04E-21 DDA 1	1,170	--	--	1,700	64	--	27	--		Arbuckle Group	USGS files
01N-04E-22 DDA 1	780	--	--	2,500	24	24	104	--		Simpson Group	
				1,000	12	6	83				
01S-04E-16 CBA 1	122	--	--	16.2	61.8	2	0.26	--	05-08-79	Arbuckle Group	
02S-03E-11 DBB 1	146	--	--	48.8	28.6	2.1	1.7	2,460	05-10-79	Simpson Group	Recovery data analyzed

Table 11. Summary of hydraulic characteristics at selected wells in the Arbuckle-Simpson aquifer—Continued

[ft, foot; (gal/min)/ft, gallons per minute per foot of drawdown; ft^2/d, square foot per day; hr, hour; --, no data. Modified from Fairchild, Hanson, and Davis (1990), except as noted in remarks]

Local identifier	Well depth (ft)	Depth below land surface of perforated interval or open hole		Yield (gal/min)	Draw-down (ft)	Duration of test (hr)	Specific capacity ([gal/min]/ft)	Trans-missivity T (ft^2/d)	Date of test	Geologic unit	Remarks
		Top (ft)	Bottom (ft)								
MURRAY COUNTY—Continued											
02S-03E-12 CAA 1	58	40	55	39.6	14.0	0.56	2.8	--	05-10-79	Arbuckle Group	
02S-03E-13 CCD 1	79	--	--	9.3	55.4	0.74	0.17	--	05-08-79	Simpson Group	Well cased to bottom and perforated; zone of perforations unknown
02S-03E-25 DCD 1	361	25	360	85	49.5	2.0	1.7	--	12-06-78	Arbuckle Group	USGS files
02S-04E-18 BBD 1	85	0	85	42.2	60.3	2.6	0.70	382	05-09-79	Arbuckle Group	Recovery data analyzed
PONTOTOC COUNTY											
01N-05E-27 DCC 1	2,500	325	2,500	670	19	168	35	--	02-04-59	Arbuckle Group	USGS files
02N-05E-10 DDD 1	534	71	534	37.1	79	2.05	0.47	40	05-18-79	Arbuckle-Simpson Groups	Recovery data analyzed
02N-05E-22 ADC 1	850	60	850	34.5	33.8	2.0	1.02	--	05-17-79	Arbuckle Group	USGS files
02N-05E-25 CCC 1	1,527	250	1,527	555	43	44	13	--	01-19-59	Arbuckle Group	USGS files
	1,527	250	1,527	570	43.5	105	13		01-22-59		
02N-05E-36 AAD 1	2,048	--	--	390	115	120	3.4	--	03-15-57	Arbuckle Group	USGS files

drawdown of 85 ft. In applying the model, Barthel varied storage coefficient and transmissivity values for successive simulations of the measured pumping rate until the simulated drawdown matched the observed drawdown. Best fit values were: *K* ranging between 0.0047 and 0.047 ft/d, *S*=0.00017, *T* ranging between 2.4 and 24 ft^2/d, and a specific capacity of 6.3 gal/min/ft of drawdown. These results must be considered questionable, however, because no-flow boundaries 0.5 mi from the pumped well were simulated rather than boundaries of infinite extent that may be more representative for this hydrologic system. Also, the effective pumpage rate for this simulation may be inaccurate, because total pumpage during the test included an artesian flow component.

Barthel (1985) attempted to use the National Park Service's East and West Wells as observation wells for this analysis, but the East Well was inoperable during the test and no significant drawdown was observed in the West Well during pumping. Limited response in the West Well may be due to asphalt in the well.

Barthel (1985) also estimated the transmissivity of the Arbuckle-Simpson aquifer using Darcy's law ($T=q/iw$) where:

T is the transmissivity,
q is spring discharge,
i is hydraulic gradient, and
w is width of aquifer contributing flow to the spring.

This analysis indicates that the transmissivity for the aquifer supplying fresh water to Antelope and Buffalo Springs is 43,000 ft^2/d and that transmissivity for the aquifer supplying mineralized water to Hillside, Pavilion, and Black Sulphur Springs is 3,900 ft^2/d. The analysis assumes that the contributing width of the aquifer is 1 mi for both the fresh and mineralized sources. Barthel (1985) used a combined average discharge from Antelope and Buffalo Springs during January and February 1985 of about 2,200 gal/min and a combined average discharge from Hillside, Pavilion, and Black Sulphur Springs of about 100 gal/min.

Kamal (1986) used stage data from Antelope and Buffalo Springs and water-level data from nearby wells to determine a range of *T* and *S* values dependent on the recharge from precipitation. He applied time-series analysis techniques to derive estimates of *T* and *S* of the Arbuckle-Simpson aquifer for recharge amounts ranging from 4 to 15 percent of annual precipitation. Kamal (1986) considered 6 percent of precipitation to be the most reasonable recharge, resulting in T = 13,000 gallon per day per foot (1,740 ft^2/d) and S = 0.248.

Recharge

Spring and artesian-well flow in the Park originates primarily from precipitation that recharges the outcrop of the Arbuckle and Simpson Groups. Some recharge also may occur from streamflow infiltrating through rock fractures in stream channels. Recharge contributing to the freshwater springs at the east end of the Park occurs northeast, east, and southeast of the Park; however, the full extent of this recharge area is not well defined, based on present information.

Gould and Schoff (1939), in an interpretation of Hazlett's (1935) geologic map, state that a 12 mi^2 outcrop of the Simpson Group, southeast of the Park, "forms the intake for the water in the Sulphur artesian basin," at an altitude averaging 200 ft higher than the City of Sulphur. Schornick, Harp, and Laguros (1976) estimate that the recharge areas of about 40 mi^2 of Arbuckle outcrop and about 20 mi^2 of Simpson outcrop provide ground water to the Park. The determination of these areas is not discussed or supported by potentiometric data, however.

Fairchild, Hanson, and Davis (1990) indicate that the regional ground-water divides follow fairly closely the regional surface-water drainage divides; however, lack of detailed ground-water-level data in the Park vicinity precludes an accurate delineation of the outcrop area contributing ground water to the Park. The potentiometric map (fig. 6) indicates, however, that the ground-water divide may correspond approximately with a north- and south-trending topographic high about 4 mi east of the Park, and with an east-west trending topographic high about 1.5 mi south of the Park.

Barthel (1985) concludes from a 1985 potentiometric map of the study area that the recharge area contributing flow to Antelope and Buffalo Springs is 5 mi^2 and lies north of the west-northwest trending Sulphur Fault (plate 1), which is at the surface 1.5 mi east of the Park. He indicates that the recharge area for the remaining springs in the Park is only about 2 mi^2.

These studies give estimates of the recharge area contributing water to the fresh and mineralized springs in the Park ranging from 7 to 60 mi^2. This wide disparity is due, in part, to the limited ground-water-level data available in and adjacent to the Park and the resulting coarse definition of the potentiometric surface. Another factor controlling the extent of the recharge area is the complex system of faults along the ground-water flow paths, which may be either barriers to or conduits of ground-water movement, depending on factors such as their location, orientation, juxtaposition of rocks on either side of the fault, and amount of fracturing near the fault.

The rate of recharge varies from place to place because of differences in permeability of the aquifer and soil; however, Fairchild, Hanson, and Davis (1990) show hydrographs of water levels in the outcrop of the Arbuckle-Simpson aquifer indicating a rapid response of ground-water levels to rainfall. Fairchild, Hanson, and Davis (1990) assumed that ground-water discharge into the stream represents that part of the precipitation that recharges the ground-water system and they estimated this recharge by separating base flow from the streamflow hydrograph. Their analysis of base flow for the principal streams and tributaries draining the Arbuckle-Simpson outcrop indicates that recharge to the aquifer averages 4.7 in. per year for water years 1969–71 and 1977–79. This estimate of recharge may be low because precipitation during their study period was about 80 percent of the long-term average precipitation. They also found that the ratio of recharge to precipitation for selected storms ranged from 0.12 to 0.34.

Water Quality

Several previous studies have investigated the water-quality characteristics of streams, lakes, and ground water in and adjacent to the Park (Gould, 1906; Gould and Schoff, 1939; Cumiford and others, 1968; D.L. Hart, Jr., written commun., 1972; Streebin and Harp, 1977).

Most water-quality studies of the streams and lakes have been independently conducted, with different objectives and different sampling and analytical methods applied. Therefore, correlation of these different data sets is difficult. To date, the following two studies are the most comprehensive and applicable to the present study area.

Streebin and Harp (1977) studied the nutrient and fecal coliform levels of Lake of the Arbuckles and the principal streams in the CNRA. Their study included an evaluation of dispersion of point-source surface-water pollution and the levels of oxygen concentration and eutrophication in the lower Rock Creek drainage and the Rock Creek arm of Lake of the Arbuckles. They reported that notable differences in chloride and total dissolved solids (TDS) occur throughout the study area. These differences were attributed to different land uses within the watershed and the effects of high concentrations of chloride and TDS discharging from the OG&E power plant into Rock Creek upstream from the City of Sulphur. Differences in concentrations of nutrients and fecal coliform among sampling sites were attributed to differing agricultural and recreational activities adjacent to the sites. Nutrient and fecal coliform concentrations in Rock Creek were significantly higher than the standards set by the Oklahoma Water Resources Board. Travertine Creek was found to be relatively uncontaminated except below swimming areas. Streebin and Harp (1977) concluded that Buckhorn and Guy Sandy Creeks, although of better quality than Rock Creek, received larger nutrient loads from agricultural activity in these two watersheds.

Fairchild, Hanson, and Davis (1990) indicate that the chemical characteristics of stream water vary seasonally and that concentrations of most dissolved constituents are lower during storm periods than during dry periods because of dilution from storm runoff. The stream base flows are derived from springs emanating from the Arbuckle-Simpson aquifer. For this reason, the water-quality characteristics of streams during low-flow periods is similar to that of springs. At higher flows, concentrations of TDS in streams generally is less than waters from either wells or springs.

The USGS National Water Information System contains water-quality data for 59 surface-water sites in the study area. All sites have pH, conductivity, and temperature data. About thirty of these sites have major anion and cation analyses.

The first detailed evaluation of water quality of the Park springs was conducted by Cumiford and others (1968). Their study indicates that the chemical constituents evaluated were, with some exceptions, within the U.S. Public Health Service Drinking Water Standards in effect at the time.

D.L. Hart, Jr. (U.S. Geological Survey, written commun., 1972) collected water-quality data at selected springs and wells in the study area and used this information to show that the source of water may be distinguished by the relative concentration of TDS and major ions. These concentrations are shown in figure 10 for selected springs and wells in the study area. Each diagram displays the concentration of all major ions of a water sample in milliequivalents per liter (meq/L).

The USGS National Water Information System contains water-quality data for about 135 wells in the study area (table 10). All sites have pH, conductivity, and temperature data, and about a third of the sites have data for the major anions and cations. Selected water-quality data are stored in the USGS National Water Information System for seven springs: Antelope, Buffalo, Pavilion, Hillside, Beach (Black Sulphur), Bromide, and Medicine. All spring sites have conductivity and temperature data, and many have major anion and cation analyses.

Flow from Antelope and Buffalo Springs in the eastern part of the Park is derived from the Arbuckle aquifer. This aquifer is composed of limestone and dolomite and is recharged from the uplifted Arbuckle Group that crops out northeast of the Park. The chemistry of this spring water corresponds to these rock types in that the water is primarily a calcium magnesium bicarbonate type with a TDS content of about 300 mg/L (fig. 10).

Flow from the highly mineralized Bromide Springs Group (Bromide and Medicine Springs) near the west end of the Park is believed to originate from the Simpson aquifer. Rocks of the Simpson Group crop out south of the Sulphur Fault in the Sulphur Syncline southeast of the Park (plate 1). This syncline is considered by several investigators to be the recharge area for these springs. Water from Bromide and Medicine Springs, which ceased to flow in about 1973, was of a sodium chloride type with a TDS content of about 4,000 mg/L (fig. 10).

Spring water in the central part of the Park (Pavilion, Hillside, and Beach Springs Groups, table 3) and water from flowing wells north of the Park including Vendome, Wyandotte, Belleview, Plunge, and Townsley wells (table 6) is believed by D.L. Hart, Jr. (U.S. Geological Survey, written commun., 1972) to be a mix of ground water originating from rocks of the Arbuckle and Simpson Groups. A more complete sampling and analysis of chemical constituents is necessary, however, to verify that ground-water mixing occurs. Water from these springs and wells has a TDS content ranging from about 530 mg/L at Hillside Spring (not included in fig. 10) to 1,200 mg/L at the Vendome Well. All analyses indicate larger concentrations of sodium and chloride than present in water from the Arbuckle Group (fig. 10).

Figure 10 shows that the City of Sulphur wells and the shallow Turner Ranch well (01N–04E–36 BBB 1, located northeast of Sulphur's wells) have water-quality characteristics similar to the Buffalo and Antelope Springs water, with TDS at these sites ranging from 293 to 356 mg/L. Wells and springs within T. 1 N.–T. 2 S. and R. 3 E.–R. 4 E. were sampled and analyzed by the OG&E during July 7, 8, and 9, 1953. They sampled 74 wells, 4 springs (Black Sulphur from the Beach Springs Group, Pavilion, Medicine, and Bromide) and Rock Creek below the OG&E plant (plate 2). The results of their analyses

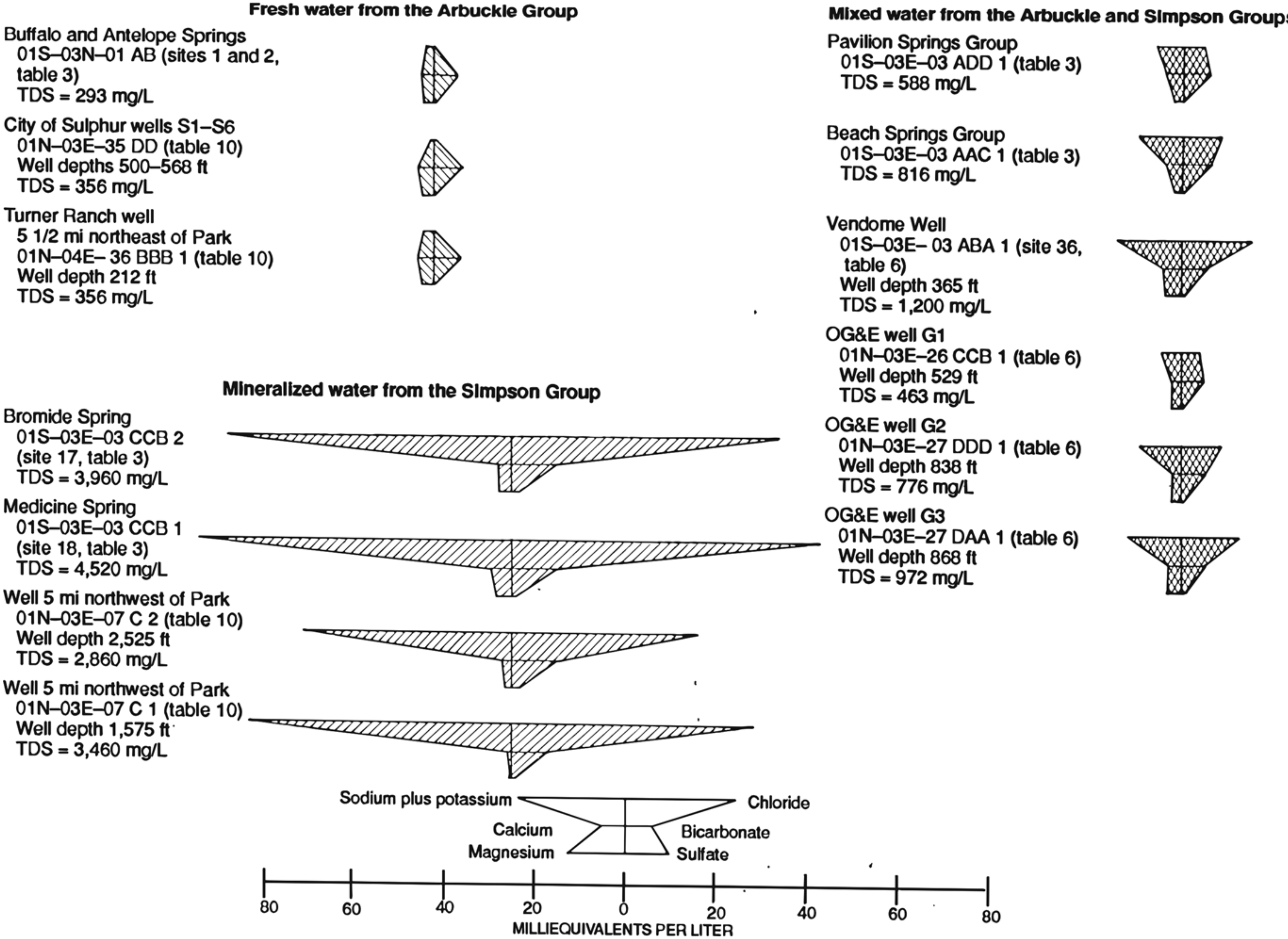


Figure 10. Water-quality diagrams of samples from selected and springs and wells (modified from D.L. Hart, Jr., U.S. Geological Survey, written commun., 1972).

have not been published, but the results are summarized in an OG&E memorandum dated July 30, 1953. This memorandum includes: (1) Tabulations giving the location, ownership, description, and results of their analyses for each site; and (2) maps showing sample locations. Water quality in samples from three OG&E power-plant wells (G1, G2, and, in particular, G3) is similar to the water from the Vendome Well. TDS of water in these wells ranges from 463 to 972 mg/L.

Water-quality samples were collected at the National Park Service East and West Wells during August 1972, September 1972, and July 1987 and analyzed for common anions and cations. These analyses indicate that the water is a bicarbonate type commonly associated with limestone rocks of the Arbuckle Group. The results of all analyses at these two wells are available in the USGS National Water Information System.

Analyses of water from two deep wells in the Simpson Group 5 mi northwest of the Park (01N–03E–07 C1 and C2) and from Bromide and Medicine Springs indicate that water quality in these wells and springs is similar, with large TDS ranging from 2,860 to 4,520 mg/L. Although the direction of ground-water flow in the Simpson is uncertain, a comparison of the chemistry in the springs and the two wells indicates that a deep circulation system may exist in the Simpson. For example, these springs, wells, and several flowing wells, such as the Vendome Well, contain sodium chloride (fig. 10), yet no rocks containing sodium chloride are found within either the Simpson or Arbuckle Groups. Therefore, earlier interpretations about the sources of water for the mineralized springs and artesian well waters are questionable. The existing water-quality data suggest, in fact, that water may be derived from deeper or more distant sources than previously believed. Additional information about the geology, hydrology, and geochemistry is necessary to determine flow systems in the study area.

Discussion of Results

Effect of Precipitation on the Hydrologic System

Seasonal and annual variations in streamflow, spring flows, artesian well flows, and ground-water levels are strongly influenced by corresponding precipitation variations. Precipitation at the Park (fig. 2) is the principal climatic parameter used in this report to describe climatic influences on the local hydrologic system.

Of particular interest are prolonged droughts that generally correspond with a significant reduction in discharge in the streams and springs and declines in the regional ground-water levels. Dunn (1953) attributes much of the decline in flow from wells, mineral springs, and freshwater springs (Antelope and Buffalo) prior to 1953 to many years of below-normal precipitation. He believed, however, that excessive withdrawals from the aquifer also caused these declines and that a continued increase in withdrawals would be “certain to exhaust the supply in the near future.” Barthel (1985) studied the relation between local precipitation, ground-water levels, and spring flows at Antelope and Buffalo Springs. He concluded that water withdrawal from the Sulphur “artesian basin” exceeded the water available in the area by about 15 percent. He also estimated that the freshwater springs in the Park may cease to flow within the next 40 years if local ground-water levels continue to decline at observed recession rates. Wold (1986) applied a simplified mathematical model of the regional hydrologic system to simulate ground-water levels in the study area. By imposing selected ground-water withdrawal scenarios on the system, he estimated that Antelope and Buffalo Springs could cease to flow within the next 10 years.

A comparison of the annual precipitation at the CNRA in figure 2 with the streamflow of Rock Creek at Dougherty in figure 3 indicates that variations in streamflow correspond to similar variations in precipitation. Most of the Rock Creek record (1950–67) probably represents below-normal streamflow discharges because precipitation averaged about 13 percent below normal from 1957 to 1967.

Freshwater spring flows in the study area also correlate closely with precipitation and most likely follow the same annual trends as the Rock Creek streamflows; no concurrent data are available, however, to verify trends between the spring flows and streamflows. During the 20 years of flow record (1968–87) at Antelope and Buffalo Springs, precipitation was above normal 50 percent of the time with an extremely wet year occurring in 1973 (58.9 in.). Figure 4A shows that the flow in both springs responded to this precipitation as well as other less-significant rainfall. Surprisingly, however, both springs ceased to flow for at least 4 months in 1984 (fig. $4A_2$, table 5), even though precipitation had been consistently above normal since 1981.

Figures 2 and $4A_2$ and table 5 show those periods when Antelope and Buffalo Springs were dry. No-flow conditions commonly occur during extended periods of below-normal precipitation. When precipitation is below normal for 3 or more years, Antelope and Buffalo Springs both generally go dry as indicated in the late 1930’s, mid–1950’s, mid–1960’s, and late 1970’s to early 1980’s. The best-known drought in Oklahoma and other large areas of the midwest occurred during 1931–39. figure 2, however, shows that in the study area the dry period from 1950 through 1957 appears to be more severe than in the 1930’s with a longer and more persistent period of no flow (1952–57) at the two freshwater springs. Table 5 indicates that Antelope Spring went dry several weeks or months before Buffalo Spring for several of the no-flow periods. However, both springs began flowing within a few days of each other once precipitation recharged the local ground-water system.

A common measure of drought severity is the Palmer Drought Severity Index (PDSI) developed by Palmer (1965) for the National Weather Service. This index was derived for each climatic division in the United States based on 30 years of historic precipitation and air-temperature records. The Index depicts prolonged periods of several months (or years) of abnormal dryness or wetness, responds slowly to changes in climate, and reflects long-term runoff, deep percolation of rainfall, and ground-water recharge. The Index also is considered to be a measure of the average evapotranspiration deficit for a given climatic division. PDSI is expressed as a numerical value ranging from +4 (or greater) representing very wet conditions to –4 (or less) representing very dry conditions. Figure 11 shows the monthly PDSI values for Oklahoma Climatic Division 8 which encompasses 12 counties in south-central Oklahoma, including Murray County, for 1895 to 1987. A comparison of the PDSI with precipitation values shown in figure 2 indicates that periods when the PDSI is less than zero correspond closely with periods of below-normal precipitation. In all instances, when the PDSI remained below zero for 3 or more years, Antelope and Buffalo Springs went dry. Reported no-flow periods during 1911–13 and 1918 (table 5), which preceded the CNRA precipitation record, also correspond to extended periods when the PDSI was less than zero. A close inspection of the PDSI trends shows that low values commonly lag below-normal precipitation by about 1 year. This lag most likely exists because the amount of soil moisture depletion required to substantially reduce the PDSI may take several weeks or months. The good correlation between the no-flow periods for Antelope Springs and antecedent low PDSI values indicate that the index may be a good indicator of potential drought conditions prior to cessation of these fresh-water spring flows.

No relation describing long-term trends between precipitation or the PDSI and the discharge of mineralized springs in the western part of the Park is possible because no long-term record of spring discharge is available. The limited discharge data available for the mineralized springs (table 3) do show, however, that many of the springs first observed by Gould (1906) no longer flow and all of the currently flowing mineralized springs discharge substantially less water than was reported in 1906.

The only mineralized spring with several years of periodic discharge data is Hillside Spring (table 3). These discharges were estimated to be as much as 90 gal/min in 1911 even though the PDSI was very low (–6) during this period (fig. 11). The next recorded observation in November 1939 indicates that the flow declined to 10 gal/min, probably reflecting the drought conditions that prevailed during most of the 1930’s (fig. 2). More recent measurements (1967–69) indicate that Hillside Spring appears to have a base flow in the range of 10 to 15 gal/min. The maximum flow measured during 1967–69 was 52 gal/min on October 30, 1969. Some variability in flow from Hillside Spring may be explained by rainfall that caused the high flows of 29 and 39 gal/min on April 12, 1967, and May 12, 1969, respectively. However, other periods when discharge from Hillside Spring substantially exceeded the base flow, such as the September 24, 1969, flow of 47 ft^3/sec, do not appear to be related to a specific rainfall.

Ground-water levels in the study area tend to follow both seasonal and year-to-year changes in precipitation as indicated by the water levels in the East and West Wells (fig. 4B) and well 01N–05E–27 DCC 1 in the recharge area east of the Park (fig. 8). A close inspection of seasonal variations in the East and West Wells shows that they reach minimum levels several weeks after the end of extended dry periods.

The influence that precipitation has on the flowing wells in the Park vicinity is not fully understood because few discharge data are available to identify any reliable comparative trends. Several flowing wells were drilled in the 1920’s or earlier (plate 2 and table 6) and, even though flow from many of the wells was contained by installing shut-off valves at the well head, some wells, such as the Townsley Well (no. 30) and Vendome Well (no. 36), have flowed uncontrolled since they were drilled. Discharges from all of the flowing wells have declined appreciably and several have ceased to flow. Discharges estimated for some of the wells (table 6) before, during, and immediately following the 1931–39 drought indicate, however, that flows apparently were not affected by this drought.

The Vendome Well (fig. 5B and table 7), has a stage recorder that was used to obtain a continuous record of discharge from November 1985 to December 1987. The record shows that discharge from this flowing well has fluctuated only within the range of 0.8 through 1.6 ft3/s during this 26–month period and does not appear to respond promptly to substantial rainfall such as the 10.06 in. monthly rainfall during May 1987. The stage recorder and the weir for controlling flow past the gage from the Vendome Well are not sufficiently sensitive to register subtle changes in discharge that may occur as a result of small changes in ground-water levels induced by rainfall. Historic discharge records for this well indicate, however, that flow has declined from 2,500 gal/min (5.57 ft^3/s) in 1922 to about 620 gal/min (1.38 ft^3/s) in 1986–87. These declines in discharge from the flowing wells can be attributed to a gradual reduction in the hydraulic head of the Arbuckle-Simpson aquifer (which the wells penetrate) caused by many years of uncontrolled discharge, which apparently has exceeded the recharge to the aquifer.

Effect of Geology on the Hydrologic System

A review of the geologic literature of the study area indicates that the structure and stratigraphy are very complex and not well understood. Studies of the surface geology and available oil and water-well logs indicate that a network of faults exists throughout the region (plate 1). Their locations and influence on the hydrology of the Park are not well known because conglomerate of the Vanoss Formation unconformably overlies the faulted Simpson and Arbuckle Groups. The regional fault system is suspected to strongly influence the direction and rate of ground-water movement into and through the Park and may

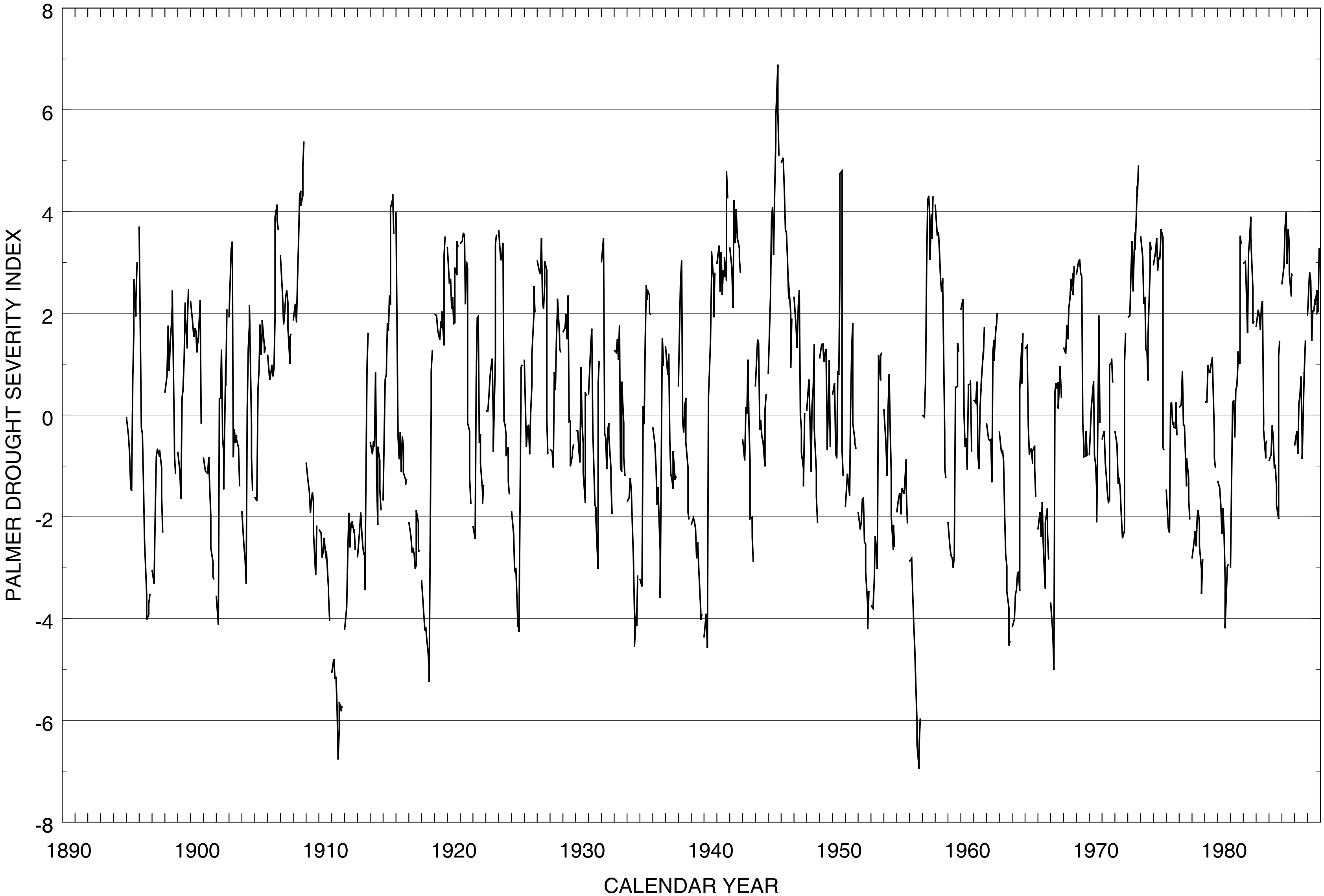


Figure 11. Monthly Parmer Drought Severity Index for Oklahoma Climatic Division 8, 1895–1987 (data from national Climatic Center, National Oceanic and Atmospheric Administraion).

be the principal factor controlling the distribution and flow rate of the freshwater and mineralized springs in the Park.

A better understanding of the influence of geologic structure upon the hydrologic system within the study area could be obtained by capping the Vendome Well and other nearby flowing wells and conducting a shut-in aquifer test. This test may provide information on the location of nearby major faults and indicate whether the faults are barriers to or conduits of ground-water flow into the Park. A shut-in test also could provide estimates of the local hydraulic characteristics of the aquifer, which presently are not well known in the immediate Park vicinity. However, given the age of the Vendome Well (more than 65 years), it may be difficult to conduct a test without damaging the well casing. Such a test also could cause a permanent reduction in flow from the well or loss of flow entirely.

Seismic surveys, test-hole drilling, and sampling of ground water at selected depths in test holes in and adjacent to the Park would define the thickness of the formations that underlie the Park and may provide information about the geology and chemical characteristics of the deeper rocks of the massive Arbuckle Group, which underlie the freshwater segment of the Arbuckle-Simpson aquifer. Age dating the water by sampling for the occurrence of carbon 14 and tritium would help to identify residence time of water in the aquifer and contribute to an improved understanding of the flow system. Lithologic data collected during test drilling also may help to verify the location of faults hidden by the overlying Vanoss Formation and provide information about the hydraulic conductivity of the aquifer. Measurement of hydraulic heads at selected depths in the test holes may be used to discern if the flowing wells and mineral springs in the Park are receiving a significant contribution of ground water from deep sources.

Relation Between Ground-Water Levels and Discharge from Springs and Artesian Wells

The period of common continuous record between ground-water levels and spring flows is limited to 1974–87 when Antelope and Buffalo Springs water-surface altitudes (fig. $4A_2$) can be compared with water-level altitudes for the East and West Wells (fig. 5B). Unfortunately, much of the ground-water-level record is not considered reliable because asphalt accumulations in the wells inhibit well response to head changes in the aquifer. These graphs do show, however, that for most of the record ground-water levels in the two wells correlate closely with water-surface altitudes recorded at the two springs.

Water-level altitude is highest at the East Well, averaging about 1,090 ft above sea level and lowest at the West Well, averaging about 1,050 ft above sea level. The water-surface altitude at Antelope and Buffalo Springs lies between these two altitudes, averaging about 1,079.5 ft above sea level. A close inspection of the graphs in figure 4B shows that the springs dry up when the East Well drops below about 1,080 ft and National Park Service records indicated that Antelope Spring commonly goes dry before Buffalo Spring, with a lag of 2 or more weeks.

Water levels in the East Well show a much greater range in stage than levels in the West Well and maximum and minimum levels in the East Well generally lag behind those in the West Well by several weeks. The similarity between seasonal trends in these wells and seasonal trends in Antelope and Buffalo Springs reflects the common source of recharge to the local ground-water system by seasonal precipitation on the outcrop of the Arbuckle rocks.

The graphs show that the ground-water levels and the spring levels followed a gradual, but continued, decline from 1975 to January 1980. The springs dried up intermittently from December 1976 until October 1981 (table 5). Ground-water levels in the East and West Wells followed a general decline throughout this period, but started to rise again early in 1981 in response to recharge from rainfall on the outcrop.

No continuous records of ground-water levels exist for the recharge area east of the Park. A common period of spring-stage and ground-water-level data exists at well 01N–05E–27 DCC 1 in the Arbuckle outcrop area about 10 mi east of the Park for 1977–79. Ground-water-level trends in this well are probably representative of trends in the recharge area for Antelope and Buffalo Springs. A comparison of the ground-water altitudes in this well (fig. 8) with the water-surface altitudes of Antelope and Buffalo Springs (fig. $5A_2$) indicate that the springs closely followed the seasonal maximum and minimum levels for the same 3–year period of record; rising in the winter and spring during periods of high rainfall, and declining throughout the summer and fall dry season. A detailed inspection of the record shows, however, that the springs take several weeks to respond to declines in the ground-water levels in well 01N–05E–27 DCC 1. The time required for ground-water-level changes in the outcrop to propagate the 10 mi to the springs reflects the transmissivity and storage properties of the aquifer.

Insufficient artesian flow data exist to evaluate fully the relation between artesian flows, ground-water levels, and spring flows. However, the common short period of discharge record (November 1985–December 1987) between the Vendome Well and Antelope Spring (fig. 5B) does not indicate that the artesian discharge for the well follows the general seasonal fluctuations in the discharge for Antelope Spring, which is characterized by maximum flows in the winter and spring and minimum flows during mid- and late summer.

More reliable ground-water-level data and additional ground-water-level monitoring sites are needed in the study area to adequately describe the response of the ground-water system to local recharge, the direction of ground-water movement in the vicinity of the Park, and the effect that local pumping may have on ground-water levels. To correct the persistent problem of asphalt accumulation at the East and West Wells, these wells could be plugged and new wells drilled, if possible, at a depth within a zone not contaminated by the naturally occurring asphalt. The new wells should be cased, screened, and finished in a manner to assure that no asphalt can enter the screened interval. No continuous record of ground-water levels in the recharge areas east of the Park is available to fully describe the relation between rainfall, ground-water recharge, local pumpage, and corresponding response of the Park springs and flowing wells. Ground-water monitoring wells established 2 to 3 mi north and east of the Park in the Arbuckle aquifer and 1 to 2 mi southeast of the Park in the Simpson aquifer would help to describe the response of ground-water levels and spring flow to precipitation.

Effect of Ground-water Withdrawals on the Hydrologic System

Annual withdrawals from the City of Sulphur wells (fig. 9A) increased from 1965 through 1980—probably to meet increasing demands for municipal and domestic use—but the effect of these withdrawals on discharge from Antelope and Buffalo Springs is questionable. Large withdrawals from the Sulphur wells during 1978–80 corresponds with frequent low spring-pool levels at Antelope and Buffalo Springs and occasional flow cessation. However, this period also coincides with an extended period (1975–80) of below-normal precipitation (fig. $4A_1$). In 1982, withdrawals from the Sulphur wells was again relatively large, but the Springs actually recovered from a previous 2–year dry period probably as a result of above-normal precipitation during 1981–82.

In 1984 Antelope and Buffalo Springs were dry from July to November, even though precipitation was above normal that year. Monthly pumpage from the Sulphur wells was large during this period but not as large as occurred in succeeding years during which the springs did not go dry. These data suggest that pumpage from the Sulphur wells does not appear to have a significant effect on these freshwater spring flows—particularly during periods when precipitation is at or above normal. Pumpage may exacerbate the rate of decline of flows during extended dry periods, but spring-flow data are insufficient to evaluate adequately the influence that pumping may have on dry-weather spring flows.

The graphs in figures 12, 13, and 14 have been constructed to show the correlation in fluctuations and trends between precipitation, the PDSI, spring altitude, ground-water levels, and pumpage for the common period 1973–80. This 8–year period was selected because it is characterized by a downward trend in PDSI and a significant drought during 1976–80 (fig. 12).

Declines in the surface-water levels of Antelope and Buffalo Springs (fig. 13A) during the fall and winter months appear to occur in response to increased pumpage of the Sulphur wells (fig. 14A) to meet a summer high water demand. However, the effect that pumpage may have on spring flow is not readily discernible. For example, the comparatively large pumpage from June 1977 through most of 1978 and into September 1979 does not appear to have influenced substantially the seasonal high May-October spring flows in these three years—even though the springs went dry each winter during this period. The fact that precipitation was below normal throughout 1975–80 (fig. $4A_1$), supports a concept that several years of below-normal annual precipitation is the primary controlling factor in causing the freshwater springs to go dry each year from 1977 through 1980.

Any effect that pumpage of the OG&E wells may have on discharge from Antelope and Buffalo Springs also is not readily discernible. Periods of high pumpage (fig. 14B) coincide with the summer months when temperatures are high and precipitation (fig. 12A) is low. The maximum seasonal pumping of the OG&E wells during 1973–80 (fig. 14B) occurred from June through September of 1979 and the minimum pumping during this 8–year period occurred from April through June of 1976. Because water-surface altitudes at Antelope and Buffalo Springs were not appreciably different during these two periods, pumpage from the OG&E wells alone does not appear to have a measurable effect on the springs' discharge.

The effect that pumping from the City of Sulphur and OG&E wells has on the regional ground-water system also is questionable. For example, the typical seasonal ground-water-level recessions in the East and West Wells during the summer pumping of 1974 (fig. 13B) were quickly reversed in September by 8.6 in. of rainfall (fig. 12A).

High monthly pumpage occurred from June through October of 1979 at both the Sulphur and OG&E wells (fig. 14B) but ground-water levels did not reach minimum levels until August 1980 in the West Well and early 1981 in the East Well (fig. 4B). The water level in the West Well, which is the closest observation well to the Sulphur well field, indicates, however, a marked decline in July 1979 that may be attributed, in part, to large pumpage, but is most likely caused by removal of asphalt during the month. The East Well water level started its summer recession by July 1979 but no significant decline due to pumpage is apparent.

Minimum pumpage during the common period of pumping record 1965–87 occurred during May-June 1976 at the OG&E wells (fig. 9B) and during January-March 1981 at the Sulphur wells (fig. 9A). No marked increases in ground-water levels in the East or West Wells are apparent as a result of these reduced pumpages. In fact, the period of minimum pumpage in early 1981 by the Sulphur wells (fig. 9A) corresponds with a period of minimum water levels in the East and West Wells (fig. 4B).

These comparisons suggest that past pumpage from the aquifer has not had a significant effect on the ground-water levels within the study area. Subtle drawdown may occur, however, during extended dry periods when ground-water levels are already low. The effect pumping has on ground-water-level declines can be determined only by closely monitoring both pumpage rates and ground-water levels in multiple wells during periods of large pumpage and negligible precipitation.

Hillside Spring is the only mineralized spring in the Park with sufficient discharge data to evaluate possible pumping effects on the mineralized springs in the Park. Discharge values at this site are available for selected dates during January 28, 1967, to May 22, 1967, and June 26, 1968, to November 21, 1969. These measurements are listed in table 3 and are plotted in figure 15B. Annual precipitation averaged about 4 in. above normal during 1967–69 (fig. 2), and annual pumpage of the City

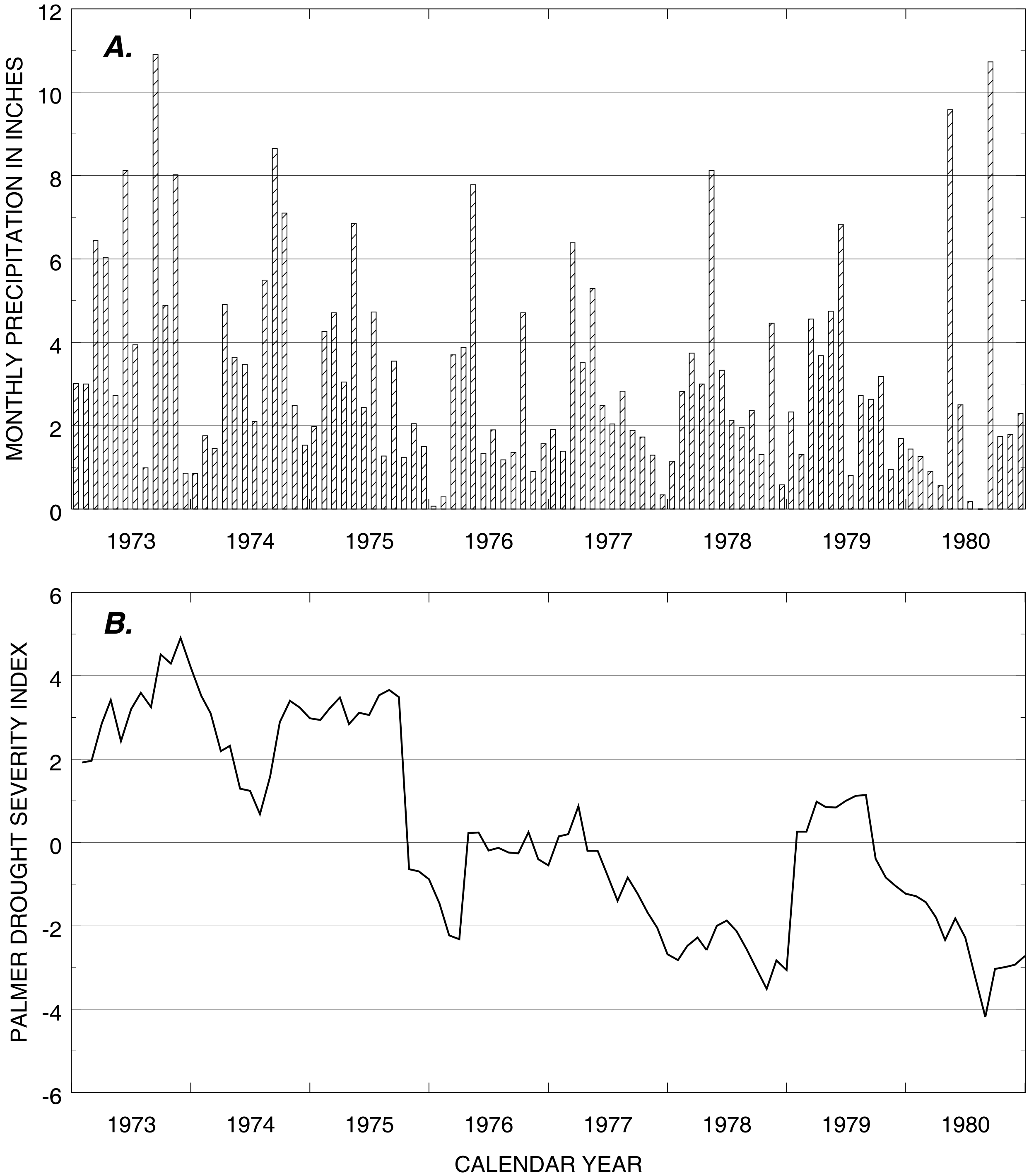


Figure 12. (A) Monthly precipitation at Chickasaw National Recreation Area, 1973–80 (data from National Park Service), and (B) monthly Palmer Drought Severity Index for Climatic Division 8, 1973–80 (National Climatic Center, National Oceanic and Atmospheric Administration).

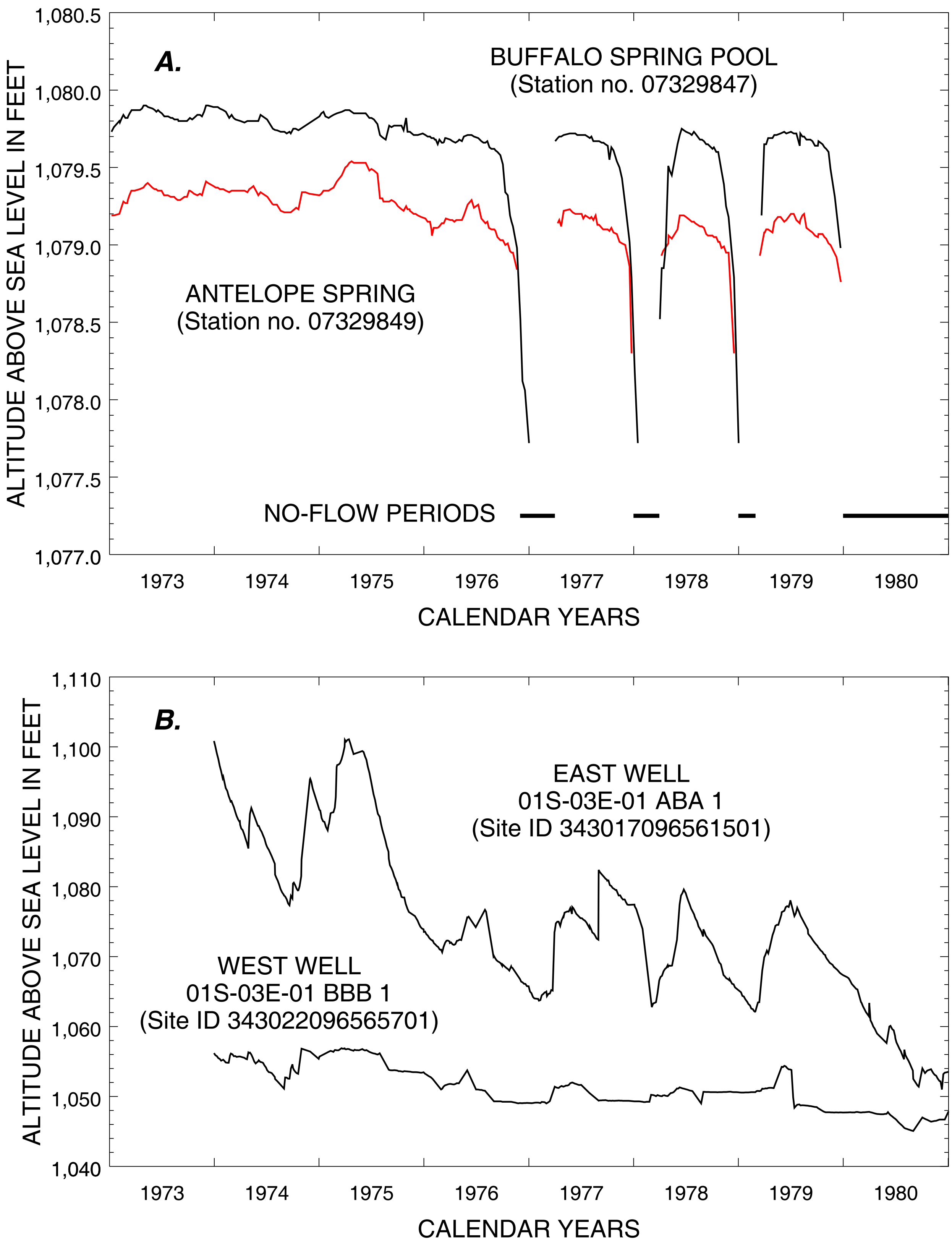


Figure 13. (A) Altitude of water surface for Antelope Spring and Buffalo Spring Pool, 1973–80, and (B) altitude of ground-water levels in East and West Wells, 1974–80.

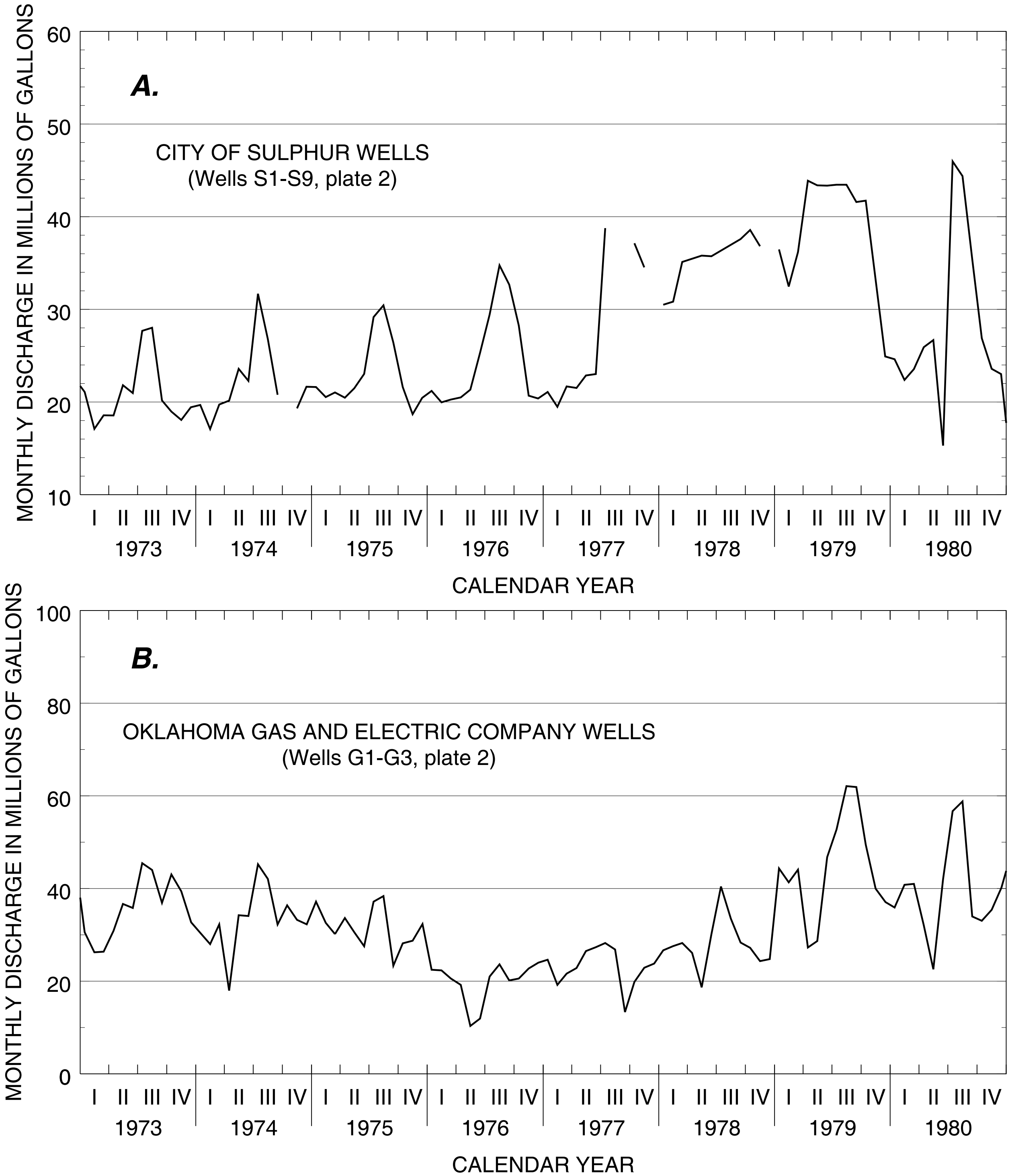


Figure 14. (A) Total monthly discharge of City of Sulphur waterworks wells (data from City of Sulphur) and (B) total monthly discharge of Oklahoma Gas and Electric Company power-plant wells (data from Oklahoma Gas and Electric Company), 1973–80.

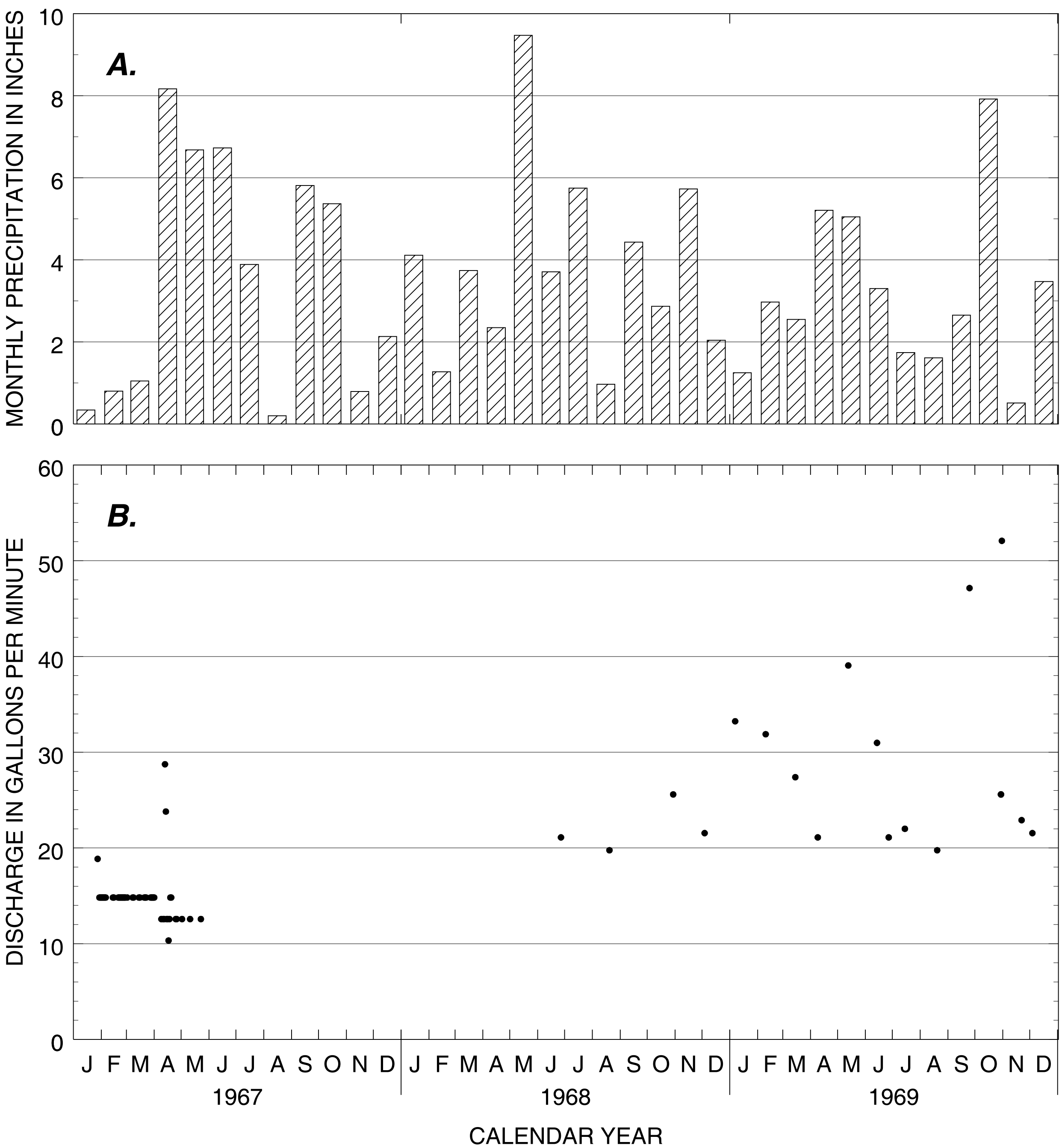


Figure 15. (A) Monthly precipitation at Chickasaw National Recreation Area and (B) periodic discharge measurements of Hillside Spring, 1967–69 (data from National Park Service).

of Sulphur and OG&E wells was considerably less during this 3–year period (fig. 16) than during most subsequent years (figs. 9A and 9B).

Figure 15B shows that Hillside Spring discharge was considerably higher in 1969 than in 1967 even though no appreciable decreases in pumpage or increases in precipitation (fig. 16B) occurred during this 3–year period. The minimum discharge observed was 10 gal/min on April 16, 1967, and the maximum discharge observed was 52 gal/min on October 30, 1969. The increased discharge may be the result of possible higher regional ground-water levels in 1969 than in 1967; unfortunately, no ground-water-level data (other than the levels at well 01N–05E–27 DCC 1) or stream base-flow data are available to substantiate the status of regional ground-water levels during this 3–year period.

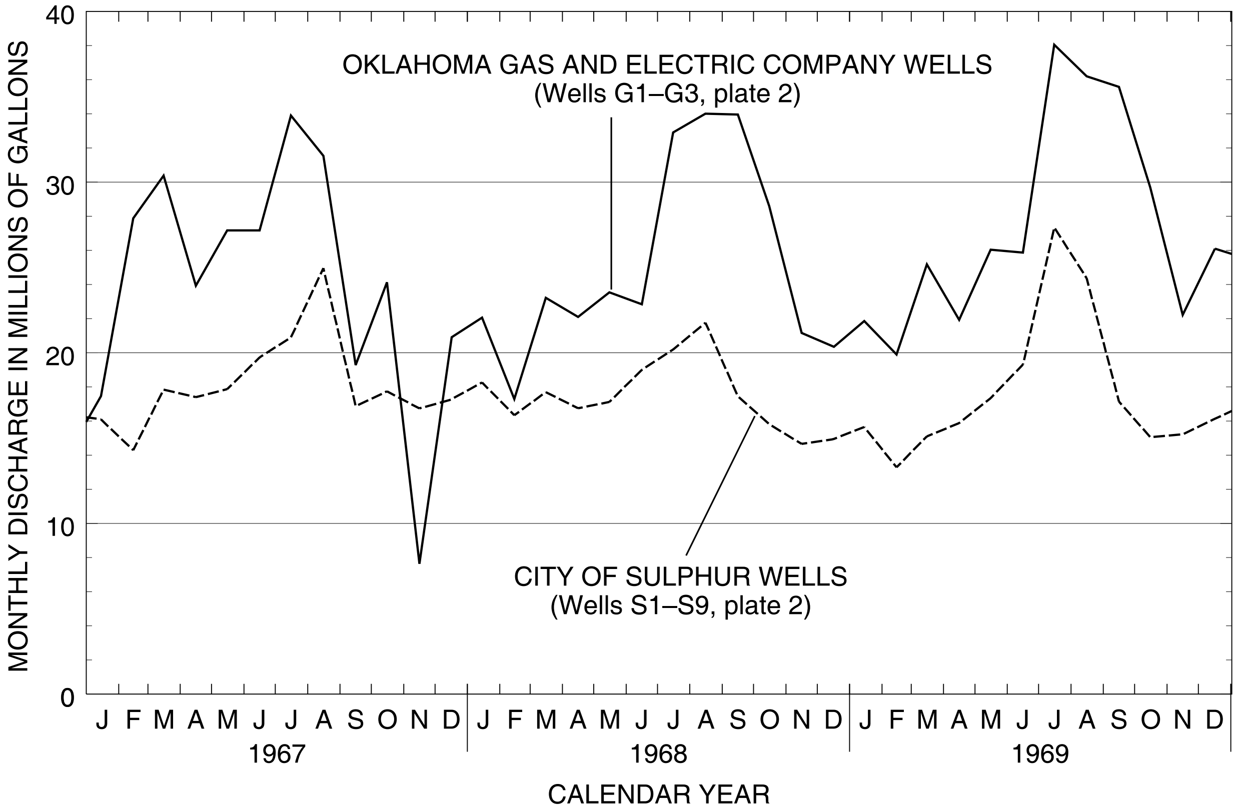


Figure 16. Monthly discharge from City of Sulphur waterworks wells (data from City of Sulphur), and from Oklahoma Gas and Electric Company power-plant wells, 1967–69 (data from Oklahoma Gas and Electric Company).

The pumpage and spring data do indicate that seasonally high pumpage rates during June-September coincide with low discharges from Hillside Spring. However, in order to evaluate the effect that pumping may have on Hillside Spring, concurrent measurements of discharge at the spring and pumpage rates at the OG&E and City of Sulphur wells would be required during periods of minimal precipitation.

Historic discharge data for the flowing artesian wells also are insufficient to adequately determine the pumping effects that the City of Sulphur or OG&E wells may have on the artesian flows. The limited artesian well data (table 6) indicate, however, that artesian flows have gradually declined with time and many of the wells drilled in the 1920's and 1930's no longer flow. The reasons for this decline and cessation of flow have not been documented, but it is reasonable to assume that the potentiometric surface near the flowing artesian wells has lowered with time in response to the continuous free-flowing discharge from the wells.

No correlation appears to exist between the brief record of continuous discharge for Vendome Well (November 1985 to December 1987) and pumping from the City of Sulphur wells and OG&E wells. In fact, complete cessation of pumping at the OG&E wells after December 1986 does not appear to have affected discharge from the Vendome Well (fig. 5B).

Summary and Conclusions

The Travertine District (Park), which presently contains 1.33 mi^2, was established in 1902 by the National Park Service to preserve 6 freshwater springs and 27 mineralized springs. In 1976 the 15 mi^2 Chickasaw National Recreation Area, which includes the Park, was established to include Lake of the Arbuckles. This study includes geologic and hydrologic information covering a 576 mi^2 area encompassing the Chickasaw National Recreation Area. Most of the information in this report, however, describes stream and spring flows, ground-water levels, ground-water pumpage, artesian-well flows, and water quality within and immediately adjacent to the Park.

Data from a National Weather Service station established in the Park in 1918 indicate that mean annual precipitation is 38.29 in. Since 1918 the longest continuously wet period, when annual precipitation was above normal, was from 1981 through

1985. The wettest decade was the 1940's. The longest continuously dry period, when precipitation was below normal, was from 1950 through 1956.

Evapotranspiration is a major component of the hydrologic budget for the Park. Water use by evapotranspiration has not been determined, but probably increased significantly following the introduction by the Civilian Conservation Corps of some 800,000 plants in 1933. Historical spring-flow data are not adequate to document possible reductions in spring flow following the establishment of these plants, but water use by dense vegetation throughout the Park may reduce the discharge from some springs, particularly during extended dry periods.

The deepest geologic unit referred to in this study is the Arbuckle Group of Upper Cambrian to Middle Ordovician age, composed primarily of dolomitic limestone. Overlying these rocks is the Simpson Group, of Ordovician age, composed of sandstone, limestone, and shales. These two Groups constitute the Arbuckle and Simpson aquifers, which are exposed northeast, east, and south of the Park and provide the source of water for the fresh and mineralized springs within the Park. Because of the similarity of these two rock groups, most investigators do not differentiate between the two and commonly refer to the water-bearing rocks within the study area as the Arbuckle-Simpson aquifer. Throughout the Park, the Arbuckle-Simpson aquifer is confined by an overlying tightly cemented limestone conglomerate referred to as the Vanoss Formation of Pennsylvanian age. Wells drilled through this confining conglomerate and into the underlying aquifer commonly flow.

Two streams flow through the Park: Rock Creek, which heads 10 mi north of the Park, and Travertine Creek, which heads immediately east of the Park. Dry-weather flow from both Rock and Travertine Creeks is derived primarily from springs and several uncontrolled flowing artesian wells.

The two freshwater springs, Antelope and Buffalo Springs, are located near the east boundary of the Park. The earliest record of discharge from these springs was July 12, 1906 when Antelope Spring had an estimated discharge of 4.5 ft^3/s and Buffalo Spring had an estimated discharge of 3.5 ft^3/s. Occasional esti-

mates of discharge have been made since that time and, in 1968, the National Park Service established reference pins at each site and began collecting periodic water-surface elevations of the pools at each spring. In November 1985, a gaging station was established at Antelope Spring to collect a continuous water-surface elevation record. The maximum discharges observed at each spring were 6.24 ft^3/s at Antelope Spring on June 13, 1969, and 6.52 ft^3/s at Buffalo Spring on April 16, 1987. Both springs have been dry on numerous occasions with the longest continuous dry period occurring from April 1954 to May 1957 (33 months).

Seasonal and annual variations in ground-water levels and in the flow of springs is strongly influenced by the local precipitation. When precipitation has been below normal for 3 or more years, Antelope and Buffalo Springs have gone dry but both springs begin flowing within a few days of each other once precipitation recharges the ground-water system. A comparison of the Palmer Drought Severity Index with dry periods for Antelope and Buffalo Springs indicates that the springs cease to flow when the Index remains below zero for 3 or more years. This Index, therefore, may be a good indicator of potential drought conditions prior to cessation of spring flow.

Only limited historical discharge data are available for the other fresh and mineralized springs in the Park. During an inventory of the springs in November 1939 only 19 of the original 33 springs located in 1906 could be found. By 1969 the only mineralized springs flowing in the Park were Bromide, Medicine, Pavilion, Hillside, and Beach (Black Sulphur). In about 1973, Bromide and Medicine Springs quit flowing.

The source of fresh water for Antelope and Buffalo Springs is believed to be from the Arbuckle aquifer. Similarity in the water-quality characteristics of the Simpson aquifer and the highly mineralized springs of the Bromide Group (Bromide and Medicine Springs) in the western part of the Park suggest that the Simpson aquifer is the source of water for these springs. The less mineralized waters in the central part of the Park (Pavilion, Hillside, and Beach Springs) are believed to be a mix of the Arbuckle and Simpson aquifer waters.

Aquifer tests of selected wells in the study area give a wide range of values of hydraulic properties. The highest storage coefficient of the Arbuckle-Simpson aquifer determined by these tests was 0.008, the highest hydraulic conductivity was 1.6 ft/d, and the highest specific capacity was 104 gal/min/ft of drawdown. One estimate of the transmissivity of the Arbuckle aquifer was as high as 43,000 ft^2/d. The large range in derived hydraulic properties and the limiting constraints associated with the computational methods used make the values questionable. Additional testing of selected wells would be required to better define these hydraulic properties.

Recharge to the Arbuckle-Simpson aquifer occurs on the outcrop of the rocks northeast, east, and southeast of the Park. The total areal extent of the recharge area is uncertain, however, and estimates range from 5 to 60 mi^2. A review of past studies indicates that only one estimate of recharge rate, 4.7 in/year, has been made.

Depth to water has been measured in about 400 wells within the 576 mi^2 study area. A potentiometric-surface map derived from some of these data indicates that movement of ground water into the Park is from the south and east. Considerable structural relief and fractures exist in the Arbuckle rocks. As a result, ground-water movement in this area probably is controlled more by fractures than by permeable beds. Additional ground-water-level data—particularly north of the Park—are needed to better define regional ground-water levels and flow paths.

In 1973 the National Park Service drilled two wells along the north boundary of the Park to be used in determining if localized pumping from the Arbuckle-Simpson aquifer affected ground-water levels. The records show that localized pumping from the City of Sulphur waterworks wells and OG&E powerplant wells appears to have no substantial influence on ground-water levels at these two well sites. The records also show a relatively close correlation between ground-water-level fluctuations and discharge from Antelope and Buffalo Springs.

Previous studies refer to about 43 flowing wells; however, only 40 can be documented as to their specific location. The earliest known flowing well (Bridgeman well) was drilled in 1889, but most of the wells were drilled in the 1920's. The most prominent flowing well is the Vendome Well, drilled in 1922. Estimated flow from this well was 2,500 gal/min in 1922, but the flow has declined to a present average annual flow of about 550 gal/min. By 1987 only 16 flowing wells were known to exist in the study area and preliminary estimates of discharge from these 16 wells is only about 10 percent of the total flow reported in 1939. These declines can be attributed to a gradual reduction in the hydraulic head of the Arbuckle-Simpson aquifer resulting from the many years of continued uncontrolled discharge from flowing wells in the study area.

The continuous record of discharge from the Vendome Well shows that discharge appears to have little response to rainfall. A better understanding of how the geologic structure influences the ground-water system could be obtained by conducting shut-in tests on the Vendome Well and other nearby flowing wells. These tests may be difficult to conduct without damaging the well because a pressure build-up in the wells may damage the casings, causing a permanent reduction or complete loss of flow from the wells. Geophysical surveys, test-hole drilling, and water-quality sampling of wells and springs would help to better understand the hydrogeologic system in the study area.

Large-capacity pumpage from the Arbuckle-Simpson aquifer has been from 9 City of Sulphur wells, 3 OG&E powerplant wells, and 1 State Veterans Hospital well. Maximum annual pumpage occurred in 1979 when over 430 million gallons were pumped by the City of Sulphur wells and about 536 million gallons were pumped by OG&E wells.

Surface-water-quality data collected in the 1970's indicated that nutrients and fecal coliform concentrations in Rock Creek were significantly higher than State standards. Travertine Creek, however, was found to be relatively uncontaminated. The chemical concentration of most dissolved constituents in streams is lower during storm-runoff periods than during baseflow periods and the surface-water type is generally similar to the spring waters.

Water-quality data from springs indicate that the highly mineralized springs near the west end of the Park are a sodium chloride type with total dissolved solids greater than 4,500 mg/L. The source of sodium chloride in the mineralized spring water (and flowing wells) is uncertain, considering that the Arbuckle-Simpson aquifer does appear to contain sodium chloride-bearing rocks. These saline waters suggest that a deep-circulating ground-water system may exist in the area with the spring and flowing-well waters derived from deeper or more distant sources than most investigators have assumed. The freshwater springs near the east end of the Park are a calcium bicarbonate type with total dissolved solids of less than 400 mg/L. Water-quality data from Vendome Well and the springs located in the central part of the Park indicate that this water may be a mix of fresh and mineralized water.

Pumpage from either the City of Sulphur well field or from the OG&E wells does not appear to have a substantial influence on the rate of discharge from the fresh or mineralized springs during years of normal precipitation. Several years of below-normal precipitation are believed to be the primary controlling factor in causing the freshwater springs to go dry, but pumpage may exacerbate the rate of decline of flows during extended dry periods. Pumpage from the Arbuckle-Simpson aquifer has not had a substantial effect on regional ground-water levels; subtle drawdowns may occur during extended dry periods when ground-water levels are already below normal. The effect that pumping has on the ground-water system can only be determined by monitoring both pumpage rates and ground-water levels in multiple wells during periods of large pumpage and negligible precipitation. Insufficient data exist to determine if pumpage has caused the discharge from flowing wells to decline.

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Table 1. Miscellaneous discharge measurements at selected streams in the study area

[ft^3/s, cubic feet per second; mi^2, square mile. All measurements by the U.S. Geological Survey, except as noted.]

Name (Station number)	Local Identifier	Latitude	Longitude	Date of measurement	Discharge (ft^3/s)	Drainage area (mi^2)
Rock Creek below Cunningham Well near Sulphur (07329840)	01N–03E–23 CCDC 1	343208	0965751	11–05–58	1.12	29.0
				02–19–59	0.23	
				08–22–62	0.52	
Rock Creek north of Sulphur (07329843)	01N–03E–26 CCCD 1	343140	0965800	10–30–58	0.85	33.0
				11–05–59	0.97	
				09–16–59	0.11	
Rock Creek below Highway 177 at Sulphur (07329844)	01N–03E–34 ADAC 1	343056	0965806	05–12–53	[a] 14,600	35.1
				07–18–58	2.00	
				10–30–58	0.85	
				11–05–58	0.97	
				02–19–59	0.99	
				08–22–62	0.88	
Rock Creek above Travertine Creek at Sulphur (07329846)	01S–03E–03 AABD 1	343017	0965817	10–16–76	[b] 2.68	35.2
				11–14–76	[b] 2.62	
				11–30–76	[b] 3.30	
				12–12–76	[b] 2.16	
				12–19–76	[b] 3.92	
				01–21–77	[b] 2.78	
				03–20–77	[b] 2.46	
				04–01–77	[b] 2.26	
				06–13–77	[b] 3.58	
				07–01–77	[b] 2.15	
				07–03–77	[b] 2.14	
Rock Creek at Bromide Springs at Sulphur (073298515)	01S–03E–03 CBC 1	342944	0965859	10–16–76	[b] 4.88	43.3
				11–14–76	[b] 4.69	
				11–30–76	[b] 5.78	
				12–12–76	[b] 4.80	

Table 1. Miscellaneous discharge measurements at selected streams in the study area—Continued

[ft^3/s, cubic feet per second; mi^2, square mile. All measurements by the U.S. Geological Survey, except as noted.]

Name (Station number)	Local Identifier	Latitude	Longitude	Date of measurement	Discharge (ft^3/s)	Drainage area (mi^2)
				12–19–76	[b] 6.50	
				01–21–77	[b] 5.98	
				03–20–77	[b] 4.95	
				04–01–77	b 4.97	
				06–13–77	b 6.19	
				07–01–77	b 5.51	
				07–03–77	[b] 5.50	
Rock Creek above Buckhorn Creek near Sulphur (07329875)	01S–03E–31 AAA 1	342559	0960114	08–22–62	6.5	52.6
Rock Creek at Dougherty (07329900)	02S–03E–07 CBB 1	342350	0970210	11–30–49	14.8	138
				02–08–50	32.6	
				09–10–51	28.2	
				10–10–51	9.19	
				11–27–51	14.7	
				01–16–52	10.8	
				03–05–52	17.5	
				04–22–52	534	
				06–12–52	13.5	
				07–28–52	5.48	
				09–02–52	3.30	
				10–07–52	6.39	
				11–18–52	14.9	
				12–23–52	10.4	
				02–04–53	8.23	
Rock Creek at Dougherty (07329900)—Continued				03–10–53	13.7	
				04–14–53	6.92	
				06–02–53	13.2	
				06–23–53	5.74	
				08–19–53	15.5	
				10–01–53	5.43	
				11–17–53	9.70	

Table 1. Miscellaneous discharge measurements at selected streams in the study area—Continued

[ft^3/s, cubic feet per second; mi^2, square mile. All measurements by the U.S. Geological Survey, except as noted.]

Name (Station number)	Local Identifier	Latitude	Longitude	Date of measurement	Discharge (ft^3/s)	Drainage area (mi^2)
				01–12–54	13.1	
				02–24–54	8.60	
				04–19–54	6.19	
				05–27–54	53.6	
				07–13–54	6.90	
				08–23–54	3.87	
				09–15–54	2.00	
				11–01–54	8.16	
				12–07–54	7.20	
				01–17–55	13.3	
				03–01–55	12.7	
				04–11–55	0.68	
				06–14–55	6.27	
				07–27–55	2.93	
				09–20–55	0.37	
				03–07–56	3.78	
				03–15–56	7.13	
				03–29–56	5.01	
Buckhorn Creek below Lowrance Spring near Drake (07329882)	01S–03E–24 CDD 1	342656	0965635	02–22–77	4.83	1.8
				09–27–77	1.88	

Table 1. Miscellaneous discharge measurements at selected streams in the study area—Continued

[ft^3/s, cubic feet per second; mi^2, square mile. All measurements by the U.S. Geological Survey, except as noted.]

Name (Station number)	Local Identifier	Latitude	Longitude	Date of measurement	Discharge (ft^3/s)	Drainage area (mi^2)
Buckhorn Creek above fish hatchery near Drake (07329884)	01S–03E–25 BAD 1	342649	0965632	08–22–77	3.23	2.1
				02–14–79	3.06	
Buckhorn Creek near Dougherty (07329886)	01S–03E–32 BBB 1	342556	0970124	07–18–58	3.95	27.0
				10–30–58	4.67	
				02–19–59	3.07	
				08–22–62	1.17	
Guy Sandy Creek near Sulphur (07329888)	01N–03E–31 CCD	343024	970130	07–18–58	0.17	34.0
				10–30–58	0.0	
				02–19–59	0.0	
Wilson Creek above inlet to Veterans Lake near Sulphur (07329858)	01S–03E–10 ABAC 1	342923	0965823	07–15–87	0.04	2.46
Travertine Creek below Antelope Spring at Sulphur (07329850)	01S–03E–01 BAD 1	343015	0965659	10–16–76	[b] 0.62	0.43
				11–14–76	[b] 0.0	
				11–30–76	[b] 0.1	
				12–12–76	[b] 0.0	
				12–19–76	[b] 0.0	
				01–21–77	[b] 0.0	
				03–20–77	[b] 0.0	
				04–01–77	[b] 0.1	
				06–13–77	[b] 2.0	
				07–01–77	[b] 0.95	
				07–03–77	[b] 0.88	

Table 1. Miscellaneous discharge measurements at selected streams in the study area—Continued

[ft^3/s, cubic feet per second; mi^2, square mile. All measurements by the U.S. Geological Survey, except as noted.]

Name (Station number)	Local Identifier	Latitude	Longitude	Date of measurement	Discharge (ft^3/s)	Drainage area (mi^2)
Travertine Creek below Vendome Well at Sulphur (073298513)	01S–03E–03 AACB	343015	0965817	07–10–57	[c] 10.4	3.82
				07–18–58	12.8	
				10–30–58	5.75	
				02–19–59	2.78	
				07–15–59	2.16	
				08–22–62	3.51	
				10–16–76	[b] 2.13	
				11–14–76	[b] 1.98	
				11–30–76	[b] 2.35	
				12–12–76	[b] 2.33	
				12–19–76	[b] 2.23	
				01–21–77	[b] 2.01	
				03–20–77	[b] 2.09	
				04–01–77	[b] 2.22	
				06–13–77	[b] 2.19	
				07–01–77	[b] 3.04	
				07–03–77	[b] 3.03	

[1a] Flood peak determined by indirect measurement by U.S. Geological Survey.

[2b] Measurements by Streebin and Harp, 1977.

[3c] Measurements by U.S. Bureau of Reclamation..

Table 3. Estimated and measured discharges of freshwater and mineralized springs in the Park, 1906–74

[gal/min, gallons per minute.]

Site number[a]	Local identifier	Site ID	Spring name[a]	Date of measurement	Discharge (gal/min)	Remarks[a]
Sulphur Creek Group[a]						
1.	01S–03E–01 ABB 1	343016096562801	Antelope	See table 2	See table 2	Freshwater
2.	01S–03E–01 ABD 1	343009096562001	Buffalo	See table 2	See table 2	Freshwater
Chalybeate Group[a]						
3.	01S–03E–02 ABD 1	343013096571901	Cunningham	07– –06	[a]Weak	Said to contain iron
4.	01S–03E–02 ACA 1	343005096572101	Buse	07– –06	[a]Weak	Said to contain iron
Pavilion Group[a]						
5–11.	01S–03E–03 AACD 1	343004096580501	Pavilion Springs	09– –11	[c]139	
				11– –39	[d]12	
				08– –53	[e]12	
5.	01S–03E–03 ADD 2	[b]343004096580502	Big Tom	07– –06	[a]40	Sulphur odor
6.	01S–03E–03 ADD 3	[b]343004096580503	Arsenic	07– –06	[a]8	Sulphur odor; 30 ft SE of Big Tom Spring
7.	01S–03E–03 ADD 4	[b]343004096580504	Little Tom	07– –06	[a]3	Sulphur odor; 6 ft NW of Big Tom Spring
8.	01S–03E–03 ADD 5	[b]343004096580505	Swords	07– –06	[a]5	Sulphur odor; 12 ft NW of Big Tom Spring
9.	01S–03E–03 ADD 6	[b]343004096580506	Townsley	07– –06	[a]2	Sulphur odor; 50 ft NE of Big Tom Spring
10.	01S–03E–03 ADD 7	[b]343004096580507	Dog	07– –06	[a]2	Sulphur odor; 65 ft NE of Big Tom Spring
11.	01S–03E–03 ADD 8	[b]343004096580508	Unnamed	07– –06	[a]2	Sulphur odor; 35 ft NW of Big Tom Spring
Hillside Spring[a]						
12.	01S–03E–03 ADBB 1	[b]3430100965813	Hillside	07– –06	[a]80	
				09– –11	[c]90	
				11– –39	[d]10	
				07– –53	[e]10	
				07– –57	[f]20	
				01–28–67	[g]19	
				01–30–67 thru 03–31–67	[g]15	

Table 3. Estimated and measured discharges of freshwater and mineralized springs in the Park, 1906–74—Continued

[gal/min, gallons per minute.]

Site number[a]	Local identifier	Site ID	Spring name[a]	Date of measurement	Discharge (gal/min)	Remarks[a]
Hillside Springs Group[a]—Continued				04–08–67 thru 04–11–67	[g]13	
				04–12–67	[g]29	
				04–13–67	[g]24	
				04–14–67	[g]13	
				04–15–67	[g]13	
				04–16–67	[g]10	
				04–17–67	[g]13	
				04–18–67	[g]15	
				04–19–67	[g]15	
				04–24–67 thru 05–22–67	[g]13	
				06–26–68	[h]21	
				08–19–68	[h]20	
				10–29–68	[h]26	
				12–03–68	[h]22	
				01–01–69	[h]33	
				02–10–69	[h]32	
				03–14–69	[h]27	
				04–08–69	[h]21	
				05–12–69	[h]39	
				06–13–69	[h]31	
				07–14–69	[h]22	
				09–24–69	[h]47	
				10–30–69	[h]52	
				11–21–69	[h]23	

Table 3. Estimated and measured discharges of freshwater and mineralized springs in the Park, 1906–74—Continued

[gal/min, gallons per minute.]

Site number[a]	Local identifier	Site ID	Spring name[a]	Date of measurement	Discharge (gal/min)	Remarks[a]
Beach Springs Group[a]						
13–15.	01S–03E–03 AAC 1	[b]342749096590401	Beach (Black Sulphur)[c]	07– –06	[a]70	Sulfur odor; springs 10 ft apart
				09– –11	[c]87	
				11– –39	[d]16	
				08– –53	[e]16	
16.	01S–03E–03 AAC 5	342749096590405	Sand	07– –06	Unknown[a]	Sulfur odor; bubbles rising from Rock Creek stream bed
Bromide Springs Group[a]						
17–19.	01S–03E–3 CBDB 1	[b]342944096590001	Unnamed	09– –11	[C]0.8	
				1969	[h]<1	
				12– –73	[c]<1	
				08– –74	[i]2	
17.	01S–03E–3 CBDB 2	[b]342944096590002	Bromide	07– –06	[a]1	Bromide odor
18.	01S–03E–3 CCB 3	[b]342944096590003	Cliff Bromide (Medicine)[c]	07– –06	[a]0.5	Bromide odor; 300 ft E of Bromide Springs
19.	01S–03E–3 CCB 4	[b]342944096590004	Unnamed	07– –06	Unknown[a]	Bromide odor; 60 ft NE of Bromide Springs
Ravine Group[a]						
20–26.	01S–03E–03 DCB 1	[b]342944096582901	Unnamed	09– –11	[c]0.4	
20.	01S–03E–03 DCB 2	[b]342944096582902	Black Sulphur	07– –06	[a]2	Sulphur and bromide odor, in old swamp
21.	01S–03E–03 DCB 3	[b]342944096582903	Sulphur	07– –06	Unknown[a]	Sulphur odor; 60 ft E of Black Sulphur Spring
22.	01S–03E–03 DCB 4	[b]342944096582904	Taff's	07– –06	[a]3	Sulphur odor; 300 ft W of Black Sulphur Spring
23.	01S–03E–03 DCB 5	[b]342944096582905	Iron	07– –06	Unknown[a]	Iron; 600 ft SW of Taff's Spring
24.	01S–03E–03 DCB 6	[b]342944096582906	Soda	07– –06	Unknown[a]	Near Iron Spring
25.	01S–03E–03 DCB 7	[b]342944096582907	Sulphur	07– –06	[a]2	Sulphur odor; 300 ft NW of Iron Spring
26.	01S–03E–03 DCB 8	[b]342944096582908	Sulphur	07– –06	[a]2	Sulphur odor; 42 ft W of Sulphur Spring No. 25

Table 3. Estimated and measured discharges of freshwater and mineralized springs in the Park, 1906–74—Continued

[gal/min, gallons per minute.]

Site number[a]	Local identifier	Site ID	Spring name[a]	Date of measurement	Discharge (gal/min)	Remarks[a]
Churchill Park Group[a]						
27–33	01S–03E–02 CCC 1	342937096575701	Unnamed	09– –11	[c]0.8	
27.	01S–03E–02 CCC 2	342937096575702	Wilson	07– –06	[a]6	Sulphur odor
28.	01S–03E–02 CCC 3	342937096575703	Churchill	07– –06	[a]5	Sulphur odor; 120 ft SW of Wilson Spring
29.	01S–03E–02 CCC 4	342937096575704	Rucker’s	07– –06	[a]3	Freshwater; 75 ft S of Wilson Spring
30.	01S–03E–02 CCC 5	342937096575705	Iron	07– –06	Unknown[a]	Iron; 300 ft NE of Wilson Spring
31.	01S–03E–02 CCC 6	342937096575706	Jericho	07– –06	[a]3	Freshwater; 30 ft W of NE corner of Churchill Park
32.	01S–03E–02 CCC 7	342937096575707	Unnamed	07– –06	Unknown[a]	Freshwater; between Wilson and Jericho Springs
33	01S–03E–02 CCC 8	342937096575708	Unnamed	07– –06	Unknown[a]	Freshwater; between Wilson and Jericho Springs

[4a] Gould, 1906.

[5b] Latitude and longitude differ from Site ID.

[6c] National Park Service.

[7d] Gould and Schoff, 1939.

[8e] Dunn, 1953.

[9f] U.S. Bureau of Reclamation, written commun., 1957.

[10g] Cumiford and others, 1968.

[11h] D.L. Hart, Jr., U.S. Geological Survey, written commun., 1972.

[12i] Harp, 1976.

Table 6. Location and discharge of flowing artesian wells in and near the Park, 1889–1987

[ft, feet; gal/min, gallons per minute; F, well presently free flowing; C, well capped or has ceased to flow, as of 1987; --, no data]

Well number (fig. 2)	Well name	Year drilled	Local identifier	Well depth (ft)	Date discharge measured	Discharge (gal/min)	Remarks
S3	City of Sulphur Well No. 3	1922	01N-03E-35 DDA 1	460	1940	Unknown	C
S4	City of Sulphur Well No. 4	1936	01N-03E-35 DDA 2	517	1940	Unknown	F
S5	City of Sulphur Well No. 5	1922	01N-03E-35 DDD 1	Unknown	1940	Unknown	F
S6	City of Sulphur Well No. 6	1922	01N-03E-35 DDA 3	Unknown	1940	Unknown	C
S7	City of Sulphur Well No. 7	Unknown	01N-03E-35 DDA 4	Unknown	Unknown	Unknown	C
S8	City of Sulphur Well No. 8	1955	01S-03E-01 BAA 1	675	1958	[1]50	F; Horseman Well
S9	City of Sulphur Well No. 9	1983	01N-03E-36 CBD 1	750	03- -83	[2]150	C
G1	OG&E Well No. 1	1951	01N-03E-26 CCB 1	529	08-17-51	[3]68	C
					09-03-51	[3]56	
G2	OG&E Well No. 2	1951	01N-03E-27 DDD 1	838	04-02-52	[3]1,560	C
G3	OG&E Well No. 3	1952	01N-03E-27 DAA 1	868	1952	[3]2,000	C
1	Artesian Hotel	1922	01N-03E-34 DDD 1	850	1922	[4]1,000	C
					1937	[5]1,000	Cleaned out, 1937
					1939	[5]1,000	
2	Lewis Sanitarium	1954	01S-03E-03 BDC 1	569	09-23-54	[4]15	C; Driller's log
3	Bridgeman	1889	01N-03E-34 CCC 1	181	1904	[5]500	C
				243	1940	[5]500	Deepened in 1937
4	Carter	1907	01N-03E-34 DDC 1	440	1907	[4]500	C
					1937	[5]500	Cleaned out, 1937
5	Wyandotte	Unknown	01S-03E-04 AAA 1	Unknown	Unknown	[6]Unknown	F; Colbert well
7	Commercial Hotel	1910	01N-03E-34 CC 1	618	1910	[4]100	C
					1940	[4]100	
8	Cotton	1924	01S-03E-03 CBA 3	602	1924	[4]200	F
					1940	[5]150	
9	Cunningham	1911	01N-03E-23 CCC 1	1,280	1911	[4]2,500	F
					1937	[5]2,500	
					1940	[4]2,500	

Table 6. Location and discharge of flowing artesian wells in and near the Park, 1889–1987—Continued

[ft, feet; gal/min, gallons per minute; F, well presently free flowing; C, well capped or has ceased to flow, as of 1987; --, no data]

Well number (fig. 2)	Well name	Year drilled	Local identifier	Well depth (ft)	Date discharge measured	Discharge (gal/min)	Remarks
11	Caylor Bath House	1926	01S-03E-03 CBA 2	650	1926	[4]1,000	C
					1937	[5]1,000	
					1939	[5]750	
					1940	[4]750	
13	Frye Sanitarium	1917	01S-03E-03 CBA 1	540	1917	[4]1,000	C
					1937	[5]1,000	
					1939	[5]1,000	
16	Keith No. 2	[7]1915	01N-03E-35 CBC 2	450	1915	[4]1,000	C
					1939	[5]100	
					1940	[4]100	
17	Ketchem	1939	01S-03E-03 ADD 1	665	1939	[5]25	F
					1940	[4]25	
18	Lacey No. 1	1923	01N-03E-34 AAA 1	460	1923	[4]1,500	F
					1937	[5]2,500	Includes Lacey No. 2 flow
					1939	[5]1,010	Includes Lacey No. 2 flow
					1940	[4]1,000	
19	Lacey No. 2	1925	01N-03E-34 ACB 1	555	1925	[4]1,000	C
					1937	Unknown	See Lacey No. 1 flow
					1939	Unknown	See Lacey No. 1 flow
					1940	10	
20	Lacey No. 3	1925	01N-03E-35 B	500	1925	[4]100	C; Exact location uncertain
					1940	[4]50	
21	Sulphur Steam Laundry	1905	01N-03E-34 DDAD 1	400	1905	[4]100	C
22	Lewis	1931	01N-03E-34 CCA 2	618	1931	[4]500	C
				700	1937	[5]50	Hole deepened in 1937
					1940	[4]50	
24	Molacek No. 1	1906	01N-03E-33 DAC 1	829	1906	[4]2,300	F; Bellview Plunge
				835	1937	[5]5,000	Includes Molacek No. 2 flow; deepened in 1928
					1939	[5]1,000	

Table 6. Location and discharge of flowing artesian wells in and near the Park, 1889–1987—Continued

[ft, feet; gal/min, gallons per minute; F, well presently free flowing; C, well capped or has ceased to flow, as of 1987; --, no data]

Well number (fig. 2)	Well name	Year drilled	Local identifier	Well depth (ft)	Date discharge measured	Discharge (gal/min)	Remarks
24	Molacek No. 2	1935	01N-03E-33 DAC 2	678	1935	[4]2,000	F; Bellview Plunge
					1937	Unknown	See Molacek No. 1 flow
					1940	[4]2,000	
28	Renfro	1905	01N-03E-34 DBA 1	Unknown	1940	[4]100	C
29	Ross	1939	01N-03E-35 BCA 1	440	1939	[4]100	C
					1940	[4]100	
30	Townsley	1905	01N-03E-34 DCD 1	550	1905	[4]200	F
					1907	[4]500	
					1937	[5]500	
					1940	[4]200	
31	Tribble	1925	01N-03E-34 DDA 1	595	1925	[4]50	C; Southland Hotel
					1937	[5]1,000	
33	White	[7]1926	01S-03E-02 BBA 1	385	1937	[5]1,000	C
35	Wyley	1908	01N-03E-34 DDD 2	Unknown	1908	[4]50	C
36	Vendome	1922	01S-03E-03 ABA 1	365	1922	[4]2,500	F
					1937	[5]2,500	
					11-15-55	[8]763	
					07-10-57	[9]740	
					10-29-85	[8]628	
					[10]11-18-85	[8]597	
					12-12-85	[8]610	
					01-23-86	[8]736	
					03-06-86	[8]660	
					04-17-86	[8]619	
					06-03-86	[8]619	
					07-09-86	[8]669	
					08-21-86	[8]525	
					01-29-87	[8]633	
					04-16-87	[8]601	

Table 6. Location and discharge of flowing artesian wells in and near the Park, 1889–1987—Continued

[ft, feet; gal/min, gallons per minute; F, well presently free flowing; C, well capped or has ceased to flow, as of 1987; --, no data]

Well number (fig. 2)	Well name	Year drilled	Local identifier	Well depth (ft)	Date discharge measured	Discharge (gal/min)	Remarks
					08-21-87	[8]552	
43	Golf Course	Unknown	01N-03E-34 BAC 1	Unknown	Unknown	[6]Unknown	F
45	Freeman	Unknown	01N-03E-27 ADD 1	800	Unknown	[6]Unknown	F
46	Jamie Jack	Unknown	01N-03E-22 DCD 1	Unknown	Unknown	[6]Unknown	F
48	Old Creamery	Unknown	01S-03E-03 BBAA 1	Unknown	Unknown	[6]Unknown	F
	West Sulphur	Unknown	Unknown	Unknown	1936	[11]500	C; Location unknown
	Original	Unknown	Unknown	Unknown	1936	[11]500	C; Location unknown
	Opposite Glover	Unknown	Unknown	Unknown	1936	[11]1,000	C; Location unknown

[1]D.L. Hart, Jr., U.S. Geological Survey, written comm., 1974

[2]City of Sulphur records

[3]Oklahoma Gas and Electric Company records

[4]National Park Service records

[5]Gould and Schoff, 1939

[6]Flow observed by authors after 1987.

[7]Well drilled before date shown

[8]U.S. Geology Survey

[9]Bureau of Reclamation

[10]Continuous record of stage began November 20, 1985

[11]Dunn, 1953

Table 10. Location and characteristics of selected well sites in the study area

[Water levels and well depths in feet below land surface; altitude in feet above sea level. Remarks: A, latitude and longitude differ from Site ID; C, continuous recorder; D, dry well; F, flowing well; M, multiple water-level measurements made following indicated date; L, well-log information available; P, pumping water level; Q, multiple water-quality analyses; R, water level reported (not measured); r, water level affected by recent pumping]

Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343442097043501	01N-02E-10 AAB 1	Sloan	910	38.3	13.20	06-04-81	06-04-81	
343444097031801	01N-02E-11 AAA 1	Lee	1040	50.5	1.10	06-03-81	06-03-81	
343442097035401	01N-02E-11 BAA 1	Unknown	1010	98.2	2.18	06-04-81	06-04-81	
343440097035402	01N-02E-11 BAA 2	Unknown	990	17.1	.16	06-04-81	06-04-81	
343359097031801	01N-02E-11 DDA 1	Brown, W.C.	975	55.8	1.55	06-04-81	06-04-81	
343443097030601	01N-02E-12 ABB 1	Lancaster, Bob	1045	28.3	.80	06-03-81	06-03-81	A
343312097045001	01N-02E-15 DCB 1	Low	890	18	--	--	06-04-81	
343203097040501	01N-02E-23 CBC 1	Grider, Oscar	875	15	7.13	12-05-68	--	A
343156097044601	01N-02E-27 ABC 1	Hottel, R.E.	875	20	14.90	06-02-81	06-02-81	
343148097045601	01N-02E-27 ABC 2	Crawford	875	26.0	20.10	06-02-81	06-02-81	P
343154097045201	01N-02E-27 BDA 1	Pope, James	860	22.7	17.41	06-02-81	06-02-81	
343123097051901	01N-02E-27 CCB 1	Thomasson, Lee	850	18.2	11.52	06-01-81	06-01-81	P
343111097062501	01N-02E-33 BBB 1	Lewis	850	40	32	06-05-81	06-05-81	P, R
343115097023501	01N-02E-36 ABA 1	Coll	980	13.7	8.70	06-02-81	06-02-81	
343107097031401	01N-02E-36 BBC 1	Dale, Jimmy	995	40.3	0	06-03-81	06-03-81	
343500097005001	01N-03E-05 CAC 1	Brown, Griffin	1005	15	7.56	12-06-68	--	
343443097021401	01N-03E-07 BBB 1	Lancaster	1060	28.5	9.90	06-03-81	06-03-81	
343408097015701	01N-03E-07 C 1	Unknown	1050	1575	--	--	--	
343408097015702	01N-03E-07 C 2	Unknown	1050	2525	--	--	--	
343430096565901	01N-03E-11 AAD 1	Cain	1075	640	0	06-11-81	--	
343438096575601	01N-03E-11 BBB 1	Castlebury, Lena	1185	7.0	0	06-11-81	06-11-81	
343410096562001	01N-03E-12 DBC 1	Meeks, Wilber	1045	167	4.05	06-10-81	06-10-81	
343406096561501	01N-03E-12 DBD 1	Meeks, Wilber	1065	30.3	6.39	06-10-81	06-10-81	
343357096562201	01N-03E-12 DCB 1	White, B.L.	1075	--	3.34	06-11-81	--	
343352096562601	01N-03E-12 DCC 1	White, B.L.	1060	--	1.82	06-11-81	--	
343351096565601	01N-03E-12 DCC 2	White, B.L.	1060	41.2	.39	06-11-81	06-11-81	A
343356096561601	01N-03E-12 DCD 1	White, B.L.	1055	12.4	0	06-11-81	06-11-81	

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343352096560901	01N-03E-12 DDC 1	Meeks, Wilber	1065	21.8	3.36	06-10-81	06-10-81	
343335096574601	01N-03E-14 BCA 1	Boles, R.L.	1030	17.0	4.38	06-10-81	06-10-81	
343334097575901	01N-03E-14 BCB 1	Boles, R.L.	1075	100	23.15	06-10-81	06-10-81	A
343347097001201	01N-03E-17 AAA 1	Knight	1030	34.9	5.30	06-09-81	06-09-81	
343300097014001	01N-03E-18 DCC 1	Mobly	985	48.7	35.37	06-04-81	06-04-81	
343206097012101	01N-03E-19 DDC 1	Schultz	940	12.3	7.98	06-03-81	06-03-81	
343214096582901	01N-03E-22 DCD 1	Jack, Jamie	980	--	--	--	--	F, A
343207096570701	01N-03E-23 CCC 1	Cunningham Brothers	1100	1280	--	- -11	--	F, R, A
343125096575301	01N-03E-26 CCB 1	Oklahoma Gas and Electric Co., Well 1	985	529	--	--	--	F, R, L, A
343143096580501	01N-03E-27 ADD 1	Freeman, Jim	990	800	--	--	--	F
343138096580901	01N-03E-27 DAA 1	Oklahoma Gas and Electric Co., Well 3	970	868	15	10-15-58	--	R, L, A
343125096580901	01N-03E-27 DDD 1	Oklahoma Gas and Electric Co., Well 2	965	838	--	- -51	07-02-87	F, R, L, A
343141097001001	01N-03E-29 ADD 1	Stanford, Bennett	1035	91.7	12.84	06-10-81	06-10-81	
343206097014901	01N-03E-30 BAA 1	Arms	985	29.7	3.62	06-03-81	06-03-81	
343116097011201	01N-03E-30 DDD 1	Jayne, Josie	970	14.1	1.30	06-09-81	06-09-81	
343109097021101	01N-03E-31 BBB 1	Dalley	980	27.2	-1.44	06-03-81	06-03-81	
343102097021001	01N-03E-31 CBB 1	Chandler	980	67.6	.60	06-02-81	06-02-81	P, A
343046097004001	01N-03E-32 CAA 1	Fleming	995	5178	--	--	--	L
343047097000601	01N-03E-33 CBB 1	Gaunt, Royce	980	495	400	07-18-85	--	R, L
343040096592001	01N-03E-33 D 1	Molacek, Tom E.,	940	928	--	08-17-61	--	F, L
343036096585201	01N-03E-33 DAC 1	Molacek, Tom E., well 1	995	835	--	- -06	--	F, R, A
343030096585201	01N-03E-33 DAC 2	Molacek, Tom E., well 2	958	678	--	- -35	--	F, R, A
343033096585201	01N-03E-33 DAC 3	Molacek, Tom E., well 3	990	625	--	--	--	A

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343115096580501	01N-03E-34 AAA 1	Lacey, O.L., well 1	970	460	--	- -23	--	F, R
343106096581701	01N-03E-34 ACB 1	Lacey, O.L., well 2	970	555	--	- -25	--	F, R, A
343106096584801	01N-03E-34 BAC 1	Golf course	995	--	--	--	--	F
343028096585001	01N-03E-34 CCA 1	Commercial Hotel	980	618	--	- -10	--	F, R
343004096585201	01N-03E-34 CCA 2	Lewis, J.J.	950	700	--	- -31	--	F, R, A
343025096590201	01N-03E-34 CCC 1	Bridgeman, Oscar	950	243	--	- -04	--	F, R
343049096585201	01N-03E-34 DBA 1	Renfro, I.C.	985	--	--	09- -40	--	F, R, A
343030096582101	01N-03E-34 DCD 1	Townsley, John	960	550	--	- -05	--	F, R
343030096580401	01N-03E-34 DDA 1	Southland Hotel (Tribble)	1010	595	--	- -25	--	F, R
343035096575901	01N-03E-34 DDAD 1	Sulphur Steam Laundry	1010	400	--	- -05	--	F, R, A
343030096582102	01N-03E-34 DDC 1	Carter, R.J.	995	440	--	- -07	--	F, R, A
343036096580501	01N-03E-34 DDD 1	Artesian Hotel, Bill Allen	995	850	--	- -22	04-13-50	F, R, A
343038096575901	01N-03E-34 DDD 2	Wyley, Ethyl	1010	--	--	- -08	--	F, R, A
343115096575501	01N-03E-35 B 1	Lacey, O.L., well 3	970	500	--	- -25	--	F, R
343115096574901	01N-03E-35 BCA 1	Ross, R.D.	970	440	--	- -39	--	F, R, A
343043096573401	01N-03E-35 CAD 1	Mosley, J.B.	1050	580	--	--	--	F
343043096575702	01N-03E-35 CBC 1	Keith, B.F., well 1	1015	450	--	--	--	
343043096575701	01N-03E-35 CBC 2	Keith, B.F., well 2	1010	450	--	- -15	--	F, R
343043096574901	01N-03E-35 CBD 1	Glover, Joe B.	1040	300	--	--	--	
343049096571001	01N-03E-35 DAB 1	Oklahoma State School for the Deaf	1100	1014	--	--	--	
343030096570701	01N-03E-35 DDA 1	Sulphur, City of, Well 3	1040	460	--	--	--	F
343029096570501	01N-03E-35 DDA 2	Sulphur, City of, Well 4	1030	517	--	--	--	
343029096570201	01N-03E-35 DDA 3	Sulphur, City of, Well 6	1020	--	--	--	--	
343032096570001	01N-03E-35 DDA 4	Sulphur, City of, Well 7	1020	--	--	--	--	
343031096571101	01N-03E-35 DDB 1	Sulphur, City of, Well 1	1080	500	--	--	--	

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343031096570901	01N-03E-35 DDB 2	Sulphur, City of, Well 2	1065	568	18	12-06-56	--	
343029096570301	01N-03E-35 DDD 1	Sulphur, City of, Well 5	1020	--	--	--	--	F
343038096564601	01N-03E-36 CBD 1	Sulphur, City of, Well 9	1065	750	-13.42	10-06-82	--	F, R, L
343444096494201	01N-04E-01 DDD 1	Roos, C.	1245	71.0	--	05-23-77	--	D
343535096504301	01N-04E-02 AAA 1	Bradford, M	1280	360	185.78	12-02-76	--	
343450096504501	01N-04E-02 DDA 1	Sanders, J.	1270	335	144.70	12-03-76	--	M
343510096521901	01N-04E-03 CAA 1	Lee, Jess	1240	270	25	08-17-60	--	R, L
343533096532601	01N-04E-04 BAA 1	Latham	1190	29.0	12.15	06-11-81	06-11-81	
343450096525801	01N-04E-04 DDA 1	Latham, Cary	1245	12.5	6.70	05-15-62	--	A
343413096535801	01N-04E-08 DAB 1	Woodruff, Debbie	1175	12.06	--	--	--	
343423096522701	01N-04E-10 BDC 1	Grimm, Alfred	1225	210	--	--	12-03-76	Q
343358096524201	01N-04E-10 CCC 1	Lee, Jess	1210	28	5.71	11-08-61	--	
343418096514701	01N-04E-10 DAA 1	Lee, Jess	1210	56.5	17.08	11-08-61	--	
343440096511001	01N-04E-11 ABB 1	Franklin, Ray	1260	300	80	04-02-83	--	R, L
343444096513901	01N-04E-11 BBB 1	Unknown	1230	172	115.84	11-09-61	--	
343437096514001	01N-04E-11 BBC 1	Unknown	1230	121	--	12-03-76	--	D
343415096514001	01N-04E-11 CBB 1	Hudson	1230	122	89.81	06-03-77	06-03-77	
343418096505201	01N-04E-11 DAB 1	Glass sand plant, Joe King, owner	1255	178	120	11-09-61	--	R
343358096494101	01N-04E-12 DDD 1	Chapman, Jim A.	1205	301	80	08-17-61	--	R, L
343313096503801	01N-04E-13 CBC 1	Muntz	1260	57.0	17.73	06-03-77	06-03-77	
343327096504201	01N-04E-14 ADD 1	Epperly	1260	120	40.50	06-03-77	06-03-77	r
343326096512401	01N-04E-14 CAB 1	Heuatt, Otis M.	1205	157	15.16	11-09-61	--	
343324096513301	01N-04E-14 CBA 1	Hickory Baptist Church	1215	131.7	5.85	06-02-77	--	r
343308096513801	01N-04E-14 CCB 1	De Moss, James	1240	119.4	17.12	06-02-77	--	
343326096510801	01N-04E-14 DBB 1	Moore, Harold	1230	230	25	08-17-61	--	R, L

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343352096514701	01N-04E-15 AAA 1	Easley, Dr. G.T.	1200	145.5	71.65	11-08-61	--	
343345096514601	01N-04E-15 AAD 1	Easley, Dr. G.T.	1200	136.9	62.50	06-03-77	06-03-77	
343337096522801	01N-04E-15 BDA 1	Lee, Jeff	1190	133	30.61	06-03-77	--	
343326096514701	01N-04E-15 DAA 1	Hickory, Town of	1205	14	6.96	11-10-61	--	
343221096542501	01N-04E-20 CDA 1	Jennings, J.B.	1195	325	13.44	05-15-62	--	A
343213096525201	01N-04E-21 DDA 1	Turner, Roy J.	1180	1170	92.44	10-21-76	--	A
343216096514501	01N-04E-22 DDA 1	Turner, Roy J.	1250	780	170	03-23-57	--	R, M
343208096494101	01N-04E-25 AAA 1	Turner, Roy J.	1205	1020	150	12-29-58	--	R, M
343127096500901	01N-04E-25 DBC 1	L.B. Land Co.	1210	155	150.66	12-07-76	--	
343201096525801	01N-04E-28 AAC 1	Powell, George	1180	194.5	77.84	11-10-61	--	r
343208096532201	01N-04E-28 BAA 1	Donoghe	1155	90.5	44.60	11-10-61	--	A
343132096530401	01N-04E-28 DBD 1	Powell, George	1170	165	102.95	11-12-76	11-12-76	
343158096543101	01N-04E-29 BAB 1	Standifer	1200	249	124.02	11-18-76	--	
343201096544001	01N-04E-29 BBD 1	Jennings, J.B.	1210	248	70	05-15-62	--	R
343141096550901	01N-04E-30 ADB 1	Johnston, H.	1200	307	133.28	11-18-76	11-18-76	
343121096545701	01N-04E-30 DDA 1	Hood, Carl	1195	190	128.05	11-18-76	--	
343037096552101	01N-04E-31 CAD 1	King, Paul	1190	195	105.96	11-18-76	--	A
343045096554201	01N-04E-31 CBA 1	Richardson, Cal	1220	225	100	08-28-61	--	R, M, A
343111096543301	01N-04E-32 BBA 1	Brown	1160	800	84	11-12-76	--	A
343051096542901	01N-04E-32 BDD 1	Powell, George	1160	188	54.59	10-22-76	10-22-76	r
343036096542501	01N-04E-32 CDA 1	Powell, George	1150	188.5	73.12	11-10-61	--	A
343030096535301	01N-04E-32 DDD 1	Powell, George	1150	121.5	33.94	05-15-62	--	A
343105096525001	01N-04E-33 AAD 1	Powell, George	1200	170	111.25	11-12-76	- -56	Q, M A
343105096534401	01N-04E-33 BBC 1	Powell, George	1150	180	69.70	11-12-76	11-12-76	
343057096513701	01N-04E-35 CCC 1	Hardesty	1220	152	120.50	01-17-77	--	A

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343100096503001	01N-04E-36 BBB 1	Turner, Roy J.	1210	212	40	09-23-56	09-23-56	R, Q, A
343527096432001	01N-05E-01 AAD 1	Underhill, J.	1155	116.71	76.51	10-19-76	--	M
343530096454501	01N-05E-03 AAB 1	Unknown	1210	168	122.52	01-13-59	--	P
343534096453701	01N-05E-03 ABB 1	Roos Ranch	1215	157	132.85	12-02-76	--	
343445096462001	01N-05E-03 CCB 1	Eager, J.B.	1210	160	60	10-03-56	10-03-56	R, A
343447096453801	01N-05E-03 DDB 1	L.B. Land Co.	1180	142	96.42	12-10-76	--	
343534096470001	01N-05E-04 BAA 1	Roos Ranch	1215	143	134.70	12-02-76	--	
343530096470001	01N-05E-04 BAA 2	Chapman, Jim A.	1210	300	130	10-03-56	--	R
343535096485001	01N-05E-06 AAA 1	Roos Ranch	1255	195	174.50	12-02-76	--	r
343525096490001	01N-05E-06 AB 1	Chapman, Jim A.	1235	300	127.92	01-14-59	--	
343530096491501	01N-05E-06 BAA 1	Chapman, Jim A.	1240	300	130	10-03-56	10-03-56	R
343440096481601	01N-05E-08 BAB 1	Roos Ranch	1205	--	120.56	12-08-76	--	
343423096463301	01N-05E-09 ADA 1	Buxton	1195	150	108.64	12-08-76	12-08-76	r, M
343345096413001	01N-05E-10 CCC 1	Unknown	1180	106	75.75	11-14-58	--	A
343353096453401	01N-05E-10 DCC 1	L.B. Land Co.	1180	105	93.63	12-08-76	--	
343352096453401	01N-05E-10 DDD 1	Buxton	1180	103	56.97	10-20-76	--	
343440096451501	01N-05E-11 BBA 1	L.B. Land Co.	1180	95.0	92.97	12-10-76	--	
343352096451501	01N-05E-11 CCD 1	Green, Sidney	1160	118	69.62	10-20-76	--	
343352096444001	01N-05E-11 DCD 1	Parrish	1192	259	114.38	10-20-76	10-20-76	
343432096434801	01N-05E-12 ABC 1	Herd, Larry	1155	113	85.53	10-19-76	--	
343402096432201	01N-05E-12 DDA 1	Herd, Larry	1168	187	104.87	10-19-76	10-19-76	
343345096431501	01N-05E-13 AAA 1	Unknown	1120	112	54.98	11-14-58	--	
343348096434901	01N-05E-13 ABB 1	Wyche	1132	108	55.73	10-20-76	--	
343323096452201	01N-05E-14 CBB 1	Buxton	1165	194	82.42	12-10-76	--	
343340096455501	01N-05E-15 ABB 1	Buxton	1160	--	71.32	11-14-58	--	M

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343329096461401	01N-05E-15 BCA 1	Unknown	1185	56.0	--	10-20-76	--	D
343330096471501	01N-05E-16 B 1	Buxton Horseshoe Ranch	1205	770	40	09-23-56	09-23-56	R
343317096463001	01N-05E-16 DAD 1	Buxton Horseshoe Ranch	1190	168	92.65	11-14-58	12-10-76	M
343305096475501	01N-05E-17 DCB 1	Buxton Horseshoe Ranch	1185	--	96.27	01-06-59	--	
343643096470701	01N-05E-21 CDB 1	L.B. Land Co.	1145	235	63.88	12-07-76	--	A
343232096462001	01N-05E-22 CBB 1	Parrish	1135	153	49.48	01-22-59	10-20-76	
343230096452701	01N-05E-22 DAA 1	L.B. Land Co.	1155	--	92.40	12-08-76	--	
343219096442701	01N-05E-23 DDA 1	Unknown	1120	76.0	45.65	01-19-59	--	
343254096434201	01N-05E-24 ABA 1	Young	1135	125	69	00-00-66	10-21-76	R
343230096431501	01N-05E-24 DAA 1	Norris Estate	1120	125	42.47	01-19-59	--	
343115096444501	01N-05E-26 AC 1	Norris Estate	1135	--	76.54	01-20-59	--	A
343120096455801	01N-05E-27 CDD 1	Roy Turner Ranch	1145	267	83.89	11-21-58	--	
343120096455001	01N-05E-27 DCC 1	Norris Estate	1150	2500	61.28	12-03-58	--	C, M
343120096455301	01N-05E-27 DCC 2	US Geological Survey	1150	115	72.19	01-06-59	12-03-58	Q, A
343135096472501	01N-05E-28 ACC 1	Turner, Roy J.	1145	--	110.25	01-14-59	--	A
343608096470001	01N-05E-28 CAA 1	L.B. Land Co.	1190	220	115.03	12-08-76	--	A
343610096483701	01N-05E-30 ADD 1	L.B. Land Co.	1210	--	107.85	12-07-76	--	A
343137096491801	01N-05E-30 CAC 1	Roos	1040	--	--	--	12-07-76	
343036096491801	01N-05E-31 CDB 1	Davisson, W.G.	1220	187	144.00	01-20-77	01-20-77	Q
343453096473701	01N-05E-32 DDC 1	Davisson, W.G.	1170	205	97.43	01-20-77	--	A
343525096464501	01N-05E-33 ACA 1	Davisson, W.G.	1180	187	99.33	01-20-77	--	A
343107096443001	01N-05E-35 AAC 1	L.B. Land Co.	1180	165	76.23	12-08-76	--	
343049096450601	01N-05E-35 CAB 1	Norris	1185	220	98.76	01-14-59	--	r
342951097032101	01S-02E-02 DAA 1	Birch, Odell G.	945	152	6.98	06-09-81	06-09-81	
342948097031901	01S-02E-02 DAD 1	Birch, Odell G.	945	16.0	3.05	06-09-81	06-09-81	

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
342858097031601	01S-02E-12 CBB 1	Danyaur	990	40.0	8.32	06-09-81	06-09-81	
342850097031801	01S-02E-12 CCB 1	Macy, V.	980	18.4	2.27	06-09-81	06-09-81	
342818097031201	01S-02E-13 BCC 1	Stag, Cecil	980	26	17.48	02-12-68	02-12-68	
342818097032801	01S-02E-14 ADC 1	Stag, Cecil	1000	120	16.00	02-12-68	02-12-68	
342528097080901	01S-02E-31 CAC 1	Chapman, Bill	1115	225	23.35	12-29-77	12-29-77	Q
343017096561501	01S-03E-01 ABA 1	National Park Service, East Well	1140	238	68.5	08-14-72	08-03-72	L, Q, C, M, A
343021096563701	01S-03E-01 BAA 1	Sulphur, City of, Well 8	1110	675	--	08-21-55	04-16-68	F,R,A
343022096565701	01S-03E-01 BBB 1	National Park Service, West Well	1080	436	27.0	08-14-72	08-00-72	R ,L, Q, C, M
343030096581301	01S-03E-02 BBA 1	White	970	385	--	- -37	--	F,R,A
342947096574501	01S-03E-02 C 1	Anderson	1050	27	3.0	03-27-68	--	
342939096574501	01S-03E-02 CDB 1	State Veteran's Hospital	1070	--	--	--	--	L
343020096582301	01S-03E-03 ABA 1	National Park Service, Vendome Well	945	365	--	- -22	11-15-55	F, R, L, Q
343004096590001	01S-03E-03 ADD 1	Ketchem	920	665	--	- -39	--	F, R, A
343029096584501	01S-03E-03 BAB 1	City Drug	980	300	--	--	--	F
343025096585001	01S-03E-03 BBAA 1	Jarman, Eddy (Old Creamery)	980	--	--	--	--	F, A
343004096584501	01S-03E-03 BDC 1	Lewis Sanitarium	950	569	--	09-23-54	--	F, R, L, A
342957096585201	01S-03E-03 CBA 1	Frye Sanitarium	935	540	--	- -17	--	F, R, A
343025096591001	01S-03E-03 CBA 2	Caylor Bath House	950	650	--	- -26	--	F, R, A
343028096585401	01S-03E-03 CBA 3	Cotton, Henry	970	602	--	- -24	--	F, R, A
343020096590901	01S-03E-04 AAA 1	Colbert (Wyandotte)	945	--	--	--	07-02-87	F
342929096575801	01S-03E-11 BBB 1	Porter, Walter	1020	210	--	--	06-19-81	
342923096580001	01S-03E-11 BBC 1	Dresser, Bill	1020	180	4.30	06-19-81	06-19-81	
342846096570401	01S-03E-11 DDA 1	Wade, M.A.	1165	110	35	06-01-77	06-01-77	R
342838096571501	01S-03E-11 DDC 1	Wade, M.A.	1170	171	--	--	--	L
342842096565801	01S-03E-12 CCC 1	Lewis, R.	1130	101	12.61	06-16-81	--	

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
342836096560201	01S-03E-13 AAA 1	Mize, Richard L.	1130	94.4	42.50	06-16-81	06-16-81	
342837096560801	01S-03E-13 AAB 1	Mize, Don L.	1135	112	67	06-16-81	06-16-81	
342836096562801	01S-03E-13 ABB 1	Aaron, A.R.	1180	68.0	10.64	02-09-77	--	
342832096572301	01S-03E-14 ABD 1	Allen, Fred	1170	49.2	19.86	02-09-77	02-09-77	Q, M, A
342831096571901	01S-03E-14 ABD 2	Chadwick, E.M.	1170	37.5	11.43	06-17-81	06-17-81	
342828097012701	01S-03E-18 AAC 1	Baumgardner	1000	68.4	14.17	06-10-81	06-10-81	
342742096591901	01S-03E-21 AAC 1	Hunt, Luther	1030	188	87.89	02-10-77	--	
343224096592601	01S-03E-21 DBD 1	Travertine Properties, Inc.	940	166	72	06-20-83	--	R, L, A
342734096584901	01S-03E-22 BAC 1	Griffitts, G.	1045	254	45.99	02-10-77	--	M
342727096560301	01S-03E-24 ADA 1	Lowrance, Allice	1100	102	59.13	02-09-77	--	
342731096563001	01S-03E-24 BDA 1	Lowrance, Charles	1045	162.5	--	--	02-22-77	Q
342658096570001	01S-03E-24 CCC 1	Lowrance, Mrs. Bill	1060	58.0	10	06-16-81	06-16-81	P, R
342654096564201	01S-03E-24 CDC 1	Lowrance, Robert	1035	10.6	3.45	06-15-81	06-15-81	
342654096560601	01S-03E-25 AAA 1	Lowrance, Oscar, Jr.	1060	60.0	12.08	02-10-77	--	
342701096570401	01S-03E-35 AAA 1	Cast, Charles M.	970	35.6	10.70	06-15-81	06-15-81	r, A
342602097572801	01S-03E-35 ABB 1	Allmon, Gary	950	11.2	4.69	06-15-81	06-15-81	r
343018096505001	01S-04E-02 AAB 1	L.B. Land Co.	1210	185	131.00	01-18-77	--	
343010096521501	01S-04E-03 AAC 1	J.R. Long & Sons Highway Ranch	1240	203	60	03-28-61	--	R
343008096515301	01S-04E-03 ACA 1	Freez	1245	230	169.93	01-19-77	01-19-77	
342933096535601	01S-04E-05 DDD 1	Watson, Ralph	1165	133	61.24	01-19-77	01-19-77	
342954096554701	01S-04E-06 CB 1	Hunt, Mrs. Scott	1215	197	131.60	03-07-68	--	
342952096545801	01S-04E-06 DAA 1	Collins, Ernest	1160	400	10	06-19-81	06-19-81	P, R
342931096552001	01S-04E-07 ABB 1	Scott Hunt Estate	1160	90	6.38	05-17-62	--	
342901096550101	01S-04E-07 DAA 1	Moss, Calvin	1190	252	95	04-29-55	06-18-81	R, L
342842096550001	01S-04E-07 DDD 1	Flurry, Robert E.	1175	62.6	8.65	06-17-81	06-17-81	r

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342911096535601	01S-04E-08 ADA 1	Kirby, Bob	1165	80.0	47.22	06-18-81	06-18-81	P
342905096535501	01S-04E-08 ADD 1	Chaffin, Melvin I.	1150	50	27	06-18-81	06-18-81	P, R
342928096534401	01S-04E-08 BBA 1	Mckinley, Rossy E.	1160	99.6	33.70	06-18-81	--	A
342903096540501	01S-04E-08 DAB 1	Curry, Buster	1145	105	72.25	02-09-77	--	
342840096535701	01S-04E-08 DDD 1	Stout, J.A.	1130	98.0	14.60	02-10-77	--	
342901096532901	01S-04E-09 CAA 1	Long, J.R.	1115	16.0	11.35	06-17-81	06-17-81	
342905096532801	01S-04E-09 CAA 2	Long, J.R.	1130	23.8	11.00	06-17-81	06-17-81	
342904096535101	01S-04E-09 CBB 1	Long, J.R.	1145	85.8	73.20	06-17-81	06-17-81	
342904096534802	01S-04E-09 CBB 2	Long, J.R.	1145	140	40	06-17-81	06-17-81	R
342848096535001	01S-04E-09 CCB 1	Chaffin, Paul	1135	35.0	10	06-18-81	06-18-81	r, R
342841096532801	01S-04E-09 CDD 1	Chaffin, Paul	1100	124	35.45	06-18-81	06-18-81	r
342843096505201	01S-04E-11 DCC 1	Sparks, John	1190	148	94.87	01-18-77	--	
342835096505501	01S-04E-11 DDD 1	Unknown	1185	130	62.36	03-28-61	--	A
342917096494301	01S-04E-12 ADA 1	Sparks, John	1135	110	48.00	01-25-77	08-25-77	M
342930096504201	01S-04E-12 BBB 1	L.B. Land Co.	1170	--	110.20	01-18-77	--	
342835096501201	01S-04E-13 ABB 1	Clement, Coke	1165	235	115.20	01-18-77	--	
342820096505001	01S-04E-13 BCA 1	Grace, W.M.	1180	44.0	16.38	03-29-61	--	A
342810096501301	01S-04E-13 CAA 1	Clements, Perry	1200	75	51.28	06-02-77	06-02-77	r
342837096521201	01S-04E-15 ABB 1	Gist, Roy	1150	100	70.00	02-08-77	--	
342818096525901	01S-04E-16 ADC 1	Runyams, Clyde	1095	40.0	16.33	07-27-77	--	
342832096535101	01S-04E-16 BBB 1	Unknown	1125	102	11.06	04-28-77	--	
342831096534501	01S-04E-16 BBC 1	Unknown	1120	47.5	12.22	05-16-62	--	
342834096534301	01S-04E-16 CBA 1	Freeman, Steve	1105	122	19.46	04-28-77	05-08-79	A
342810096534501	01S-04E-16 CBA 2	Freeman, Steve	1100	57	17	06-18-81	06-18-81	P, R
342803096525401	01S-04E-16 DAD 1	Runyans, Clyde	1085	--	16.38	07-27-77	12-05-78	

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342835096535801	01S-04E-17 AAA 1	Malloy, C.V.	1130	180	40	06-17-81	06-17-81	P
342835096545501	01S-04E-17 BBB 1	Goble, D.	1175	186	43.38	06-01-77	06-01-77	r
342817096545901	01S-04E-18 ADD 1	Parks, Lonzo	1120	150	31.80	02-09-77	--	
342837096553301	01S-04E-18 BAA 1	Neal, Gene	1180	118	6.84	02-10-77	--	
342836096555001	01S-04E-18 BBA 1	Neal, Anna B.	1160	144	21.70	06-17-81	06-17-81	P
342759096545801	01S-04E-18 DDA 1	Chadwick, Otis	1135	218	76.24	02-09-77	--	
342758096545801	01S-04E-18 DDA 2	Chadwick, Otis	1145	106	72.60	02-09-77	--	A
342728096525201	01S-04E-21 ADA 1	Brown, Jerry	1100	135	29.04	04-27-77	06-01-77	
342745096523001	01S-04E-22 BAA 1	Campbell, Tommie	1100	30.0	26.14	03-28-61	--	
342655096522501	01S-04E-22 CDC 1	Hancock, Byran	1095	135	47.20	02-08-77	05-24-77	M
342745096511501	01S-04E-23 ABA 1	Unknown	1110	35.0	20.78	03-28-61	--	
342745096504201	01S-04E-24 BBB 1	Gay, Royce	1135	119	27.93	02-04-77	--	
342633096494401	01S-04E-25 ADD 1	Daube	1095	86.0	61.72	01-27-77	--	
342604096501701	01S-04E-25 CDD 1	Goodson	1130	185	72.76	04-27-77	--	
342648096555101	01S-04E-30 BBB 1	Rackley, H.	1060	60.0	29.04	02-09-77		
342553096535401	01S-04E-32 AAD 1	Hancock, Byran	1150	80.0	5.32	04-27-77	--	
342533096531201	01S-04E-33 DBA 1	Hancock, Byran	1090	156	2.27	04-27-77	--	
342513096511701	01S-04E-35 CDD 1	Colvert, Paul	1095	83.0	19.06	02-04-77	--	
342947096451701	01S-05E-02 CAC 1	Davisson, W.G.	1180	173	128.88	01-20-77	--	
342950096454501	01S-05E-03 DBD 1	Thompson, Dorothy	1220	230	121.70	01-21-77	--	
343534096490701	01S-05E-06 BDA 1	Davisson, W.G.	1190	190	113.42	01-20-77	--	A
342908096481501	01S-05E-08 BDD 1	Sparks, John	1120	104	39.30	01-25-77	--	
342845096483001	01S-05E-08 CAA 1	Fred Hunt Ranch	1025	147	19.54	03-29-61	--	A
342928096465701	01S-05E-09 ABB 1	Thompson, Dorothy	1190	176	115.51	01-21-77	--	
342928096441501	01S-05E-12 BBA 1	Davisson, W.G.	1160	170	118.95	01-20-77	--	

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342840096442401	01S-05E-12 CCC 1	Davisson, W.G.	1140	160	114.45	01-20-77	--	
342817096462601	01S-05E-15 BCC 1	Thompson, Dorothy	1100	129	52.00	01-21-77	--	
342811096465501	01S-05E-16 DBA 1	Thompson, Dorothy	1120	200	--	--	01-21-77	
342750096474501	01S-05E-17 DDC 1	Cook, Horace	1105	202	22.03	04-29-77	04-29-77	
342830096484701	01S-05E-18 AAC 1	McDonald, W.E.	1110	106	11.28	04-29-77	04-29-77	
342740096485501	01S-05E-19 ACC 1	Daube Corp.	1185	155	75.37	02-03-77	--	A
342718096474301	01S-05E-20 DAA 1	Sparks, John	1105	80.0	48.70	04-29-77	--	
342733096443901	01S-05E-23 ADB 1	Daube Corp.	1090	171	30.50	05-24-77	--	
342600096450001	01S-05E-26 CDD 1	Patrick, George W.	1060	114	75.10	10-30-68	--	
342654096454001	01S-05E-27 AAB 1	Daube Corp.	1105	267	55.79	05-24-77	05-24-77	Q, M
342624096454501	01S-05E-27 DBA 1	Daube Corp.	1095	113	71.51	02-02-77	02-02-77	M
342613096472401	01S-05E-28 CCA 1	Daube Corp.	1090	80.0	61.90	02-03-77	--	
342600096484501	01S-05E-29 CCC 1	Daube Corp.	1085	165	90.90	10-30-68	--	A
342528096493401	01S-05E-31 CBC 1	Daube Corp.	1060	--	27.45	02-03-77	--	
342553096483001	01S-05E-32 BBD 1	Daube Corp.	1145	203	112.77	02-03-77	--	
342535096481001	01S-05E-32 CAA 1	Daube Corp.	1155	212	122.80	02-03-77	--	
342545096465301	01S-05E-33 ACC 1	Daube Corp.	1100	95.0	88.25	02-03-77	--	
342542096444801	01S-05E-35 ACA 1	Gray, Roger	1090	110	64.15	02-02-77	--	
342516096441701	01S-05E-36 CCC 1	Unknown	1065	93.0	67.52	12-09-76	--	
343724097072401	02N-02E-20 CCC 1	Green, Jesse	895	62.0	33.86	12-05-68	--	
343658097032101	02N-02E-26 ADD 1	Rose, Dean	965	30.0	7.28	12-05-68	--	
343920096583101	02N-03E-10 DBC 1	Hickman, Johnny	1165	120	12	07-08-85	--	R, L
343802096574501	02N-03E-23 BAA 1	Edwards, W.W.	1125	123	--	04-09-64	04-09-64	F, A
343810096580001	02N-03E-23 BBB 1	Murray County Rural Water District No. 1	1130	200	6	01-19-82	--	R, L
343718096563001	02N-03E-25 BAA 1	Odom, Ruby	1210	100	6	05-15-85	--	R, L

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343715097040501	02N-03E-30 AAA 1	Private owner	1085	44.0	2.17	12-05-68	--	A
344045096534501	02N-04E-04 BBA 1	Larsh, K.P.	1160	324	100	10- -56	--	R, L
344045096535001	02N-04E-04 BBB 1	Piper, Earnest	1170	173	50	06-26-55	--	R, L
343815096500501	02N-04E-13 DC 1	Midcontinent Glass Co.	1200	500	60	09-23-56	09-23-56	R
343815096495501	02N-04E-13 DCD 1	Midcontinent Glass Co.	1200	402	56.09	12-01-76	--	L
343820096545001	02N-04E-17 CCD 1	Lynch, Oliver M.	1155	60.0	11.88	11-05-68	--	A
343723096522301	02N-04E-22 CDC 1	Grueber, V.W.	1270	205	178.18	12-01-76	--	
343741096504601	02N-04E-23 DAA 1	Roff, City of	1225	1101	120	09-10-53	11-30-76	R, Q, A
343720096510001	02N-04E-23 DCD 1	Frisco Railroad	1225	95.5	74.45	11-07-61	--	
343745096495001	02N-04E-24 AD 1	Midcontinent Glass Co.	1205	380	60	01-14-59	--	R
343635096403501	02N-04E-25 CBC 1	Boyles, R.C.	1290	270	43.70	11-07-61	--	A
343645096514501	02N-04E-26 CBB 1	Unknown	1270	76.5	13.74	11-06-61	--	
343627096504501	02N-04E-35 AAA 1	Ray, J.R.	1305	160	53.69	12-01-76	--	A
343615096512501	02N-04E-35 BA 1	Midcontinent Glass Co.	1290	356	110	01-14-59	--	R
343612096503001	02N-04E-36 BCD 1	Roos Ranch	1270	173	164.10	12-02-76	--	
343958096442801	02N-05E-02 DDD 1	McDaniels	1300	204	73.69	02-02-77	02-02-77	
343950096454501	02N-05E-03 DCD 1	Barton, J.L.	1305	170	26.98	08-09-61	--	
344002096463101	02N-05E-04 DDD 1	Fitzhugh School	1255	650	--	--	11-30-76	
343945096463001	02N-05E-09 AAA 1	Jones, O.W.	1240	432	200	01-12-55	--	R, L
343945096464001	02N-05E-09 AAB 1	Alexander, Troy	1245	312	50	08-18-61	--	R, L, A
343945096464002	02N-05E-09 AAB 2	Baptist Church parsonage	1240	365	200	03-07-55	--	R, L
343954096471201	02N-05E-09 BAB 2	Sandmann	1200	2017	19.57	11-30-76	--	M
343954096474301	02N-05E-09 BBA 1	Webb, Richard	1215	318	62.35	11-30-76	11-30-76	A
343908096453001	02N-05E-10 DDD 1	Wingard, Tobe	1240	534	42.22	05-18-79	05-18-79	L
343903096443201	02N-05E-14 AAB 1	Wartchow, Bill	1245	73.0	59.60	02-01-77	02-01-77	

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343837096465601	02N-05E-16 CAA 1	Lucas, W.D.	1200	58.6	20	10-27-76	--	R, A
343855096474501	02N-05E-17 ABA 1	Robison, S.K.	1200	425	50	08-17-61	--	R, L
343836096474501	02N-05E-17 DAB 1	Eager, E.D.	1170	280	69.35	11-19-76	11-19-76	
343748096491401	02N-05E-19 BDC 1	Dixie Pallet	1200	110	27.72	11-19-76	11-19-76	
343723096485501	02N-05E-19 DCD 1	Kerr, Robert	1255	223	156.75	12-01-76	--	
343739096462601	02N-05E-21 CAD 1	Wingard, Harold	1170	86.0	69.90	03-25-77	--	A
343723096465001	02N-05E-21 DCD 1	Wingard, Harold	1170	130	76.52	10-27-76	11-16-77	M
343723096465002	02N-05E-21 DCD 2	Wingard, Harold	1170	165	--	--	11-16-77	
343740096453001	02N-05E-22 ADC 1	Nordean	1190	850	78.61	01-18-59	05-17-79	L
343806096442301	02N-05E-23 AAA 1	Wartchow, Leroy	1195	87.0	15.22	01-31-77	--	M
343722096444201	02N-05E-23 DCD 1	Wartchow, Cotton	1155	230	64.90	01-31-77	01-31-77	
343740096442001	02N-05E-24 CBB 1	Unknown	1195	117	76.95	12-03-58	--	
343720096433001	02N-05E-24 DCD 1	Unknown	1180	--	35.50	11-12-58	--	
343722096432801	02N-05E-24 DDC 1	Kirkland	1180	280	87.54	10-20-76	10-20-76	
343645096441501	02N-05E-25 BCC 1	Wingard, Harold	1150	98	59.14	11-07-58	--	
343640096440001	02N-05E-25 CAA 1	Unknown	1140	119	96.17	02-19-57	--	M, A
343625096441501	02N-05E-25 CCC 1	Wingard, Harold	1125	1527	16.9	11-07-58	--	L, M, A
343713096443001	02N-05E-26 AAC 1	Wingard, Lester	1175	270	100	10-19-76	10-19-76	R
343640096442501	02N-05E-26 DAD 1	Unknown	1140	121	75.92	02-19-57	--	M
343629096444001	02N-05E-26 DCD 1	Davis, H.A.	1155	108	80	10-20-76	10-20-76	R
343715096453001	02N-05E-27 AAA 1	Unknown	1160	113	71.14	12-03-58	--	
343715096462701	02N-05E-27 BBB 1	O’Neil	1150	152	44.07	12-03-58	--	M
343640096463001	02N-05E-27 CBB 1	Unknown	1160	36.0	14.10	12-03-58	--	M, A
343635096455001	02N-05E-27 DCB 1	O’Neil	1150	126	57.09	12-02-76	--	
343718096475801	02N-05E-29 ABB 1	Unknown	1210	--	118.20	12-02-76	--	

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
343707096483801	02N-05E-29 BCA 1	Pandergraf, Doug	1210	238	86.69	10-22-76	--	
343707096483701	02N-05E-30 ADA 1	Pandergraf, Doug	1220	141	118.24	10-22-76	--	
343555096484501	02N-05E-31 DAA 1	Chapman, Jim A.	1230	300	117.6	01-14-59	--	
343607096442501	02N-05E-35 ADD 1	Davis, A.	1170	121	77.12	10-19-76	09-05-30	
343555096450501	02N-05E-35 CAB 1	Chapman, Jim A.	1210	300	130	10-03-56	10-03-56	R
343620096433001	02N-05E-36 AAB 1	Unknown	1130	110	104.49	02-19-57	--	
343605096432001	02N-05E-36 AAD 1	Wingard, Tobe	1130	2048	30.61	01-16-59	09-23-56	A
343600096425501	02N-05E-36 ADA 1	Phillips, D.W.	1130	87	20.01	11-12-58	--	L, A
343555096441501	02N-05E-36 BCC 1	Unknown	1150	123.31	49.24	11-12-58	--	M, A
343545096441501	02N-05E-36 CBC 1	Pollock, Robert	1160	128.41	58.28	11-12-58	--	M, A
343557096432001	02N-05E-36 DAA 1	Phillips, D.W.	1150	140	64.90	10-19-76	- -62	M
343530096433001	02N-05E-36 DDC 1	Boyd, Jimmy	1170	147	84.36	01-09-59	--	A
342422097021901	02S-02E-01 DDD 1	Stephens, Danny	810	83.6	21.80	06-08-81	06-08-81	r
342429097081201	02S-02E-06 CDB 1	Chapman, Bill	1195	347	117.70	01-05-78	--	
342400097080301	02S-02E-07 BDA 1	Chapman, Bill	1170	424	105.06	01-05-78	01-05-78	Q
342338097070501	02S-02E-08 CDA 1	Chapman, Bill	1150	215	75.93	12-28-77	--	
342414097030501	02S-02E-12 BBA 1	Jordan, Robert A.	780	57.0	11.93	12-12-68	--	
342314097052501	02S-02E-15 BBC 1	Chapman, Bill	1150	200	90.88	12-30-77	--	
342248097051601	02S-02E-15 CBD 1	Chapman, Bill	1180	110	78.45	12-30-77	--	
342302097080401	02S-02E-18 BDB 1	Ellis (tenant)	1190	220	130	03-26-68	09-01-78	R
342417096592301	02S-03E-09 AAB 1	Dougherty	1075	2500	121.95	03-31-77	03-31-77	Q
342353096592801	02S-03E-09 ACD 1	Dougherty	1140	100	67.45	03-31-77	--	
342403096585901	02S-03E-10 BCA 1	Dougherty	1030	48.0	5.33	03-31-77	--	
342416096570301	02S-03E-11 AAA 1	Fox, G.L.	995	145	22	02-09-79	--	R, L
342340096570501	02S-03E-11 AAD 1	Myers, D.	965	29.0	11.50	03-31-77	--	r, A

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
342355096570201	02S-03E-11 ADD 1	Coleman, John	965	44	18.41	05-18-62	--	
342408096580301	02S-03E-11 BBC 1	Vickers, C.E.	955	100	16.10	03-31-77	03-31-77	
342341096575801	02S-03E-11 CBC 1	Donaho, W.H.	960	98.0	21.63	03-31-77	03-31-77	A
342408096571401	02S-03E-11 DBB 1	Myers, Dan	940	146	15.95	05-10-79	05-10-79	L, A
342417096560301	02S-03E-12 AAA 1	Williams, W.M.	1010	117	7.40	03-18-77	--	
342355096565401	02S-03E-12 BCC 1	Unknown	935	29.5	18.24	05-18-62	--	
342350096563201	02S-03E-12 CAA 1	Williams, W.M.	980	58.0	30.90	03-17-77	05-10-79	
342328096565401	02S-03E-12 CCC 1	Brown, Lee	930	80	35	08-15-61	--	R
342327096565901	02S-03E-13 BBB 1	Myers	920	614	-2.10	08-24-77	08-24-77	F
342335096565301	02S-03E-13 CCD 1	Williams, W.M.	935	79.0	17.21	03-17-77	05-08-79	M, A
342317096573601	02S-03E-14 BAD 1	Tenny, O.H.	945	44.0	4.65	03-31-77	--	
342234096574101	02S-03E-14 CDC 1	Johnston, B.W.	980	125	9.42	03-31-77	--	
342235097015001	02S-03E-18 CDD 1	Stogsdill, Bedford F.	750	380	19.31	12-12-68	--	
342156096580301	02S-03E-23 CBC 1	Kirkham, A.T.	1035	65.0	28.45	03-30-77	--	
342230096562001	02S-03E-24 ABA 1	Williams, W.M.	930	66.0	7.96	03-17-77	--	
342139096563301	02S-03E-25 BAA 1	Nelson, E.L.	895	67.0	13.82	03-18-77	03-18-77	r
342053096562201	02S-03E-25 DCD 1	McGiboney, W.	875	361	-6.30	12-06-78	03-30-77	F, L
342137096572701	02S-03E-26 ABB 1	Howe, A.H.	925	150	5.34	04-28-77	04-28-77	
342109096580401	02S-03E-26 CBB 1	Howe, A.H.	1025	24.0	6.12	04-28-77	--	
342137096580801	02S-03E-27 AAA 1	Howe, S.F.	1000	65.0	--	--	10-19-77	
342047096570601	02S-03E-35 AAA 1	Goddard	985	60.0	2.44	04-28-77	--	
342004096571501	02S-03E-35 DDB 1	Goddard	985	--	3.36	04-28-77	04-28-77	
342023096564001	02S-03E-36 BDB 1	Hale, L.V.	930	30.0	3.80	03-30-77	--	
342023096564201	02S-03E-36 BDB 2	Hale, L.V.	940	76.0	33.13	03-30-77	03-30-77	
342332096540401	02S-04E-08 DAC 1	Penner, Jack	1130	353	31.85	03-16-77	--	

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
342320096503001	02S-04E-12 CCD 1	Unknown	1000	56.0	25.77	10-23-68	--	
342238096524701	02S-04E-15 CCC 1	Penner, Jack	1110	139	25.02	03-16-77	--	
342302096532201	02S-04E-16 BDD 1	Penner, Jack	1145	235	49.78	03-16-77	--	
342300096540001	02S-04E-17 ADD 1	Penner, Jack	1110	240	51.53	03-16-77	--	
342314096554801	02S-04E-18 BBD 1	Williams, W.M.	985	85.0	20.04	03-17-77	05-09-79	
342241096551701	02S-04E-18 DCA 1	Williams, W.M.	1055	115	98.51	03-17-77	--	
342217096554601	02S-04E-19 BCA 1	Williams, W.M.	970	154	61.36	03-17-77	--	
342157096553901	02S-04E-19 CAC 1	Williams, W.M.	945	61.0	32.55	03-17-77	--	
342202096535501	02S-04E-20 DAA 1	Penner, Jack	1090	73.0	52.14	03-16-77	--	
342203096512301	02S-04E-23 CAB 1	Penner, Jack	1025	17.0	3.24	03-15-77	03-15-77	
342128096514501	02S-04E-26 BBC 1	South, E.C.	1090	125	16.72	03-14-77	--	
342113096513201	02S-04E-26 CBA 1	South, E.C.	1095	145	29.30	02-07-77	--	M
342100096513001	02S-04E-26 CBD 1	South, E.C.	1075	20.0	9.61	10-23-68	--	
342055096514501	02S-04E-26 CCB 1	South, E.C.	1050	30.0	8.23	03-14-77	--	
342101096531701	02S-04E-28 DCB 1	Penner, Jack	1070	45.5	43.40	03-16-77	03-16-77	
342012096514001	02S-04E-35 CBC 1	South, E.C.	1025	37.0	5.05	03-14-77	--	
342454096442301	02S-05E-01 BCB 1	Underwood	1055	270	46.61	12-09-76	12-09-76	
342448096441401	02S-05E-01 BCD 1	Underwood	1040	65.0	33.84	12-09-76	12-09-76	
342448096433501	02S-05E-01 DDC 1	Sullivan	1035	58.0	12.40	12-09-76	--	A
342454096454801	02S-05E-03 ACA 1	Gray, Roger	1110	140	95.70	03-25-77	01-31-77	
342432096463201	02S-05E-03 CBC 1	Gray, Roger	1130	180	100.05	01-31-77	01-31-77	M
342445096493001	02S-05E-06 B 1	Pennsylvania Glass Sand Corp.	1065	110	50	10-04-56	10-04-56	R
342415096492001	02S-05E-06 CD 1	Mill Creek, Town of	1050	250	33	12-27-63	--	R
342400096493001	02S-05E-07 BBD 1	Roberts, D.F.	1035	125	16.10	08-15-61	--	
342415096475101	02S-05E-08 ABA 1	Unknown	1030	--	57.06	03-02-81	--	

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Site ID	Local Identifier	Owner	Altitude of land surface (feet)	Depth of well (feet)	Depth to water below land surface (feet)	Date water level measured	Date quality parameter measured	Remarks
342415096480301	02S-05E-08 ABB 1	Rural Water District Well 1	1010	110	14.24	01-17-77	--	L
342417096480201	02S-05E-08 ABB 2	Rural Water District Well 2	1010	107	21.15	01-17-77	12-05-77	L
342417096480501	02S-05E-08 ABB 3	Rural Water District Well 3	1010	167	16.84	01-17-77	--	L
342414096472001	02S-05E-09 BBA 1	Gray, Roger	1095	130	55.82	01-31-77	--	
342413096453101	02S-05E-10 AAA 1	Gray, Roger	1085	180	50.52	06-02-77	02-01-77	
342326096453501	02S-05E-10 DDD 1	Gray, Roger	1075	183	46.76	02-01-77	02-01-77	Q
342322096440801	02S-05E-13 BAB 1	Gray Ranch	980	51.0	22.36	12-09-76	--	
342236096454301	02S-05E-15 DDC 1	Gray, Roger	1035	100	24.24	05-25-78	05-25-78	r
342315096484001	02S-05E-17 BBB 1	Unknown	980	72.0	35.58	10-23-68	--	
342144096432401	02S-05E-24 DDD 1	Unknown	955	230	45.11	01-03-77	01-03-77	
342121096432701	02S-05E-25 ADA 1	Unknown	930	33.0	14.71	01-03-77	01-03-77	
342135096450001	02S-05E-26 ABB 1	Unknown	965	25.0	9.80	10-23-68	--	
342105096481001	02S-05E-29 CAA 1	Hanvey, Jose L.	1010	31.0	19.39	10-23-68	--	

For additional information write to:

District Chief
U.S. Geological Survey
202 NW 66 St., Bldg. 7
Oklahoma City, OK 73116

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http://ok.water.usgs.gov

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