Effects of Municipal Ground-Water Withdrawals on the Arbuckle-Simpson Aquifer, Pontotoc County, Oklahoma

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Prepared in cooperation with the
CITY OF ADA and the
OKLAHOMA WATER RESOURCES BOARD

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi2)	2.590	square kilometer
cubic foot per second (ft3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06308	liter per second
gallon per day (gal/d)	3.785 x 10-3	cubic meter per day

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum 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.

EFFECTS OF MUNICIPAL GROUND-WATER WITHDRAWALS ON THE ARBUCKLE-SIMPSON AQUIFER, PONTOTOC COUNTY, OKLAHOMA

By Mark E. Savoca and DeRoy L. Bergman

ABSTRACT

The Arbuckle-Simpson aquifer in south-central Oklahoma consists of a thick sequence of folded and faulted carbonate and clastic rocks of Upper Cambrian to Middle Ordovician age. Fractures and karst features locally increase the aquifer's capacity to transmit and store ground water. The aquifer is a principal source of water for municipal and rural users.

A hydrologic study was conducted to evaluate the effects of municipal ground-water withdrawal from the Arbuckle-Simpson aquifer on local ground-water levels and discharge from nearby springs and streams in south-central Pontotoc County. A municipal well was pumped for 63 hours at an average rate of 1,170 gallons per minute. A maximum observed drawdown of 0.3 feet was recorded half a mile from the pumping well. Drawdown was observed as far as 1.2 miles from the pumping well. No measurable response was observed at any of the surface-water-discharge measurement sites; however, recharge from precipitation may have masked any decreases in discharge caused by the pumping. Simultaneous pumping of two municipal wells for 241 hours at average rates of 1,170 and 2,730 gallons per minute resulted in a maximum observed drawdown of 1.3 feet recorded at an average distance of 0.80 miles from the pumping wells. The most distant drawdown observed was at an average distance of 1.1 miles from the pumped wells. Less than 2 days after pumping stopped, increases in springflow were recorded at two springs; it is unknown whether these discharge responses reflect the effects of recharge from precipitation, or the combined effects of precipitation and the cessation of ground-water withdrawal.

The effects of the stress tests on the hydrologic system were offset by recharge from concurrent precipitation. The maximum observed drawdown represents about 6 percent of the median natural water-level fluctuation during the study period. The effect of drawdown could become critical during extended periods of low precipitation, if water levels are already near the bottom of domestic wells in the area. However, a comparison of maximum observed drawdown (1.3 ft) with the minimum saturated thickness of fresh ground water (1,500 ft) suggests that municipal pumping had little effect on the amount of ground water stored in the Arbuckle-Simpson aquifer in the study area. This evaluation is based on the limited pumping rates and times of the stress tests.

INTRODUCTION

The City of Ada, Oklahoma, began diverting water from Byrds Mill Spring for public supply in 1911. The spring, which is located approximately 12 miles (mi) south of Ada in south-central Pontotoc County, discharges water from the Arbuckle-Simpson aquifer (fig. 1). The aquifer crops out over an area of about 500 square miles (mi^2) west and south of Byrds Mill Spring, and consists of fractured carbonate and clastic rocks. The City of Ada completed three public-supply wells in the Arbuckle-Simpson aquifer during 1959–60. These wells, located between 1 and 2 mi south of Byrds Mill Spring, supply water to the City when spring flow is insufficient to meet Ada's needs. The wells were last used to supplement spring flow in 1980.

The U.S. Geological Survey (USGS), in cooperation with the City of Ada and the Oklahoma Water Resources Board, conducted a hydrologic study to evaluate the effects of municipal ground-water withdrawal from the Arbuckle-Simpson aquifer on local ground-water levels and discharge from nearby springs and streams that flow from the aquifer. Results

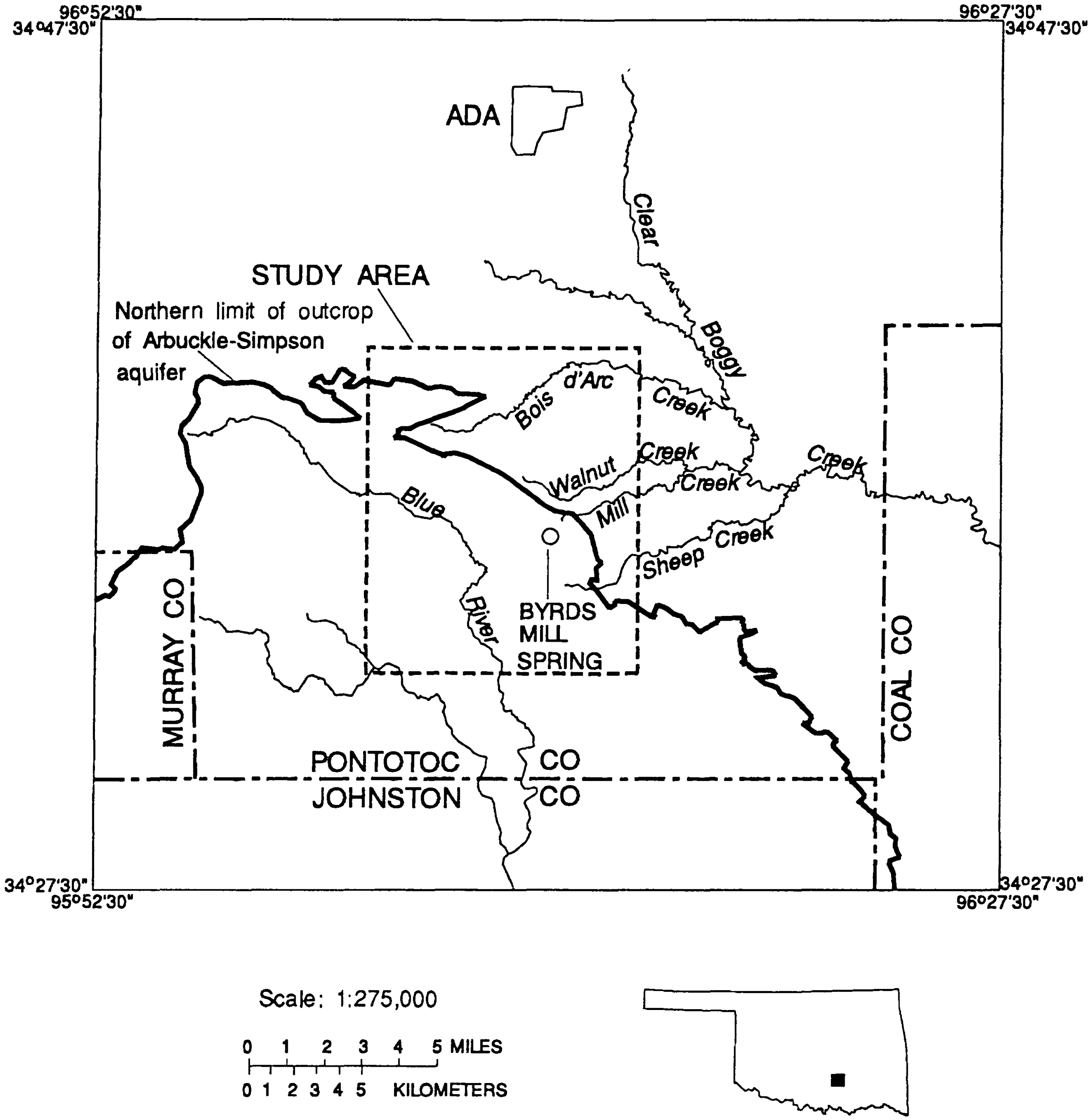

Figure 1. Location of study area, showing outcrop area of the Arbuckle-Simpson aquifer, principal streams, Byrds Mills Spring, and the City of Ada.

of the study will contribute toward an improved understanding of the hydrologic system, and provide a basis for ground-water development and management decisions.

Purpose and Scope

This report presents the results of a study to evaluate the effects of municipal ground-water withdrawal from the Arbuckle-Simpson aquifer. The scope of the work included a well, spring, and stream inventory to identify potential data-collection sites; construction of a potentiometric-surface map to determine the direction of ground-water movement in the study area; stress testing of the aquifer using municipal wells; water-level measurements and spring and stream discharge measurements to document the effects of municipal pumping; and the collection of rainfall data to aid in understanding climatic effects on the hydrologic system. The collection and analysis of water-quality data, and the determination of aquifer hydraulic properties (transmissivity and storativity) from an analysis of the stress-test drawdown data were beyond the scope of this study. Data used in preparing this report were obtained in the field and from published and unpublished records and reports of the USGS and other Federal, State, and local agencies.

Previous Studies

Descriptions of the geology of the area are given by Morgan (1924), Decker and Merritt (1928, 1931), Ham and others (1954, 1964), Ham (1955, 1956, 1969), and Fay (1968, 1969, 1989). The hydrogeology of the Arbuckle-Simpson aquifer has been described by Hart (1966, 1974), and Fairchild and others (1990).

Approach and Methods

Several types of data were collected and evaluated to document the effects of municipal pumping on the local hydrologic system. Periodic discharge-measurement sites were established at four locations along the main stem of Blue River, one location on Sheep Creek, and one location on an unnamed tributary to Mill Creek (pl. 1). A V–notch weir was installed at the unnamed tributary site. Temporary datums were established at each location, and periodic discharge measurements were made using current meters. Discharge measurements were made about once a week prior to the stress testing, and once a day during and after stress testing (table 1). Continuous discharge at Byrds Mill Spring was measured by a permanent gaging facility that records flow over a weir near the spring and flow in a pipe that diverts variable amounts of spring flow to the City of Ada (pl. 1, table 1).

Several existing privately owned wells were fitted with float-driven, automatic digital recorders to record water levels hourly, or with transducers to record water levels every fifteen minutes (pl. 1, table 2). Periodic water-level measurements were obtained from other wells in the area (pl. 1) using chalked steel tapes. Periodic measurements (table 2) varied from once a month prior to stress testing, to once a day during and after stress testing. All observation wells were selected on the basis of: lack of use during the study period to prevent the masking of antecedent conditions and stress-test effects; and proximity to, and radial coverage around, the pumping municipal wells to increase the probability of observing and defining the distribution of stress-test effects.

Precipitation data were collected by a tipping-bucket recorder installed at the Byrds Mill Spring gage house (pl. 1). Precipitation records also were obtained from the National Weather Service (NWS) station at Ada, Oklahoma. These data were used to examine the relations among precipitation, ground-water levels, and surface-water discharge.

Two different pumping stresses were placed on the aquifer. First, one municipal well was pumped at an average rate of 1,170 gallons per minute (gal/min) for 63 hours. Then two municipal wells were pumped simultaneously at a combined average rate of 3,900 gal/min for 241 hours. Water-level, streamflow, spring-flow, and rainfall data were used to evaluate the response of the aquifer to pumping.

Site-Numbering System

The number used to identify a well site is based on its location in a particular township, range, section, and quarter-section subdivisions. As shown in figure 2, the subdivisions are given from larger to smaller areas of the section; the final digit is the sequence number of a site within the smallest quarter-section subdivision. Discharge sites are identified with an eight-digit station number.

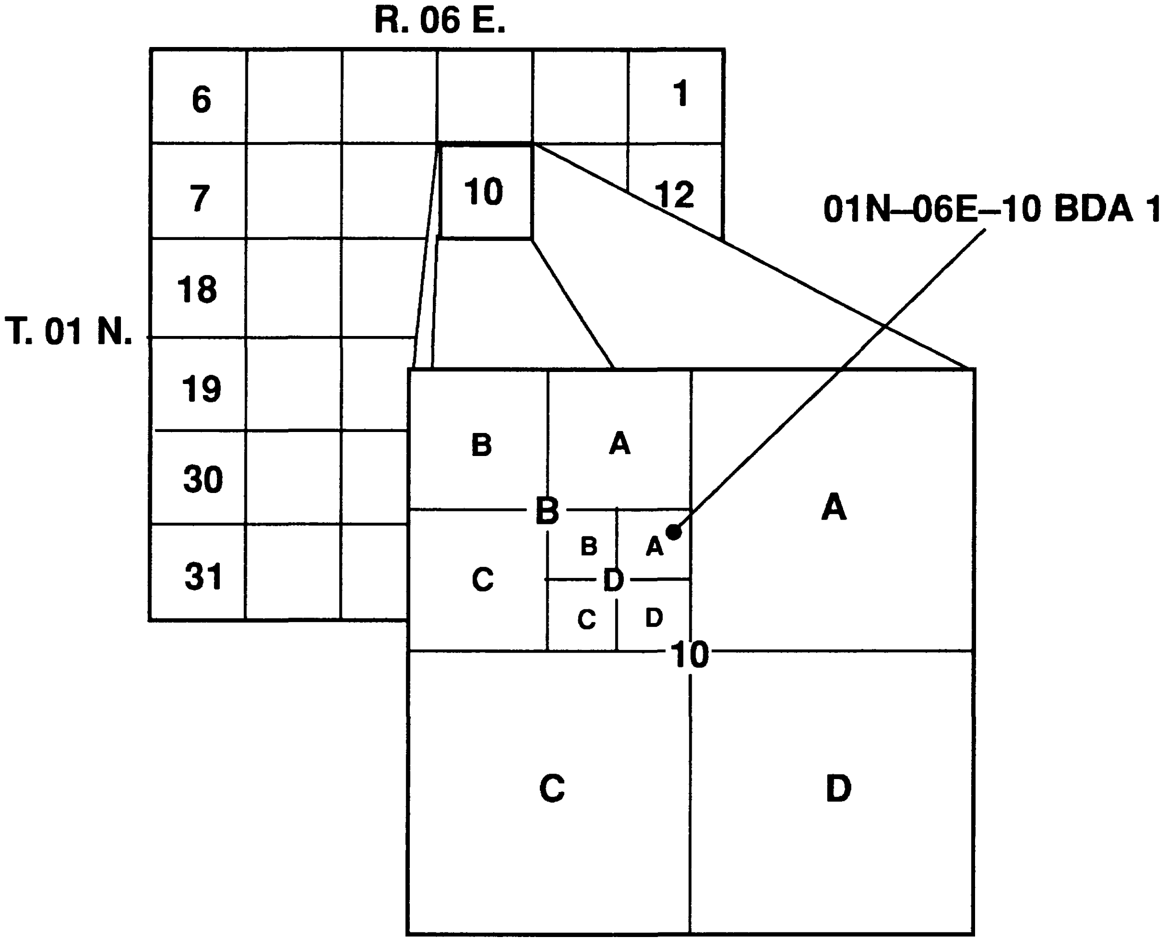

Figure 2. Site-numbering system.

Acknowledgments

The authors thank the residents of the study area for their cooperation and assistance in providing information about wells, ground-water use, and the location of karst features. City of Ada officials permitted the use of City wells for stress tests. Information and assistance were provided by members of the Ada Public Works Department.

DESCRIPTION OF THE STUDY AREA

Geography and Geology

Rocks forming the Arbuckle-Simpson aquifer are of Upper Cambrian to Middle Ordovician age and crop out over an area of about 500 mi^2 in south-central Oklahoma. The study area includes Byrds Mill Spring and adjacent parts of the Arbuckle-Simpson aquifer (fig. 1). The area is characterized by low ridges and dissected uplands and has relief of 50 to 250 feet (ft). Elevations within the study area generally are highest in the north and west. The highest altitude is about 1,320 ft above sea level in the northern part of the study area; the lowest altitude is about 850 ft above sea level in the southeast.

The Arbuckle-Simpson aquifer consists of a thick sequence of carbonate (dolomite and limestone) and clastic rocks of shallow-marine origin (pl. 1). These units were broadly folded and extensively faulted and jointed during several Middle and Late Pennsylvanian orogenic events (Ham, 1956, 1969). Northwest- and northeast-trending faults dominate the area. Karst features are present throughout the area.

Most of the study area is drained by the southward-flowing Blue River and its tributaries. Ground-water outflow from springs along the faulted northeastern margin of the aquifer is conveyed to the east and northeast by Bois d'Arc, Walnut, Mill, and Sheep Creeks (fig. 1, pl. 1).

Climate

The study area has a moist subhumid climate. Average annual precipitation, computed from the long-term NWS station at Ada is 39.37 inches (fig. 3). Most precipitation occurs in the spring during April, May, and June and in the fall during September and October (fig. 3).

Annual precipitation for each of the 3 years preceding this study, 1989, 1990, 1991, exceeded the long-term average by 26, 63, and 21 percent respectively. Precipitation for the first 7 months of 1992 exceeded the 7–month, long-term average by 40 percent. NWS precipitation data were not collected at the Ada station during August 1992. Precipitation for the month of September 1992 exceeded the long-term average for the month by 27 percent. Months and years with missing values were not used in statistical calculations.

Streamflow

Streamflow in the study area is sustained by ground-water discharge from the Arbuckle-Simpson aquifer during most years. No-flow conditions were observed periodically between 1976 and 1978 in the main stem of Blue River near site 07332310, as well as in several of its tributaries (R. W. Fairchild, U.S. Geological Survey, written commun., 1976–78). During the present study, streamflow in the main stem of Blue River was continuous; however, no-flow conditions were observed periodically in most of its tributaries.

Rain fell three times during the first 10 days of September 1992 (fig. 4). Direct runoff and subsequent increases in base flow produced increases in discharge in Blue River during and after each rainfall (fig. 4). Less pronounced increases in discharge were observed at Sheep Creek and the unnamed tributary to Mill Creek (fig. 5). The proximity of the discharge measurement sites to the spring discharge sources of these two streams probably minimized the effects of direct runoff. Less pronounced increases in discharge resulting from rainfall also were observed at Byrds Mill Spring (fig. 5). Discharge measurements obtained during rainfall events were not considered when evaluating base-flow (ground-water discharge to streams) volumes.

Discharge measurements at sites 07332302 and 07332305 (pl. 1) indicated a substantial gain in streamflow from ground-water discharge along the northern 2.7 mi reach of Blue River. Fifteen discharge measurements obtained from each site from August 17 through September 18, 1992, were used to estimate the average daily discharge for that period. An average discharge gain of about 12 cubic feet per second (ft^3/s), or about 7,800,000 gallons per day (gal/d) resulted from base flow within the intervening 5.8 mi^2 drainage area. Field observations confirmed the presence of numerous active seeps and springs along this section of the main channel of Blue River.

Contemporaneous discharge measurements at site 07332310 indicated an average discharge loss of about 1.5 ft^3/s, or about 970,000 gal/d along the southern 4.4–mi reach of Blue River between sites 07332305 and 07332310. On August 17, 1992, a discharge measurement was made at site 07332307. This measurement indicated a discharge loss between sites 07332305 and 07332307.

GROUND-WATER SYSTEM

Occurrence and Movement

Rocks of the Arbuckle-Simpson aquifer contain numerous faults and joints. These fractures provide openings for ground-water movement and storage. Faults commonly juxtapose different rock types that may have different values of hydraulic conductivity. Variations in hydraulic conductivity across faults can either facilitate or impede ground-water flow. For this reason, the location and orientation of faults may influence ground-water flow paths.

Much of the aquifer consists of carbonate rocks, which are soluble in the naturally occurring, mildly acidic water of the study area. Infiltrating water slowly dissolves soluble carbonate rock, leading to the formation of networks of channel-like openings of varying size, shape, and orientation, known as karst. The formation of karst is greatest where fractures, bedding

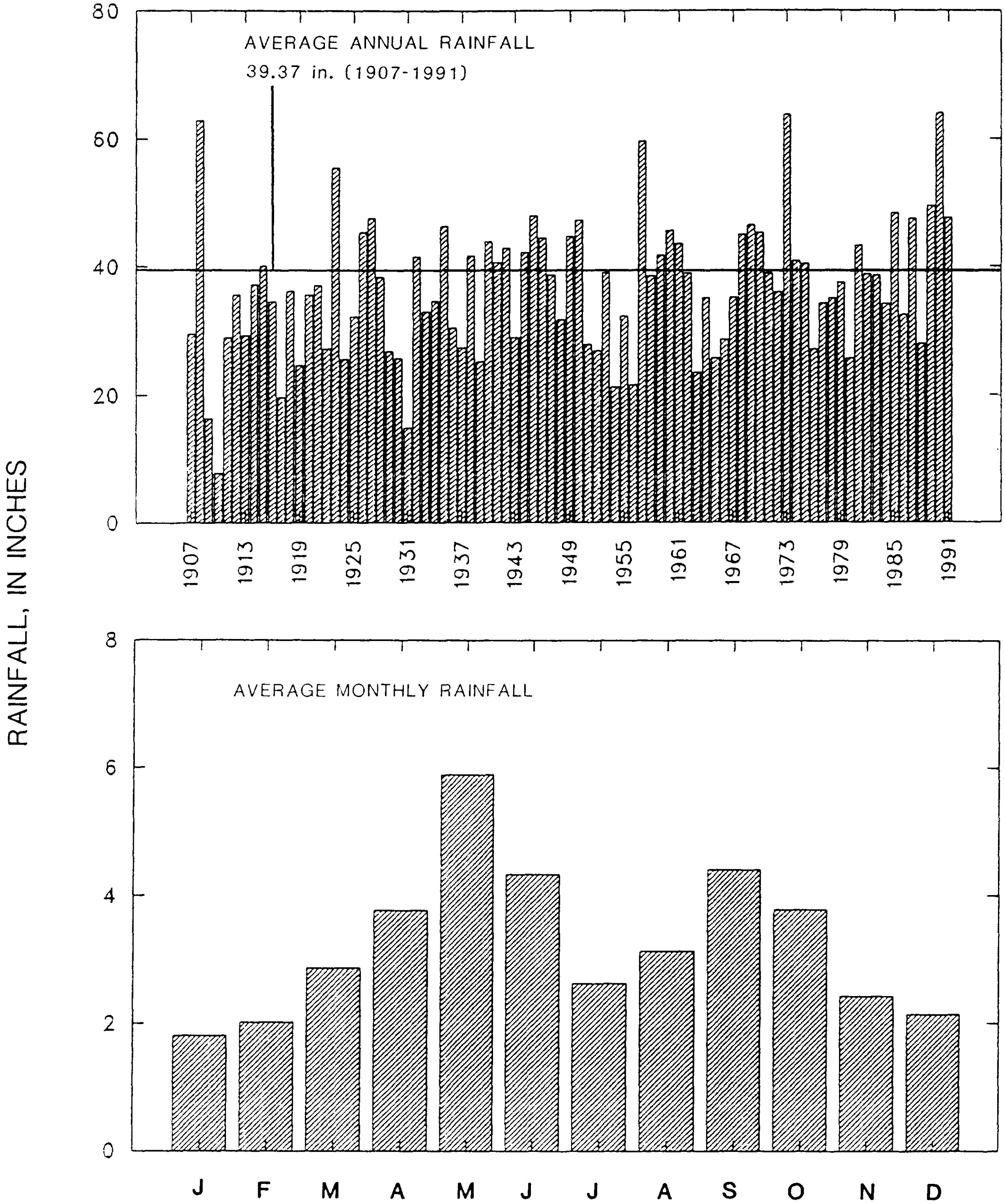

Figure 3. Average annual and average monthly rainfall at Ada 1907–91.

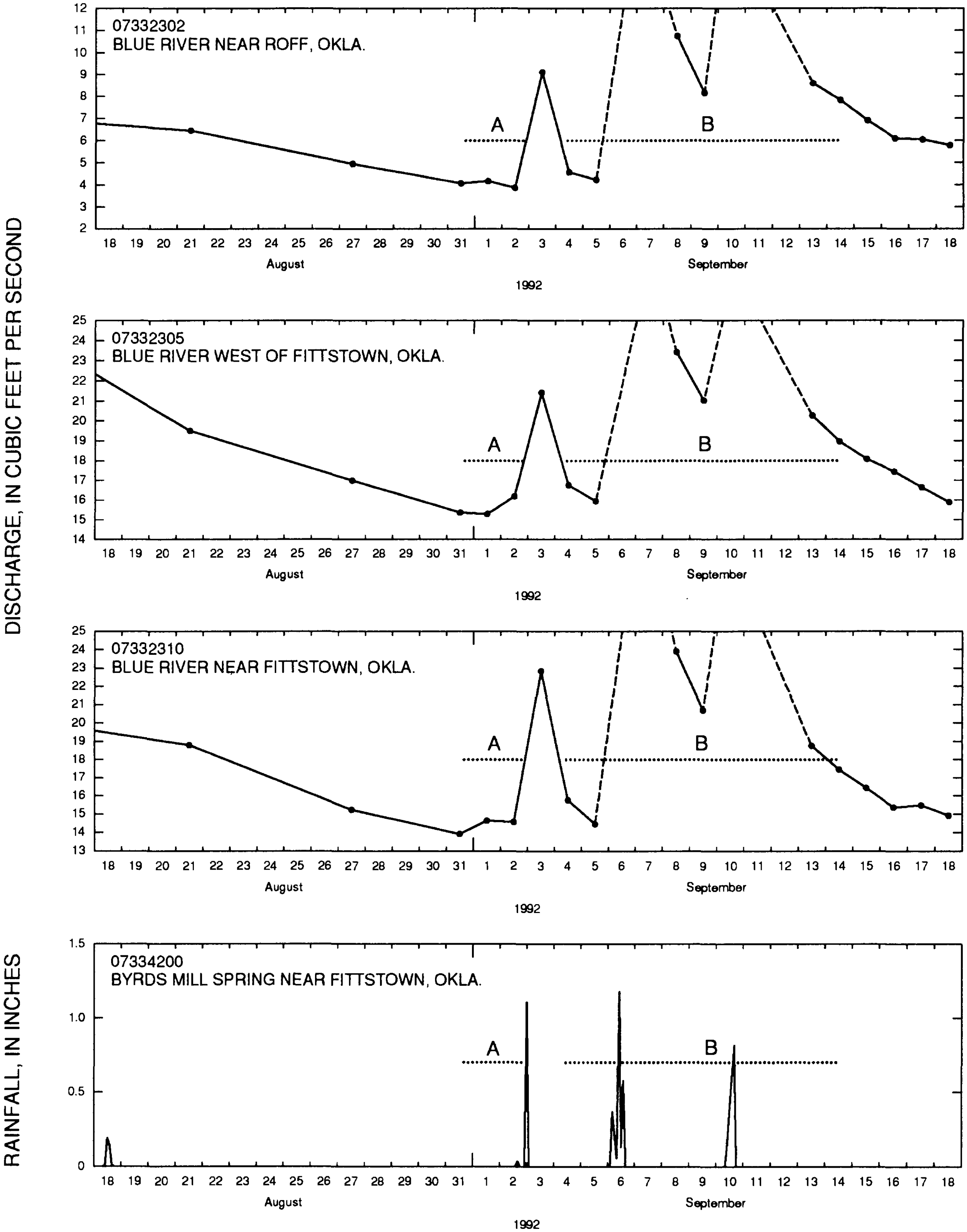

Figure 4. Rainfall at Byrds Mill Spring and discharge in Blue River during part of August and September 1992. [Dashed lines represent discharge inferred from field observations; A, single-well stress test; B, double-well stress test.]

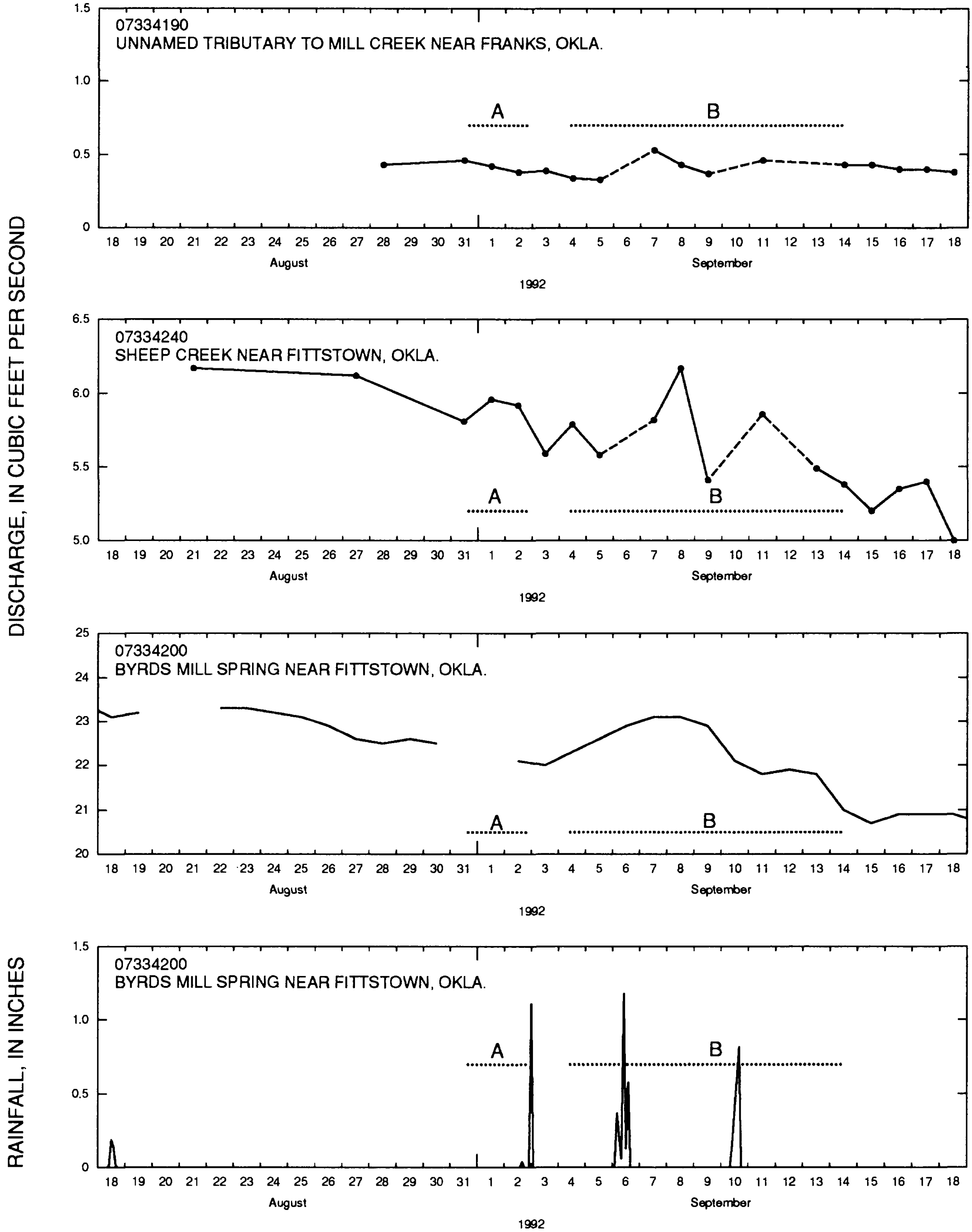

Figure 5. Rainfall at Byrds Mill Spring and discharge from springs and streams during part of August and September 1992. [Dashed lines represent discharge inferred from field observations; A, single-well stress test; B, double-well stress test.]

planes, and other incipient openings have enhanced ground-water circulation. Karst features locally increase the aquifer's capacity to transmit and store large quantities of ground water.

The spatial distribution of fractures and karst features in the study area and their hydraulic behavior are poorly known. Faults and joints commonly are covered at the surface by unconsolidated surficial sediments and vegetation. Sink holes (karst depression) often are visible in fields and dry stream beds, but most other karst features are hidden beneath land surface. Uncertainties about the location of fractures and karst features limit the understanding of ground-water flow and storage in the Arbuckle-Simpson aquifer.

Contours showing an interpretation of the generalized potentiometric surface of the Arbuckle-Simpson aquifer in the study area (pl. 1) were based on water-level measurements from 39 wells in May 1991. The localized effects of faults and karst features on the potentiometric surface may not be reflected on the potentiometric-surface map. In a general way, the potentiometric surface resembles the surface topography of the region. Ground-water elevations are highest in the north and along the western margin of the study area. Ground water from these areas generally moves to the south and east, where some discharges along the gaining reach of the Blue River. A part of the ground water is inferred to flow to the east, where it discharges at springs and streams along the eastern margin of the Arbuckle-Simpson outcrop area. A poorly defined potentiometric low, centered near well 02N–06E–32 CCC 1 in the central part of the study area, may reflect the presence of a local ground-water sink. Water-level elevations from Fairchild and others (1990) document a potentiometric low at the same location. The direction of ground-water movement in the vicinity of the low is not known.

Confined conditions occur along the margin of the Arbuckle-Simpson aquifer, where it is overlain by younger, less permeable rocks, and locally within the aquifer outcrop area (Hart, 1974; Fairchild and others, 1990). An aquifer is confined when all or part of it lies beneath beds of lower hydraulic conductivity that restrict the vertical movement of ground water to or from the underlying aquifer. Recharge to confined parts of the aquifer typically occurs in upgradient areas where hydraulically connected rocks crop out; as a result, ground-water pressures may be higher in confined than in unconfined zones. Water levels in wells that penetrate confined zones may be higher than those of the overlying unconfined aquifer, and can result in wells from which water flows at land surface all or part of the year.

Most wells in the study area are completed in the unconfined upper part of the Arbuckle-Simpson aquifer. In May 1991, the water level in well 02N–05E–25 CCC 1 (1,527 ft deep) exceeded those of the surrounding shallow wells (pl. 1). This well flowed during most of 1992. The higher water levels in this well may result from its proximity to a discharge area along a primarily gaining reach of Blue River, or from confined conditions at depth. Similar variations of water levels in relation to depth have not been observed elsewhere in the study area. However, such variations indicate that a generalized potentiometric surface, as shown in plate 1, is a simplified representation of flow in a complex aquifer.

Fairchild and others (1990) estimated the average saturated thickness of the Arbuckle-Simpson aquifer to be 3,500 ft in the outcrop area. Municipal wells in the study area produce fresh ground water from depths in excess of 1,500 ft below land surface.

Recharge

Recharge to the Arbuckle-Simpson aquifer results primarily from the infiltration of precipitation on the outcrop area. Infiltration occurs through unconsolidated surficial sediments, exposures of permeable rock, and fractures, sink holes, and other openings. Periods of soil-moisture deficiency can reduce recharge. Recharge to the aquifer also occurs along losing reaches of the Blue River and tributary channels. Recharge was estimated from base-flow records to average 4.7 in/yr (Fairchild and others, 1990).

Water-Level Fluctuations

Water levels fluctuate in response to changing rates of recharge to and discharge from the aquifer. When recharge exceeds discharge, the amount of water stored in the aquifer increases and water levels rise; when discharge exceeds recharge, ground-water storage decreases and water levels fall. Maximum water levels in the Arbuckle-Simpson aquifer commonly occur during the winter, when evapotranspiration (evaporative loss and plant consumption) is minimal. Water levels typically are lowest during late summer, when evapotranspiration rates are high and rainfall is relatively low.

The time required for water levels in wells within the study area to respond to recharge from precipitation generally ranges from a few hours to several days. The variation in response times depends on antecedent soil moisture, the rate and duration of rainfall, the permeability of the aquifer, the depth to ground water, and the depth of the well and screened intervals. Figure 6 illustrates a close relation among precipitation events, corresponding rises in ground-water level, and increases in spring flow. Fairchild and others (1990) noted a similar relation among precipitation, ground-water levels, and surface-water discharges.

Water levels were measured periodically from September 1991 through September 1992 (table 2) at eight wells in the study area. Two of these wells (02N–06E–32 CBA 1 and 01N–06E–10 DCC 1) were fitted with continuous water-level recorders from October 1991 through September 1992. Continuous water-level records were obtained from well 01N–06E–04 CAD 1 for the entire period. Water levels were measured periodically at two City of Ada wells (01N–06E–03 CCC 1 and 01N–06E–16 AAA 1) during August and September 1992 (table 2).

The largest water-level fluctuation during the study period was observed in well 02N–06E–32 CCC 1. The water level rose 57.61 ft between May 23, 1991, and January 3, 1992. Water-level fluctuations in the remaining wells ranged from 1.11 ft to 26.57 ft during the same period. Water levels were highest during December and January, and lowest during September and October (fig. 7).

Discharge

Ground-water is discharged from the Arbuckle-Simpson aquifer by discharge to streams, evapotranspiration, and well withdrawals. The mean daily ground-water discharge to streams in the study area from August 17 through September 18, 1992 was about 25,065,000 gal/d, from a drainage area of about 20 mi^2. This discharge estimate includes base flow to Blue River (between sites 07332302 and 07332310), Sheep Creek, the unnamed tributary to Mill Creek, and discharge from Byrds Mill Spring. Periodic discharge-measurement data were not collected at Bois d'Arc and Walnut Creeks and the discharge estimate does not include base flow from these creeks. Evapotranspiration and withdrawals from wells in the study area were not considered; Fairchild and others (1990) estimated that ground-water discharge from base flow greatly exceeds that from evapotranspiration and withdrawals for the entire Arbuckle-Simpson aquifer.

EFFECTS OF MUNICIPAL GROUND-WATER WITHDRAWALS

As water is pumped from an aquifer, the amount of ground water stored in the vicinity of the pumping well decreases, causing water levels to decline in nearby wells (Driscoll, 1986). With continued pumping, water-level declines (drawdown) propagate outward, affecting increasingly larger parts of the aquifer. Discharge of nearby streams and springs that receive ground water from affected parts of the aquifer may decrease as a result of declining water levels. The relation between declining ground-water levels, and decreasing discharge in streams and springs has been documented by Wahl and Wahl (1988) in the Oklahoma Panhandle, and Fairchild and others (1990) in the current study area.

Ground-water and surface-water conditions were monitored before the start of the stress tests to define antecedent water-level trends for each observation well and antecedent discharge trends for each discharge site. Differences between projected trends and measured water-level declines and discharge reductions during the test period were attributed to the effects of pumping. Differences between projected trends and measured water-level rises and discharge increases during and shortly after the test period were attributed to precipitation recharge to the aquifer and water-level recovery after pumping stopped.

No large-yield wells were in use before, during, or after the stress tests. Domestic and livestock ground-water usage does not appear to have affected water-level and discharge data.

A 63–hour (2.6 day) single-well stress test was begun at 1500 hours on August 31, 1992. During this test, well 01N–06E–09 ADD 1 was pumped at an average rate of 1,170 gal/min. The test ended when lightning strikes shut down the pump at about 2100 hours on September 2, 1992. Precipitation during this storm (fig. 8) resulted in an undetermined amount of recharge.

Drawdown resulting from the single-well stress test was observed in wells 01N–06E–04 CAD 1,

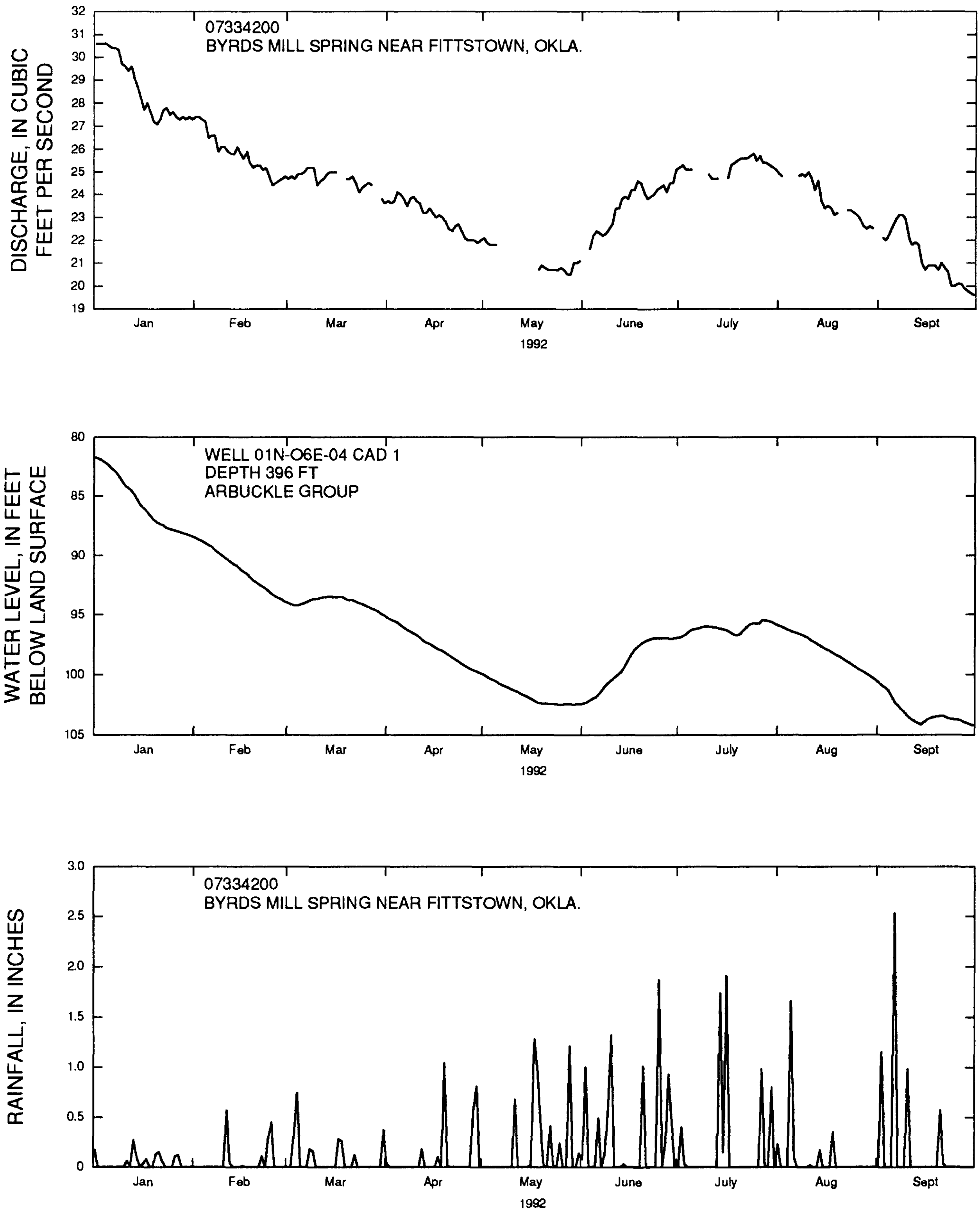

Figure 6. Rainfall and discharge at Byrds Mill Spring and water levels in well 01N–06E–04 CAD 1 from January through September 1992.

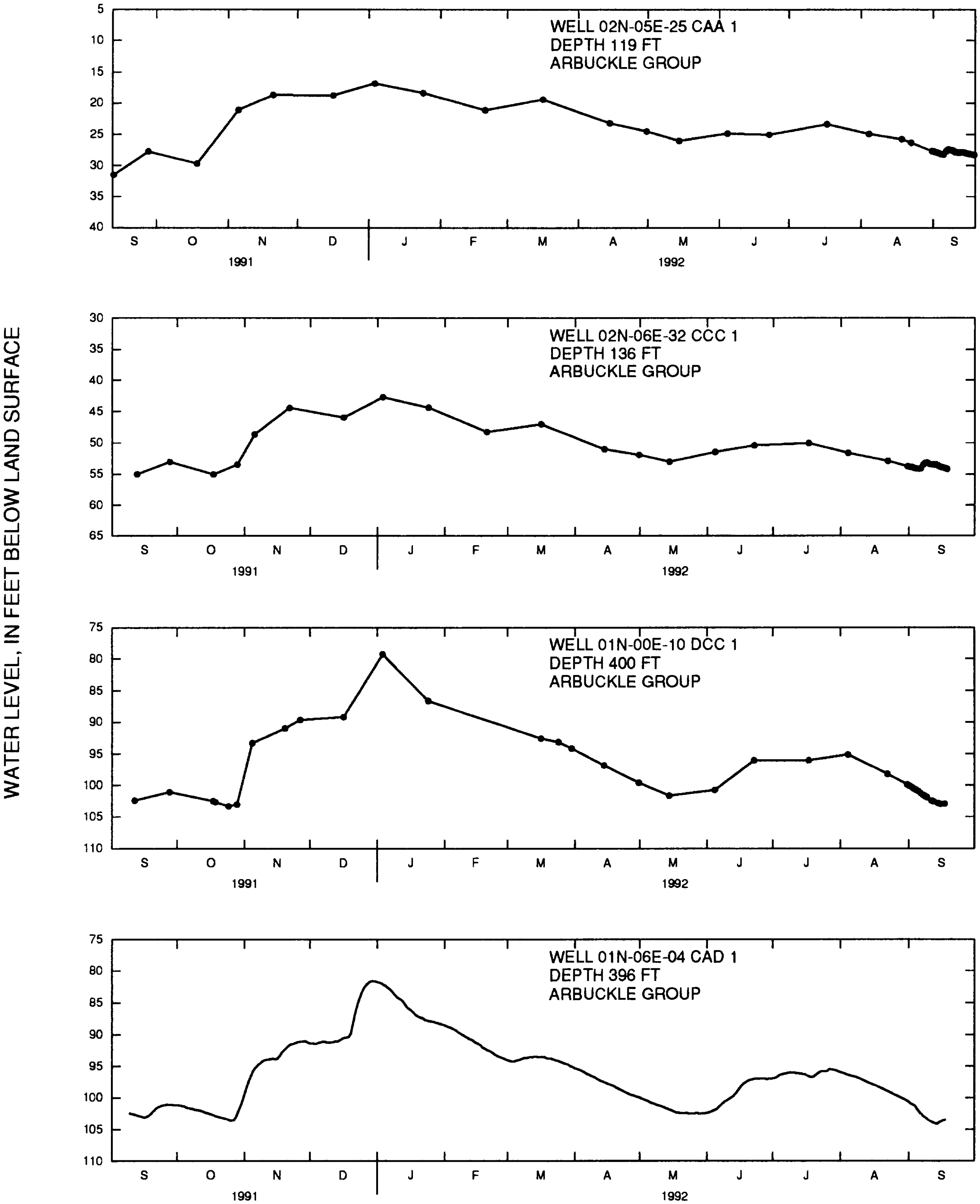

Figure 7. Water levels in selected wells from September 1991 through September 1992.

01N–06E–16 AAA 1, 01N–06E–03 CCC 1, and 01N–06E–05 DDD 1 (fig. 8). The time required for a measurable response in water level in these wells ranged from about 50 hours in well 01N–06E–05 DDD 1 to about 10 hours in the other three wells. The maximum observed drawdowns resulting from this test ranged from about 0.3 ft in well 01N–06E–03 CCC 1 (0.5 mi from the pumping well) to about 0.2 ft in the other three wells. The most distant drawdown was observed in well 01N–06E–05 DDD 1, at 1.2 mi from the pumping well. Water-level declines in wells 01N–06E–10 DCC 1 and 02N–06E–32 CBA 1 (fig. 8) exceeded their projected trends by about 0.1 ft. It is unclear if these deviations represent drawdown caused by pumping or natural water-level fluctuations.

No response to the single-well stress test was observed at any of the surface-water discharge measurement sites (figs. 4 and 5). However, recharge from precipitation on September 2 may have masked any decreases in discharge caused by pumping.

A 241–hour (10 day) double-well stress test was begun on September 4, 1992, at 0900 hours. During this test, well 01N–06E–09 ADD 1 was pumped at an average rate of 1,170 gal/min, and well 01N–06E–03 CCC 1 was pumped at an average rate of 2,730 gal/min. Lightning strikes shut down the pumps in both wells for about 2 hours during the morning of September 6, 1992. The test ended at 1000 hours on September 14, 1992. Rain fell twice during the test (fig. 8), resulting in an undetermined amount of recharge.

Drawdown resulting from the double-well stress test was observed in wells 01N–06E–04 CAD 1, 01N–06E–16 AAA 1, 01N–06E–10 DCC 1, and 01N–06E–05 DDD 1 (fig. 8). Water-level trends prior to the start of the test were partly obscured by rising water levels caused by recharge from precipitation and water-level recovery following the single-well stress test. The maximum observed drawdowns resulting from the double-well stress test ranged from about 1.3 ft in well 01N–06E–04 CAD 1 at an average distance of 0.8 mi from the pumped wells, to about 0.4 ft in well 01N–06E–10 DCC 1 at an average distance of 0.9 mi from the pumped wells. The most distant drawdown was observed in well 01N–06E–05 DDD 1, at an average distance of 1.1 mi from the pumped wells. The water-level decline in well 02N–06E–32 CBA 1 (fig. 8) appears to have exceeded the projected trend by about 0.2 ft. A reduced water-level response to recharge from precipitation (characteristic of wells in which drawdown had been documented) also was observed for this well.

Water levels began to rise, in wells that had shown drawdown, several hours before the end of the double-well stress test and continued to rise after the pumping was stopped (fig. 8). The earlier water-level recovery was attributed to recharge from precipitation; water-level recovery after the pumps were turned off is thought to have resulted from the combined effect of recharge and the cessation of ground-water withdrawal. Water levels in observation wells 01N–06E–04 CAD 1 and 01N–06E–16 AAA 1 responded within a few hours to the cessation of pumping. Water levels in observation wells 01N–06E–05 DDD 1 and 01N–06E–10 DCC 1 responded in about 50 hours.

Less than 2 days after pumping stopped, discharge measurements from Byrds Mill Spring (07334200) and Sheep Creek (07334240) showed increases in discharge (fig. 5). Discharge measurements from the other sites indicated either a slight increase in discharge, or a decrease in the rate of discharge decline (figs. 4 and 5). It is unknown whether these discharge responses reflect the effects of recharge from precipitation, or the combined effects of precipitation and the cessation of ground-water withdrawal.

The effects of the stress tests on the hydrologic system were offset by recharge from concurrent precipitation. The distribution and magnitude of the drawdowns in ground-water levels, and the reductions in springflow and surface-water discharge would have been more extensive had it not rained during the stress tests.

The effect of municipal ground-water withdrawals on local ground-water levels can be illustrated by a comparison of maximum observed drawdown caused by the double-well stress test (1.3 ft at a distance of 0.8 mi) with naturally occurring seasonal water-level fluctuations in observation wells. Water-level fluctuations in 9 observation wells in the study ranged from 1.11 to 57.61 ft between May 1991 and August 1992; the median fluctuation was 22.03 ft. The maximum observed drawdown represents about 6 percent of the median natural water-level fluctuation during the study period. The effect of drawdown could become critical during extended periods of low precipitation, if water levels are already near the bottom of small- yield, shallow, domestic wells in the area. However, a comparison of maximum observed drawdown (1.3 ft) with the

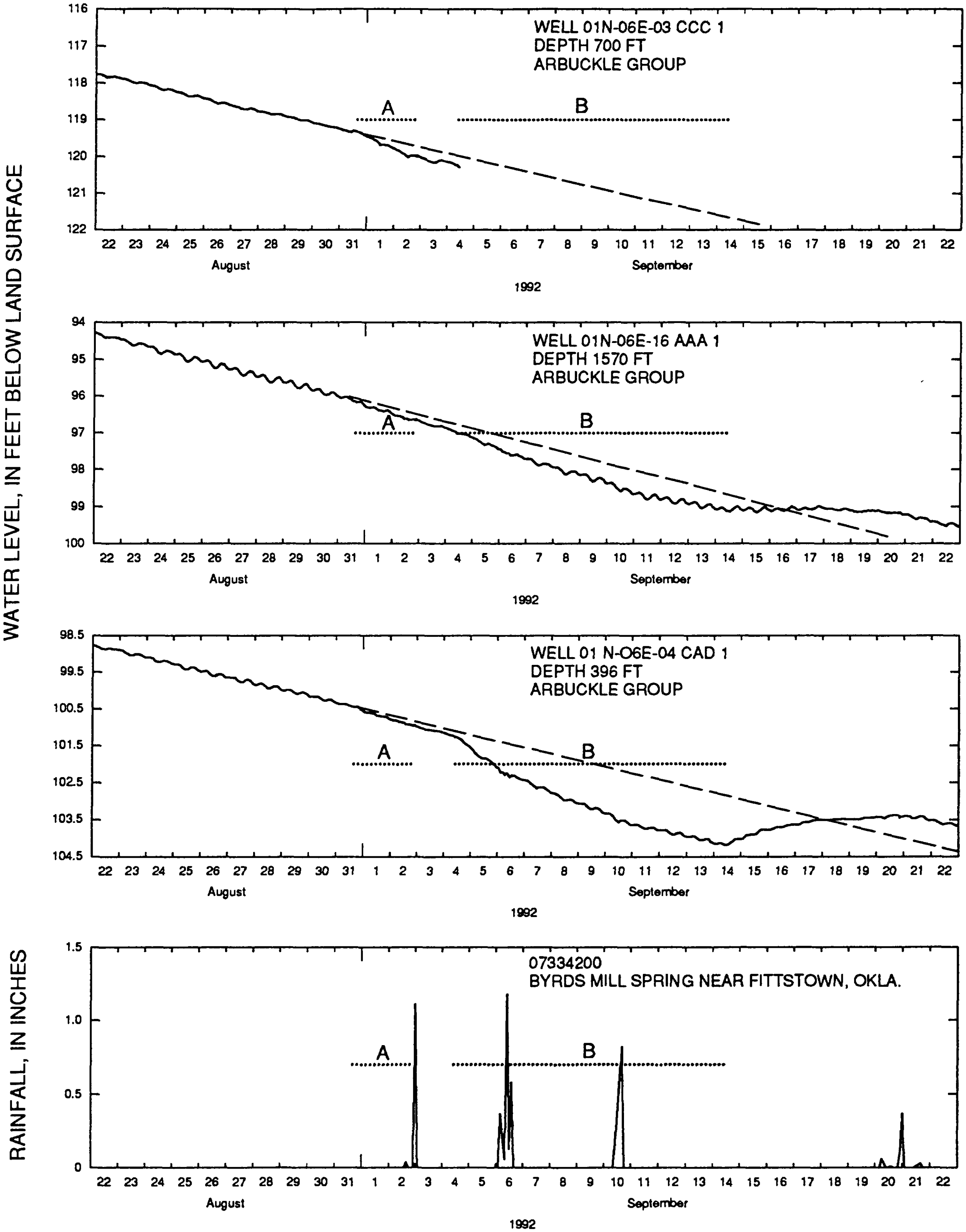

Figure 8. Rainfall at Byrds Mill Spring and water levels in observation wells during part of August and September 1992. [Dashed lines represent projected water-level trends; A, single-well stress test; B, double-well stress test.]

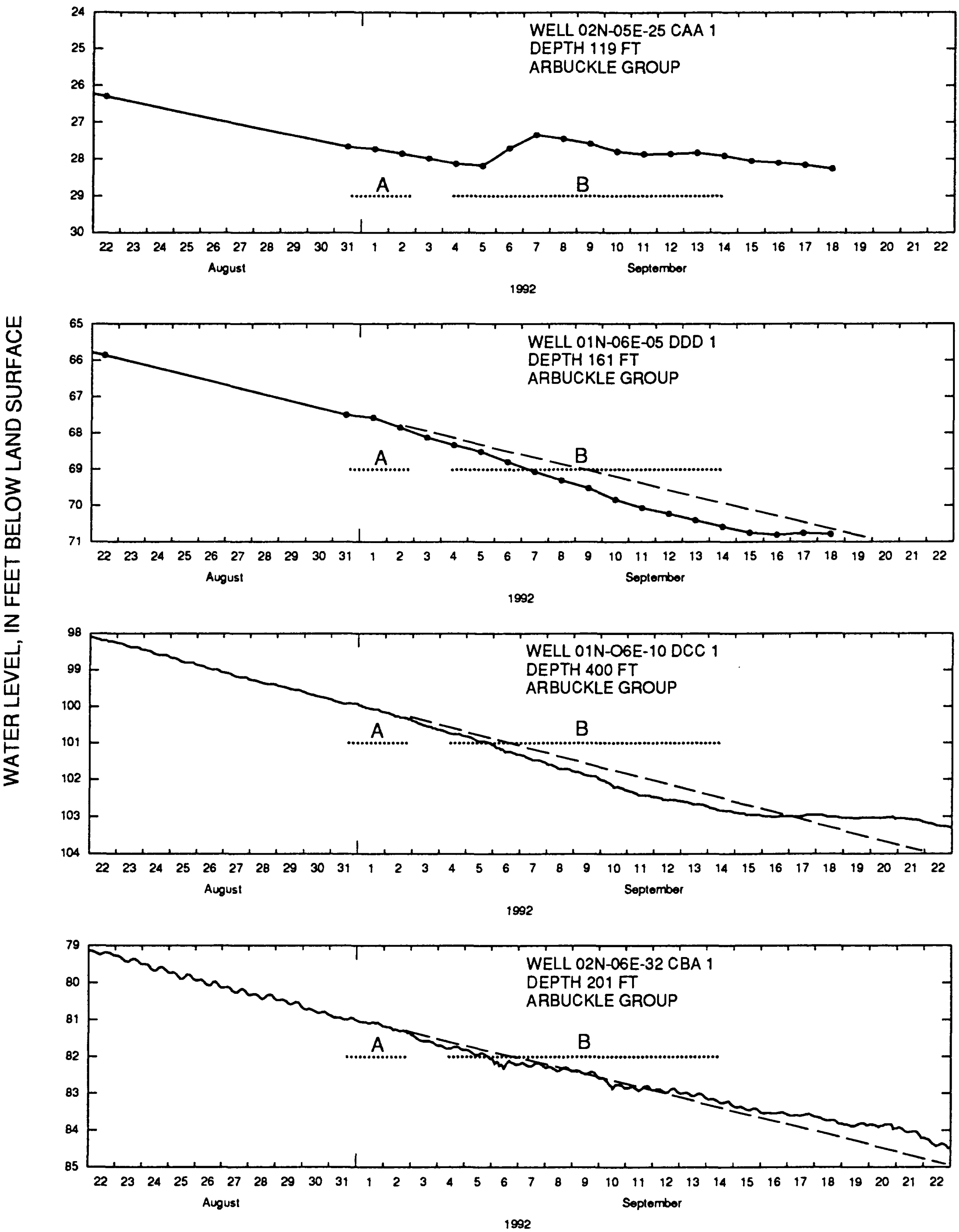

Figure 8. Rainfall at Byrds Mill Spring and water levels in observation wells during part of August and September 1992—Continued.]

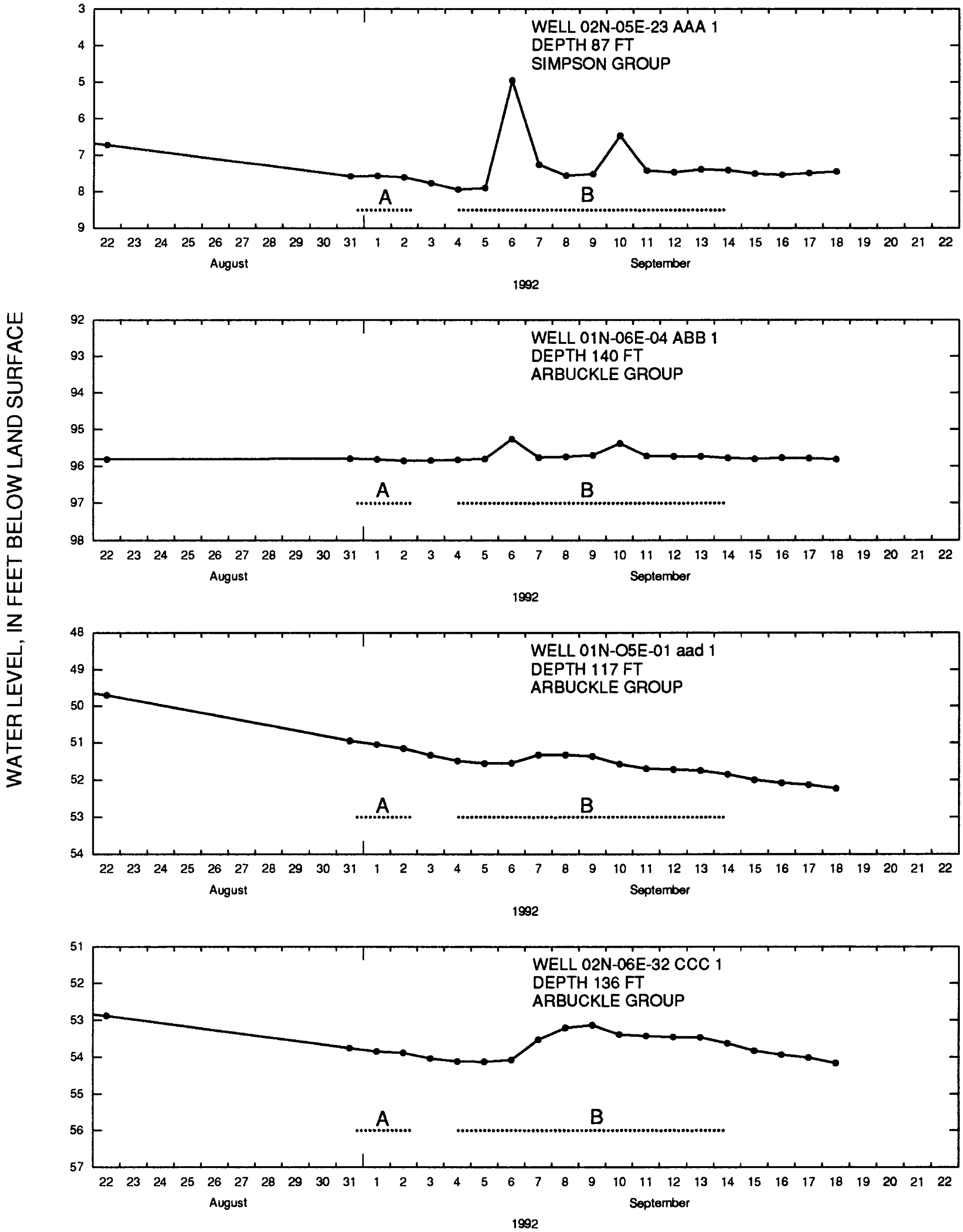

Figure 8. Rainfall at Byrds Mill Spring and water levels in observation wells during part of August and September 1992—Continued.]

minimum saturated thickness of fresh ground water (1,500 ft) suggests that municipal pumping had little effect on the amount of ground water stored in the Arbuckle-Simpson aquifer in the study area. This evaluation does not address effects beyond the limited pumpages and times of the stress tests.

SUMMARY

The U.S. Geological Survey, in cooperation with the City of Ada and the Oklahoma Water Resources Board, conducted a hydrologic study to evaluate the effects of municipal ground-water withdrawal from the Arbuckle-Simpson aquifer on local ground-water levels and discharge from nearby springs and streams that flow from the aquifer.

The Arbuckle-Simpson aquifer consists of a thick sequence of shallow marine carbonate and clastic rocks of Upper Cambrian to Middle Ordovician age. These folded and faulted units contain karst features. Fractures and karst features locally increase the aquifer's capacity to transmit and store ground-water.

The aquifer is recharged from precipitation on the outcrop area. The time required for ground-water levels to respond to precipitation ranged from a few hours to several days. Precipitation before and during the study period produced wetter-than-normal conditions.

Ground-water levels during the study were highest in the north and along the western margin of the study area. Ground water from these areas generally moves to the south and east where it discharges along a gaining reach of Blue River and at several springs and streams along the eastern margin of the Arbuckle-Simpson outcrop area. Water levels were highest during December and January and lowest during September and October. Most wells in the study area are completed in the unconfined upper part of the aquifer.

Streamflows in the study area are sustained during most years by ground-water discharge from the Arbuckle-Simpson aquifer. The mean ground-water discharge from the study area, from August 17 through September 18, 1992, was about 25,065,000 gal/d from a drainage area of about 20 mi^2.

A municipal well was pumped for 63 hours at an average rate of 1,170 gallons per minute. A maximum observed drawdown of 0.3 feet was recorded half a mile from the pumping well. Drawdown was observed as far as 1.2 miles from the pumping well. No measurable response was observed at any of the surface-water-discharge measurement sites; however, recharge from precipitation may have masked any decreases in discharge caused by the pumping. Simultaneous pumping of two municipal wells for 241 hours at average rates of 1,170 and 2,730 gallons per minute resulted in a maximum observed drawdown of 1.3 feet recorded at an average distance of 0.80 miles from the pumping wells. The most distant drawdown observed was at an average distance of 1.1 miles from the pumped wells. Less than 2 days after pumping stopped, increases in springflow were recorded at two springs; it is unknown whether these discharge responses reflect the effects of recharge from precipitation, or the combined effects of precipitation and the cessation of ground-water withdrawal.

The effects of the stress tests on the hydrologic system were offset by recharge from concurrent precipitation. The maximum observed drawdown represents about 6 percent of the median natural water-level fluctuation during the study period. The effect of drawdown could become critical during extended periods of low precipitation, if water levels are already near the bottom of domestic wells in the area. However, a comparison of maximum observed drawdown (1.3 ft) with the minimum saturated thickness of fresh ground water (1,500 ft) suggests that municipal pumping had little effect on the amount of ground water stored in the Arbuckle-Simpson aquifer in the study area. This evaluation is based on the limited pumping rates and times of the stress tests.

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Table 1. Records of selected streams and springs, south-central Pontotoc County, Oklahoma

[mi^2, square miles; ft^3/s, cubic foot per second; *, measured discharges not used in base-flow calculations due to the probable inclusion of direct surface runoff; **, intervening drainage area between spring and discharge measurement site; Byrds Mill Spring discharge reported as daily mean]

Station number and name	Location	Drainage area (mi^2)	Measurement date	Discharge (ft^3/s)
07332302 Blue River near Roff, Okla.	Lat 34 36' 39", Long 096 44' 23" NE 1/4 SE 1/4 SE 1/4 sec. 26, T. 02 N., R. 05 E., Pontotoc County, Hydrologic Unit 11140102. At county road bridge 6 miles east and 0.8 mile south of Roff.	39.1	09-11-91	1.64
			08-17-92	6.81
			08-21-92	6.45
			08-27-92	4.95
			08-31-92	4.07
			09-01-92	4.17
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-03-92	9.11*
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-04-92	4.57
			09-02-92	3.87
			09-02-92	3.87
			09-05-92	4.23
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-08-92	10.8*
			09-02-92	3.87
			09-02-92	3.87
			09-02-92	3.87
			09-09-92	8.15

Table 1. Records of selected streams and springs, south-central Pontotoc County, Oklahoma—Continued

Station number and name	Location	Drainage area (mi^2)	Measurement date	Discharge (ft^3/s)
07332302 Blue River near Roff, Okla.—Continued			09-02-92	3.87
			09-02-92	3.87
			09-13-92	8.59
			09-14-92	7.82
			09-15-92	6.90
			09-16-92	6.09
			09-17-92	6.04
			09-18-92	5.78
07332305 Blue River west of Fittstown, Okla.	Lat 34 35' 35", Long 096 42' 21" SE 1/4 SE 1/4 SE 1/4 sec. 31, T. 02 N., R. 06 E., Pontotoc County, Hydrologic Unit 11140102. At county road bridge about 4.3 miles west- southwest of Fittstown. or 2.2 miles west of Byrds Mill Spring.	44.9	08-17-92	22.8
			08-21-92	19.5
			08-27-92	17.0
			08-31-92	15.4
			09-01-92	15.3
			09-02-92	16.2
			09-03-92	21.4*
			09-04-92	16.8
			09-05-92	16.0
			09-08-92	23.4*
			09-09-92	21.0
			09-13-92	20.3
			09-14-92	19.0
			09-15-92	18.1
			09-16-92	17.5
			09-17-92	16.7
			09-18-92	15.9
07332307 Blue River near Franks, Okla.	Lat 34 34' 41', Long 096 41' 55" NW 1/4 NE 1/4 NW 1/4 sec. 8 T. 01 N., R. 06 E, Pontotoc County, Hydrologic Unit 11140102. At county road bridge about 3.3 miles south- west of Franks.	49.2	08-17-92	20.7
07332310 Blue River near Fittstown, Okla.	Lat 34 32' 58", Long 096 41' 33' SE 1/4 SW 1/4 SE 1/4 sec. 17, T. 01 N., R. 06 E., Pontotoc County, Hydrologic Unit 11140102. At county road bridge 9.7 miles east of Hickory.	56.6	09-11-91	6.23
			08-17-92	19.7
			08-21-92	18.8
			08-27-92	15.2
			08-31-92	13.9
			09-01-92	14.6
			09-02-92	14.6
			09-03-92	22.9*

Table 1. Records of selected streams and springs, south-central Pontotoc County, Oklahoma—Continued

Station number and name	Location	Drainage area (mi^2)	Measurement date	Discharge (ft^3/s)
07332310 Blue River near Fittstown, Okla.—Continued			09-04-92	15.8
			09-05-92	14.5
			09-08-92	23.9*
			09-09-92	20.7
			09-13-92	18.8
			09-14-92	17.5
			09-15-92	16.4
			09-16-92	15.4
			09-17-92	15.5
			09-18-92	14.9
07334200 Byrds Mill Spring near Fittstown, Okla.	Lat 34 35' 40", Long 096 39' 55" SW 1/4 SW 1/4 sec. 34 T. 02 N., R. 06E., Pontotoc County, Hydrologic Unit 11140104. Upstream from weir outlet of Byrds Mill Spring, 2.0 miles west of Fittstown.	None	08-18-92	23.1
			08-19-92	23.2
			08-23-92	23.3
			08-24-92	23.2
			08-25-92	23.1
			08-26-92	22.9
			08-27-92	22.6
			08-28-92	22.5
			08-29-92	22.6
			08-30-92	22.5
			09-03-92	22.0
			09-04-92	22.3
			09-05-92	22.6
			09-06-92	22.9
			09-07-92	23.1
			09-08-92	23.1
			09-09-92	22.9
			09-10-92	22.1
			09-11-92	21.8
			09-12-92	21.9
			09-13-92	21.8
			09-14-92	21.0
			09-15-92	20.7
			09-16-92	20.9
			09-17-92	20.9
			09-18-92	20.9

Table 1. Records of selected streams and springs, south-central Pontotoc County, Oklahoma—Continued

Station number and name	Location	Drainage area (mi^2)	Measurement date	Discharge (ft^3/s)
07334190 Unnamed tributary to Mill Creek near Franks, Okla.	Lat 34 36' 07", Long 096 40' 07" NW 1/4 SW 1/4 NW 1/4 sec. 34, T. 02 N., R. 06 E., Pontotoc county, Hydrologic Unit 11140104. Downstream from un-named spring on Logsdon ranch, below culvert on the private access road to Logsdon ranch, about 1.5 miles west-southwest of Franks.	0.25**	08-28-92	0.43
			08-31-92	0.46
			09-01-92	0.42
			09-02-92	0.38
			09-03-92	0.39
			09-04-92	0.34
			09-05-92	0.33
			09-07-92	0.53
			09-08-92	0.43
			09-09-92	0.37
			09-11-92	0.46
			09-14-92	0.43
			09-15-92	0.43
			09-16-92	0.40
			09-17-92	0.40
			09-18-92	0.38
07334240 Sheep Creek near Fittstown, Okla.	Lat 34 34' 42", Long 096 38' 01" SW 1/4 SW 1/4 SW 1/4 sec. 01, T. 01 N., R. 06 E., Pontotoc County, Hydrologic Unit 11140104. Downstream from un-named springs in upper Sheep Creek basin, just upstream from State Highway 99 bridge, 2.4 miles south of Fittstown.	1.26**	09-12-91	6.23
			08-21-92	6.17
			08-27-92	6.12
			08-31-92	5.81
			09-01-92	5.96
			09-02-92	5.92
			09-03-92	5.59
			09-04-92	5.79
			09-05-92	5.58
			09-07-92	5.82
			09-08-92	6.17
			09-09-92	5.41
			09-11-92	5.86
			09-13-92	5.49
			09-14-92	5.38
			09-15-92	5.20
			09-16-92	5.35
			09-17-92	5.40
			09-18-92	5.00

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma

[Depth of well and water level in feet below land surface. Aquifer codes: 367ABCKU, Arbuckle Limestone upper; 367KDBD, Kindblade Formation; 364SMPS, Simpson Group; 367WSCK, West Spring Creek Formation. Remarks: C, City of Ada municipal well; R, well equipped with continuous water-level recorder; O, observation well.]

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
343527096432001	01N-05E-01 AAD 1	343537	0964320	1155	117	5.06	05-21-91	367ABCKU	O
						54.06	09-12-91		
						51.36	09-27-91		
						55.13	10-18-91		
						46.05	11-05-91		
						42.53	11-20-91		
						42.02	12-16-91		
						38.25	01-03-92		
						41.24	01-24-92		
						44.28	02-20-92		
						44.06	03-16-92		
						47.36	04-14-92		
						49.00	04-30-92		
						50.42	05-14-92		
						49.92	06-04-92		
						48.17	06-22-92		
						47.02	07-17-92		
						47.82	08-04-92		
						49.70	08-22-92		
						50.95	08-31-92		
						51.05	09-01-92		
						51.16	09-02-92		
						51.34	09-03-92		
						51.49	09-04-92		
						51.56	09-05-92		
						51.55	09-06-92		
						51.33	09-07-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						51.33	09-08-92		
						51.37	09-09-92		
						51.58	09-10-92		
						51.70	09-11-92		
						51.72	09-12-92		
						51.75	09-13-92		
						51.85	09-14-92		
						52.00	09-15-92		
						52.08	09-16-92		
						52.13	09-17-92		
						52.23	09-18-92		
343516096441201	01N-05E-01 BCA 1	343516	0964412	1175	157	59.30	05-22-91	367WSCK	
343352096444001	01N-05E-11 DCD 1	343352	0964440	1192	259	80.15	05-30-91	367ABCKU	
343402096432201	01N-05E-12 DDA 1	343402	0964322	1168	187	75.57	05-31-91	367ABCKU	
343348096434901	01N-05E-13 ABB 1	343348	0964349	1132	108	22.50	05-30-91	367ABCKU	
343259096432901	01N-05E-13 DDC 1	343259	0964329	1145	143	46.90	05-30-91	367KDBD	
343526096394201	01N-06E-03 BAD 1	343526	0963942	1075	72.3	41.13	05-29-91	367WSCK	
343443096401001	01N-06E-03 CCC 1	343343	0964009	1171	700	119.12	05-08-91	367ABCKU	C, R, O
						117.90	05-31-91		
						115.81	08-10-92		
						116.39	08-13-92		
						117.80	08-22-92		
						119.39	08-31-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						119.67	09-01-92		
						119.97	09-02-97		
						120.13	09-03-92		
						120.31	09-04-92		
343450096404001	01N-06E-04 ABB 1	343532	0964035	1165	140	95.50	05-29-91	367ABCKU	O
						95.70	09-12-91		
						95.70	09-27-91		
						95.85	10-16-91		
						95.86	10-18-91		
						95.86	10-24-91		
						95.25	10-28-91		
						95.66	11-04-91		
						95.17	11-18-91		
						95.15	11-20-91		
						95.27	11-26-91		
						95.20	12-16-91		
						94.75	01-03-92		
						95.24	01-24-92		
						95.32	03-16-92		
						95.52	03-30-92		
						95.66	04-14-92		
						95.73	04-30-92		
						95.71	04-14-92		
						95.34	06-04-92		
						95.31	06-22-92		
						95.41	07-17-92		
						95.71	08-04-92		
						95.72	08-10-92		
						95.81	08-22-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						95.79	08-31-92		
						95.81	09-01-92		
						95.85	09-02-92		
						95.84	09-03-92		
						95.82	09-04-92		
						95.80	09-05-92		
						95.26	09-06-92		
						95.76	09-07-92		
						95.74	09-08-92		
						95.70	09-09-92		
						95.38	09-10-92		
						95.72	09-11-92		
						95.73	09-12-92		
						95.73	09-13-92		
						95.77	09-14-92		
						95.80	09-15-92		
						95.77	09-16-92		
						95.78	09-17-92		
						95.81	09-18-92		
343457096404501	01N-06E-04 CAD 1	343457	0964045	1155	396	98.62	05-29-91	367ABCKU	R, O
						96.32	08-04-92		
						98.88	08-22-92		
						100.41	08-31-92		
						100.68	09-01-92		
						100.88	09-02-92		
						101.09	09-03-92		
						101.28	09-04-92		
						101.85	09-05-92		
						102.30	09-06-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						102.64	09-07-92		
						102.95	09-08-92		
						103.20	09-09-92		
						103.75	09-11-92		
						103.87	09-12-92		
						104.18	09-14-92		
						103.91	09-15-92		
343435096403001	01N-06E-04 DCD 1	343443	0964034	1190	• --	111.62	05-29-91	367ABCKU	
343525096415001	01N-06E-05 BAA 1	343529	0964147	1145	112	70.16	05-30-91	367ABCKU	
343500096412001	01N-06E-05 DAD 1	343455	0964116	1160	134	86.57	05-29-91	367ABCKU	
343455096411701	01N-06E-05 DDD 1	343444	0964117	1120	161	66.70	05-31-91	367WSCK	O
						69.89	09-11-91		
						68.29	09-27-91		
						70.05	10-18-91		
						63.32	11-05-91		
						58.98	11-20-91		
						57.14	12-16-91		
						47.97	01-03-92		
						54.05	01-24-92		
						58.60	02-20-92		
						59.87	03-16-92		
						64.16	04-14-92		
						66.80	04-30-92		
						68.79	05-14-92		
						69.82	06-04-92		
						63.99	06-22-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						63.60	07-17-92		
						63.14	08-04-92		
						65.85	08-22-92		
						67.49	08-31-92		
						67.57	09-01-92		
						67.84	09-02-92		
						68.12	09-03-92		
						68.33	09-04-92		
						68.51	09-05-92		
						68.79	09-06-92		
						69.06	09-07-92		
						69.30	09-08-92		
						69.51	09-09-92		
						69.83	09-10-92		
						70.06	09-11-92		
						70.22	09-12-92		
						70.40	09-13-92		
						70.58	09-14-92		
						70.74	09-15-92		
						70.80	09-16.92		
						70.75	09-17-92		
						70.78	09-18-92		
343439096423901	01N-06E-07 ABA 1	343439	0964239	1130	153	70.98	05-23-91	367KDBD	
343438096420501	01N-06E-08 BBA 1	343438	0964205	1100	107	40.80	05-23-91	367ABCKU	
343417096401201	01N-06E-09 ADD 1	343417	0964012	1148	1500	96.82	05-08-91	367ABCKU	C
						95.72	05-31-91		
						93.69	08-10-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
343439096394201	01N-06E-10 BAA 1	343439	0963942	1175	198	128.53	05-07-91	367WSCK	
343357096393401	01N-06E-10 DCC 1	343350	0963938	1145	400	97.01	05-30-91	367ABCKU	R, O
						102.40	09-11-91		
						101.08	09-27-91		
						102.50	10-17-91		
						102.66	10-18-91		
						103.32	10-24-91		
						103.04	10-28-91		
						93.31	11-04-91		
						90.99	11-19-91		
						89.64	11-26-91		
						89.16	12-16-91		
						79.28	01-03-92		
						86.62	01-24-92		
						92.57	03-16-92		
						93.15	03-24-92		
						94.14	03-30-92		
						96.84	04-14-92		
						99.58	04-30-92		
						101.64	05-14-92		
						100.74	06-04-92		
						96.04	06-22-92		
						96.04	07-17-92		
						95.13	08-04-92		
						98.20	08-22-92		
						99.91	08-31-92		
						100.10	09-01-92		
						100.31	09-02-92		
						100.58	09-03-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						100.76	09-04-92		
						100.95	09-05-92		
						101.25	09-06-92		
						101.49	09-07-92		
						101.70	09-08-92		
						101.89	09-09-92		
						102.43	09-11-92		
						102.57	09-12-92		
						102.85	09-14-92		
						102.95	09-15-92		
						102.96	09-17-92		
343349096401201	01N-06E-16 AAA 1	343349	0964012	1145	1570	93.91	05-08-91	367ABCKU	C, R, O
						93.54	05-31-91		
						92.21	08-10-92		
						92.81	08-13-92		
						94.37	08-22-92		
						96.14	08-31-92		
						96.41	09-01-92		
						96.61	09-02-92		
						96.78	09-03-92		
						97.05	09-04-92		
						97.31	09-05-92		
						97.66	09-06-92		
						97.88	09-07-92		
						98.13	09-08-92		
						98.31	09-09-92		
						98.79	09-11-92		
						98.86	09-12-92		
						99.15	09-14-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						99.13	09-15-92		
						99.10	09-18-92		
343331096405601	01N-06E-16 BDB 1	343331	0964056	1155	175	96.9	05-30-91	367ABCKU	
343319096411501	01N-06E-17 DAA 1	343319	0964114	1110	160	52.73	05-30-91	367ABCKU	
343806096442301	02N-05E-23 AAA 1	343806	0964423	1195	87.0	8.55	05-24-91	364SMPS	O
						11.58	09-12-91		
						10.40	09-27-91		
						11.18	10-18-91		
						5.19	11-05-91		
						2.78	11-21-91		
						2.71	12-16-91		
						2.06	01-03-92		
						2.03	01-24-92		
						3.38	02-20-92		
						3.01	03-16-92		
						4.48	04-14-92		
						4.36	04-30-92		
						5.32	05-14-92		
						2.66	06-04-92		
						4.37	06-22-92		
						4.78	07-17-92		
						6.21	08-04-92		
						6.41	08-18-92		
						6.72	08-22-92		
						7.58	08-31-92		
						7.57	09-01-92		
						7.61	09-02-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local Identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						7.77	09-03-92		
						7.94	09-04-92		
						7.90	09-05-92		
						4.95	09-06-92		
						7.26	09-07-92		
						7.56	09-08-92		
						7.52	09-09-92		
						6.46	09-10-92		
						7.42	09-11-92		
						7.47	09-12-92		
						7.39	09-13-92		
						7.41	09-14-92		
						7.51	09-15-92		
						7.54	09-16-92		
						7.49	09-17-92		
						7.45	09-18-92		
343734096442601	02N-05E-23 DAD 1	343734	0964426	1180	175	31.65	05-31-91	367WSCK	
343722096444201	02N-05E-23 DCD 1	343722	0964442	1155	230	35.29	05-24-91	367ABCKU	
343640096440001	02N-05E-25 CAA 1	343651	0964354	1140	119	30.95	05-29-91	367ABCKU	O
						31.53	09-12-91		
						27.74	09-27-91		
						29.67	10-18-91		
						21.07	11-05-91		
						18.67	11-20-91		
						18.73	12-16-91		
						16.80	01-03-92		
						18.35	01-24-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						21.10	02-20-92		
						19.39	03-16-92		
						23.20	04-14-92		
						24.50	04-30-92		
						26.00	05-14-92		
						25.85	06-04-92		
						25.03	06-22-92		
						23.37	07-17-92		
						24.91	08-04-92		
						25.75	08-18-92		
						26.30	08-22-92		
						27.66	08-31-92		
						27.73	09-01-92		
						27.85	09-02-92		
						27.98	09-03-92		
						28.13	09-04-92		
						28.18	09-05-92		
						27.70	09-06-92		
						27.34	09-07-92		
						27.45	09-08-92		
						27.58	09-09-92		
						27.80	09-10-92		
						27.87	09-11-92		
						27.86	09-12-92		
						27.83	09-13-92		
						27.91	09-14-92		
						28.05	09-15-92		
						28.10	09-16-92		
						28.16	09-17-92		
						28.26	09-18-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
343625096441501	02N-05E-25 CCC 1	343628	0964421	1125	1527	2.0	05-29-91	367ABCKU	
343629096444001	02N-05E-26 DCD 1	343629	0964440	1155	108	41.66	05-21-91	367ABCKU	
343605096432001	02N-05E-36 AAD 1	343614	0964322	1120	2048	9.5	05-23-91	367ABCKU	
343555096441501	02N-05E-36 BCC 1	343603	0964420	1150	123	33.9	05-21-91	367ABCKU	
343545096441501	02N-05E-36 CBC 1	343549	0964418	1160	128	43.3	05-21-91	367ABCKU	
343536096442101	02N-05E-36 CCC 1	343536	0964421	1175	79	57.64	05-22-91	367WSCK	
343557096432001	02N-05E-36 DAA 1	343557	0964320	1150	140	42.75	05-23-91	367ABCKU	
343715096422501	02N-06E-30 AAA 1	343715	0964225	1195	192	65.68	05-20-91	367ABCKU	
343714096431001	02N-06E-30 BBA 1	343714	0964310	1165	102	17.27	05-24-91	367ABCKU	
343623096421801	02N-06E-31 AAA 1	343623	0964218	1140	115	33.38	05-20-91	367ABCKU	
343537096425001	02N-06E-31 CDD 1	343537	0964250	1135	144	39.65	05-23-91	367ABCKU	
343558096420401	02N-06E-32 CBA 1	343601	0964204	1145	201	85.83	05-07-91	367WSCK	R, O
						85.83	10-17-91		
						86.01	10-18-91		
						86.51	10-24-91		
						86.68	10-25-91		
						85.87	10-28-91		
						79.95	11-04-91		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						79.35	11-05-91		
						74.59	11-18-91		
						73.48	11-20-91		
						71.93	11-26-91		
						70.52	12-16-91		
						60.11	01-03-92		
						65.05	01-24-92		
						69.32	02-20-92		
						70.48	02-25-92		
						69.83	03-16-92		
						72.08	03-30-92		
						75.22	04-14-92		
						78.31	04-30-92		
						80.63	04-14-92		
						81.27	06-04-92		
						75.52	06-22-92		
						75.78	07-17-92		
						76.64	08-04-92		
						78.51	08-18-92		
						79.24	08-22-92		
						80.93	08-31-92		
						81.09	09-01-92		
						81.28	09-02-92		
						81.56	09-03-92		
						81.77	09-04-92		
						81.92	09-05-92		
						82.14	09-06-92		
						82.23	09-07-92		
						82.38	09-08-92		
						82.47	09-09-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						82.89	09-11-92		
						82.97	09-12-92		
						83.26	09-14-92		
						83.47	09-15-92		
						83.73	09-18-92		
343541096420901	02N-06E-32 CCC 1	343538	0964213	1120	136	100.35	05-23-91	367ABCKU	O
						55.00	09-12-91		
						53.03	09-27-91		
						55.02	10-17-91		
						53.45	10-28-91		
						48.63	11-05-91		
						44.43	11-21-91		
						45.95	12-16-91		
						42.74	01-03-92		
						44.38	01-24-92		
						48.24	02-20-92		
						47.02	03-16-92		
						50.99	04-14-92		
						51.87	04-30-92		
						52.99	05-14-92		
						51.42	06-04-92		
						50.38	06-22-92		
						50.02	07-17-92		
						51.58	08-04-92		
						52.88	08-22-92		
						53.75	08-31-92		
						53.84	09-01-92		
						53.88	09-02-92		
						54.03	09-03-92		

Table 2. Records of selected wells, south-central Pontotoc County, Oklahoma—Continued

Site-ID	Local identifier	Latitude	Longitude	Altitude of land surface (feet)	Depth of well (feet)	Water level (feet)	Date water level measured	Aquifer code	Remarks
						54.11	09-04-92		
						54.12	09-05-92		
						54.07	09-06-92		
						53.52	09-07-92		
						53.20	09-08-92		
						53.13	09-09-92		
						53.38	09-10-92		
						53.42	09-11-92		
						53.45	09-12-92		
						53.46	09-13-92		
						53.62	09-14-92		
						53.82	09-15-92		
						53.93	09-16-92		
						54.01	09-17-92		
						54.16	09-18-92		

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