Prepared in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey

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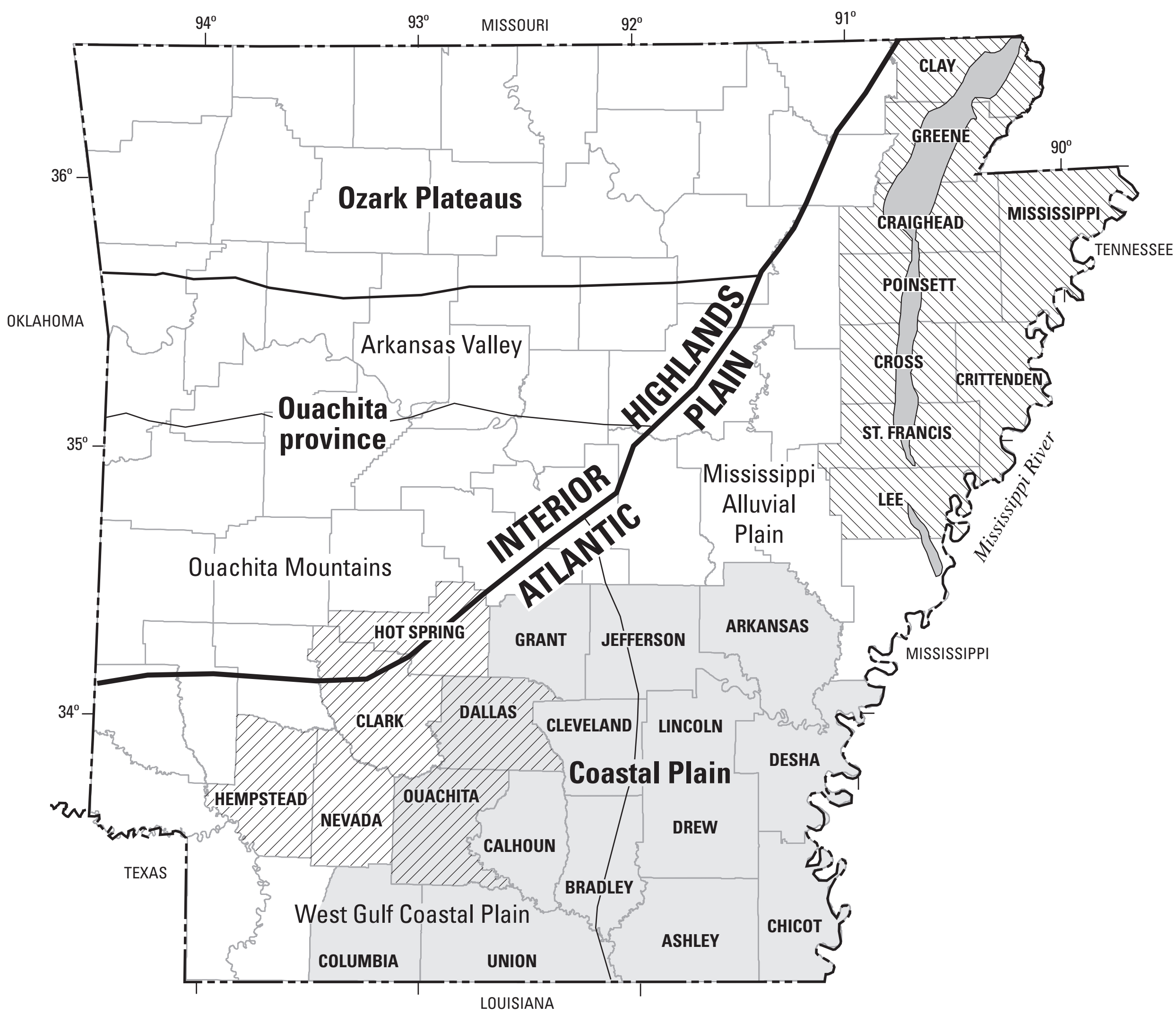

Scientific Investigations Report 2010-5014

U.S. Department of the Interior
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By Aaron L. Pugh

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KEN SALAZAR, Secretary

U.S. Geological Survey
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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
	Specific capacity	
gallon per minute per foot (gal/min)/ft)	0.2070	liter per second per meter (L/s)/m)
	Transmissivity*	
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)

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

°F=(1.8×°C)+32

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

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929).

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

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

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

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

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft3/d)/ft2]ft. In this report, the mathematically reduced form, square foot per day (ft2/d), is used for convenience.

Potentiometric Surfaces and Water-Level Trends in the Cockfield (Upper Claiborne) and Wilcox (Lower Wilcox) Aquifers of Southern and Northeastern Arkansas, 2009

By Aaron L. Pugh

Abstract

Eocene-age sand beds near the base of the Cockfield Formation of Claiborne Group constitute the aquifer known locally as the Cockfield aquifer. Upper-Paleocene age sand beds within the lower parts of the Wilcox Group constitute the aquifer known locally as the Wilcox aquifer. In 2005, reported water withdrawals from the Cockfield aquifer in Arkansas totaled 16.1 million gallons per day, while reported water withdrawals from the Wilcox aquifer in Arkansas totaled 27.0 million gallons per day. Major withdrawals from these units were for industrial and public water supplies with lesser but locally important withdrawals for commercial, domestic, and agricultural uses.

During February 2009, 56 water-level measurements were made in wells completed in the Cockfield aquifer and 57 water-level measurements were made in wells completed in the Wilcox aquifer. The results from the 2009 water-level measurements are presented in potentiometric-surface maps and in combination with previous water-level measurements.

Trends in water-level change over time within the two aquifers are investigated using water-level difference maps and well hydrographs. Water-level difference maps were constructed for each aquifer using the difference between depth to water measurements made in 2003 to 2009. Well hydrographs for each aquifer were constructed for wells with 20 or more years of historical water-level data. The hydrographs were evaluated individually using linear regression to calculate the annual rise or decline in water levels, and by aggregating the regression results by county and statistically summarizing for the range, mean, and median water-level change in each county.

The 2009 potentiometric surface of the Cockfield aquifer map indicates the regional direction of groundwater flow generally towards the east and southeast, except in two areas of intense groundwater withdrawals that have developed into cones of depression. The lowest water-level altitude measured was 43 feet and the highest water-level altitude measured was 351 feet.

A water-level difference map was constructed from 54 wells completed in the Cockfield aquifer within Arkansas. The largest rise in water level was 14.9 feet and the largest decline was 27.4 feet. Seven wells had a rise in water level, and the remaining 47 wells had a decline in water level.

Hydrographs for 33 wells completed in the Cockfield aquifer were developed. Hydrographs indicate water-level changes in individual wells ranged from rises of 0.33 feet per year to declines of 1.21 feet per year over the 20-year period (1990-2009). County summaries of the linear regression analysis indicate Cleveland and Columbia Counties have mean annual rises. Arkansas, Ashley, Bradley, Calhoun, Chicot, Desha, Drew, Lincoln, and Union Counties have mean annual declines.

The potentiometric surface for the Wilcox aquifer is presented using two maps, one for a southern area and another for a northeastern area, because of the absence of water-level data in the central part of the State. The direction of groundwater flow in the southern area is generally the east, except around two cones of depression and around two mounds of elevated water levels. Water-level altitudes in the southern area range from 147 feet to 400 feet. The direction of groundwater flow in the northeastern area is generally to the south and southeast except in an area of intense groundwater withdrawals that has altered the flow to a westerly direction.

Two water-level difference maps were constructed using water-level altitudes measured in 2003 to 2009 from 53 wells completed in the Wilcox aquifer within southern and northeastern Arkansas. In the southern area the largest rise in water level was 16.0 feet and the largest decline was 17.7 feet. Eight wells in the southern area had rising water levels and the remaining five wells had declining water levels. In the northeastern area, the largest rise in water level was 1.3 feet and the largest decline was 21.7 feet. Four wells in the northeastern area had rising water levels, 35 wells had declining water levels, and the remaining well had no change in water level.

Hydrographs for 42 wells completed in the Wilcox aquifer were developed to show water-level altitude variation over the past 20 years. Hydrographs for the southern area

indicate water-level changes in individual wells ranged from rises of 0.44 feet per year to declines of 1.68 feet per year over the 20-year period. County summaries of the linear regression analysis for the southern area indicate that Hot Spring County had a mean annual rise; all other counties had mean annual declines. Hydrographs for the northeastern area indicate water-level changes in individual wells ranged from rises of 0.51 feet per year to declines of 2.16 feet per year over the 20-year period. County summaries of the linear regression analysis for the northeastern area indicate that Greene County had a mean annual rise; all other counties had mean annual declines.

Introduction

Eocene-age sand beds near the base of the Cockfield Formation of the Claiborne Group constitute the aquifer known locally as the Cockfield aquifer and are recognized nationally as the upper Claiborne aquifer (herein referred to as the Cockfield aquifer). Upper Paleocene-age sand beds within the lower parts of the Wilcox Group constitute the aquifer known locally as the Middle and Lower Wilcox aquifer and are recognized nationally as the lower Wilcox aquifer (herein referred to as the Wilcox aquifer). The Cockfield aquifer provides groundwater in southern Arkansas, and the Wilcox aquifer provides groundwater in southern and northeastern Arkansas. In 2005, reported withdrawals from the Cockfield aquifer in Arkansas totaled 16.1 million gallons per day (Mgal/d), and reported withdrawals from the Wilcox aquifer in Arkansas totaled 27.0 Mgal/d (Holland, 2007). Major withdrawals from these units were for industrial and public water supplies with lesser but locally important withdrawals for commercial, domestic, and agricultural uses.

A study was conducted by the U.S. Geological Survey (USGS) in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey to determine the water levels associated with the Cockfield and Wilcox aquifers in southern and northeastern Arkansas. During February 2009, 56 water-level measurements were made in wells completed in the Cockfield aquifer and 57 water-level measurements were made in wells completed in the Wilcox aquifer. The 2009 water-level measurements are presented in potentiometric-surface maps and, in combination with previous years' water-level measurements, in water-level difference maps and long-term hydrographs.

The study areas of the Cockfield and Wilcox aquifers (fig. 1) are part of the Mississippi embayment which includes much of the West Gulf Coastal Plain and the Mississippi Alluvial Plain in Arkansas. The Mississippi embayment is a north-northeast trending syncline, which plunges to the south-southwest, which is filled with Cretaceous to recent sediments. The study area of the Cockfield aquifer in southern Arkansas is bounded on the east by the Mississippi River and on the south by the Louisiana State line. The western boundary is defined by the counties that contain outcrops and subcrops (Hosman, 1982) of the Cockfield Formation. The northern boundary is defined by counties that contain observation wells completed in the Cockfield aquifer. The study area boundary of the Wilcox aquifer in southern Arkansas is defined by the counties that contain outcrops of the Wilcox Group or observation wells completed in the Wilcox aquifer or both. The study area of the Wilcox aquifer in northeastern Arkansas is bounded on the north by the Missouri State line and on the east by the Mississippi River. The western and southern boundaries of the study area are defined by counties that contain outcrops in or near Crowleys Ridge, or observation wells that penetrate the Wilcox aquifer.

This report is the fifth in a triannual series of reports investigating the potentiometric surfaces of the Cockfield and Wilcox aquifers. Earlier reports with water-level measurements made in 2006, 2003, 2000, and 1996-1997 can be referenced through Schrader (2007), Yeatts (2004), Schrader and Joseph (2000), and Joseph (1998), respectively. The potentiometric surfaces for 1991were published in a plate map by Westerfield (1994). The previous report (Schrader, 2007) describes the potentiometric surfaces of the Cockfield and Wilcox aquifers developed from data measured during February and March of 2006. The 2006 report includes 56 water-level measurements of wells penetrating the Cockfield aquifer and 59 water-level measurements of wells penetrating the Wilcox aquifer. The 2006 report also includes analysis of 10 long-term hydrographs from the Cockfield aquifer and 7 long-term hydrographs from the Wilcox aquifer.

Methods

The well-numbering system used in this report is based upon the location of the wells according to the Public Land Survey System used in Arkansas. The component parts of a well number are the township number, the range number, the section number, three letters which indicate, respectively, the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section in which the well is located, and a sequence number. The letters are assigned counterclockwise, beginning with "A" in the northeast quarter or quarter-quarter or quarter-quarter-quarter section in which the well is located. For example, well 01S03W04BBD16 (fig. 2) is located in Township 1 South, Range 3 West, and in the southeast quarter of the northwest quarter of the northwest quarter of section 4. This well is the 16th well in this quarter-quarter-quarter section of section 4 from which data were collected.

Wells locations were verified using a Wide Area Augmentation System (WAAS) Global Positioning System (GPS) receiver to acquire the horizontal coordinate information and topographic maps to acquire land-surface altitude information. The horizontal coordinate information (latitude and longitude) of the wells was recorded using a WAAS GPS accurate to one-tenth of a second (approximately 10 to 20 ft), based on the North American Datum of 1983. The latitude and longitude

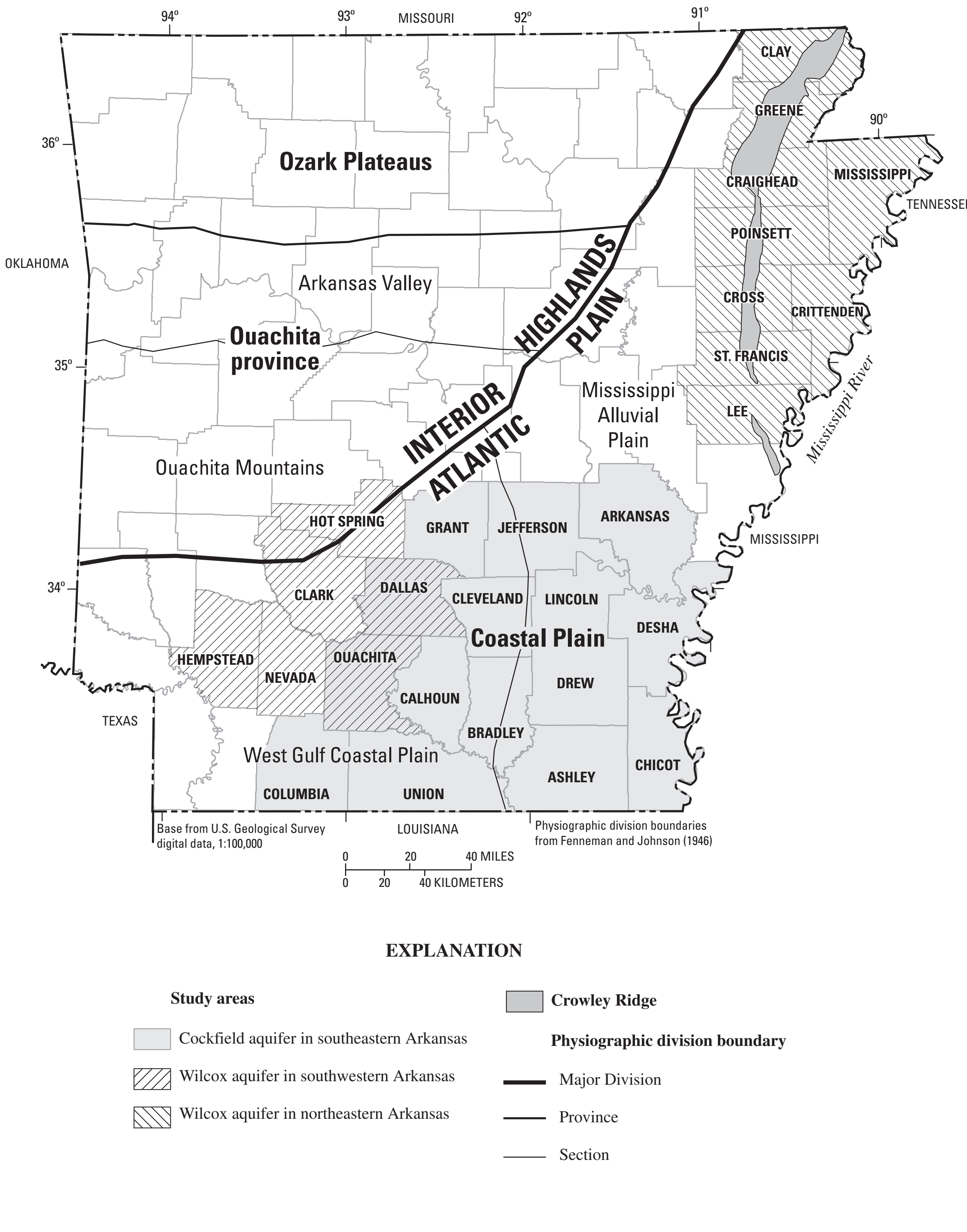

Figure 1. Location of study areas.

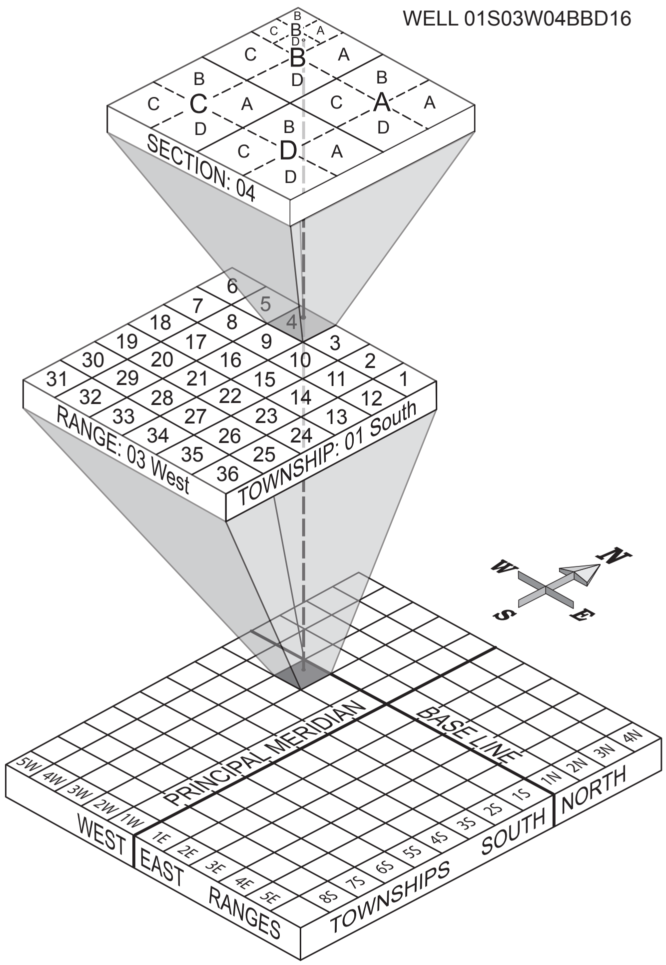

Figure 2. Well-numbering system.

of the well location was then transferred to a topographic map and the altitude of the land surface at the well was determined by interpolation of the topographic contours at the well location. The well measuring point altitude is accurate to about one-half of the contour interval (5, 10, or 20 ft) of the topographic maps, which are based on the National Geodetic Vertical Datum of 1929.

Water levels were measured by USGS personnel at public water supply, industrial, commercial, domestic, and observation wells completed in the Cockfield or Wilcox aquifers. Measurements were made using steel or electric field tapes graduated to hundredths of a foot. The steel and electric tapes used by USGS personnel were calibrated during January 2009 prior to collecting measurements from wells. Calibration of steel and electric tapes was performed by comparing the field steel or electric tape to a standardized steel tape used only for calibration of field tapes.

Potentiometric-surface maps for the Cockfield and Wilcox aquifers in Arkansas were constructed by plotting well positions with their respective water-level altitude and manually constructing contour lines along points of equal water-level altitude. The altitude of the water level in each well was determined by subtracting the measured depth to water from the known land surface altitude. The direction of groundwater flow is perpendicular to the contours in the direction of decreasing water level.

Water-level difference maps for the Cockfield and Wilcox aquifers in Arkansas were constructed using the differences between depth to water measurements made during 2003 (Yeatts, 2004) to 2009. The difference in water level was calculated by subtracting the 2009 depth-to-water value from the 2003 depth-to-water value for each individual well. Positive difference values indicate a rise and negative difference values indicate a decline in water level.

Annual rises or declines in water levels were determined by performing linear regressions on the well hydrographs. The slope, m from the regression line equation ($y = mx + b$) represents the daily rise or decline in water level. The annual rise or decline in water level is obtained by multiplying the slope, (daily rise or decline) by 365.25 days. The R^2 term is the coefficient of determination or the fraction of variance explained by the regression (Helsel and Hirsch, 1992).

Cockfield Aquifer

Hydrogeologic Setting

The Cockfield aquifer, in southern Arkansas, is part of the Cockfield Formation of the Claiborne Group (hereafter referred to as Cockfield Formation) of Eocene age and generally consists of discontinuous fine- to medium-grained sand units interbedded with silt, clay, and lignite, all of nonmarine origin. Most of the sand beds that constitute the Cockfield aquifer media are found near the base of the Cockfield Formation and are known nationally as the upper Claiborne aquifer. The Cockfield Formation and aquifer are part of a north-northeast trending syncline, which plunges to the south-southwest, approximately centered beneath the Mississippi River (fig. 3). The Cockfield Formation generally ranges from 100 to 400 ft thick near outcrop areas and thickens downdip towards the center of the syncline, reaching 625 ft thick in northeastern Chicot County (Onellion and Criner, 1955). Thicknesses of the sand beds near the base of the Cockfield Formation that compose the Cockfield aquifer generally range from 20 to 150 ft. The Cockfield Formation is underlain throughout the study area by calcareous and sandy marl, limestone, and carbonaceous clay of the Cook Mountain Formation of Claiborne Group (table 1). The Cockfield Formation is overlain by silty clays of the Jackson Group throughout much of southeastern Arkansas. In the confined part of the aquifer, the potentiometric surface can be near or above land surface. Sand beds at the base of the overlying Jackson Group in parts of southeastern Arkansas may be in hydraulic connection with the Cockfield aquifer (Ackerman, 1987).

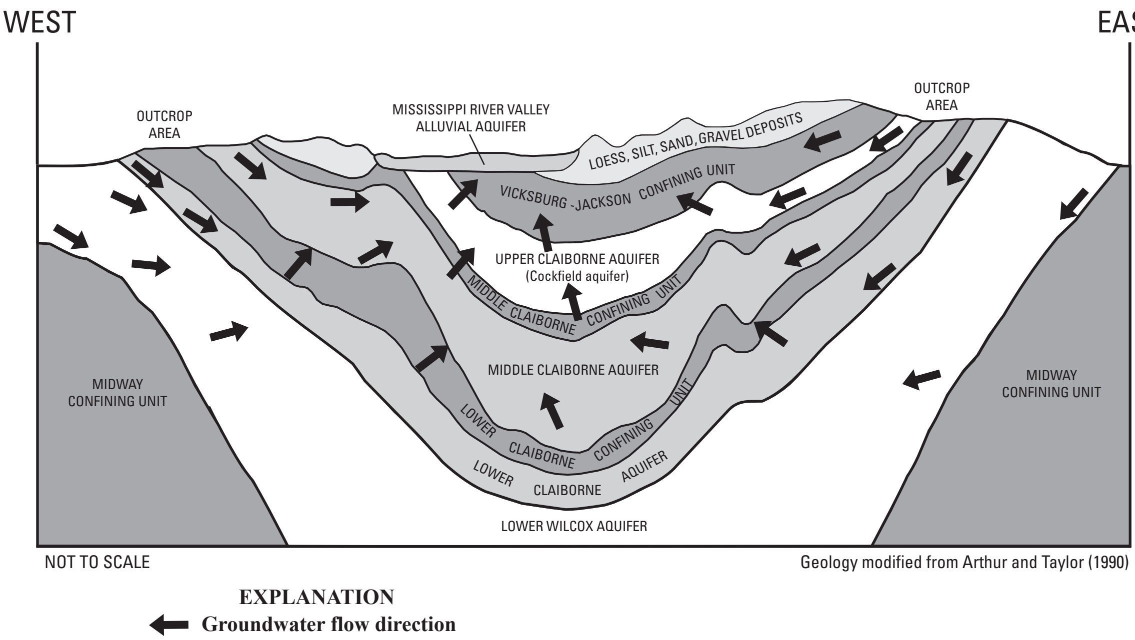

Figure 3. Generalized section of the hydrogeologic and geologic units within the Mississippi embayment (modified from Hart and others, 2008).

The Cockfield Formation and aquifer outcrop in a band trending north-northeast across the study area and dip southeastward. In the subcrop area, the Cockfield Formation is overlain by terrace deposits and alluvium of Quaternary age. The terrace deposits may attain a thickness of 40 ft, and as much as 60 ft of alluvium overlies the Cockfield Formation in some of the larger river valleys.

Most recharge to the Cockfield aquifer occurs by infiltration of rainfall on the upland outcrop areas and by inflow from the overlying alluvium or rivers that have eroded through the overburden and are hydrologically connected with the aquifer. Most discharge is to rivers in outcrop areas, to vertically adjacent units where the Cockfield aquifer is confined, and to wells (Ackerman, 1987). Well depths are shallow (less than 200 ft) and yields of most wells in the outcrop areas are small, less than 30 gallons per minute (gal/min), but in other areas downdip from the outcrop areas, wells screening the full thickness of the aquifer often yield 100 to 500 gal/min (Westerfield, 1994).

Hydraulic Properties

Specific capacity and transmissivity values are variable for the Cockfield aquifer. The following values are based on single-well pump tests and multiple-well aquifer tests (Pugh, 2008). Specific capacity values ranged from 0.15 gallon per minute per foot (gal/min/ft) to 23.7 gal/min/ft with a median of 0.76 gal/min/ft. Transmissivity values ranged from 325 square feet per day (ft^2/d) to 6,280 ft^2/d with a median of 3,350 ft^2/d. Hydraulic conductivity values were not provided by any of the well tests associated with the Cockfield aquifer. Pugh (2008) estimated a hydraulic conductivity value for the Cockfield aquifer by dividing the mean transmissivity value (3,330 ft^2/d) by the maximum aquifer thickness (400 ft), providing an estimated hydraulic conductivity value of 8.33 ft/d.

Water Use

Withdrawals from the Cockfield aquifer in the study area during 2005 totaled about 16.1 Mgal/d (Holland, 2007) (fig. 4). Withdrawals from the Cockfield aquifer have continued to rise from 1985 to 2005, producing 5.0 Mgal/d in 1985, 8.1 Mgal/d in 1990, 9.8 Mgal/d in 1995, 9.9 Mgal/d in 2000, and 16.1 Mgal/d in 2005 (Holland 1987, 1993, 1999, 2004, 2007). Withdrawals from the Cockfield aquifer were 5.2 Mgal/d in 1975 and 7.2 Mgal/d in 1980 (Halberg, 1977; Holland and Ludwig, 1981). The increase in withdrawals between 2000 (9.9 Mgal/d) and 2005 (16.1 Mgal/d) are associated with increased use of waters from the Cockfield aquifer by public supply systems in eastern Arkansas (T.W. Holland, U.S. Geological Survey written commun., 2009). Most wells completed in the Cockfield aquifer study area provide small volumes of water for domestic and livestock use. In some locations, the Cockfield aquifer yields volumes large enough to supply industrial and public supply systems.

Adjacent to Arkansas, in 2005 about 46 Mgal/d were withdrawn from the Cockfield aquifer in Mississippi (D.E. Burt, U.S. Geological Survey, written commun., 2009). Withdrawals from the Cockfield aquifer in Mississippi increased 170 percent between 1999 and 2005. Immediately across the Mississippi River from Chicot County, Arkansas, the city of Greenville, Mississippi, withdrew about 22 Mgal/d from the

Table 1. Hydrogeologic and geologic units within the Mississippi embayment of Arkansas (modified from Hart and others, 2008).

<table>
<tr><th rowspan="2">ERATHEM</th><th rowspan="2">SYSTEM</th><th rowspan="2">SERIES</th><th rowspan="2">GROUP</th><th colspan="2">GEOLOGIC UNIT</th><th rowspan="2" colspan="2">HYDROGEOLOGIC UNIT</th></tr>
<tr><th>Southern Arkansas</th><th>Northeastern Arkansas</th></tr>
<tr><td rowspan="13">CENOZOIC</td><td rowspan="2">QUATERNARY</td><td>HOLOCENE</td><td rowspan="2"></td><td rowspan="2" colspan="2">Alluvium and terrace deposits</td><td rowspan="2" colspan="2">Mississippi River Valley alluvial aquifer</td></tr>
<tr><td>PLEISTOCENE</td></tr>
<tr><td rowspan="11">TERTIARY</td><td>OLIGOCENE</td><td>Vicksburg</td><td colspan="2">Not present in study areas</td><td rowspan="2" colspan="2">Vicksburg-Jackson confining unit</td></tr>
<tr><td rowspan="6">EOCENE</td><td>Jackson</td><td colspan="2">Jackson Formation</td></tr>
<tr><td rowspan="5">Claiborne</td><td colspan="2">Cockfield Formation</td><td colspan="2">Upper Claiborne aquifer (Cockfield aquifer)</td></tr>
<tr><td colspan="2">Cook Mountain Formation</td><td colspan="2">Middle Claiborne confining unit</td></tr>
<tr><td>Sparta Sand</td><td rowspan="3">Memphis Sand</td><td></td><td rowspan="3">Middle Claiborne aquifer</td></tr>
<tr><td>Cane River Formation</td><td>Lower Claiborne confining unit</td></tr>
<tr><td>Carrizo Sand</td><td>Lower Claiborne aquifer</td></tr>
<tr><td rowspan="4">UPPER PALEOCENE</td><td rowspan="3">Wilcox</td><td rowspan="3">Undifferentiated</td><td>Flour Island Formation</td><td colspan="2">Middle Wilcox aquifer</td></tr>
<tr><td>Fort Pillow Sand</td><td rowspan="2" colspan="2">Lower Wilcox aquifer</td></tr>
<tr><td>Old Breastworks Formation</td></tr>
<tr><td></td><td colspan="2">Midway Group</td><td colspan="2">Midway confining unit</td></tr>
</table>

Modified from Hosman and Weiss, 1991

Cockfield aquifer in 2005 (D.E. Burt, U.S. Geological Survey, written commun., 2009), or about 37 percent more than was withdrawn from the Cockfield aquifer in all of Arkansas in 2005. The large amount of withdrawal from the Cockfield aquifer in Mississippi probably contributes to lower water levels in southeastern Arkansas (Ackerman, 1987; Joseph, 1998; Schrader and Joseph, 2000).

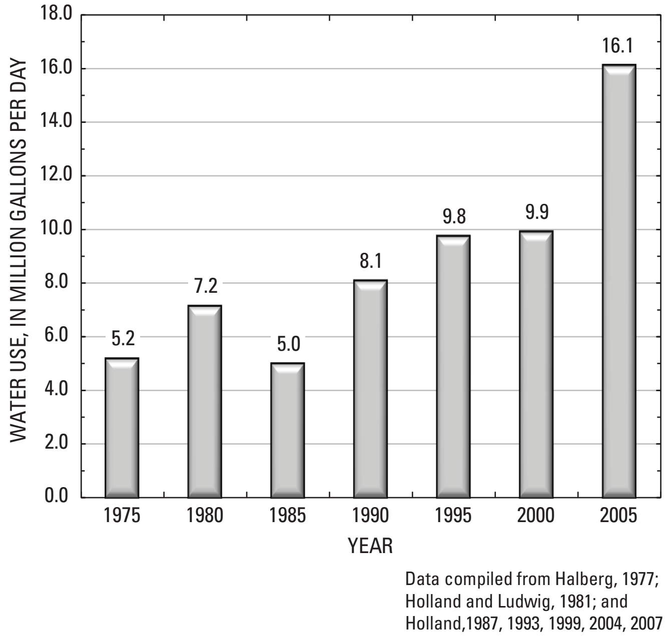

Figure 4. Water use from the Cockfield aquifer in Arkansas, 1975-2005.

Potentiometric Surface

The potentiometric-surface map shows the altitude of the water surface in tightly cased wells screened in the Cockfield aquifer (fig. 5). The map is based upon water-level data collected during February 2009 from 56 wells completed in the Cockfield aquifer in southern Arkansas (appendix 1).

The regional direction of groundwater flow generally is towards the east and southeast, except in areas of intense groundwater withdrawals, such as western Drew County, southeastern Lincoln County and near Crossett in Ashley County (Schrader and Joseph, 2000). There are two cones of depression indicated by relatively low water levels in southwestern Calhoun County and near Crossett in Ashley County. The cone of depression in southwestern Calhoun County is associated with a depression in the top surface of the Cockfield formation (Hart and others, 2008). The cone of depression near Crossett in Ashley County is associated with groundwater withdrawals. There are also two groundwater mounds indicated by relatively high water levels in central Cleveland County and bordering Ashley and Drew Counties. The lowest water-level altitude measured was 43 ft above NGVD of 1929 in Lincoln County; the highest water-level altitude measured was 351 ft above NGVD of 1929 in Columbia County.

Water-Level Trends

Water-Level Difference from 2003 to 2009

A water-level difference map (fig. 6) was constructed to spatially evaluate the short-term (6 years) change in water levels of the Cockfield aquifer within Arkansas. The water-level difference map was constructed using the difference between water-level measurements made in 2003 (Yeatts, 2004) and 2009 for 54 wells completed in the Cockfield aquifer within Arkansas. Positive values, represented with blue, upward pointing triangles, indicate a rise in water level between 2003 and 2009; whereas negative values, represented with red, downward pointing triangles, indicate a decline in water level between 2003 to 2009. The triangles are scaled in size to the relative value of rise or decline. The 2003 to 2009 water-level difference map does not necessarily equate to long-term trends, but is intended to show how water levels in the Cockfield aquifer have changed over the short term.

The 2003 to 2009 difference in water levels for the Cockfield aquifer within Arkansas ranged from -27.4 to 14.9 ft (fig. 6). The largest rise (14.9 ft) in water level was in Drew County. The largest decline (27.4 ft) was in Lincoln County. Of the 54 well data points presented, 7 wells had a rise in water level, the remaining 47 wells had a decline in water level from 2003 to 2009. Most of the declines in water levels between 2006 and 2009 were 4 ft or less. Rises in water levels occurred in Bradley, Calhoun, Chicot, Cleveland, Drew, and Union Counties. Declines in water levels occurred in Arkansas, Ashley, Bradley, Calhoun, Chicot, Cleveland, Columbia, Desha, Lincoln, and Union.

One area, northern Cleveland County, had a slight rise in water levels in the Cockfield aquifer from 2003 to 2009 (fig. 6). Parts of northern Cleveland County are within an outcrop area of the Cockfield Formation and the area is on the northwestern flank of a groundwater mound (fig. 5). The outcrop areas provide recharge to the Cockfield aquifer and the groundwater mound separates the area from the falling water levels to the south.

The remaining areas of the Cockfield aquifer study have general decline in water levels from 2003 to 2009 (fig. 6). Large declines in water levels have occurred along the eastern and southern Arkansas borders. In Arkansas, Desha, and Chicot Counties, on or near the eastern border, water levels generally have declined 2 to 4 ft. In Columbia County, along the southern border, water levels generally have declined 3.5 to 6 ft. Water levels in the remaining parts of the Cockfield aquifer study area generally have declined 1 to 3 ft.

Long-Term Hydrographs

Two methods are used to evaluate long-term water-level trends for the Cockfield aquifer in Arkansas. The first method was to develop hydrographs for each well with 20 or more

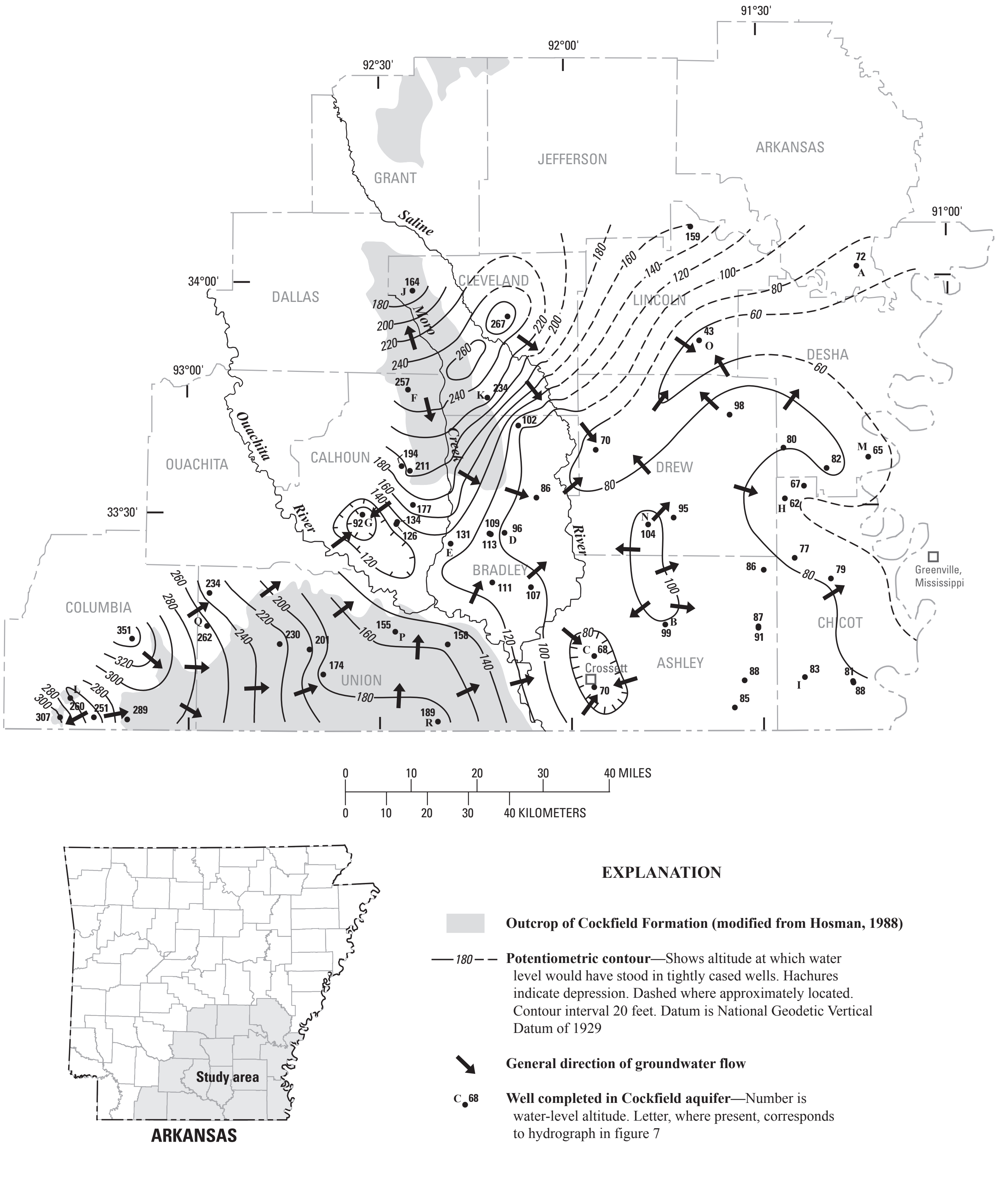

Figure 5. Potentiometric surface of the Cockfield aquifer in southern Arkansas, 2009.

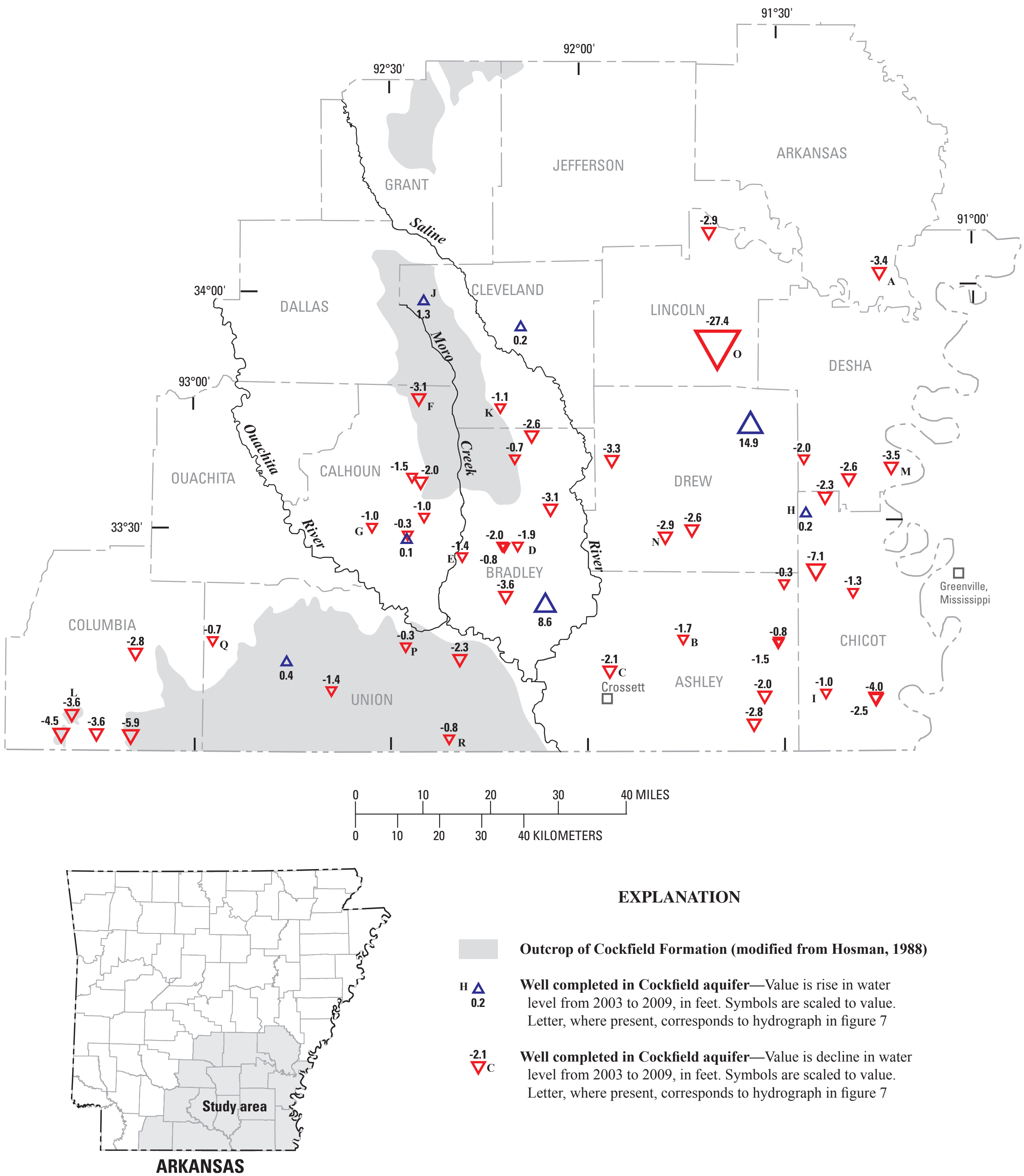

Figure 6. Water-level difference from 2003 to 2009 of the Cockfield aquifer in southern Arkansas.

years of records by plotting the water-level values in relation to time (fig. 7). The second method was to calculate the annual rise or decline in water levels over the past 20 years (1990-2009), aggregate the data by county, and statistically evaluate the range, mean, and median of water-level change in each county (table 2).

Hydrographs for 33 wells with 20 or more years of historical water-level data were developed and examined. Selected hydrographs for 18 wells are presented in figure 7 (wells A-R). The locations of these wells are plotted on figures 5 and 6 and are designated by the letters A through R next to the well location.

Examination of the hydrographs is divided into three geographic areas: the area south and west of the Ouachita River, the area between the Ouachita and Saline Rivers, and the area east of the Saline River. The area south and west of the Ouachita River, including Columbia (fig.7-L) and Union (fig. 7-P, -Q, and -R) Counties, contains an outcrop area with overlying Quaternary-age terrace deposits along the western edge. All of these hydrographs are relatively flat indicating only a small, 1- to 3-ft drop in water levels over the past 30 to 40 years. The hydrograph for well 17S13W17DDC1 (fig. 7-P) in Union County has a water-level rise of approximately 3 ft over the more than 40-year period of record. The area between the Ouachita and Saline Rivers, including Bradley (fig. 7-D and -E), Calhoun (fig. 7-F and -G), and Cleveland (fig. 7-J and -K) Counties, is a mixed area with the northern part being in an outcrop area, the eastern part being confined by the Eocene-age Jackson Group (confining unit), and the southern part underlying Quaternary-age terrace deposits. These hydrographs display both rises and declines ranging from a decline of approximately 20 ft (well 14S10W31DBA1, fig. 7-D) over the period of record to rises of approximately 2 ft (well 15S12W11CAB1, fig. 7-E and well 11S11W23BBD1, fig. 7-K) over the period of record. The area east of the Saline River, including Arkansas (fig. 7-A), Ashley (fig. 7-B and -C), Chicot (fig. 7-H and -I), Desha (fig. 7-M), Drew (fig. 7-N), and Lincoln (fig. 7-O) Counties, is within a confined part of the aquifer. These hydrographs all show declining water levels over their period of record ranging from approximately 60 ft (Well 10S05W06CAC1, fig. 7-O) to approximately 5 ft (well 18S03W14CCC1, fig. 7-I).

Hydrographs for 33 wells with historical water-level data from 1990 to 2009 were evaluated using linear regression to calculate the annual rise or decline for each well and the data aggregated by county and statistically evaluated for the range, mean, and median of water-level change in each county (table 2). Arkansas, Columbia, Desha, Drew, and Lincoln Counties only had one well with a minimum of 20 years of record. Of the counties with more than one well with over 20 years of record, annual rise-decline calculations associated with wells in Ashley and Chicot Counties indicated declining water levels. Annual rise-decline calculations associated for wells with over 20 years of record in the remaining counties, Bradley, Calhoun, Cleveland, and Union, indicate both rising and declining water levels. Cleveland and Columbia Counties have mean annual water-level rises of 0.11 and 0.03 ft/yr, respectively. Arkansas, Ashley, Bradley, Calhoun, Chicot, Desha, Drew, Lincoln, and Union Counties have mean annual well water-level declines ranging from 0.02 to 1.46 ft/yr (table 2).

Table 2. Range, mean, and median of annual rise/decline in water level by county for wells completed in the Cockfield aquiifer in Arkansas, 1990-2009.

[Annual rise or decline in water level for each well is calculated using linear regression; negative value indicates decline; positive value indicates rise; R^2: coefficient of determination]

County	Number of wells	Range or values of annual rise (+) or decline (-) in water level (feet/year)	Mean annual rise (+) or decline (-) in water level (feet/year)	Median annual rise (+) or decline (-) in water level (feet/year)	Range of R^2 values for trend lines
Arkansas[1]	1	-0.11	-0.11	-0.11	0.08
Ashley	6	-0.69 to -0.07	-0.44	-0.49	0.02 to 0.94
Bradley	4	-0.44 to 0.26	-0.17	-0.26	0.21 to 0.91
Calhoun	3	-022 to 0.11	-0.02	0.04	0.02 to 0.65
Chicot	5	-0.77 to -0.22	-1.46	-0.33	0.46 to 0.91
Cleveland	2	-0.11 to 0.33	0.11	0.11	0.29 to 0.71
Columbia[1]	1	0.03	0.03	0.03	0.01
Desha[1]	1	-1.21	-1.21	-1.21	0.87
Drew[1]	1	-0.51	-0.51	-0.51	0.97
Lincoln[1]	1	-0.73	-0.73	-0.73	0.28
Union	8	-0.55 to 0.23	-0.11	-0.13	0.03 to 0.77

[1] County included only one well with 20 or more years of measurements.

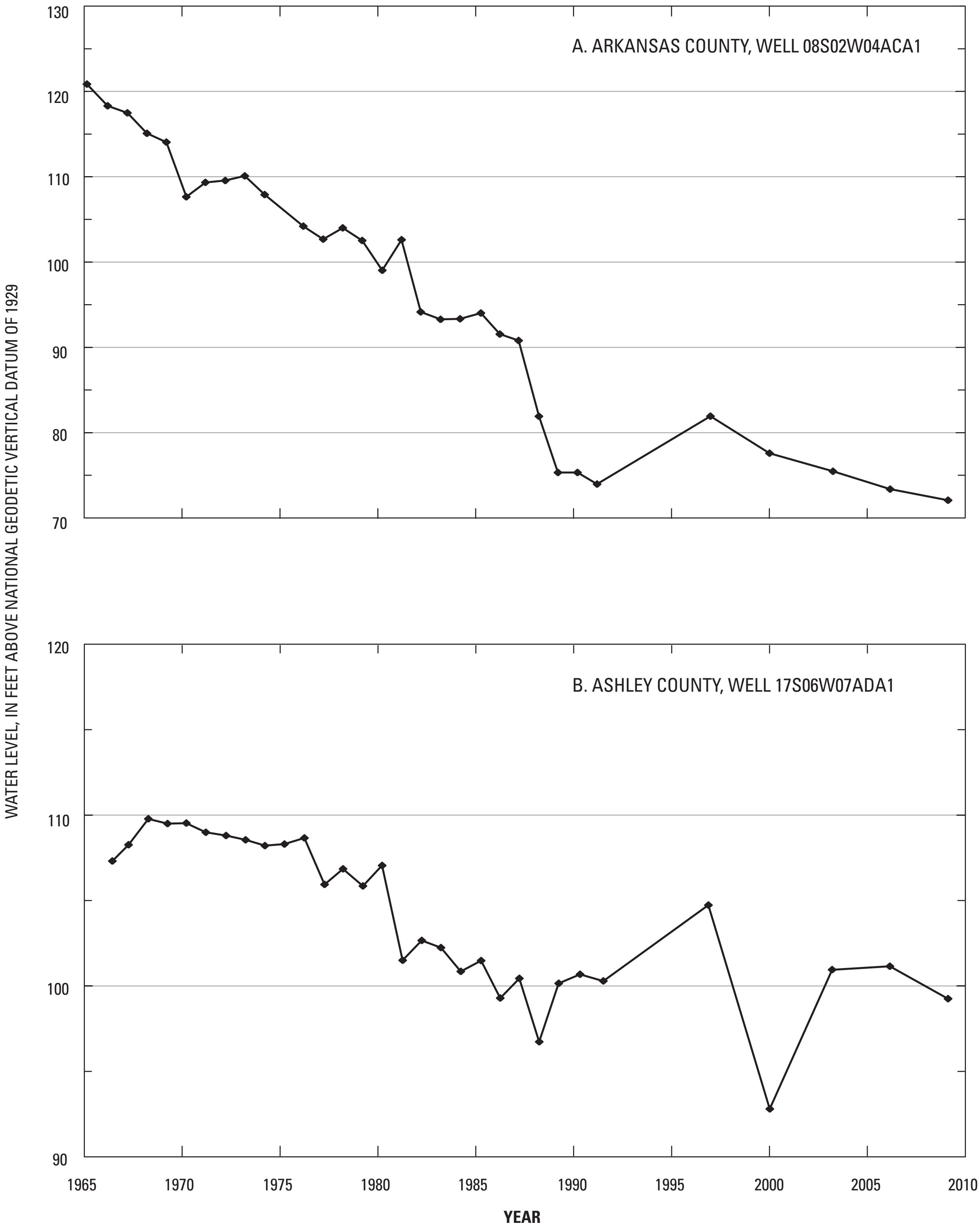

Figure 7. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southern Arkansas.

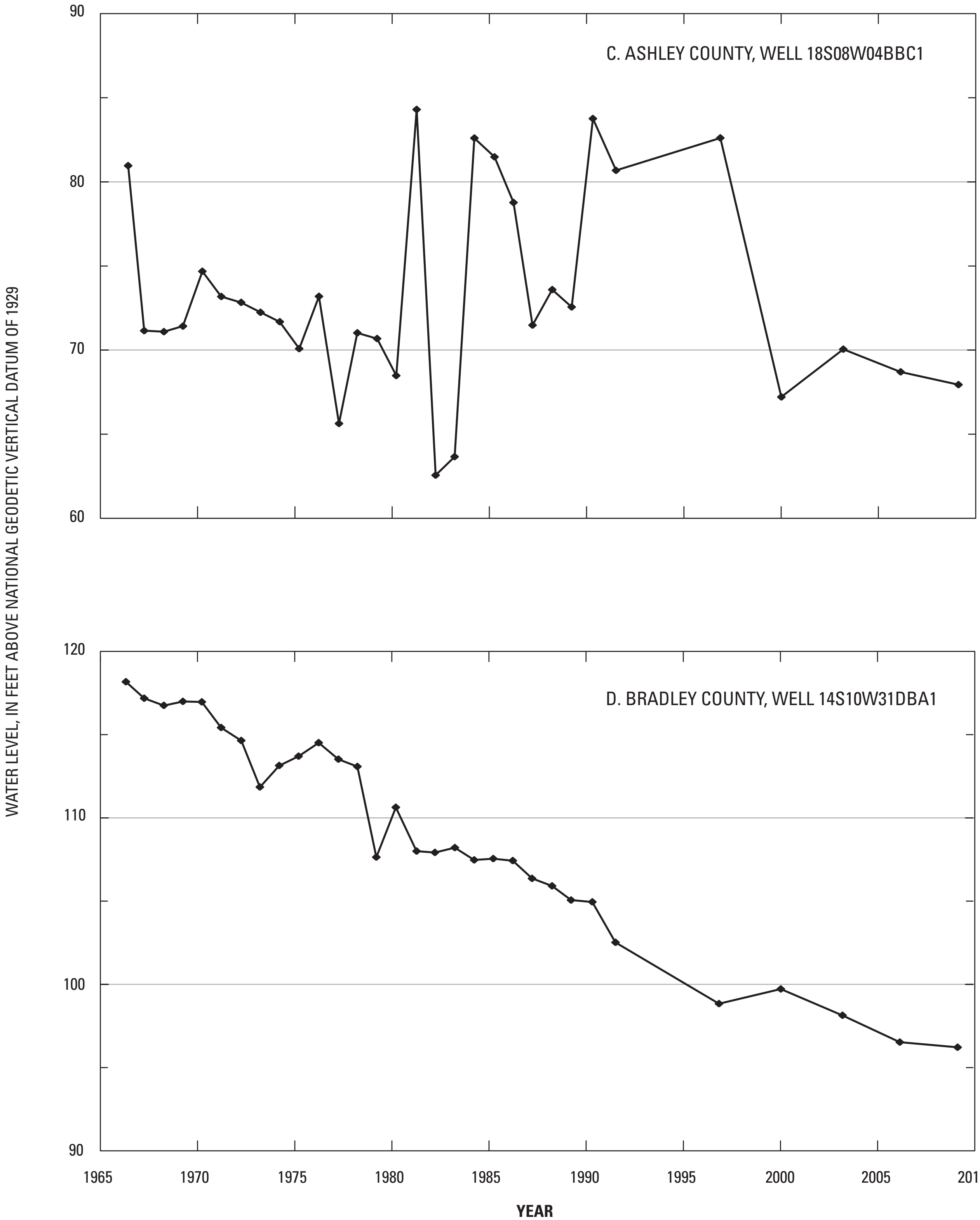

Figure 7. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southern Arkansas.—Continued

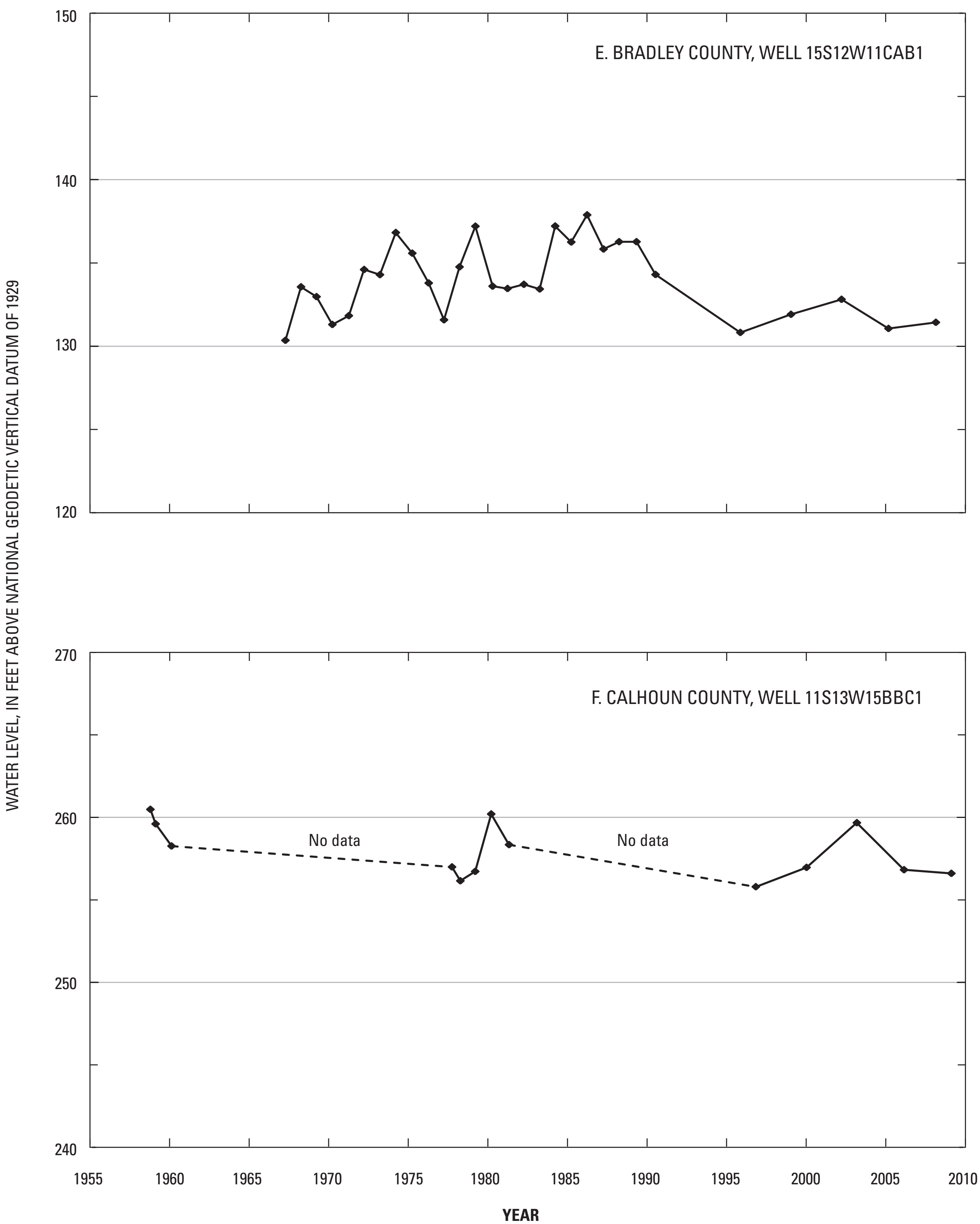

Figure 7. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southern Arkansas.—Continued

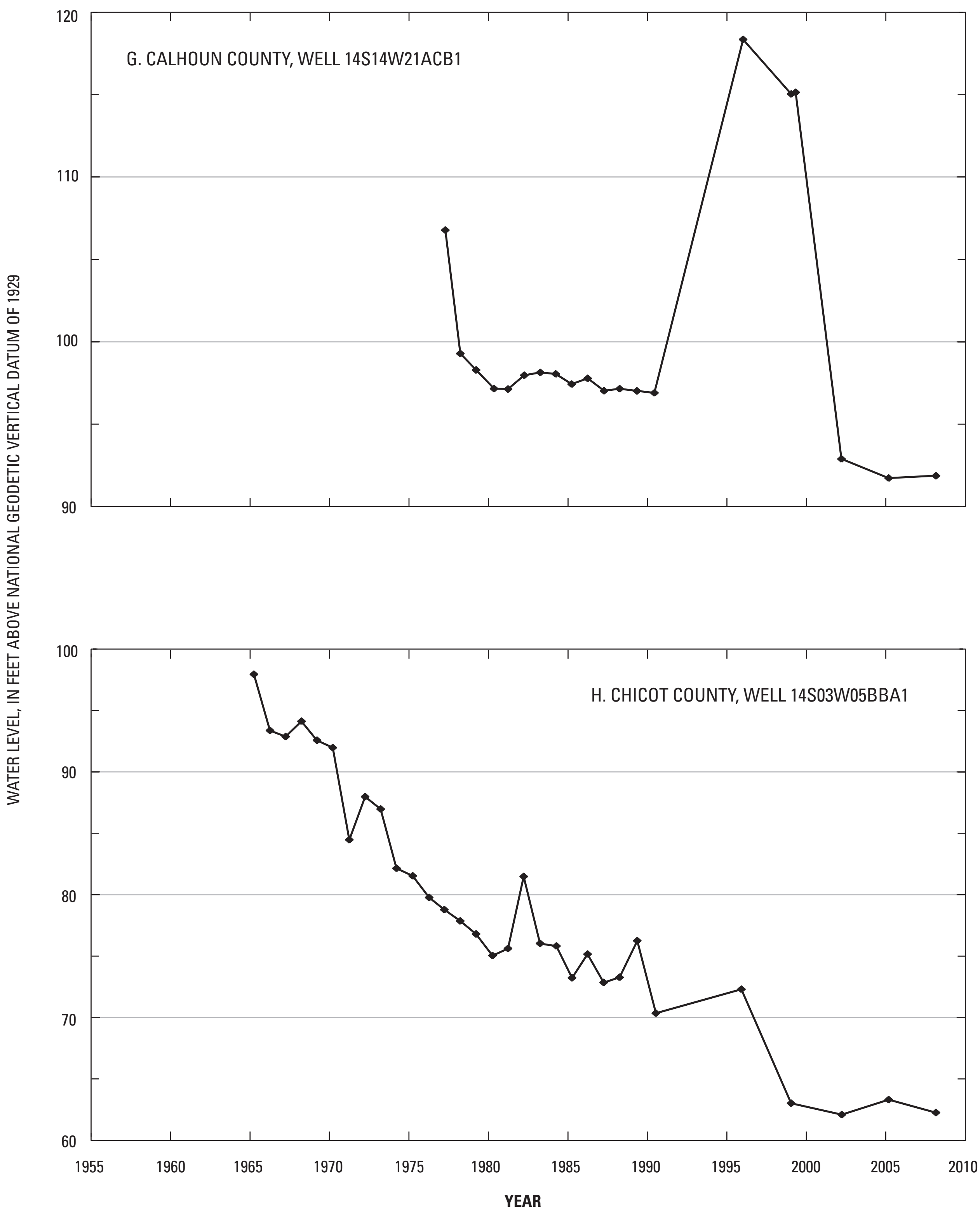

Figure 7. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southern Arkansas.—Continued

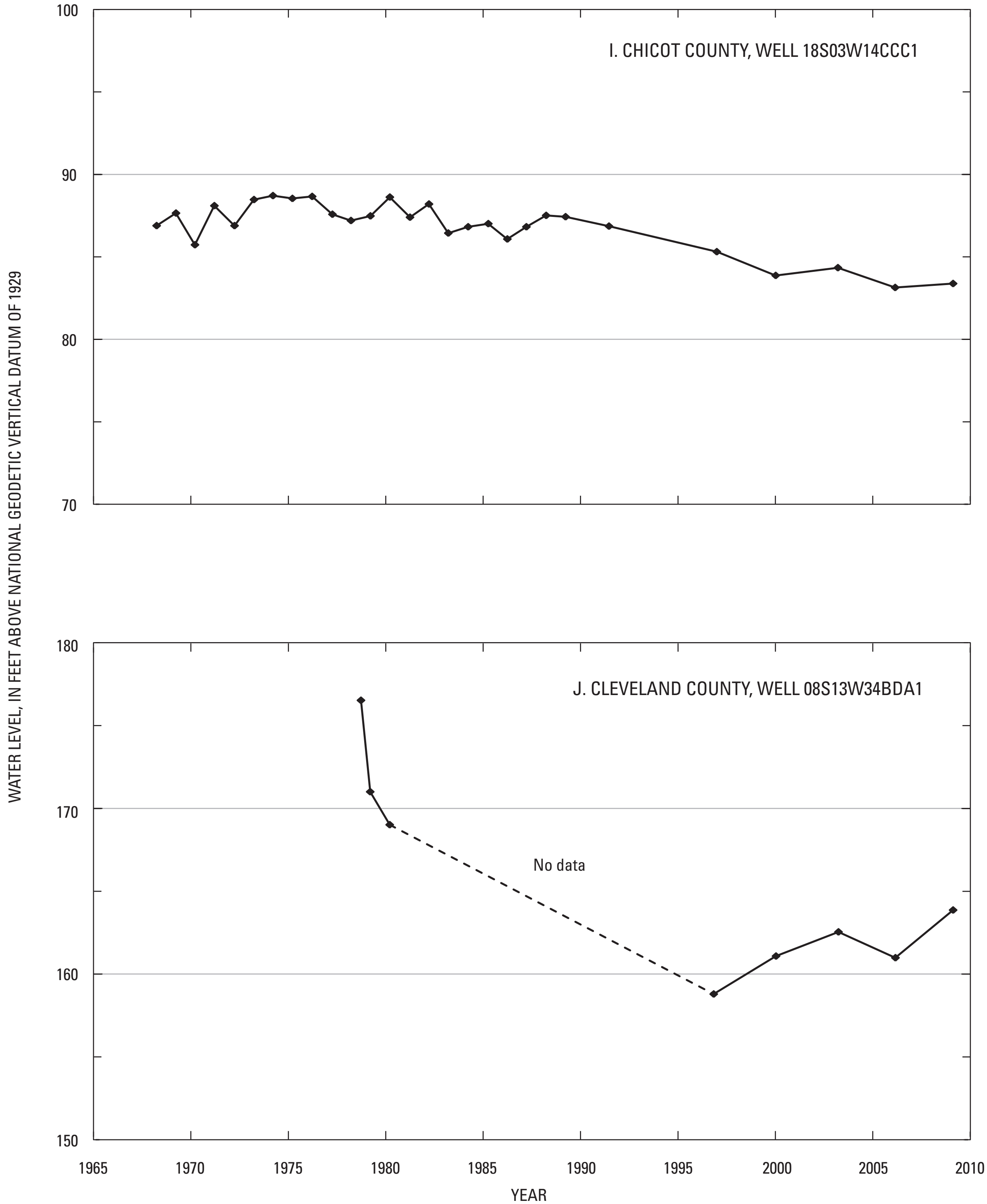

Figure 7. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southern Arkansas.—Continued

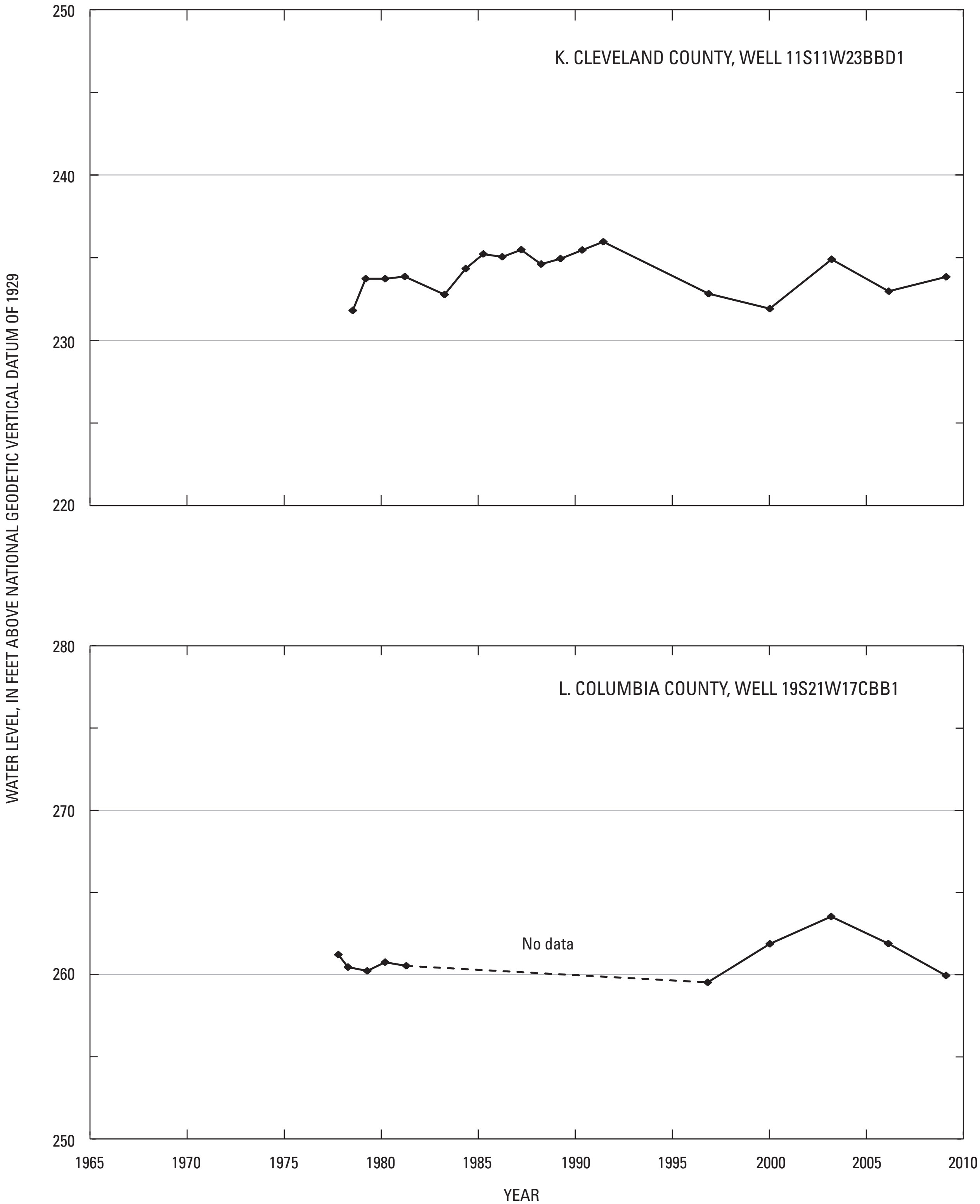

Figure 7. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southern Arkansas.—Continued

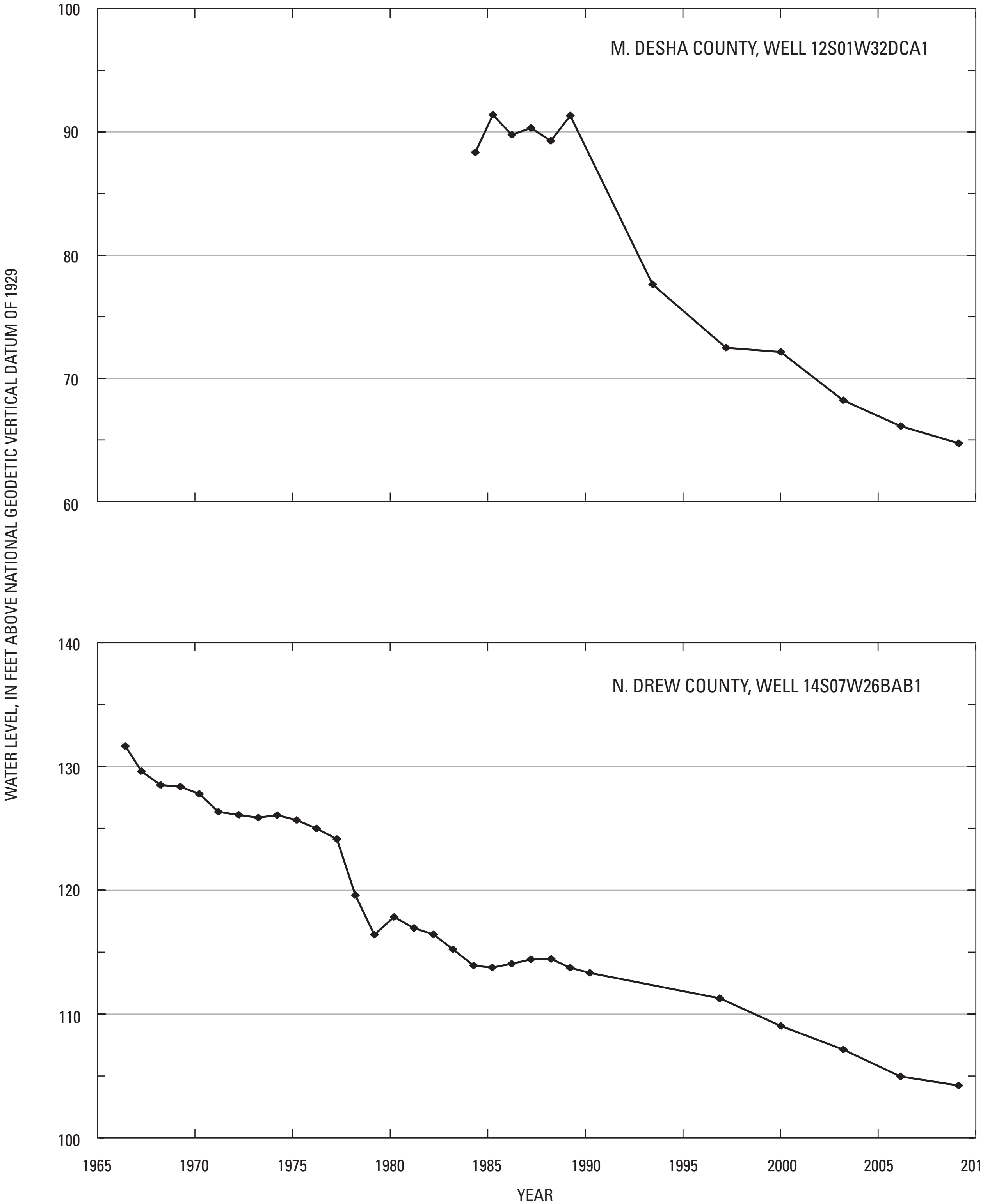

Figure 7. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southern Arkansas.—Continued

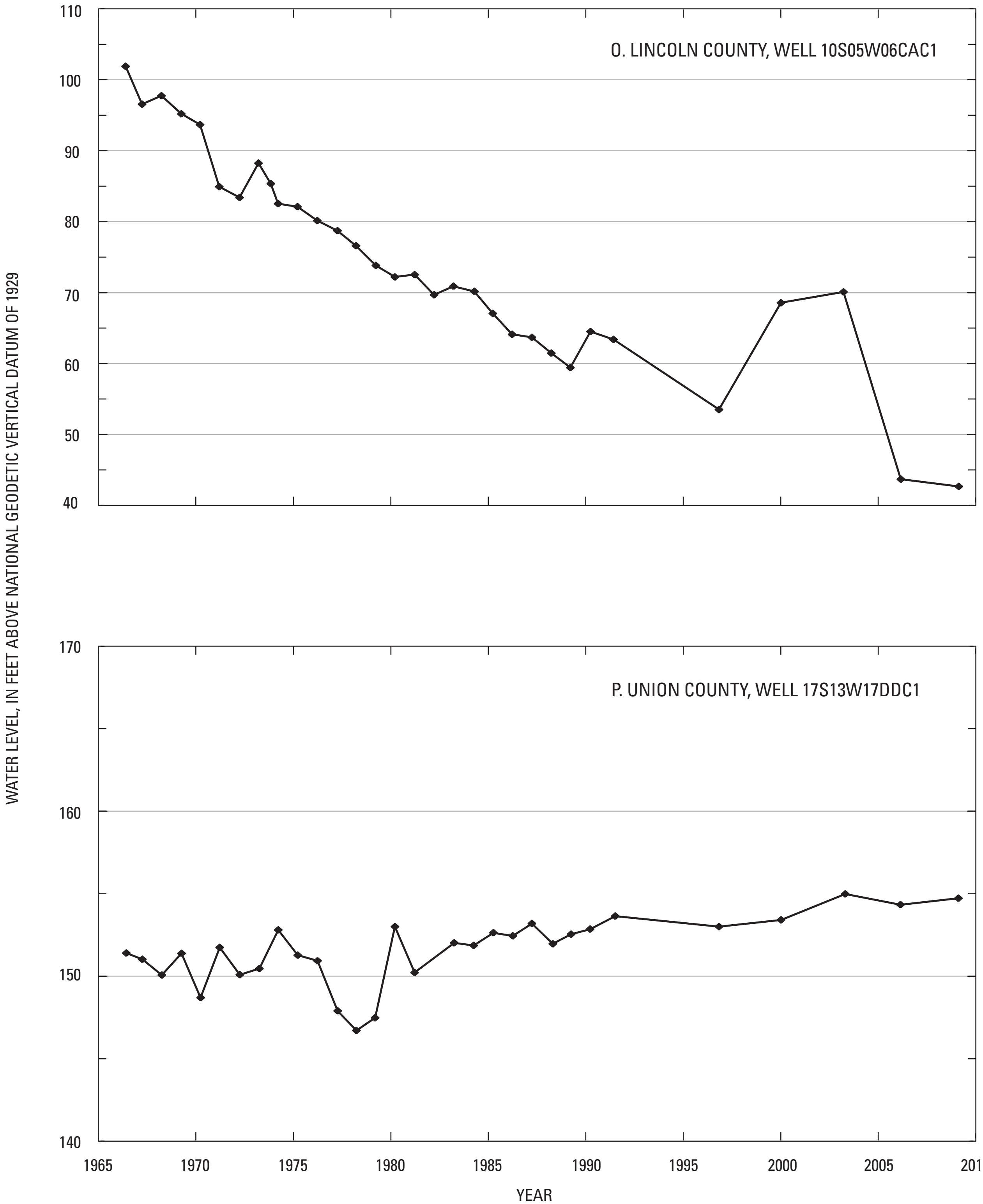

Figure 7. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southern Arkansas.—Continued

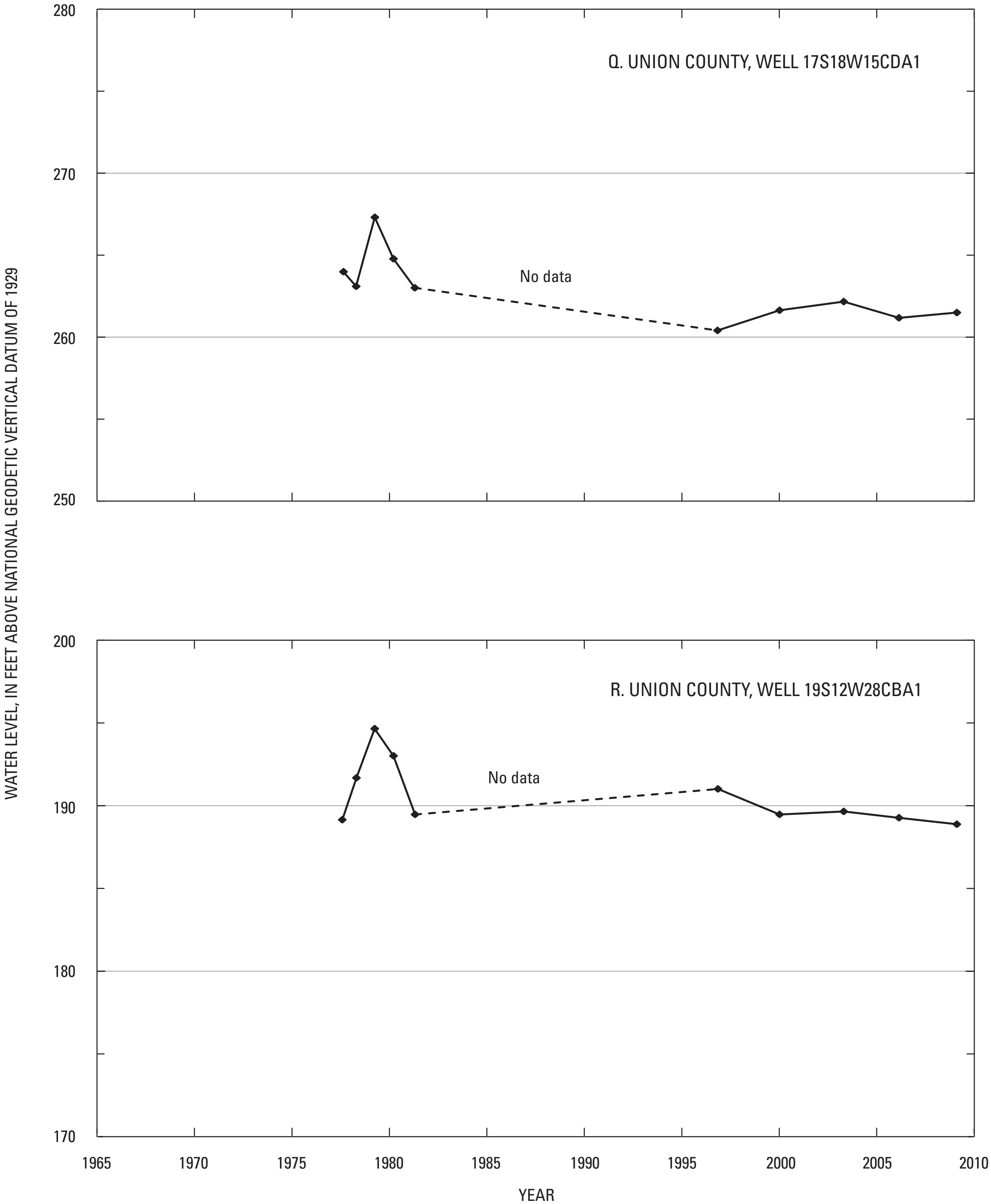

Figure 7. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southern Arkansas.—Continued

Wilcox Aquifer

Hydrogeologic Setting

The Wilcox aquifer is composed of the Wilcox Group of Upper Paleocene age and is distributed throughout the Mississippi Embayment including most of southern and eastern Arkansas. The group is part of a north-northeast trending syncline, which plunges to the south-southeast, approximately centered beneath the Mississippi River (fig. 3). The Wilcox aquifer in central Arkansas is not extensively used, and water-level data are insufficient to determine the potentiometric surface. Because water-level altitude data are discontinuous, the potentiometric surface of the Wilcox aquifer is constructed in two parts; one in southern Arkansas and the other in northeastern Arkansas. The Wilcox Group in southern Arkansas is undifferentiated, while in northeastern Arkansas, the Wilcox Group is divided into three units: Flour Island Formation, Fort Pillow Sand, and Old Breastworks Formation (table 1).

The Wilcox Group in the southern area consists of interbedded layers of clay, sandy clay, sand, and lignite. Sand beds generally are thin and are not continuous over large areas. In most of the southern area, the Wilcox Group overlies the Midway Group and is overlain by terrace deposits and alluvium of Quaternary age or crops out. The Wilcox Group becomes progressively thicker downslope from the outcrop, ranging in thickness from a few feet in the outcrop to about 750 ft at the center of the syncline (Albin, 1964). The Wilcox aquifer comprises water-yielding strata within the basal sand beds of the Wilcox Group in southern Arkansas.

The Wilcox Group in most of the northeastern area consists of thin interbedded layers of lignitic sand and clays. The Wilcox Group crops out at or near Crowleys Ridge in Clay, Greene, and Craighead Counties (Broom and Lyford, 1981). East of Crowleys Ridge, the Wilcox Group, including the Fort Pillow Sand and the Old Breastworks Formation, contains a sand bed of 200 ft or more in thickness (Petersen and others, 1985), which is referred to as the “1,400-foot sand” (Ryling, 1960; Plebuch, 1961) or the “lower Wilcox aquifer” (Hosman and others, 1968). The Wilcox aquifer in the northeastern area is confined above by a clay bed of the Wilcox Group and underlain by a clay bed of the Wilcox Group or by the Midway Group.

Within Crowleys Ridge, part of the Wilcox aquifer is perched and hydrologically separated from the aquifer in the surrounding Mississippi Alluvial Plain. Four water-level measurements were made from wells completed in this perched portion of the Wilcox aquifer, two in Green County and two in Clay County.

Recharge to the aquifer occurs in locations where the Wilcox Group crop outs or subcrops. The Wilcox Group crops out in southern Arkansas in discontinuous, 1- to 3-mile (mi) wide bands along the western edge of the aquifer. In subcrop areas, the Wilcox Group is overlain by terrace deposits and alluvium of Quaternary age. Terrace deposits may attain thicknesses of 40 ft, and as much as 60 ft of alluvium overlie the Wilcox Group in some of the major river valleys. In northeastern Arkansas, the Wilcox Group crops out along a narrow, discontinuous band along the western edge of Crowleys Ridge (not shown at map scales used in this report).

Recharge to the Wilcox aquifer in the southern area occurs by infiltration of rainfall in the outcrop areas and by inflow from overlying terrace and alluvial deposits. Discharge flows into streams in the outcrop area, to overlying formations where the aquifer is confined, and to wells (Westerfield, 1994). Well depths range from 14 ft within the recharge area in Hempstead County to 533 ft in Ouachita County. Well yields range from 10 to 100 gal/min (Schrader and Joseph, 2000).

Recharge to the Wilcox aquifer in the northeastern area occurs by infiltration of rainfall in the outcrop areas along the western side of Crowleys Ridge. Discharge occurs from well withdrawals (Westerfield, 1994). Well depths range from 120 ft on Crowleys Ridge in Greene County to 1,885 ft in Lee County. Well yields range from 100 to 2,000 gal/min (Schrader and Joseph, 2000).

Hydraulic Properties

Specific capacity and transmissivity values are extremely variable for the Wilcox aquifer. The following values are based on single-well pump tests and multiple-well aquifer tests (Pugh, 2008). Specific capacity values ranged from 0.25 gal/min/ft to 641 gal/min/ft with a median of 21.1 gal/min/ft. Transmissivity values ranged from 30 ft^2/d to 32,000 ft^2/d with a median of 8,170 ft^2/d. Hydraulic conductivity values were not provided by any of the well tests associated with the Wilcox aquifer. Pugh (2008) estimated a hydraulic conductivity value for the Wilcox aquifer by dividing the mean transmissivity value (10,700 ft^2/d) by the maximum aquifer thickness (1,100 ft), providing an estimated hydraulic conductivity value of 9.7 ft/d.

Water Use

Reported withdrawals from the Wilcox aquifer in Arkansas totaled 27.0 Mgal/d during 2005 (fig. 8), most of which occurred in the northeastern area (Holland, 2007). Withdrawals from 1975 through 2005 have remained relatively constant, between 21.0 Mgal/d and 27.0 Mgal/d, except in 1990 (30.9 Mgal/d) and 1995 (41.0 Mgal/day). During the reporting years of 1990 and 1995, the increase in reported water use is attributed to withdrawals by a power generation plant that was operating during this time period (T.W. Holland, U.S. Geological Survey written commun., 2009). In the southern area, the primary use of water from the aquifer was for domestic supplies, usually from wells in or near the outcrop areas. In the northeastern area, the primary use of water from the aquifer was for public supplies, but the aquifer is also important locally as a source of water for commercial, domestic, and industrial users.

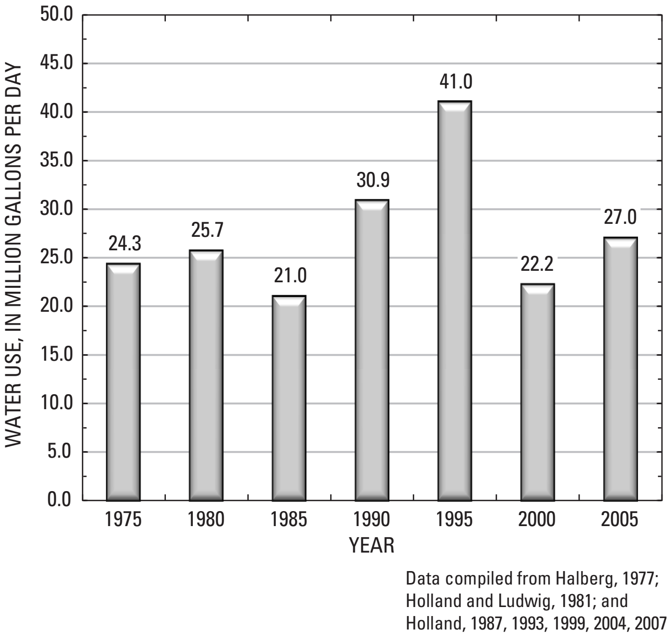

Figure 8. Water use from the Wilcox aquifer in Arkansas, 1975-2005.

Potentiometric Surface

The potentiometric-surface maps show the altitude of the water surface in tightly cased wells screened in the Wilcox aquifer (figs. 9 and 10). The maps are based upon water-level data collected from 57 wells during February 2009, 16 of the wells were in the southern area and the remaining 41 wells were in the northeastern area. The direction of groundwater flow is perpendicular to the contours in the direction of decreasing water level.

The direction of groundwater flow in the southern area (fig. 9) is generally to the east, except around two cones of depression, one in Nevada County and the other in Clark County, and around two mounds of elevated water levels, one in Hot Spring County and the other in Hempstead County. Water flows into the cone of depression in Nevada County from all directions. The direction of water flow toward the cone of depression in Clark County is generally from the north, west, and south. The direction of water flow from the northern mound in Hot Spring County is generally to the south and east with some to the north. The direction of water flow from the southwestern mound in Hempstead County is generally to the south and east. The lowest water-level altitude measured in the southern area was 147 ft at the center of the cone of depression near the Ouachita River in Clark County. The highest water-level altitude measured was 400 ft at the center of the potentiometric-surface mound in an outcrop area of Hempstead County (appendix 3).

The direction of groundwater flow in the northeastern area (fig. 10) is generally to the south and southeast except in the northern part of the area (Clay, Greene, and Craighead Counties) where the flow is in a westerly direction towards Paragould. Groundwater withdrawals have altered the natural direction of flow near centers of pumping at Paragould and West Memphis (Joseph, 1998). The lowest water-level altitude measured in the northeastern area was 114 ft near West Memphis in Crittenden County; the highest water-level altitude measured was 368 ft on Crowleys Ridge in Clay County.

Crowleys Ridge is an erosional remnant of Cretaceous and Tertiary rocks covered with loess deposits. Crowleys Ridge varies from 0.5 to 12 mi wide, rises 250 to 550 ft above the surrounding Mississippi Alluvial Plain, and extends approximately 150 mi southwest and south from southeastern Missouri to east-central Arkansas. Water levels measured in wells on Crowleys Ridge are higher than measurements collected in the surrounding Mississippi Alluvial Plain because of the higher altitude of the Wilcox aquifer underlying Crowleys Ridge and the influence of direct recharge from outcrops and subcrops on the ridge. Water-level measurements collected on Crowleys Ridge (four wells) were not considered in the construction of the potentiometric surface. The waters of the remnant Wilcox Group deposits, locally considered the Upper Wilcox aquifer, within Crowleys Ridge tend to be perched at higher altitudes than the surrounding Mississippi Alluvial Plain, and control points were too few for contouring.

Water-Level Trends

Water-Level Difference from 2003 to 2009

Water-level difference maps for the Wilcox aquifer in Arkansas (figs. 11 and 12) were constructed using 53 water-level measurements made during 2003 (Yeatts, 2004) and 2009. Positive values indicate a rise and negative values indicate a decline in water level. In figures 11 and 12, rises in the water level are indicated using upward pointing, blue triangles; while declines in the water level are indicated using downward pointing, red triangles. The triangles are scaled to the relative value of the rise or decline in water level. Water-level differences do not necessarily equate to water-level trends, but are intended to show where water levels have increased or decreased between 2003 and 2009.

The difference in water levels from 2003 to 2009 in the southern area (fig. 11) ranged from -17.7 to 16.0 ft with the largest decline (17.7 ft) in water level in Nevada County, and the largest rise (16.0 ft) in water level in Hempstead County. Water levels rose in the northern and eastern parts of the southern area (eight wells in Hempstead, Hot Spring, Clark, and Ouachita Counties), and the water levels in the southern part of the area declined (five wells in Hempstead and Nevada Counties) (appendix 5).

The differences in water levels from 2003 to 2009 in the northeastern area (fig. 12) ranged from -21.7 to 1.3 ft, with the largest decline (21.7 ft) in water level in Greene County, and the largest rise (1.3 ft) in water level in Crittenden County. Four well in the northeastern area had rising water levels, 35

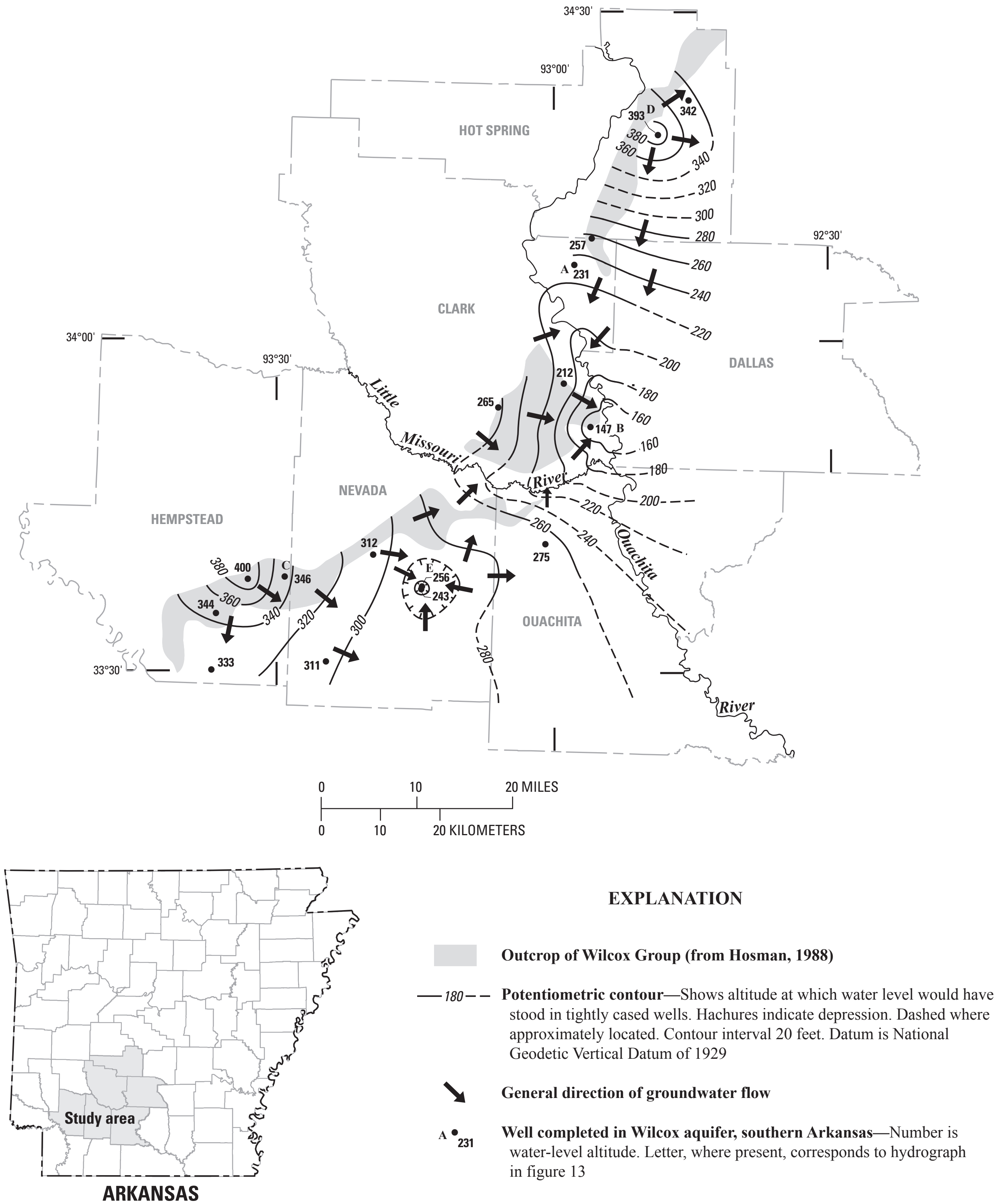

Figure 9. Potentiometric surface of the Wilcox aquifer in southern Arkansas, 2009.

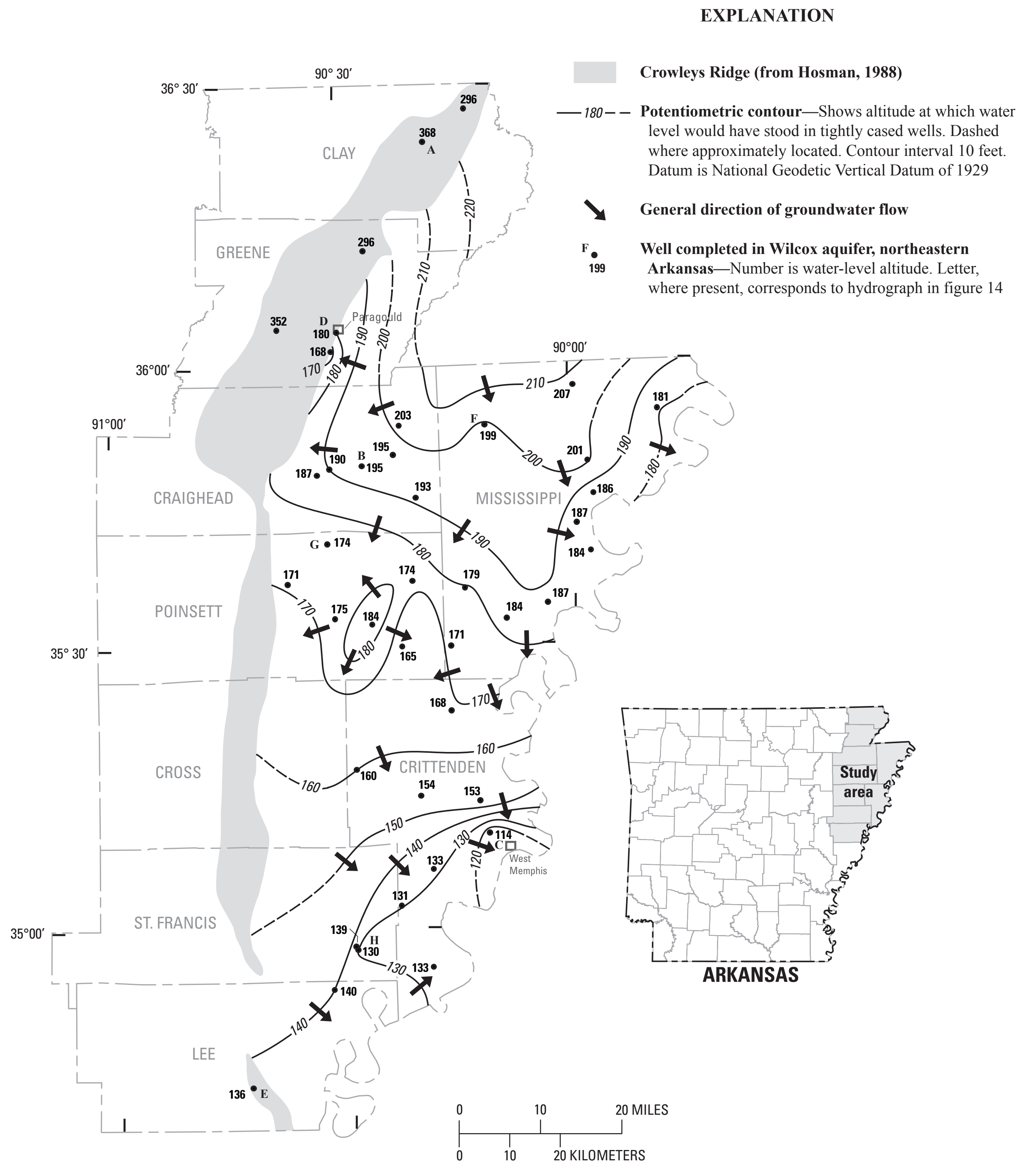

Figure 10. Potentiometric surface of the Wilcox aquifer in northeastern Arkansas, 2009.

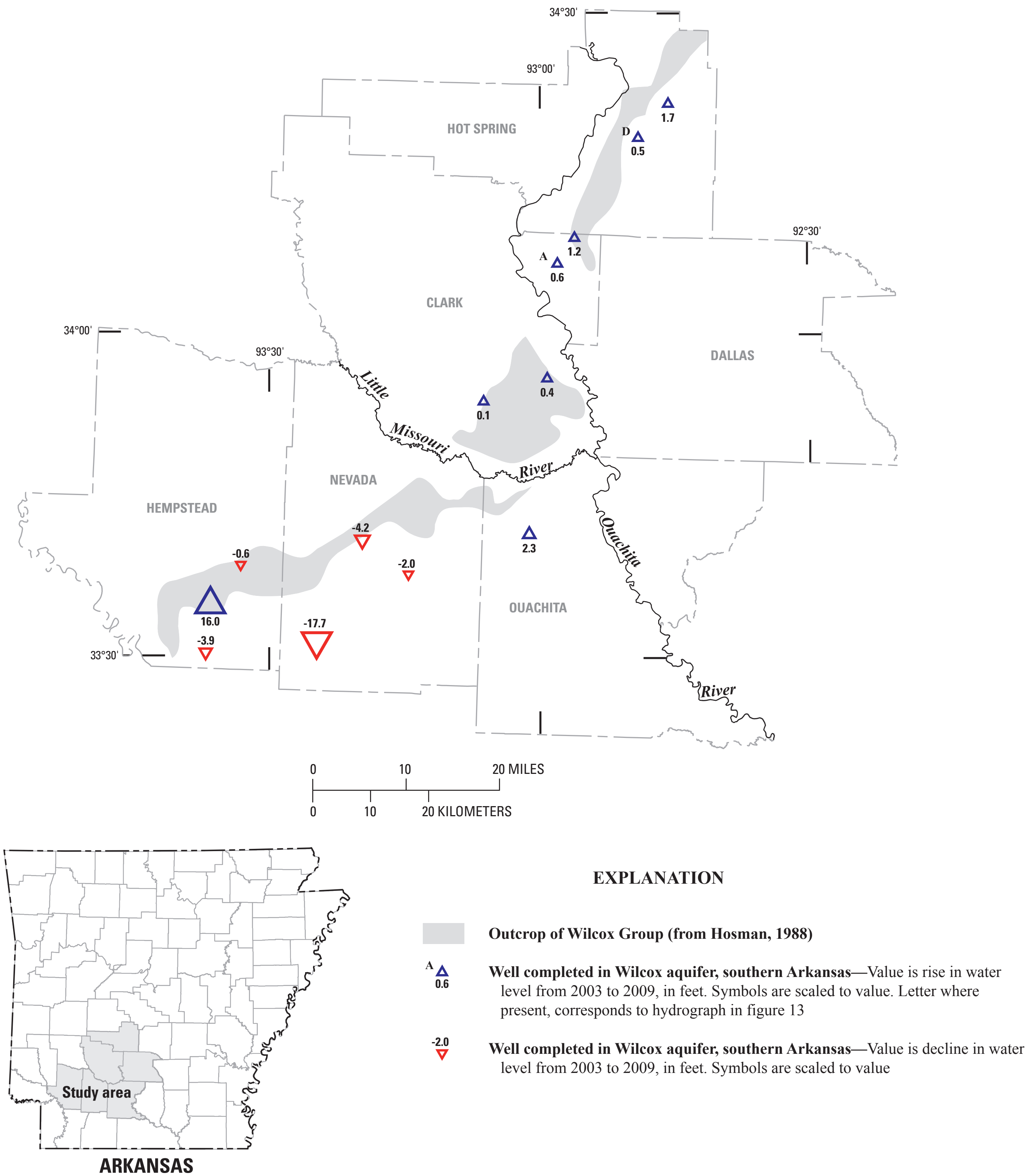

Figure 11. Water-level difference from 2003 to 2009 for the Wilcox aquifer in southern Arkansas.

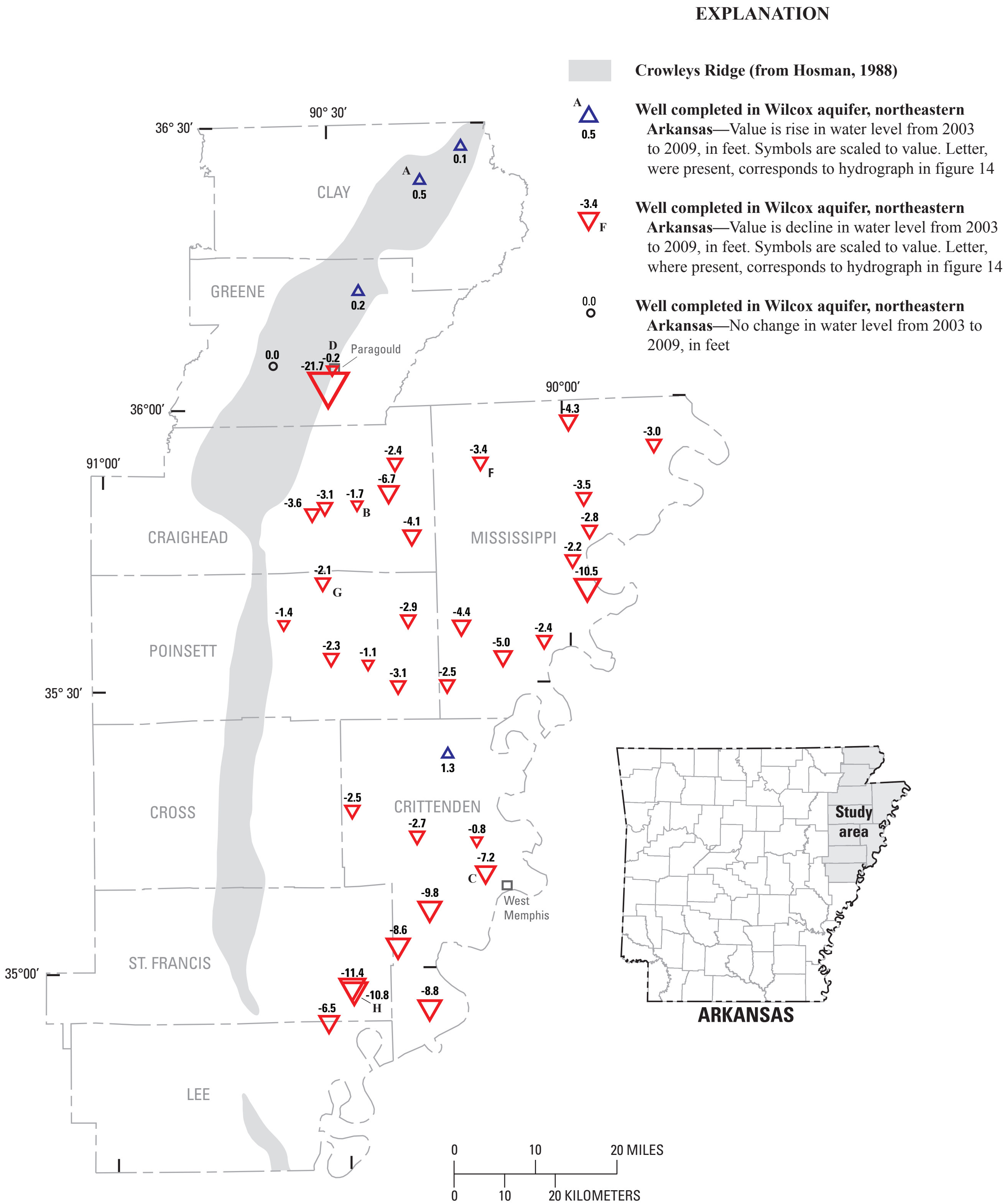

Figure 12. Water-level difference from 2003 to 2009 for the Wilcox aquifer in northeastern Arkansas.

had declining water levels, and the remaining well had no change in water level. Water levels declined throughout the northeastern area with the exception of one well in Crittenden County. Three other wells, one in Greene County and two in Clay County, also indicate a rise in water levels from 2003 to 2009. These three wells are located within the upper, perched part of the Wilcox aquifer on Crowleys Ridge (appendix 6).

Long-Term Hydrographs

Hydrographs from 42 wells with a minimum of 20 years of USGS water-level measurements were constructed (10 in the southern area and 32 in the northeastern area). Selected hydrographs are shown in figures 13-14 with locations indicated on figures 9-12. The minimum 20-year period of record was used to evaluate long-term trends not dominated by variations in climate and localized pumping rates on water levels in a single well. A trend line using linear regression was calculated for the period from 1990 to 2009. The slope of the trend line represents the computed annual decline or rise in water level during the 20-year period. A statistical summary of the number of wells, the range of the annual rise or decline in water level for the county, the mean, the median, and the range of the R^2 values for each county are listed in table 3. Negative values denote a decline in water level. The statistical summary for Clay, Hempstead, and St. Francis Counties was for a single well in each county.

Mean annual water-level rise and decline data for the period from 1990 to 2009 varied by county. In the southern area, Hot Spring County mean annual water-level rose 0.15 ft/yr, and mean annual declines between 0.03 ft/yr and 0.71 ft/yr were computed for Clark, Hempstead, and Nevada Counties. In the northeastern area, Greene County mean annual water-level rose 0.46 ft/yr, and mean annual declines between 0.03 ft/yr and 2.12 ft/yr were computed for Clay, Craighead, Crittenden, Lee, Mississippi, Poinsett, and St. Francis Counties.

Hydrographs for the southern area indicate water-level changes in individual walls ranged from rises of 0.44 ft/yr to declines of 1.68 ft/yr over the 20-year period (fig. 13). Hydrograph A, well 07S18W20ABB2 in Clark County (fig. 13), shows approximately a 6 ft increase in water level over the period of record. This well is unconfined and is located in the subcrop, receiving vertical recharge. Hydrograph B, well 10S18W10DDB1, also in Clark County (fig. 13), is located at the eastern edge of the outcrop and is under semiconfined conditions, receiving limited vertical recharge. This hydrograph shows a general decline through most of the period of record. Hydrographs A and B demonstrate the variability within this area caused by different confining conditions.

Table 3. Range, mean, and median of annual rise/decline in water level by county for wells completed in the Wilcox aquifer in Arkansas, 1990-2009.

[Annual rise or decline in water level for each well is calculated using linear regression; negative value indicates decline; positive value indicates rise; R2: coefficient of determination]

County	Number of wells	Range or values of annual rise (+) or decline (-) in water level (feet/year)	Mean annual rise (+) or decline (-) in water level (feet/year)	Median annual rise (+) or decline (-) in water level (feet/year)	Range of R^2 values for trend lines
Southern area					
Clark	5	-0.33 to 0.44	-0.03	-0.22	0.10 to 0.82
Hempstead[1]	1	-0.07	-0.07	-0.07	0.32
Hot Spring	2	0.11 to 0.18	0.15	0.15	0.53 to 0.56
Nevada	2	-1.68 to 0.26	-0.71	-0.71	0.32 to 0.68
Northeastern area					
Clay[1]	1	-0.03	-0.03	-0.03	0.30
Craighead	4	-0.80 to -0.47	-0.61	-0.58	0.29 to 0.70
Crittenden	8	-2.16 to -0.69	-1.38	-1.41	0.55 to 0.93
Greene	2	0.40 to 0.51	0.46	0.46	0.26 to 0.61
Lee	2	-1.83 to -0.80	-1.31	-1.31	0.89 to 0.99
Mississippi	8	-1.53 to -0.55	-0.89	-0.80	0.32 to 0.95
Poinsett	4	-1.79 to -0.18	-0.99	-0.99	0.07 to 0.98
St. Francis[1]	1	-2.12	-2.12	-2.12	0.91

[1] County included only one well with 20 or more years of measurements.

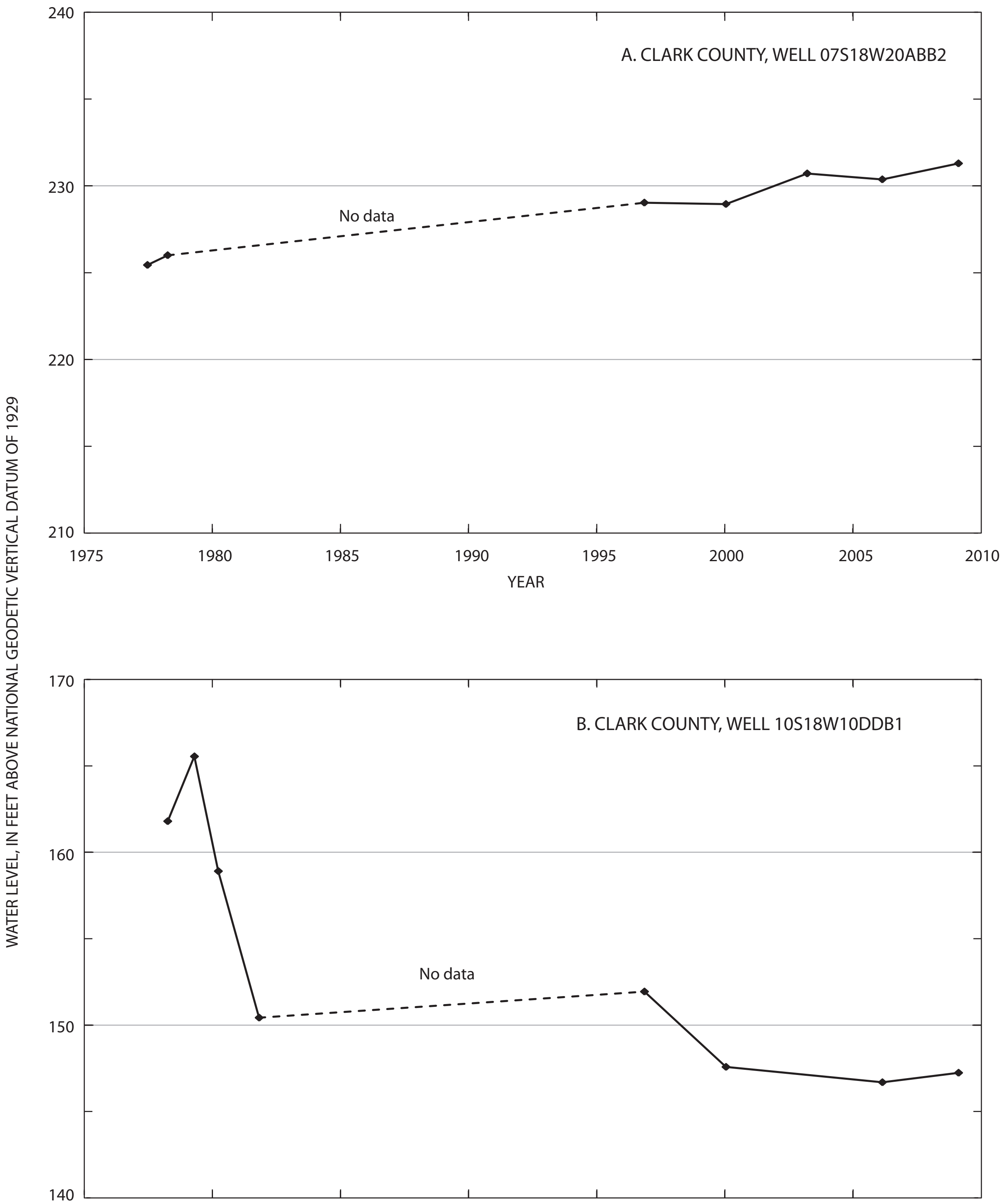

Figure 13. Water-level hydrographs for selected wells completed in the Wilcox aquifer in southern Arkansas.

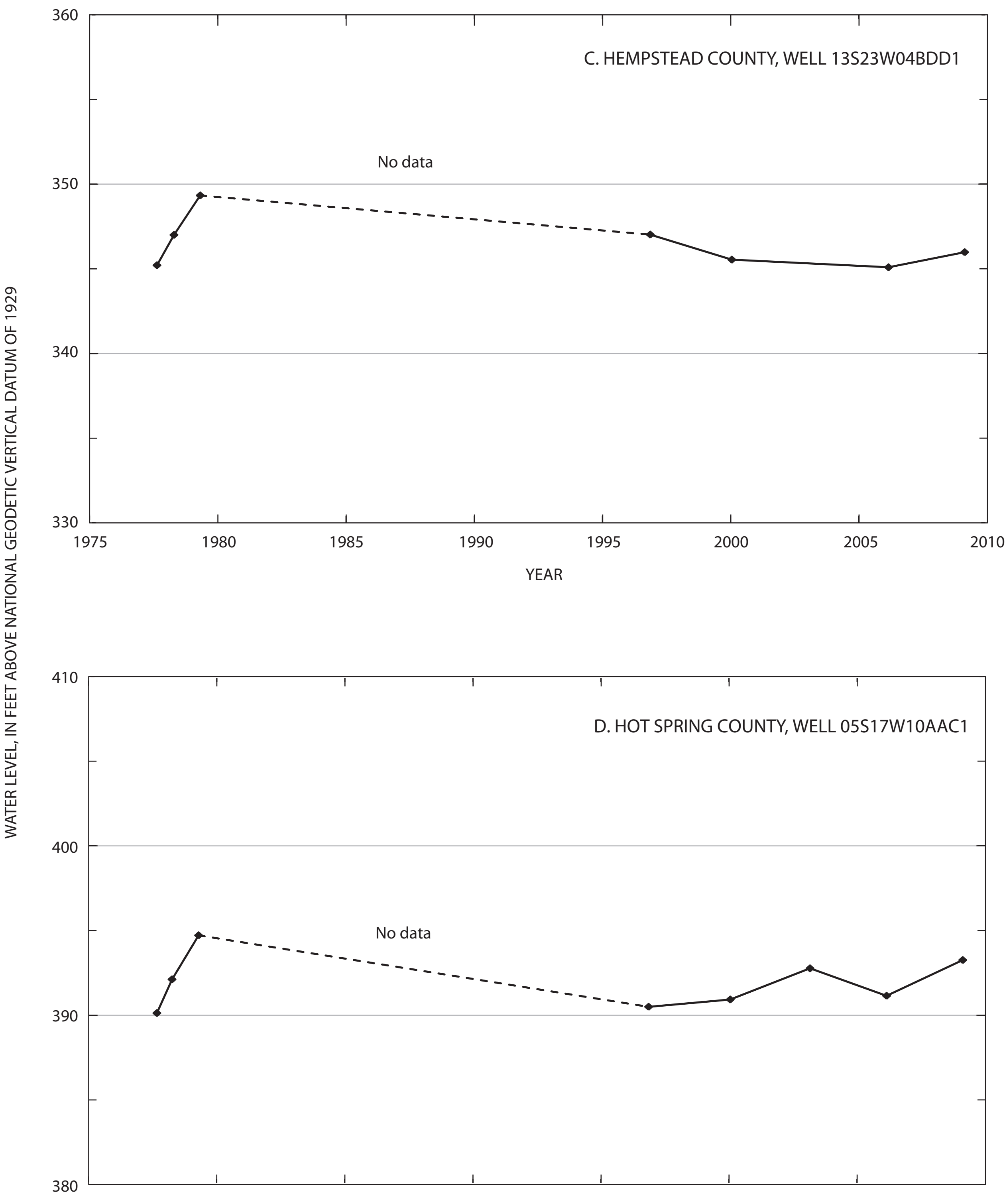

Figure 13. Water-level hydrographs for selected wells completed in the Wilcox aquifer in southern Arkansas.—Continued

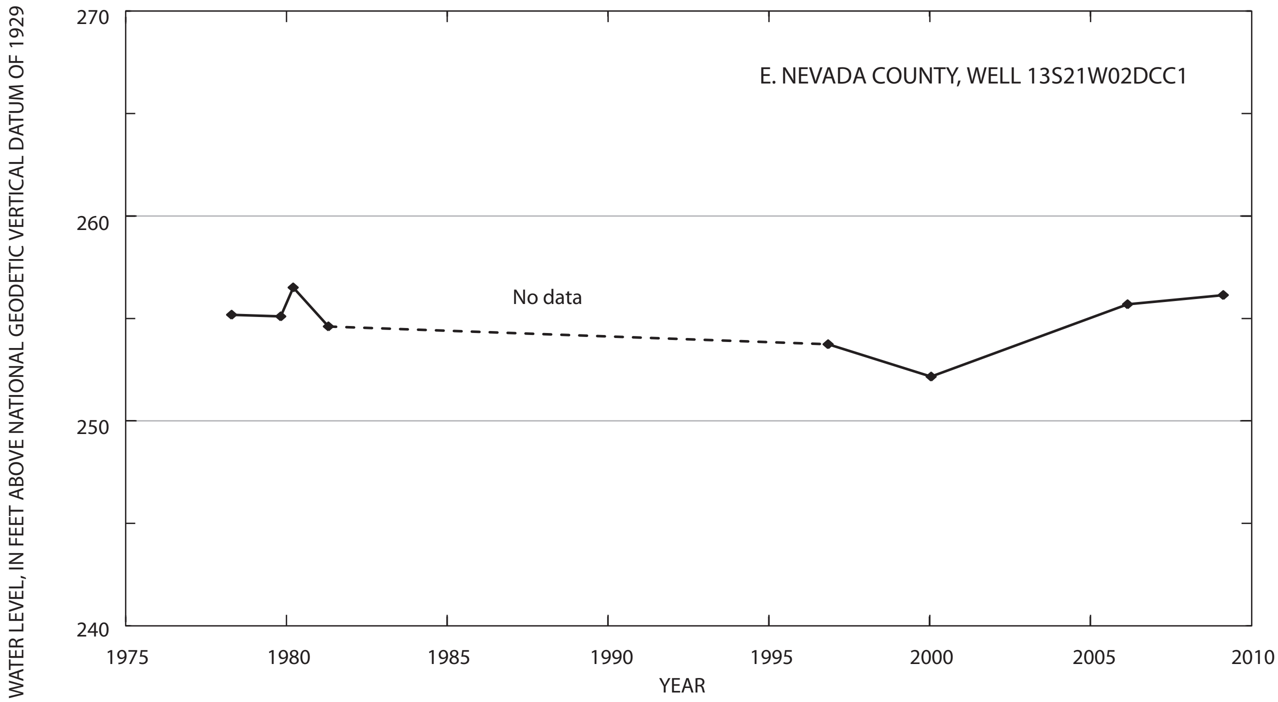

Figure 13. Water-level hydrographs for selected wells completed in the Wilcox aquifer in southern Arkansas.—Continued

Hydrographs for the northeastern area indicate water-level changes in individual wells ranged from rises of 0.51 ft/yr to declines of 2.16 ft/yr over the 20-year period (fig.14). Note there is an inconsistency between the long-term hydrograph data (fig. 14-D and table 3) and the 2003 to 2009 water-level difference data for Greene County (fig. 12 and appendix 6). The summary of long-term hydrograph data for Greene County indicates a slight rise in water levels because only two wells have 20 or more years of data. The analysis of long-term hydrograph data for Greene County does not include well 16N05E13BAB1, which has the decline of 21.7 ft in the 2003 to 2009 water-level difference data, because the well does not have 20 or more years of water-level measurements. Three hydrographs (fig. 14) indicate declining water levels in the Wilcox aquifer in counties located on the eastern Arkansas border. Hydrograph C, well 06N09E07CAC1 in Crittenden County, shows a decline for the period of record and supports the existence of the cone of depression near West Memphis. This well has an annual decline of 1.57 ft/yr for the period 1990 to 2009. The annual decline is in reasonable agreement with the difference from 2003 to 2009 (fig. 12) of -7.2 ft or -1.2 ft/yr. Hydrograph E, well 01N04E09DCC1 in Lee County, shows a decline for the period of record and has an annual decline of 1.83 ft/yr for the period 1990 to 2009. Hydrograph F, well 15N09E31ACD1 in Mississippi County, shows a general decline for the period of record and has an annual decline of 0.77 ft/yr for the period 1990 to 2009.

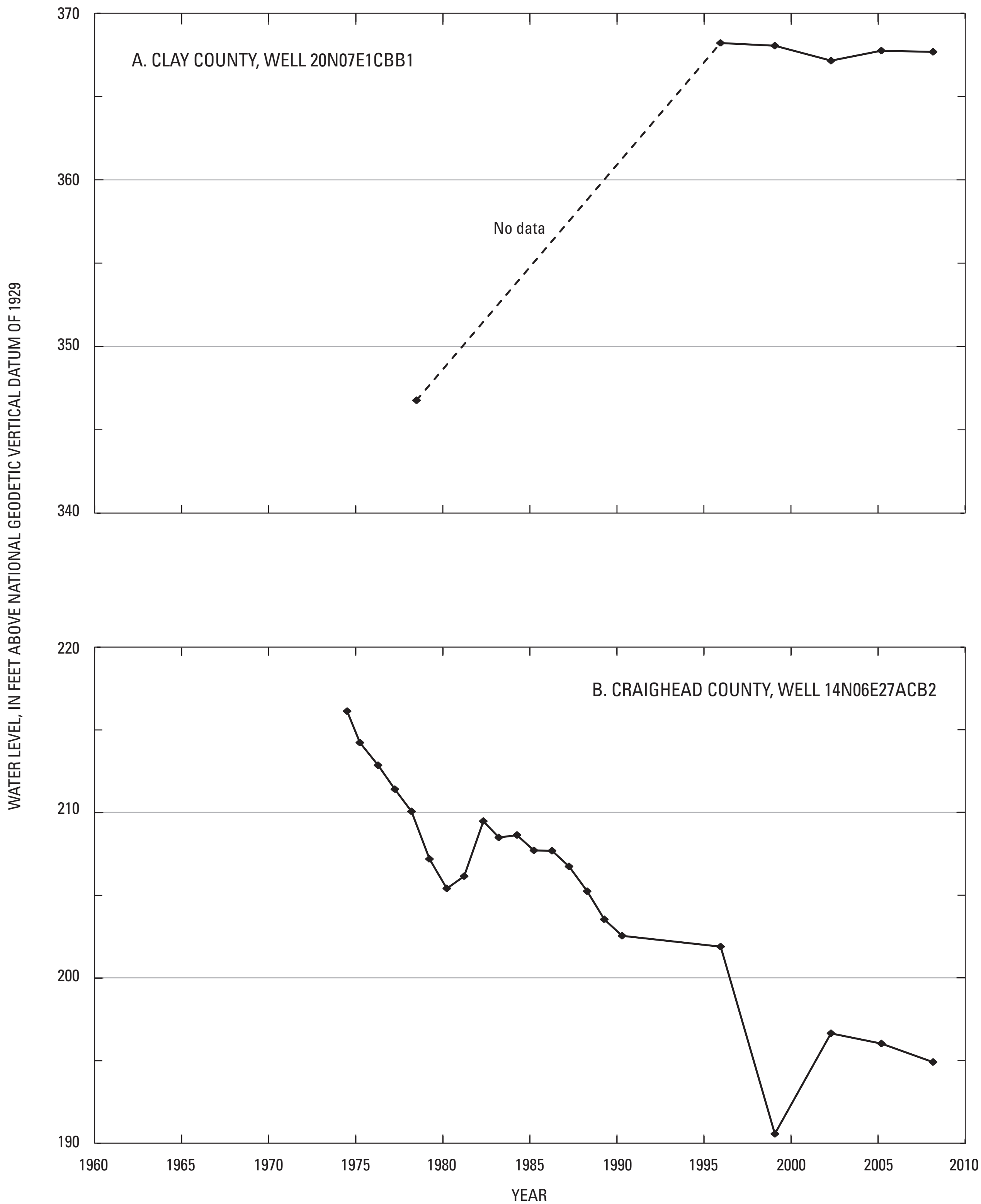

Figure 14. Water-level hydrographs for selected wells completed in the Wilcox aquifer in northeastern Arkansas.

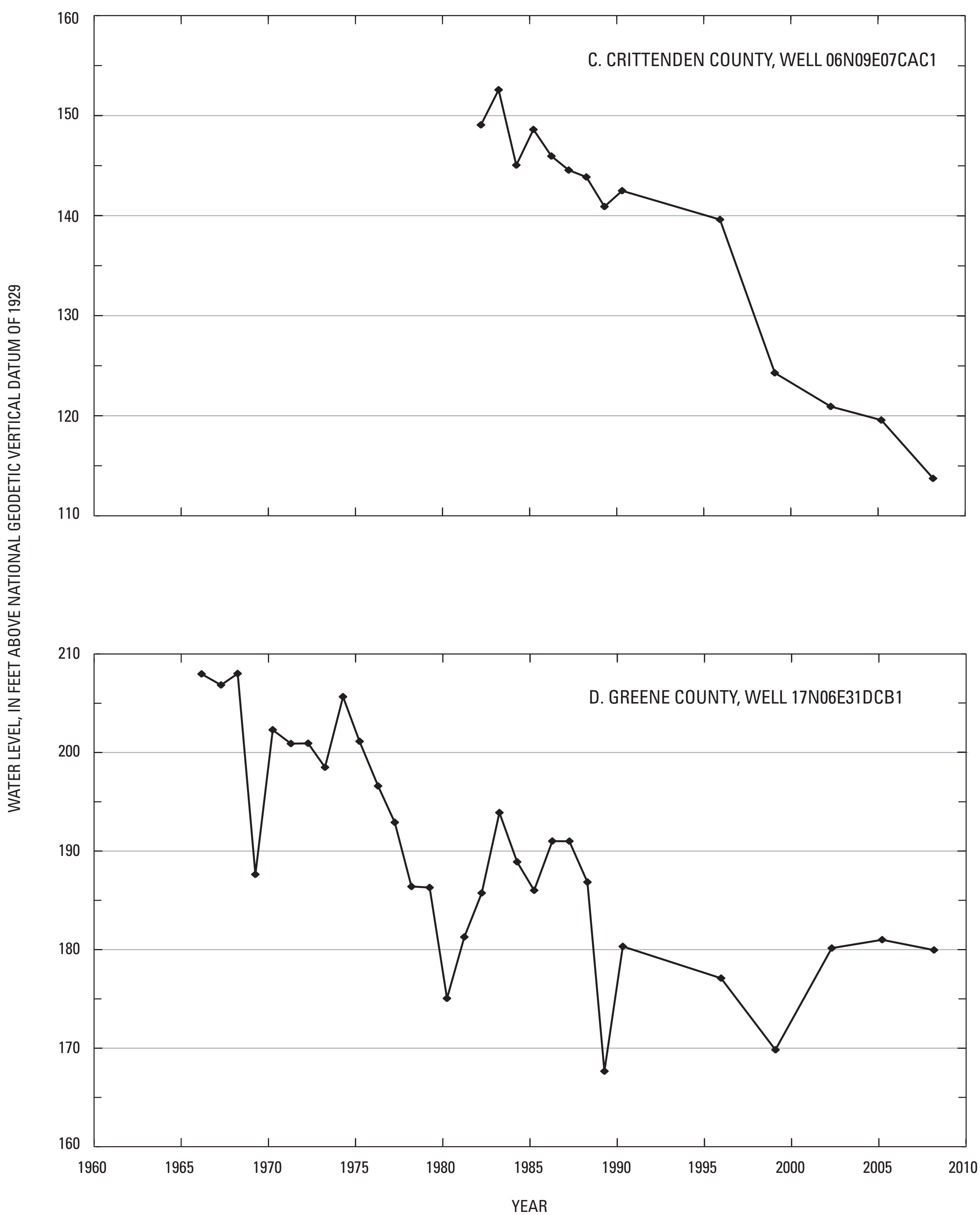

Figure 14. Water-level hydrographs for selected wells completed in the Wilcox aquifer in northeastern Arkansas.—Continued

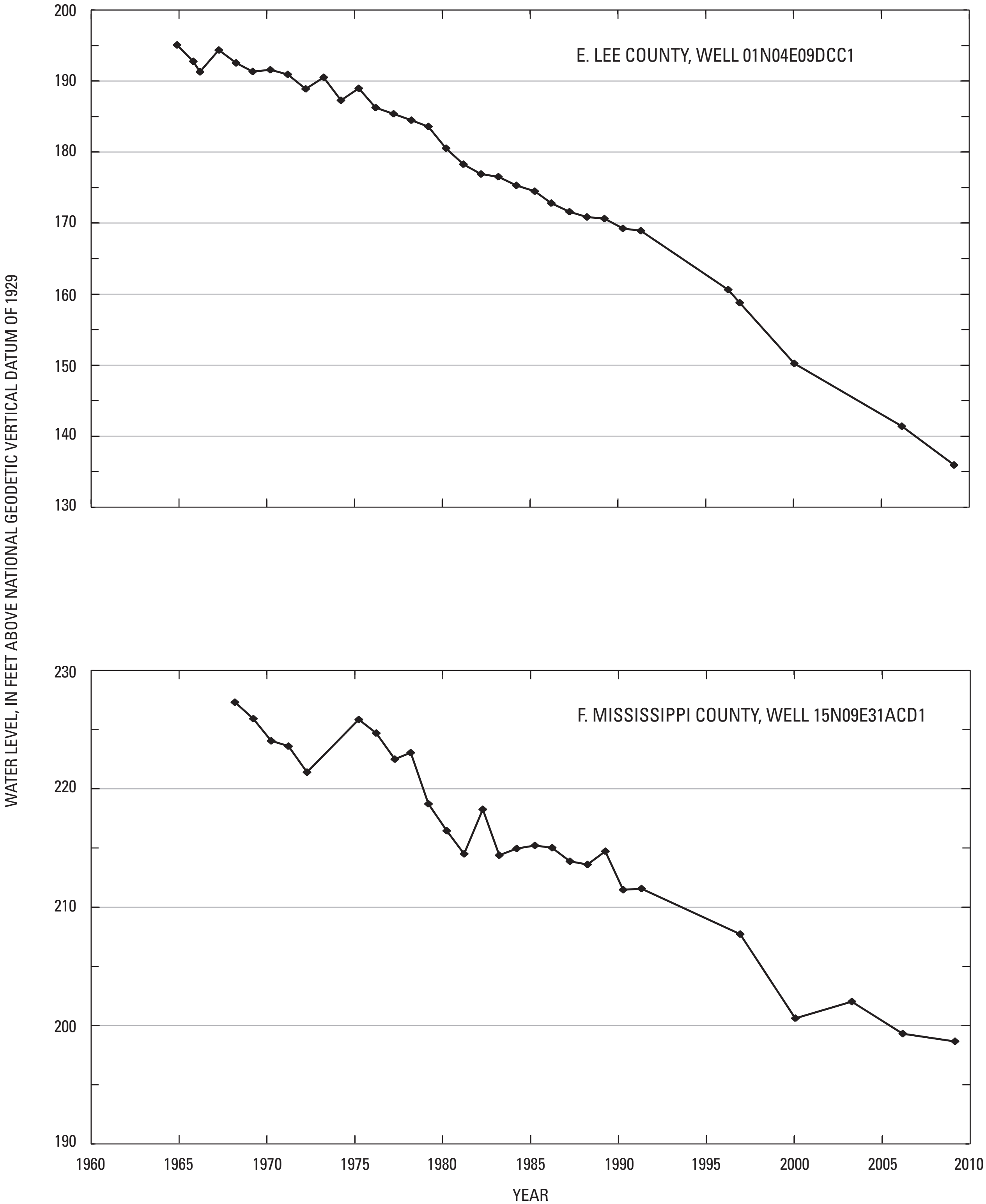

Figure 14. Water-level hydrographs for selected wells completed in the Wilcox aquifer in northeastern Arkansas.—Continued

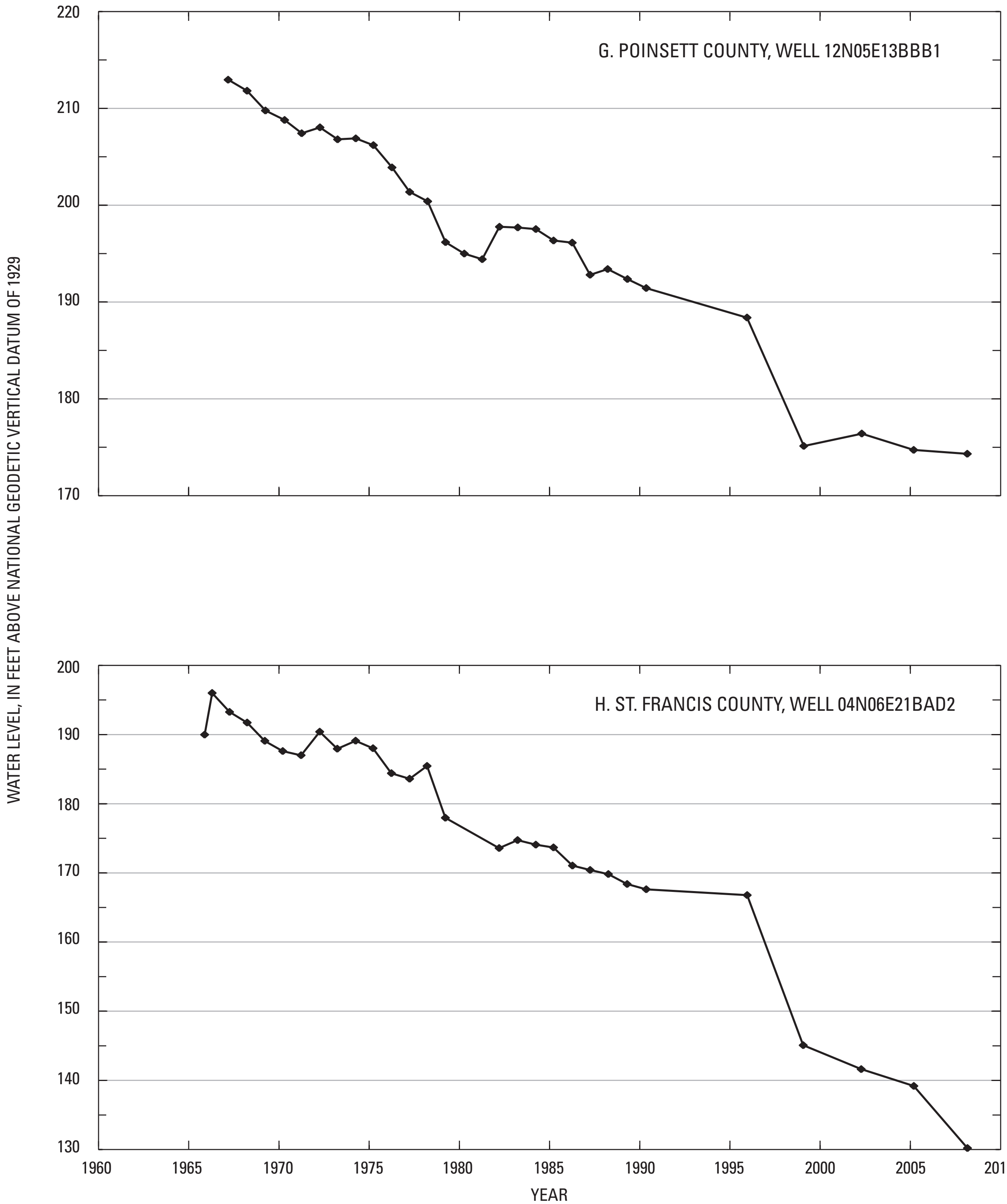

Figure 14. Water-level hydrographs for selected wells completed in the Wilcox aquifer in northeastern Arkansas.—Continued

Summary

Eocene-age sand beds near the base of the Cockfield Formation of the Claiborne Group constitute the aquifer known locally as the Cockfield aquifer. Upper Paleocene-age sand beds within the lower parts of the Wilcox Group constitute the aquifer known locally as the Wilcox aquifer. In 2005, reported water withdrawals from the Cockfield aquifer in Arkansas totaled 16.1 million gallons per day, while reported water withdrawals from the Wilcox aquifer in Arkansas totaled 27.0 million gallons per day. Major withdrawals from these units were for industrial and public water supplies with lesser but locally important withdrawals for commercial, domestic, and agricultural uses.

During February 2009, 56 water-level measurements were made in wells completed in the Cockfield aquifer and 57 water-level measurements were made in wells completed in the Wilcox aquifer. The results from the 2009 water-level measurements are presented in potentiometric-surface maps and in combination with previous years' water-level measurements.

Trends in water-level change over time within the two aquifers are investigated using water-level difference maps and well hydrographs. Water-level difference maps were constructed for each aquifer using the difference between depth to water measurements made in 2003 and 2009. Well hydrographs for each aquifer were constructed for wells with 20 or more years of historical water-level data. The hydrographs were evaluated individually using linear regression to calculate the annual rise or decline in water levels and by aggregating the regression results by county and statistically summarizing for the range, mean, and median water-level change in each county.

The 2009 potentiometric surface of the Cockfield aquifer map indicates the regional direction of groundwater flow generally towards the east and southeast, except in two areas of intense groundwater withdrawals that have developed into cones of depression. The lowest water-level altitude measured was 43 feet in Lincoln County; the highest water-level altitude measured was 351 feet in Columbia County.

A water-level difference map was constructed from 54 wells completed in the Cockfield aquifer within Arkansas. The largest rise in water level (14.9 feet) was in Drew County. The largest decline (27.4 feet) was in Lincoln County. Seven wells had a rise in water level, and the remaining 47 wells had a decline in water level for the 6-year period. The largest declines in water levels have occurred along Arkansas' eastern and southern borders.

Hydrographs for 33 wells with 20 or more years of historical water-level data for the Cockfield aquifer were developed. Examination of the hydrographs is divided into three geographic areas: the area south and west of the Ouachita River, the area between the Ouachita and Saline Rivers, and the area east of the Saline River. The hydrographs in the area south and west of the Ouachita River are relatively flat indicating only a small, 1- to 3-foot drop in water levels over the 30- to 40-year period. The hydrographs in the area between the Ouachita and Saline Rivers display mixed results ranging from a decline of approximately 20 feet to rises of approximately 2 feet over the period of record. The hydrographs in the area east of the Saline River show declining water levels over their period of record ranging from approximately 60 feet to approximately 5 feet.

County summaries of the linear regression analysis of the 33 well hydrographs for the Cockfield aquifer indicate water level changes in individual wells ranged from a rise of approximately 0.11 ft/yr to a decline of approximately of 1.46 ft/yr over the 20-year period. Cleveland and Columbia Counties have mean annual rises 0.11 and 0.03 ft/yr respectively. Wells in Arkansas, Ashley, Bradley, Calhoun, Chicot, Desha, Drew, Lincoln, and Union Counties have mean annual declines ranging from 0.02 to 1.46 ft/yr.

The potentiometric-surface for the Wilcox aquifer is presented using two maps, one southern Arkansas and another for northeastern Arkansas, because of the absence of water-level data in the central part of the State. The direction of groundwater flow in the southern area is generally the east, except around two cones of depression and around two mounds of elevated water levels. The lowest water-level altitude measured in the southern area was 147 feet in Clark County; the highest water-level altitude measured was 400 feet in Hempstead County. The direction of groundwater flow in the northeastern area is generally to the south and southeast except in an area of large groundwater withdrawals that has altered the flow to a westerly direction. The lowest water-level altitude measured in the northeastern area was 114 feet near West Memphis in Crittenden County; the highest water-level altitude measured was 368 feet on Crowleys Ridge in Clay County.

Water-level difference maps for the Wilcox aquifer in Arkansas were constructed using water-level measurements collected from 53 wells made during 2003 and 2009. In the southern area, the largest decline in water level (17.7 feet) was in Nevada County, and the largest rise in water level (16.0 feet) was in Hempstead County. Water levels rose in the northern and eastern parts of the southern area, but declined in the southern part of the area with the exception of one well in Hempstead County. The largest water-level decline in the northeastern area was in Greene County (21.7 feet), and the largest rise was in Crittenden County (1.3 feet). Water levels declined throughout the northeastern area with the exception of one well in Crittenden County. Three other wells, one in Green County and two in Clay County, also indicate a rise in water levels; but these are located within the upper, perched part of the Wilcox aquifer on Crowleys Ridge which is hydrologically disconnected from the Wilcox aquifer within the surrounding Mississippi Alluvial Plain.

Mean annual water-level rise and decline data for the period 1990-2009 varied by county. In the southern area, Hot Spring County's mean annual water-level rose 0.15 ft/yr, and mean annual declines between 0.03 ft/yr and 0.71 ft/yr were computed for Clark, Hempstead, and Nevada Counties. In the

northeastern area, Greene County's mean annual water-level rose 0.46 ft/yr and mean annual declines between 0.03 ft/yr and 2.12 ft/yr were computed for Clay, Craighead, Crittenden, Lee, Mississippi, Poinsett, and St. Francis Counties. Hydrographs from 42 wells completed in the Wilcox aquifer were constructed (10 in the southern area and 32 in the northeastern area). Hydrographs for the southern area indicate water-level changes in individual wells ranged from rises of 0.44 ft/yr to declines of 1.68 ft/yr over the 20-year period. Hydrographs for the northeastern area indicate water-level changes in individual wells ranged from rises of 0.51 ft/yr for declines of 2.16 ft/yr over the 20-year period.

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Appendixes 1-6

Appendix 1. Water-level data collected during Feburary 2009 from wells completed in the Cockfield aquifer in southern Arkansas.

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929; --, missing data]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Arkansas County							
08S02W04ACA1	340139	911406	72	92.92	165	453	2/23/2009
Ashley County							
15S04W26CBC1	332144	912932	86	42.28	128	409	2/20/2009
17S04W10BCD2	331417	913030	87	38.50	125	340	2/20/2009
17S04W10CBA1	331406	913033	91	33.78	125	360	2/20/2009
17S06W07ADA1	331442	914510	99	74.75	174	426	2/20/2009
18S04W19DAA2	330710	913247	88	27.79	116	356	2/20/2009
18S08W04BBC1	331038	915627	68	81.06	149	314	2/20/2009
18S08W29DDD2	330630	915629	70	69.68	140	--	2/20/2009
19S05W12CAC1	330336	913425	85	30.03	115	320	2/20/2009
Bradley County							
12S10W10BCA1	334108	920807	102	124.79	227	425	2/19/2009
14S10W01BAD1	333139	920522	86	145.04	231	540	2/19/2009
14S10W31DBA1	332658	921025	96	96.78	193	349	2/19/2009
14S11W35CAB1	332656	921251	113	76.71	190	320	2/19/2009
14S11W35DAC1	332650	921233	109	64.78	174	345	2/19/2009
15S12W11CAB1	332536	921858	131	23.57	155	225	2/19/2009
16S10W11DCB1	331951	920619	107	44.59	152	152	2/19/2009
16S11W11ACA1	332027	921223	111	30.00	141	140	2/19/2009
Calhoun County							
11S13W15BBC1	334560	922534	257	53.40	310	70	2/19/2009
13S13W09CBD1	333555	922638	194	37.92	232	147	2/19/2009
13S13W15DBA1	333517	922520	211	21.14	232	122	2/19/2009
14S13W11CAC1	333045	922451	177	28.12	205	105	2/19/2009
14S13W29ADA1	332829	922722	134	26.00	160	81	2/19/2009
14S13W29DAC1	332815	922729	126	13.46	139	--	2/19/2009
14S14W21ACB1	332931	923249	92	40.13	132	160	2/19/2009
Chicot County							
13S03W26BBB1	333247	912301	67	72.38	139	422	2/20/2009
14S03W05BBA1	333106	912602	62	76.74	139	510	2/20/2009
15S03W21ABA1	332314	912438	77	45.33	122	400	2/20/2009
16S02W04BAC1	332027	911857	79	46.39	125	330	2/20/2009
18S02W24CDB1	330652	911547	81	48.47	129	364	2/20/2009
18S02W25ABB3	330640	911541	88	47.42	135	332	2/20/2009
18S03W14CCC1	330731	912319	83	14.62	98	320	2/20/2009

Appendix 1. Water-level data collected during Feburary 2009 from wells completed in the Cockfield aquifer in southern Arkansas.—Continued

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929; --, missing data]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Cleveland County							
08S13W34BDA1	335902	922444	164	84.14	248	181	2/19/2009
09S10W17CDD1	335534	920942	267	3.42	270	361	2/19/2009
11S11W23BBD1	334449	921258	234	41.16	275	148	2/19/2009
Columbia County							
17S20W35BBD1	331313	930914	351	10.35	361	--	2/18/2009
19S20W34ADC1	330233	930958	289	23.65	313	39.8	2/18/2009
19S21W17CBB1	330520	931857	260	46.06	306	54.8	2/18/2009
19S21W35ADC1	330247	931513	251	4.52	256	30.1	2/18/2009
19S22W36DBB1	330245	932034	307	43.70	351	68.6	2/18/2009
Desha County							
12S01W32DCA1	333628	911245	65	71.27	136	495	2/23/2009
12S03W30ADC1	333747	912611	80	72.84	153	280	2/23/2009
13S02W08CAA1	333504	911921	82	65.26	147	515	2/23/2009
Drew County							
11S05W35DDB1	334216	913438	98	81.73	180	500	2/23/2009
12S08W33AAB1	333750	915551	70	102.53	173	543	2/23/2009
14S06W21BDC1	332846	914339	95	121.33	216	--	2/23/2009
14S07W26BAB1	332754	914744	104	125.77	230	440	2/23/2009
Lincoln County							
07S06W14BBC1	340709	914026	159	22.82	182	483	2/23/2009
10S05W06CAC1	335204	913918	43	127.32	170	550	2/23/2009
Union County							
16S18W22DCD1	331913	925704	234	13.50	247	36	2/18/2009
17S12W27DCA1	331219	921929	158	12.14	170	24	2/18/2009
17S13W17DDC1	331402	922746	155	38.28	193	156	2/18/2009
17S15W31DCA2	331144	924116	201	52.12	253	110	2/18/2009
17S16W33BBA2	331229	924601	230	24.87	255	31	2/18/2009
17S18W15CDA1	331453	925723	262	28.50	290	35	2/18/2009
18S15W21DAC1	330824	923909	174	25.86	200	40	2/18/2009
19S12W28CBA1	330207	922109	189	11.12	200	25	2/18/2009

Appendix 2. Difference in depth to water from 2003 to 2009 in the Cockfield aquifer in southern Arkansas.

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929; positive differences in depth to water indicate a rise in water levels from 2003 to 2009 whereas, negative values indicate a decline in water levels from 2003 to 2009]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2003 depth to water (feet below land-surface datum)	2009 depth to water (feet below land-surface datum)	Difference in depth to water from 2003-2009 (feet)
Arkansas County					
08S02W04ACA1	340139	911406	89.53	92.92	-3.4
Ashley County					
15S04W26CBC1	332144	912932	41.99	42.28	-0.3
17S04W10BCD2	331417	913030	37.04	38.50	-1.5
17S04W10CBA1	331406	913033	32.96	33.78	-0.8
17S06W07ADA1	331442	914510	73.05	74.75	-1.7
18S04W19DAA2	330710	913247	25.75	27.79	-2.0
18S08W04BBC1	331038	915627	78.95	81.06	-2.1
19S05W12CAC1	330336	913425	27.24	30.03	-2.8
Bradley County					
12S10W10BCA1	334108	920807	122.23	124.79	-2.6
12S10W30CAC1	333815	921046	10.49	11.21	-0.7
14S10W01BAD1	333139	920522	141.96	145.04	-3.1
14S10W31DBA1	332658	921025	94.86	96.78	-1.9
14S11W35CAB1	332656	921251	74.73	76.71	-2.0
14S11W35DAC1	332650	921233	63.94	64.78	-0.8
15S12W11CAB1	332536	921858	22.19	23.57	-1.4
16S10W11DCB1	331951	920619	53.2	44.59	8.6
16S11W11ACA1	332027	921223	26.45	30.00	-3.6
Calhoun County					
11S13W15BBC1	334560	922534	50.33	53.40	-3.1
13S13W09CBD1	333555	922638	36.47	37.92	-1.5
13S13W15DBA1	333517	922520	19.11	21.14	-2.0
14S13W11CAC1	333045	922451	27.11	28.12	-1.0
14S13W29ADA1	332829	922722	25.72	26.00	-0.3
14S13W29DAC1	332815	922729	13.53	13.46	0.1
14S14W21ACB1	332931	923249	39.11	40.13	-1.0
Chicot County					
13S03W26BBB1	333247	912301	70.1	72.38	-2.3
14S03W05BBA1	333106	912602	76.91	76.74	0.2
15S03W21ABA1	332314	912438	38.2	45.33	-7.1
16S02W04BAC1	332027	911857	45.12	46.39	-1.3
18S02W24CDB1	330652	911547	45.99	48.47	-2.5
18S02W25ABB3	330640	911541	43.42	47.42	-4.0
18S03W14CCC1	330731	912319	13.66	14.62	-1.0

Appendix 2. Difference in depth to water from 2003 to 2009 in the Cockfield aquifer in southern Arkansas.—Continued

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929; positive differences in depth to water indicate a rise in water levels from 2003 to 2009 whereas, negative values indicate a decline in water levels from 2003 to 2009]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2003 depth to water (feet below land-surface datum)	2009 depth to water (feet below land-surface datum)	Difference in depth to water from 2003-2009 (feet)
		Cleveland County			
08S13W34BDA1	335902	922444	85.46	84.14	1.3
09S10W17CDD1	335534	920942	3.57	3.42	0.2
11S11W23BBD1	334449	921258	40.1	41.16	-1.1
		Columbia County			
17S20W35BBD1	331313	930914	7.57	10.35	-2.8
19S20W34ADC1	330233	930958	17.71	23.65	-5.9
19S21W17CBB1	330520	931857	42.47	46.06	-3.6
19S21W35ADC1	330247	931513	0.91	4.52	-3.6
19S22W36DBB1	330245	932034	39.18	43.70	-4.5
		Desha County			
12S01W32DCA1	333628	911245	67.78	71.27	-3.5
12S03W30ADC1	333747	912611	70.89	72.84	-2.0
13S02W08CAA1	333504	911921	62.62	65.26	-2.6
		Drew County			
11S05W35DDB1	334216	913438	96.66	81.73	14.9
12S08W33AAB1	333750	915551	99.26	102.53	-3.3
14S06W21BDC1	332846	914339	118.77	121.33	-2.6
14S07W26BAB1	332754	914744	122.87	125.77	-2.9
		Lincoln County			
07S06W14BBC1	340709	914026	19.89	22.82	-2.9
10S05W06CAC1	335204	913918	99.9	127.32	-27.4
		Union County			
17S12W27DCA1	331219	921929	9.81	12.14	-2.3
17S13W17DDC1	331402	922746	38.02	38.28	-0.3
17S16W33BBA2	331229	924601	25.25	24.87	0.4
17S18W15CDA1	331453	925723	27.83	28.50	-0.7
18S15W21DAC1	330824	923909	24.43	25.86	-1.4
19S12W28CBA1	330207	922109	10.35	11.12	-0.8

Appendix 3. Water-level data collected during Feburary 2009 from wells completed in the Wilcox aquifer in southern Arkansas.

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929; --, missing data]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
			Clark County				
07S18W03BBD1	340917	925604	257	13.36	270	47	2/17/2009
07S18W20ABB2	340652	925757	231	10.71	242	19	2/17/2009
09S18W20CBB1	335611	925905	212	17.58	230	26	2/17/2009
10S20W01BAC1	335403	930612	265	29.69	295	53	2/17/2009
10S18W10DDB1	335216	925613	147	47.76	195	215	2/17/2009
			Hempstead County				
13S23W04BDD1	333842	932911	346	4.02	350	14	2/17/2009
13S24W02DCA2	333829	933311	400	45.98	446	63	2/17/2009
13S24W29ACC1	333524	933635	344	27.05	371	60	2/17/2009
14S24W29BCA1	333017	933704	333	21.62	355	31	2/17/2009
			Hot Spring County				
04S16W20CBB1	342144	924532	342	2.90	345	18	2/17/2009
05S17W10AAC1	341836	924853	393	16.74	410	26	2/17/2009
			Nevada County				
12S22W24CDA1	334046	931941	312	31.73	344	41	2/18/2009
13S21W02DCC1	333754	931426	256	58.86	315	240	2/18/2009
13S21W11BDA1	333738	931432	243	25.39	268	--	2/18/2009
14S22W19AAA1	333105	932443	311	25.92	337	75	2/18/2009
			Ouachita County				
12S19W11DCD1	334144	930105	275	13.25	288	533	2/18/2009

Appendix 4. Water-level data collected during February 2009 from wells completed in the Wilcox aquifer in northeastern Arkansas.

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Clay County							
21N08E14CBB1	362716	901126	296	83.99	380	157	2/25/2009
20N07E01CBB1	362347	901703	368	92.32	460	200	2/25/2009
Craighead County							
15N07E33BAD1	355315	902107	203	29.29	232	1,034	2/24/2009
14N07E17DCB1	355008	902202	195	37.39	232	1,070	2/24/2009
14N06E27ACB2	354858	902613	195	32.10	227	999	2/24/2009
14N05E25DCB1	354843	903029	190	43.05	233	890	2/24/2009
14N05E34DAA1	354803	903208	187	43.25	230	865	2/24/2009
13N07E14BBA2	354526	901911	193	27.79	221	1,028	2/24/2009
Crittenden County							
09N08E29ADD1	352225	901516	168	56.61	225	1,564	2/26/2009
08N06E33CBD1	351614	902752	160	54.84	215	1,750	2/26/2009
07N07E14CCC1	351318	901930	154	69.20	223	1,584	2/26/2009
07N08E24CAB1	351238	901148	153	67.69	221	1,540	2/26/2009
06N09E07CAC1	350907	901042	114	96.27	210	1,470	2/26/2009
06N07E01ABB1	350520	901807	133	74.01	207	1,541	2/26/2009
05N07E29ACC1	350129	902225	131	69.35	200	1,700	2/26/2009
04N07E36ADB1	345449	901828	133	67.65	201	1,638	2/26/2009
Greene County							
18N06E10DCD1	361209	902520	296	24.41	320	120	2/25/2009
17N04E36BCA1	360348	903658	352	153.39	505	311	2/25/2009
17N06E31DCB1	360328	902902	180	105.04	285	462	2/25/2009
16N05E13BAB1	360123	903026	168	122.04	290	545	2/25/2009
Lee County							
03N05E01BAB1	345413	903136	140	55.94	196	1,702	2/27/2009
01N04E09DCC1	344209	904220	136	68.08	204	1,885	2/27/2009
Mississippi County							
15N10E01ADC1	355712	895806	207	40.54	248	1,350	2/25/2009
15N12E23DBC1	355426	894701	181	57.21	238	1,491	2/25/2009
15N09E31ACD1	355306	900952	199	41.34	240	1,158	2/25/2009
14N11E20CCA1	354859	895626	201	39.03	240	1,518	2/25/2009
13N11E08DDA1	354528	895547	186	59.36	245	1,445	2/25/2009
13N11E31CCCC1	354221	895807	187	54.38	241	1,500	2/25/2009
12N11E17CDD1	353917	895618	184	60.93	245	1,500	2/25/2009
11N08E10AAC2	353538	901301	179	41.47	220	1,380	2/26/2009

Appendix 4. Water-level data collected during February 2009 from wells completed in the Wilcox aquifer in northeastern Arkansas.—Continued

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Mississippi County—Continued							
11N10E20ADA1	353349	900213	187	48.03	235	1,417	2/25/2009
11N09E33AAB1	353214	900739	184	52.98	237	1,560	2/26/2009
10N08E17ADD1	352923	901505	171	53.52	225	1,521	2/26/2009
Poinsett County							
12N05E13BBB1	354038	903059	174	47.68	222	1,071	2/24/2009
11N07E03BDD1	353629	901955	174	41.79	216	1,456	2/24/2009
11N05E06CCD1	353622	903618	171	42.88	214	992	2/24/2009
11N05E36AAA1	353234	903009	175	38.83	214	1,175	2/24/2009
11N06E35CDA3	353152	902520	184	30.97	215	1,301	2/24/2009
10N07E16CBB2	352925	902129	165	52.53	218	1,500	2/24/2009
St. Francis County							
04N06E16CCB1	345712	902830	139	62.65	202	1,615	2/27/2009
04N06E21BAD2	345649	902815	130	70.79	201	1,740	2/27/2009

Appendix 5. Difference in depth to water from 2003 to 2009 in the Wilcox aquifer in southern Arkansas.

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929; positive differences in depth to water indicate a rise in water levels from 2003 to 2009 whereas negative values indicate a decline in water levels from 2003 to 2009]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2003 depth to water (feet below land-surface datum)	2009 depth to water (feet below land-surface datum)	Difference in depth to water from 2003-2009 (feet)
			Clark County		
07S18W03BBD1	340917	925604	14.51	13.36	1.2
07S18W20ABB2	340652	925757	11.29	10.71	0.6
09S18W20CBB1	335611	925905	17.97	17.58	0.4
10S20W01BAC1	335403	930612	29.75	29.69	0.1
			Hempstead County		
13S24W29ACC1	333524	933635	43.08	27.05	16.0
13S24W02DCA2	333829	933311	45.43	45.98	-0.6
14S24W29BCA1	333017	933704	17.70	21.62	-3.9
			Hot Spring County		
04S16W20CBB1	342144	924532	4.62	2.9	1.7
05S17W10AAC1	341836	924853	17.23	16.74	0.5
			Nevada County		
13S21W11BDA1	333738	931432	23.44	25.39	-2.0
12S22W24CDA1	334046	931941	27.58	31.73	-4.2
14S22W19AAA1	333105	932443	8.25	25.92	-17.7
			Ouachita County		
12S19W11DCD1	334144	930105	15.59	13.25	2.3

Appendix 6. Difference in depth to water from 2003 to 2009 in the Wilcox aquifer in northeastern Arkansas.

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929; positive differences in depth to water indicate a rise in water levels from 2003 to 2009 whereas negative values indicate a decline in water levels from 2003 to 2009]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2003 depth to water (feet below land-surface datum)	2009 depth to water (feet below land-surface datum)	Difference in water level from 2003-2009 (feet)
Clay County					
20N07E01CBB1	362347	901703	92.85	92.32	0.5
21N08E14CBB1	362716	901126	84.08	83.99	0.1
Craighead County					
14N06E27ACB2	354858	902613	30.36	32.10	-1.7
15N07E33BAD1	355315	902107	26.87	29.29	-2.4
14N05E25DCB1	354843	903029	39.96	43.05	-3.1
14N05E34DAA1	354803	903208	39.64	43.25	-3.6
13N07E14BBA2	354526	901911	23.71	27.79	-4.1
14N07E17DCB1	355008	902202	30.74	37.39	-6.7
Crittenden County					
07N08E24CAB1	351238	901148	66.87	67.69	-0.8
08N06E33CBD1	351614	902752	52.39	54.84	-2.5
07N07E14CCC1	351318	901930	66.46	69.20	-2.7
06N09E07CAC1	350907	901042	89.08	96.27	-7.2
05N07E29ACC1	350129	902225	60.72	69.35	-8.6
04N07E36ADB1	345449	901828	58.87	67.65	-8.8
06N07E01ABB1	350520	901807	64.25	74.01	-9.8
09N08E29ADD1	352225	901516	57.89	56.61	1.3
Greene County					
17N06E31DCB1	360328	902902	104.85	105.04	-0.2
16N05E13BAB1	360123	903026	100.38	122.04	-21.7
18N06E10DCD1	361209	902520	24.63	24.41	0.2
17N04E36BCA1	360348	903658	153.38	153.39	0.0
Lee County					
03N05E01BAB1	345413	903136	49.44	55.94	-6.5
Mississippi County					
13N11E31CCCC1	354221	895807	52.17	54.38	-2.2
11N10E20ADA1	353349	900213	45.62	48.03	-2.4
10N08E17ADD1	352923	901505	51.03	53.52	-2.5
13N11E08DDA1	354528	895547	56.52	59.36	-2.8
15N12E23DBC1	355426	894701	54.23	57.21	-3.0
15N09E31ACD1	355306	900952	37.98	41.34	-3.4
14N11E20CCA1	354859	895626	35.53	39.03	-3.5
15N10E01ADC1	355712	895806	36.25	40.54	-4.3

Appendix 6. Difference in depth to water from 2003 to 2009 in the Wilcox aquifer in northeastern Arkansas.—Continued

[Horizontal datum is North American Datum of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929; positive differences in depth to water indicate a rise in water levels from 2003 to 2009 whereas negative values indicate a decline in water levels from 2003 to 2009]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2003 depth to water (feet below land-surface datum)	2009 depth to water (feet below land-surface datum)	Difference in water level from 2003-2009 (feet)
Mississippi County—Continued					
11N08E10AAC2	353538	901301	37.09	41.47	-4.4
11N09E33AAB1	353214	900739	47.98	52.98	-5.0
12N11E17CDD1	353917	895618	50.40	60.93	-10.5
Poinsett County					
12N05E13BBB1	354038	903059	45.59	47.68	-2.1
11N07E03BDD1	353629	901955	38.92	41.79	-2.9
11N05E06CCD1	353622	903618	41.50	42.88	-1.4
11N05E36AAA1	353234	903009	36.57	38.83	-2.3
11N06E35CDA3	353152	902520	29.87	30.97	-1.1
10N07E16CBB2	352925	902129	49.40	52.53	-3.1
St. Francis County					
04N06E16CCB1	345712	902830	51.86	62.65	-10.8
04N06E21BAD2	345649	902815	59.38	70.79	-11.4

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