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

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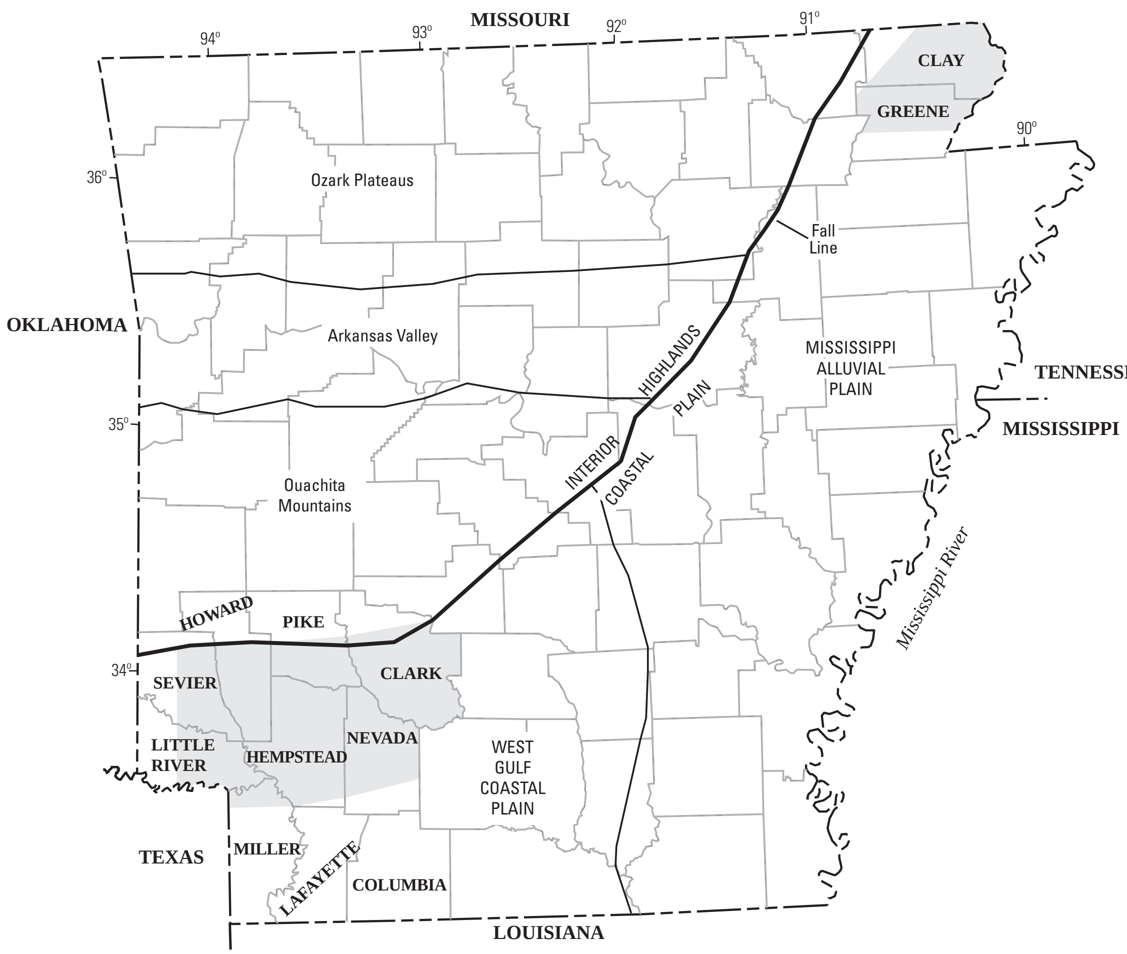

Scientific Investigations Report 2017–5090

U.S. Department of the Interior
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RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

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Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
foot per year (ft/yr)	0.3048	meter per year (m/yr)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Datum

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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

Water-Level Trends and Potentiometric Surfaces in the Nacatoch Aquifer in Northeastern and Southwestern Arkansas and in the Tokio Aquifer in Southwestern Arkansas, 2014–15

By Kirk D. Rodgers

Abstract

The Nacatoch Sand in northeastern and southwestern Arkansas and the Tokio Formation in southwestern Arkansas are sources of groundwater for agricultural, domestic, industrial, and public use. Water-level altitudes measured in 51 wells completed in the Nacatoch Sand and 42 wells completed in the Tokio Formation during 2014 and 2015 were used to create potentiometric-surface maps of the two areas. Aquifers in the Nacatoch Sand and Tokio Formation are hereafter referred to as the Nacatoch aquifer and the Tokio aquifer, respectively.

Potentiometric surfaces show that groundwater in the Nacatoch aquifer flows southeast toward the Mississippi River in northeastern Arkansas. Groundwater flow direction is towards the south and southeast in Hempstead, Little River, and Nevada Counties in southwestern Arkansas. An apparent cone of depression exists in southern Clark County and likely alters groundwater flow from a regional direction toward the depression.

In southwestern Arkansas, potentiometric surfaces indicate that groundwater flow in the Tokio aquifer is towards the city of Hope. Northwest of Hope, an apparent cone of depression exists. In southwestern Pike, northwestern Nevada, and northeastern Hempstead Counties, an area of artesian flow (water levels are at or above land surface) exists.

Water-level changes in wells were identified using two methods: (1) linear regression analysis of hydrographs from select wells with a minimum of 20 years of water-level data, and (2) a direct comparison between water-level measurements from 2008 and 2014–15 at each well. Of the six hydrographs analyzed in the Nacatoch aquifer, four indicated a decline in water levels. Compared to 2008 measurements, the largest rise in water levels was 35.14 feet (ft) in a well in Clark County, whereas the largest decline was 14.76 ft in a well in Nevada County, both located in southwestern Arkansas.

Of the four hydrographs analyzed in the Tokio aquifer, one indicated a decline in water levels, while the others remained relatively unchanged. Compared to 2008 measurements, the largest rise in water levels was 21.34 ft in Hempstead County, and the largest water-level decline was 39.37 ft in Clark County. Although changes in water levels since 2008 are spatially varied; long-term trends indicate an overall decline in water levels in both aquifers.

Introduction

As a renewable resource, groundwater is important for economic growth and quality of life. Monitoring of groundwater levels and withdrawals provides information needed to effectively plan and manage this renewable resource. Groundwater in Arkansas is used for agricultural, domestic, industrial, and public use. Groundwater resources have been subjected to increasing withdrawals for many years, raising concerns that water levels will not rebound to previous levels. The withdrawals from the Nacatoch aquifer occur in northeastern and southwestern Arkansas and from the Tokio aquifer in southwestern Arkansas.

As part of groundwater monitoring efforts, 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 measure water levels and to present the data as potentiometric-surface maps, water-level difference maps, and long-term water-level hydrographs for wells screened in the Nacatoch aquifer in northeastern and southwestern Arkansas and the Tokio aquifer in southwestern Arkansas. Potentiometric-surface maps were created from measurements made in 51 wells completed in the Nacatoch aquifer and in 42 wells completed in the Tokio aquifer during 2014 and 2015. Water-level difference maps, long-term water-level hydrographs for selected wells, and groundwater-withdrawal data from 1965 to 2010 were prepared for this report.

Study Area

The study areas of the Nacatoch and Tokio aquifers comprise parts of 10 counties in two areas of northeastern and southwestern Arkansas. The Nacatoch aquifer is divided into two study areas. The northeastern study area includes most of Clay and Greene Counties in the Mississippi Alluvial Plain physiographic section (fig. 1). This area is bounded on the north and east by the Missouri State line and on the west by the western extent of the aquifer. The southern boundary of this area is defined by the southern extent of water withdrawals from wells screened in the aquifer. The southwestern study area includes parts of eight counties (Clark, Hempstead, Howard, Little River, Miller, Nevada, Pike, and Sevier) in the West Gulf Coastal Plain physiographic region (fig. 1).

The Tokio aquifer study area covers the same counties as the southwestern Nacatoch aquifer. This area is bounded on the north by the Fall Line separating the Interior Highlands from the West Gulf Coastal Plain, on the west by the extent of use and the availability of wells, and on the east by the eastern borders of Clark and Nevada Counties. The southern boundary of the southwestern study area coincides with a freshwater-saltwater interface. To the south of this interface, the groundwater is considered saline (more than 1,000 milligrams per liter of dissolved solids) and is not suitable for most uses (Boswell and others, 1965; Petersen and others, 1985).

Methods

Water-Level Measurements

Water levels were measured by USGS personnel during 2014–15 in wells screened in the Nacatoch and Tokio aquifers. Measurements were made with electric or steel tapes graduated to hundredths of a foot. The tapes were calibrated during January 2014 and January 2015 prior to data collection. Calibration of electric and steel tapes was performed by comparing the tapes to a standardized steel tape used only for calibration (Cunningham and Schalk, 2011). All water-level data are stored in the USGS Groundwater Site Inventory (GWSI) data storage system and are publicly available from the USGS National Water Information System (NWIS) (U.S. Geological Survey, 2016).

Well locations were measured using Global Positioning System receivers to acquire the horizontal coordinate information (latitude and longitude) based upon the North American Datum of 1983 (NAD 83). Land-surface altitude, measured in feet above National Geodetic Vertical Datum of 1929 (NGVD 29), was determined for each well by superposition of the latitude and longitude of the well on a USGS topographic map and is accurate to about one-half the topographic contour interval of 5 to 10 feet (ft). Herein, all water-level and land-surface altitudes are referenced to NGVD 29. Mapped altitudes for flowing artesian wells represent the pressure head of the water within the well.

The well-numbering system used in this report is based upon the location of the wells according to the Public Land Survey System. The component parts of a well number are the township number and direction; the range number and direction; the section number; and three letters that indicate, respectively, the quarter section, quarter-quarter section, and the quarter-quarter-quarter section in which the well is located; and a sequence number of the well in the quarter-quarter-quarter section. The letters are assigned counterclockwise, beginning with “A” in the northeast quarter, quarter-quarter, or quarter-quarter-quarter section. 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 the quarter-quarter-quarter section of section 4 from which data were collected.

Linear Regression

Linear regression analysis was used to determine the annual rise or decline of water levels in selected wells using the well hydrograph. Water-level measurements made yearly during February, March, and April of the minimum 20-year period of record were used in the linear regression analysis. A 20-year minimum period of analysis reduces the effect of localized short-term pumping rates and variations in climate on water levels in a single well. The equation of the regression line or line of best fit is $Y = MX + B$. The slope, M from the equation, represents the daily rise or decline in water level; B is the water level measured in feet where the line intersects the y-axis; X is time, in years; and Y is the water level, in feet above NGVD 29. Five assumptions are associated with linear regression: (1) Y is linearly related to X, (2) data used to fit the linear regression are representative of data of interest, (3) variance of the residuals is constant and does not depend on X or on anything else, (4) the residuals are independent, and (5) the residuals are normally distributed. The assumption of a normal distribution is involved only when testing hypotheses, requiring the residuals from the regression equation to be normally distributed (Helsel and Hirsch, 2002).

Geographic Information System (GIS) Methods

Longitude and latitude of wells were obtained from NWIS and encoded using ArcGIS (Esri, 2011). The encoded data points were used to create potentiometric maps of the Nacatoch and Tokio aquifers by interpolation. This process produces a raster image that assigns a range of values to each color in the image. The image is then

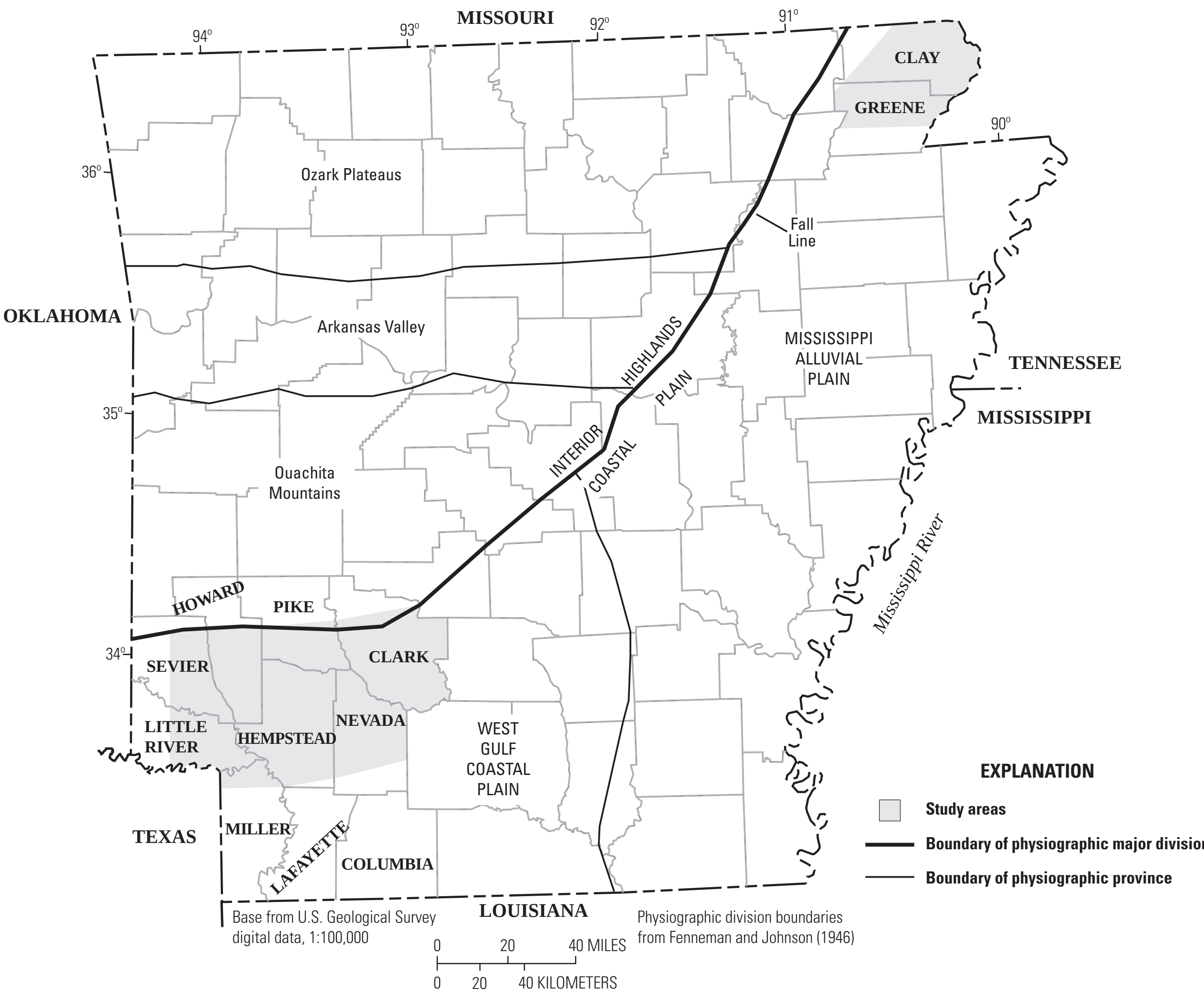


Figure 1. Location of study areas in the Nacatoch aquifer in northeastern and southwestern Arkansas and the Tokio aquifer in southwestern Arkansas.

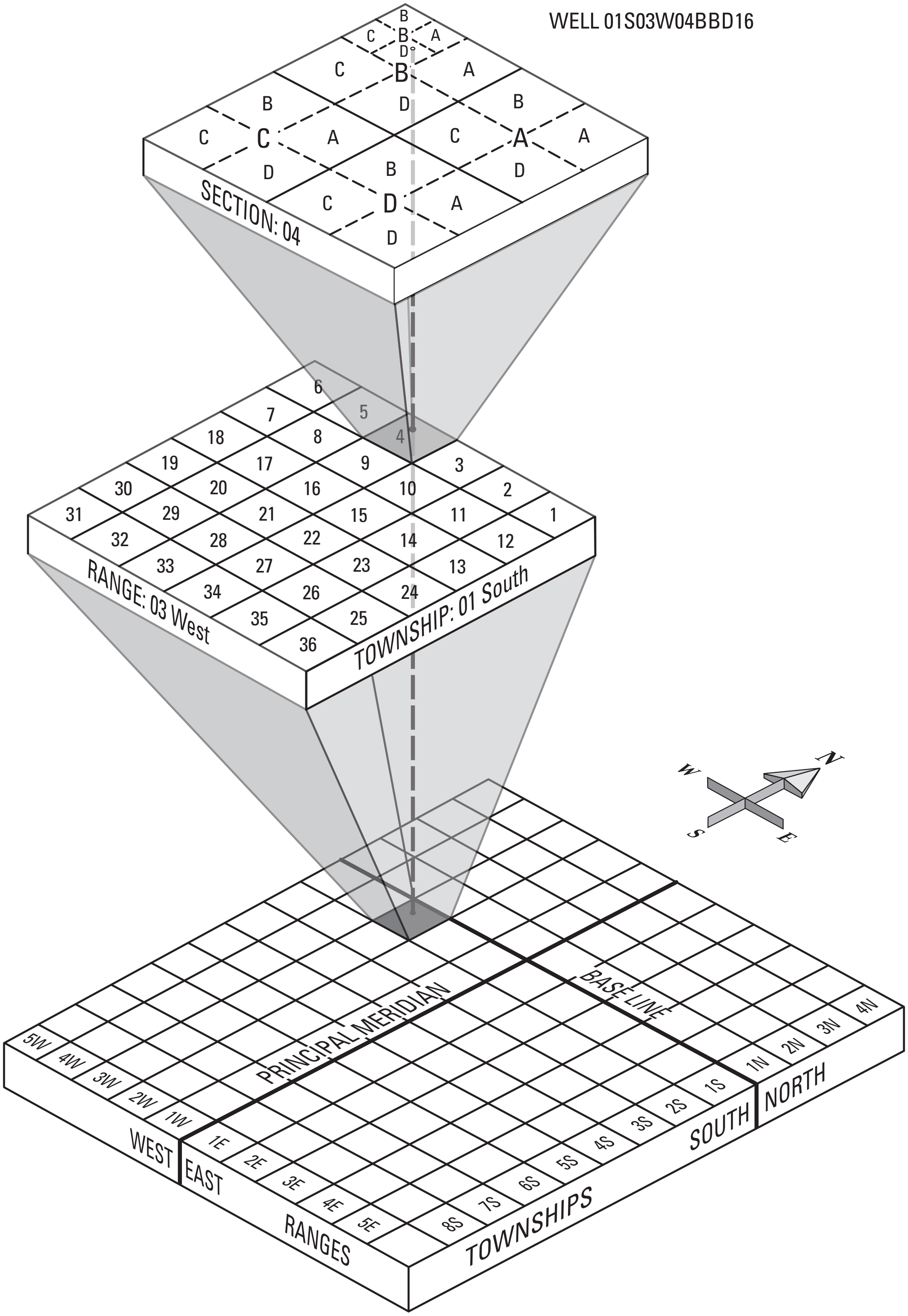


Figure 2. Well-numbering system.

converted to contour polylines using the raster-to-contour tool. Upon conversion, the contour polylines were corrected and refined using the Polynomial Approximation with Exponential Kernel (PEAK) method of smoothing, which allows for the preservation of endpoints. This algorithm uses the maximum allowable offset to smooth lines (Bodansky and others, 2002) and sets a tolerance by which lines are smoothed. A higher tolerance preserves less detail from the original interpolated contour line, and a lower tolerance preserves more detail. A 0.075-decimal degree tolerance was used to smooth the contour lines and to preserve more detail of the original potentiometric contour polylines. All GIS data used to create maps interpreted in this report can be found at Rodgers (2017).

Water-Level Differences

Water-level difference maps for wells screened in the Nacatoch aquifer in northeastern and southwestern Arkansas and the Tokio aquifer in southwestern Arkansas were created to spatially evaluate short-term (6–7 years) change in water levels. The maps were created using the difference between water-level measurements made in 2008 and 2014–15 for the Nacatoch aquifer and between 2008 and 2014 for the Tokio aquifer. Positive values indicated a rise in water levels; negative values indicated a decline in water levels.

Nacatoch Aquifer

Hydrogeologic Setting

The Nacatoch Sand of Late Cretaceous age comprises the Nacatoch aquifer and is underlain by the Saratoga Chalk and overlain by the Arkadelphia Marl (fig. 3). In the northeastern study area, the Nacatoch Sand subcrops beneath Quaternary alluvial and terrace deposits at its western extent. The altitude of the top of the Nacatoch Sand ranges from 50 to 100 ft above NGVD 29 along the western boundary and dips southeasterly to 1,200 ft below NGVD 29 at the Mississippi River. Petersen and others (1985) found this unit to be approximately 100 ft in thickness at the subcrop and increasing to near 600 ft at the downdip extent of the formation.

In the northeastern study area, the aquifer is composed of fine sand, interbedded clay and limestone in the lower part, and increases in grade to loose fine quartz sand in the upper part (Petersen and others, 1985). In western Clay and Greene Counties, the aquifer is recharged by precipitation through its outcrop and subcrop areas (Petersen and others, 1985).

In the southwestern study area, the aquifer crops out in a 3- to 8-mile (mi) wide belt from central Clark County that extends southwesterly toward western Hempstead County. In Little River County, the aquifer subcrops beneath alluvial and terrace deposits (Boswell and others, 1965). The highest altitude in the southwestern study area is approximately 300 ft above NGVD 29 in the outcrop and descends southeasterly to about 800 ft below NGVD 29 at the southern extent of the study area. At the outcrop, the Nacatoch Sand is about 100 ft thick and has a maximum thickness of 600 ft (Petersen and others, 1985).

In the southwestern study area, the Nacatoch Sand is composed of three distinct units. The lower unit contains interbedded gray clay, sandy clay and marl, dark clayey fine-grained sand, and hard irregular concretionary beds with lenses of slightly glauconitic, calcareous, fossiliferous sand (Plebuch and Hines, 1969). The middle unit is composed of dark-green sand with coarse glauconite grains. The unit is fossiliferous where it is glauconitic and contains irregular concretionary beds (Plebuch and Hines, 1969). The upper unit is the primary water-bearing unit (Counts and others, 1955; Plebuch and Hines, 1969; Ludwig, 1972; Kresse and others, 2014) and consists of gray, fine-grained, unconsolidated quartz sand that is commonly cross-bedded. The sand has a few locally hard lenses, is massive, and has beds of fossiliferous, sandy limestone.

Recharge of the Nacatoch aquifer in the southwestern study area occurs by precipitation in the outcrop in Clark, Hempstead, and Nevada Counties and through alluvium and terrace deposits in Little River County. The aquifer supplies water to northeastern Clay and Greene Counties, southern Clark County, central Hempstead County, southeastern Little River County, northern Miller County, and northwestern Nevada County.

In the valleys of Clark and Nevada Counties, artesian wells within the Nacatoch aquifer can yield from 1 to 2 gallons per minute (gal/min). Wells in Hempstead and western Nevada Counties can yield 150 to 300 gal/min (Counts and others, 1955). Groundwater flow in general is to the southeast, but an increase in clay content in the downdip direction in Lafayette, Miller, and Nevada Counties may influence flow direction. A well test in the aquifer at Hope indicated a transmissivity of 3,600 gallons per day per foot (Ludwig, 1972).

Estimated withdrawals from the Nacatoch aquifer in the northeastern study area rose 564 percent from 0.25 million gallons per day (Mgal/d) in 1965 to 1.66 Mgal/d in 2010, with a maximum usage of 2.21 Mgal/d in 1990 (fig. 4; Holland, 1993, 1999, 2004, 2007; Schrader and Rodgers, 2013; Pugh and Holland, 2015). Withdrawals from the southwestern study area reached a peak of 4.75 Mgal/d in 1980 (fig. 5) and declined by 85 percent to less than 1 Mgal/d by 2010. This decline has been attributed to public water supplies converting to surface-water sources and relying less on groundwater sources (Holland and Ludwig, 1981; Holland, 1987, 1993, 1999, 2004, 2007; Schrader and Rodgers, 2013). Withdrawal data from the aquifer were not reported for several counties and appear as 0.00 Mgal/d in the record.

Time-stratigraphic unit				Formation		Regional geohydrologic unit
Era	System	Series	Group			
Cenozoic	Quaternary	Holocene		Alluvium		Mississippi River Valley alluvial aquifer[1] Ouachita-Saline River alluvial aquifer[2] Red River alluvial aquifer[2]
		Pleistocene		Terrace deposits		
	Tertiary	Eocene	Jackson	Jackson Formation		Vicksburg-Jackson confining unit[1]
			Claiborne	Cockfield Formation		Upper Claiborne aquifer[1]
				Cook Mountain Formation		Middle Claiborne confining unit
				Sparta Sand	Memphis Sand[3]	Middle Claiborne aquifer[1]
				Cane River Formation		Lower Claiborne[1]
				Carrizo Sand		Lower Claiborne confining unit[1]
			Wilcox	Undifferentiated		Middle - Lower Wilcox aquifer[1]
		Paleocene	Midway	Porters Creek Clay Clayton Formation		Midway confining unit[1]
Mesozoic	Cretaceous	Upper Cretaceous		Arkadelphia Marl		
				Nacatoch Sand		Nacatoch aquifer[2]
				Saratoga Chalk		
				Marlbrook Marl		
				Annona Chalk		
				Ozan Formation		
				Brownstown Marl		
				Tokio Formation		Tokio aquifer[2]
				Woodbine Formation		
		Lower Cretaceous		Kiamichi Formation Goodland Limestone		
			Trinity	Paluxy Formation DeQueen Limestone Holly Creek Formation Dierks Limestone Delight Sand Pike Gravel		Trinity aquifer[2]

[1]From Hart and others, 2008.

[2]From Renken, 1998.

[3]North of 35°N latitude, the Sparta Sand, Cane River Formation, and Carrizo Sand are undifferentiated and referred to regionally as the Memphis Sand (Counts, 1957; Cushing and others, 1964; Payne, 1972; Petersen and others, 1985; Hart and others, 2008).

Figure 3. Stratigraphic column and correlated hydrogeologic units of the Mississippi Embayment and West Gulf Coastal Plain physiographic region, Arkansas.

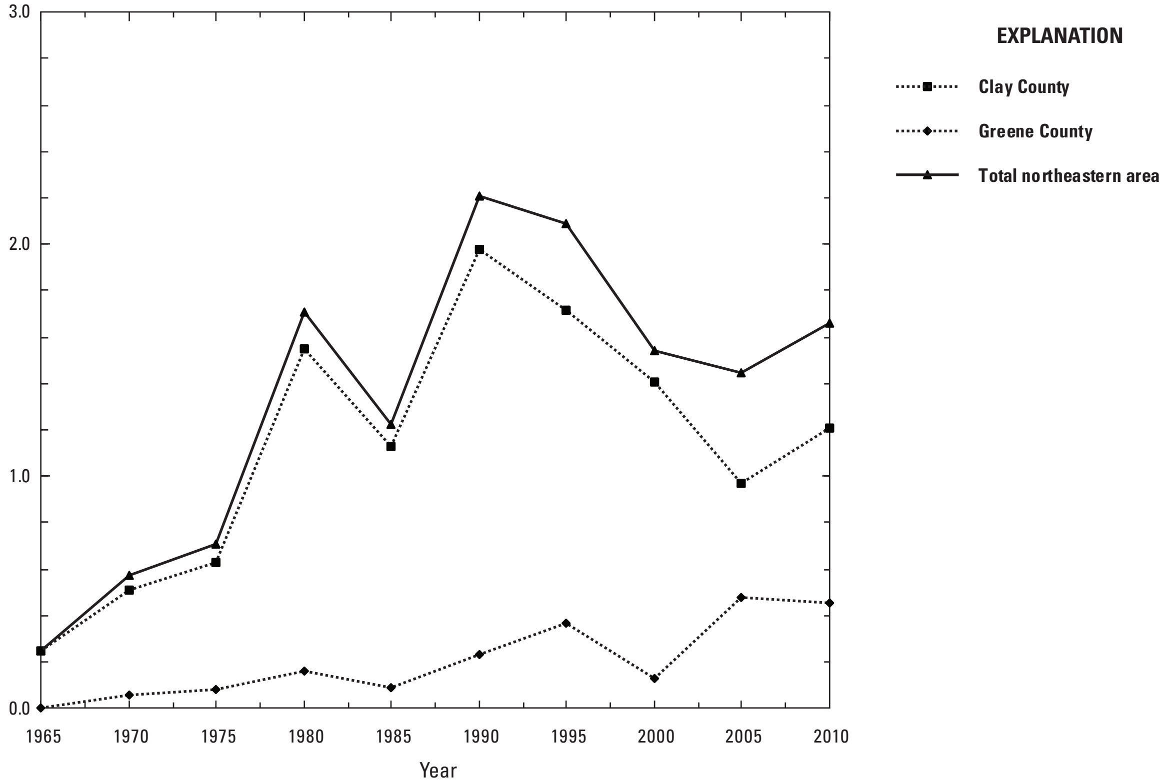


Figure 4. Estimated withdrawals by county from the Nacatoch aquifer for the northeastern study area.

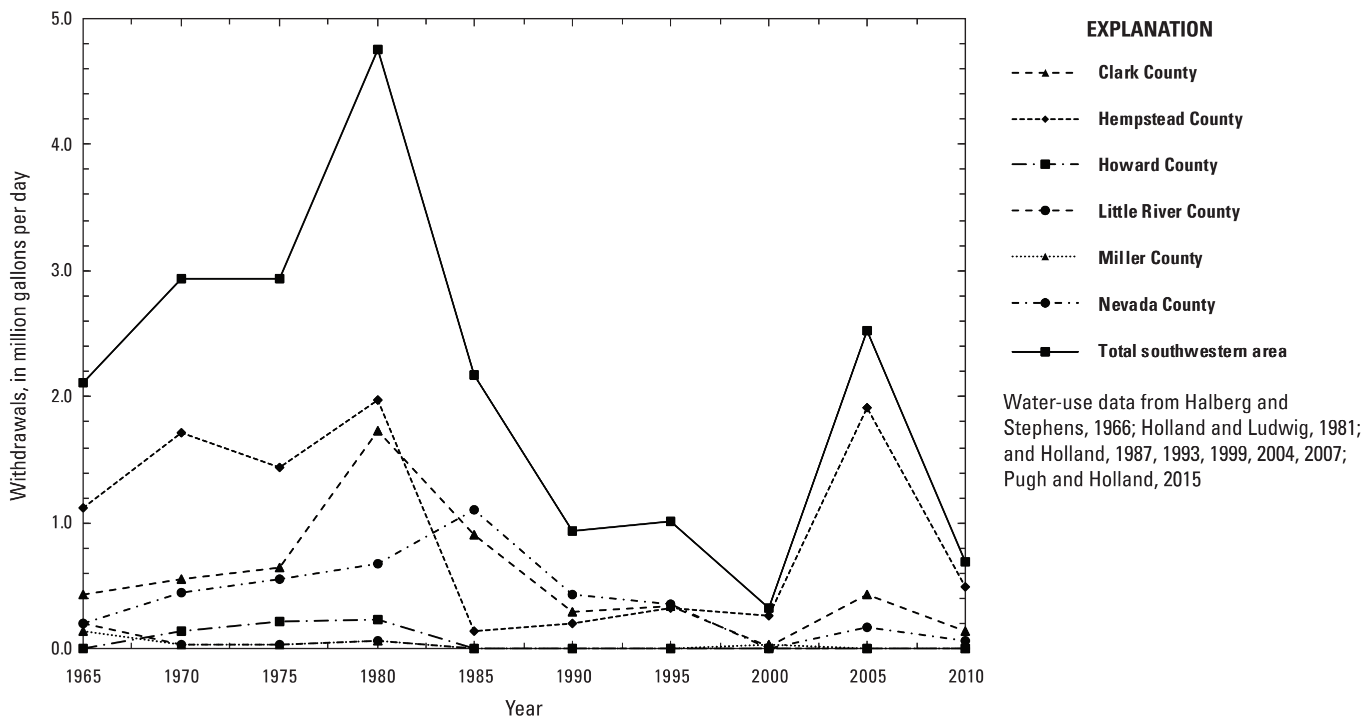


Figure 5. Estimated withdrawals by county from the Nacatoch aquifer for the southwestern study area.

Potentiometric Surface

In the northeastern study area (fig. 6), groundwater flows southeasterly toward the Mississippi River from a potentiometric high of 275 ft above NGVD 29 in north-central Clay County to a potentiometric low of 230 ft above NGVD 29 in northeastern Greene County (table 1). The direction of groundwater flow has not changed since the 2013 potentiometric mapping of the northeastern Nacatoch aquifer (Schrader and Rodgers, 2013).

The direction of groundwater flow varies in the southwestern study area. In Hempstead, Little River, and Nevada Counties, groundwater flow is towards the south and southeast (fig. 7). In Clark County, groundwater flow is towards the east and southeast. In western Miller County, groundwater flows north toward the Red River from a water-level altitude of 293 ft above NGVD 29. The highest water-level altitude measured was 423 ft above NGVD 29 in the outcrop area of the Nacatoch aquifer in western Hempstead County. A water-level altitude of 160 ft was measured near Hope in southern Hempstead County, indicating a cone of depression may exist (fig. 7). Water levels in wells near the Hope area have been less than 185 ft above NGVD 29 since at least 1942 (Ludwig, 1972; Schrader and Scheiderer, 2004). The apparent cone of depression alters groundwater flow from the regional direction with groundwater flowing from the north, northeast, and west toward Hope. Another cone of depression exists in southern Clark County and is probably drawdown related to public supply use in the area. All data in support of this report can be accessed from the USGS NWIS (U.S. Geological Survey, 2016).

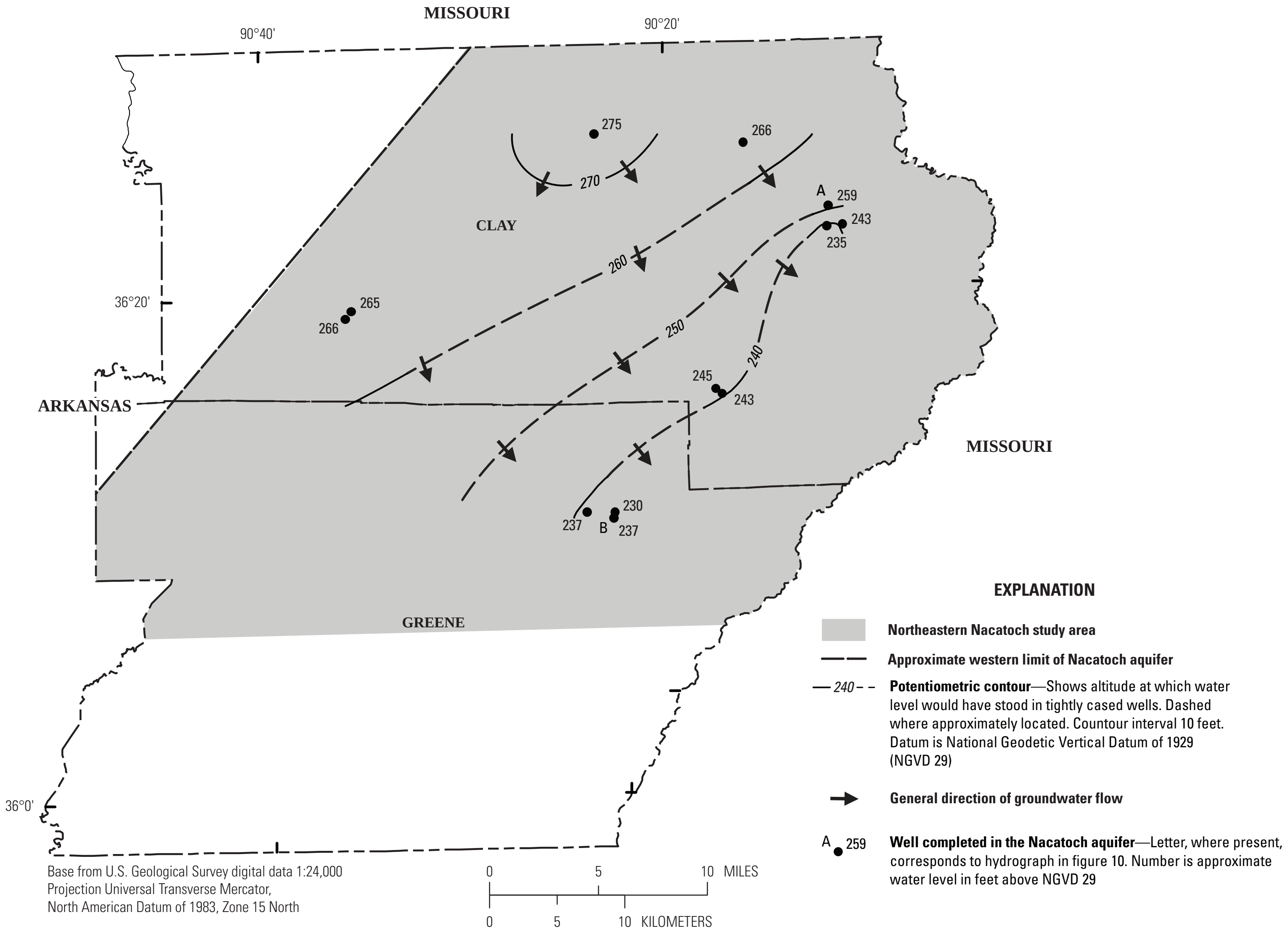


Figure 6. Potentiometric surface of the Nacatoch aquifer, northeastern Arkansas, 2015.

Table 1. Water-level data collected during 2014–15 from wells completed in the Nacatoch aquifer in northeastern and southwestern Arkansas.

[Horizontal datum is North America Datum of 1983; Vertical datum is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); letters in parentheses correspond to well locations in figures 6 and 7 and well hydrographs in figures 10 and 11; values rounded to the nearest whole number]

Site number	Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
Northeastern Arkansas							
Clay County							
361909090355902	19N04E01BDB1	361910	903560	266	14	280	6/8/2015
361601090175101	19N07E23BAC1	361602	901748	245	77	322	6/9/2015
361552090172801	19N07E23DBC1	361549	901730	243	40	283	6/9/2015
361927090354201	20N04E36DCC1	361929	903542	265	14	279	6/8/2015
362312090120201	20N08E10ABC1 (A)	362313	901202	259	81	340	6/9/2015
362227090112001	20N08E14BAB2	362227	901120	243	43	286	6/8/2015
362225090120801	20N08E15BAA1	362224	901208	235	146	381	6/8/2015
362617090232801	21N06E23DAC1	362619	902329	275	25	300	6/8/2015
362549090160601	21N07E25AAC1	362550	901607	266	76	342	6/8/2015
Greene County							
361118090242201	18N06E14CCD1 (B)	361115	902420	237	47	284	6/9/2015
361112090225601	18N06E24ABB2	361112	902256	237	31	268	6/9/2015
361058090230301	18N06E24BDA1	361058	902300	230	40	270	6/9/2015
Southwestern Arkansas							
Clark County							
340359093043301	08S19W06DCB1	340359	930433	192	78	270	3/26/2014
340322093023001	08S19W09ACC1 (A)	340323	930228	178	-1	177	2/19/2014
335950093073601	08S20W34DAB1	335954	930744	183	17	200	2/19/2014
335707093084201	09S20W16DBD1	335708	930847	170	71	241	3/26/2014
335656093084001	09S20W16DDC1 (B)	335657	930845	167	66	233	3/26/2014
335435093111101	09S20W31CAD1	335435	931111	180	79	259	3/21/2014
335447093085201	09S20W33ABD1	335447	930852	172	37	209	3/21/2014
335455093093202	09S20W33BCD2	335446	930926	176	31	207	3/21/2014
335638093143501	09S21W21DAD1	335625	931453	242	103	345	3/10/2014
335052093081401	10S20W22DCB1	335054	930757	178	82	260	2/19/2014
335327093123601	10S21W12BAB1	335321	931225	156	65	221	2/20/2014
Hempstead County							
334618093344601	11S24W21DDD1	334621	933447	332	39	371	3/10/2014
334643093334301	11S24W22ADD1	334647	933343	330	35	365	3/10/2014
334441093343801	11S24W34CBC1	334444	933438	295	25	320	3/11/2014
334605093464501	11S26W27BDD1	334611	934645	423	8	430	3/13/2014
334009093353901	12S24W28CDC1	334012	933536	160	193	353	3/20/2014
334346093433001	12S25W07ABB1	334346	934340	386	49	435	3/12/2014
334212093403101	12S25W15DBC1	334214	934036	272	39	311	3/11/2014
334002093405101	12S25W34BAC1	334002	934055	244	76	320	3/11/2014
333913093423101	13S25W05ABD1	333915	934232	242	40	282	3/12/2014
333737093433101	13S25W18AAB1	333740	934332	213	70	283	3/12/2014
333705093484501	13S26W17DDB1	333705	934845	236	55	291	3/12/2014
333318093412701	14S25W04DDD1	333317	934132	183	78	260	3/19/2014

Table 1. Water-level data collected during 2014–15 from wells completed in the Nacatoch aquifer in northeastern and southwestern Arkansas.—Continued

[Horizontal datum is North America Datum of 1983; Vertical datum is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); letters in parentheses correspond to well locations in figures 6 and 7 and well hydrographs in figures 10 and 11; values rounded to the nearest whole number]

Site number	Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
			Little River County				
333509094025101	13S28W31BCC1	333509	940251	257	54	311	3/19/2014
333423094091001	14S30W01DAA1	333426	940904	239	43	282	3/19/2014
			Miller County				
333419093512901	14S27W02AAB1	333419	935121	224	31	255	3/19/2014
333200093572501	14S28W13CCB1 (D)	333158	935727	236	30	266	3/19/2014
333234094013301	14S28W17BBC1	333240	940134	244	26	270	3/19/2014
332920093591901	14S28W34CDC1	332919	935920	293	12	305	3/19/2014
			Nevada County				
334622093090401	11S20W15CDC1	334622	930905	167	8	175	3/21/2014
334626093093001	11S20W22AAA1	334624	930926	177	-2	175	3/21/2014
334646093141101	11S21W14CAB1	334652	931434	197	-1	196	3/26/2014
334759093231302	11S22W08DAC2 (C)	334760	932314	268	38	306	3/20/2014
334756093231804	11S22W08DDB4	334757	932314	268	38	306	3/20/2014
334832093254001	11S23W12ABB1	334837	932541	312	69	381	3/10/2014
334230093224901	12S22W09CDD1	334230	932250	225	4	229	3/20/2014
334107093213201	12S22W22ACD1	334108	932135	215	127	342	3/20/2014
334103093210501	12S22W23CBA1	334102	932057	216	113	329	3/20/2014
333742093251201	13S22W07BDC1	333744	932514	215	128	343	3/20/2014

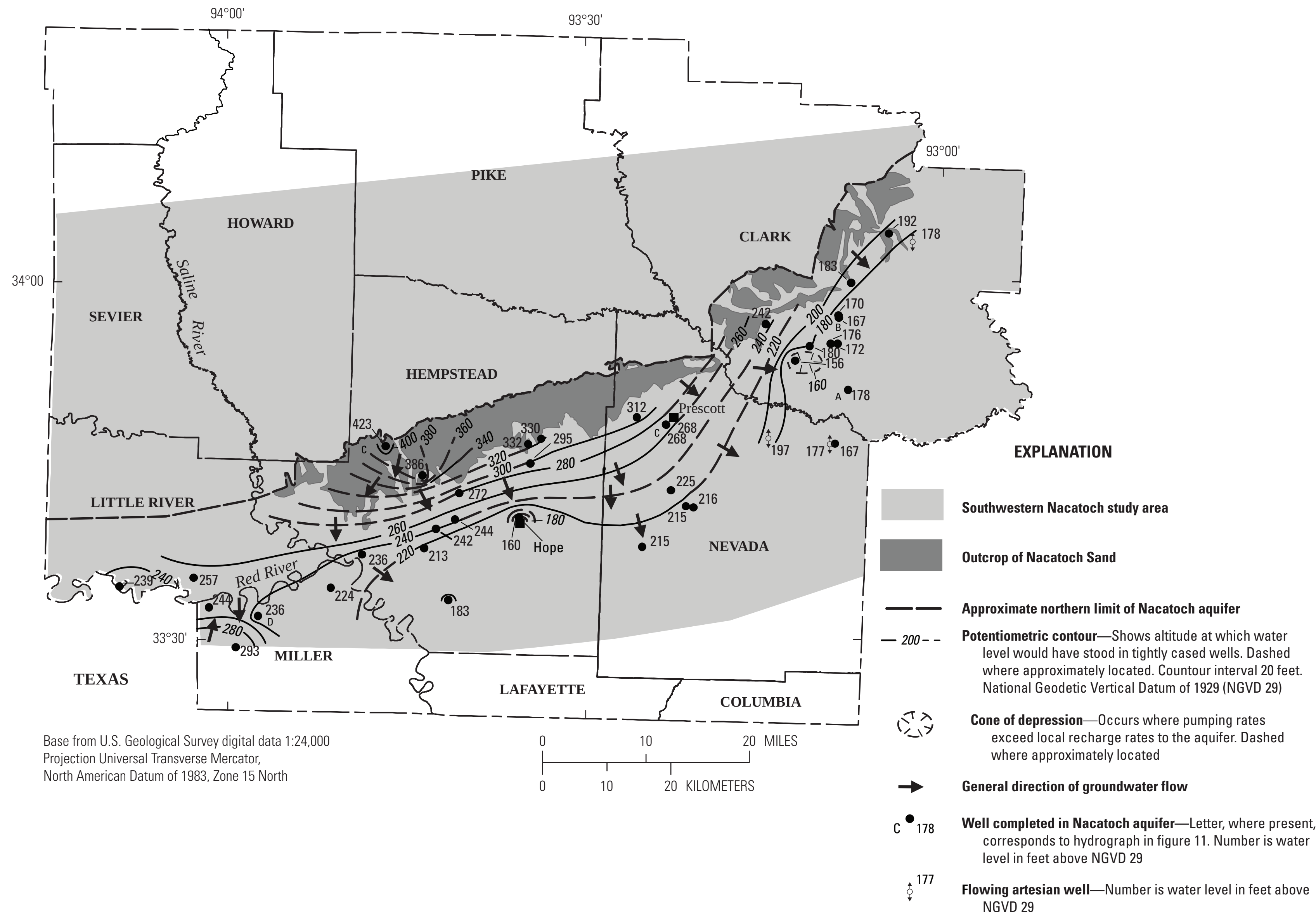


Figure 7. Potentiometric surface of the Nacatoch aquifer, southwestern Arkansas, 2014.

Water-Level Trends

Water-Level Differences from 2008 to 2014–15

Water levels rose in 29 of the 51 measured wells in the Nacatoch aquifer (table 2). Differences in water levels in the two study areas ranged from a rise of 35.14 ft in Clark County to a decline of 14.76 ft in Nevada County, both located in southwestern Arkansas. In the northeastern study area, water levels generally have risen since 2008 (fig. 8). In Clay County, water-level changes ranged between a decline of 3.27 ft in well 21N07E25AAC1 and a rise of 7.62 ft in well 20N08E10ABC1 (table 2). In Greene County, water-level changes ranged from a decline of 0.19 ft to a rise of 3.87 ft.

In the southwestern study area, water levels rose in 21 of the 39 wells measured (fig. 9). However, water-level changes varied by county. For example, water levels generally rose in Clark and Nevada Counties, and there was a general decline in Hempstead and Miller Counties. Although an apparent cone of depression exists in southern Clark County, water levels have been on the rise since 2002 (146 ft above NGVD 29 in 2002 [Schrader and Scheiderer, 2004]; 152 ft above NGVD 29 in 2011 [Schrader and Rodgers, 2013]; and 156 ft above NGVD 29 in 2014). Water-level changes in other wells screened in the aquifer are minor in comparison to those published in previous studies. The largest rise in water levels (35.14 ft) was in Clark County well 09S20W31CAD1, whereas the largest decline in water levels (14.76 ft) was in Nevada County well 11S22W08DDB4.

In Hempstead County, the highest rise (28.44 ft) was found in the southern part of the county (well 14S25W04DDD1), and the largest decline (14.09 ft) was found in the south-central part of the county (well 13S25W05ABD1). Of the four wells measured in Miller County, water levels declined in three wells. The largest decline (9.52 ft) was found in northeastern Miller County well 14S28W34CDC1. Of the wells measured in the southwestern study area, three were artesian wells.

Table 2. Difference in depth to water from 2008 to 2014–15 in the Nacatoch aquifer in northeastern and southwestern Arkansas.

[Horizontal datum is North American Datum of 1983; Vertical datum is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); positive values for water-level difference indicate a rise in water levels from 2008 to 2014–15 whereas negative values for water-level difference indicate a decline in water levels from 2008 to 2014–15; --, no data available]

Site number	Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Land-surface datum (feet above NGVD 29)	Depth of well (feet below land surface)	2014–15 Nacatoch water-level altitude (feet above NGVD 29)	2008 Nacatoch water-level altitude (feet above NGVD 29)	Water-level difference (2008 to 2014–15)
Northeastern Arkansas								
Clay County								
361909090355902	19N04E01BDB1	361910	903560	280	--	265.87	268.67	-2.80
361601090175101	19N07E23BAC1	361602	901748	322	1,100	244.81	239.36	5.45
361552090172801	19N07E23DBC1	361549	901730	283	1,114	242.86	245.32	-2.46
361927090354201	20N04E36DCC1	361929	903542	279	348	264.81	263.76	1.05
362312090120201	20N08E10ABC1	362313	901202	340	989	258.65	251.03	7.62
362227090112001	20N08E14BAB2	362227	901120	286	1,000	242.66	241.37	1.29
362225090120801	20N08E15BAA1	362224	901208	381	1,062	234.63	232.14	2.49
362617090232801	21N06E23DAC1	362619	902329	300	462	275.20	271.98	3.22
362549090160601	21N07E25AAC1	362550	901607	342	732	265.96	269.23	-3.27
Greene County								
361118090242201	18N06E14CCD1	361115	902420	287	1,153	239.79	238.88	0.91
361112090225601	18N06E24ABB2	361112	902256	270	1,081	239.18	235.31	3.87
361058090230301	18N06E24BDA1	361058	902300	276	1,105	235.97	236.16	-0.19
Southwestern Arkansas								
Clark County								
340359093043301	08S19W06DCB1	340359	930433	270	112	192.12	191.02	1.10
340322093023001	08S19W09ACC1	340323	930228	177	195	177.53	177.85	-0.32
335950093073601	08S20W34DAB1	335954	930744	200	100	182.77	181.53	1.24
335707093084201	09S20W16DBD1	335708	930847	241	228	169.69	163.17	6.52

Table 2. Difference in depth to water from 2008 to 2014–15 in the Nacatoch aquifer in northeastern and southwestern Arkansas.—Continued

[Horizontal datum is North American Datum of 1983; Vertical datum is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); positive values for water-level difference indicate a rise in water levels from 2008 to 2014–15 whereas negative values for water-level difference indicate a decline in water levels from 2008 to 2014–15; --, no data available]

Site number	Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Land-surface datum (feet above NGVD 29)	Depth of well (feet below land surface)	2014–15 Nacatoch water-level altitude (feet above NGVD 29)	2008 Nacatoch water-level altitude (feet above NGVD 29)	Water-level difference (2008 to 2014–15)
Southwestern Arkansas—Continued								
Clark County—Continued								
335656093084001	09S20W16DDC1	335657	930845	233	241	166.67	157.07	9.60
335435093111101	09S20W31CAD1	335435	931111	259	276	179.75	144.61	35.14
335447093085201	09S20W33ABD1	335447	930852	209	245	172.08	175.67	-3.59
335455093093202	09S20W33BCD2	335446	930926	207	236	176.42	180.78	-4.36
335638093143501	09S21W21DAD1	335625	931453	345	110	241.91	244.24	-2.33
335052093081401	10S20W22DCB1	335054	930757	260	500	178.33	176.82	1.51
335327093123601	10S21W12BAB1	335321	931225	221	200	155.82	151.74	4.08
Hempstead County								
334618093344601	11S24W21DDD1	334621	933447	371	90	331.96	335.03	-3.07
334643093334301	11S24W22ADD1	334647	933343	365	100	329.98	330.87	-0.89
334441093343801	11S24W34CBC1	334444	933438	320	50	294.92	293.72	1.20
334605093464501	11S26W27BDD1	334611	934645	430	32	422.50	420.84	1.66
334009093353901	12S24W28CDC1	334012	933536	353	620	160.02	152.82	7.20
334346093433001	12S25W07ABB1	334346	934340	435	100	386.27	392.86	-6.59
334212093403101	12S25W15DBC1	334214	934036	311	202	272.08	282.83	-10.75
334002093405101	12S25W34BAC1	334002	934055	320	300	244.31	245.20	-0.89
333913093423101	13S25W05ABD1	333915	934232	282	300	241.68	255.77	-14.09
333737093433101	13S25W18AAB1	333740	934332	283	335	213.33	220.01	-6.68
333705093484501	13S26W17DDB1	333705	934845	291	210	235.66	232.43	3.23
333318093412701	14S25W04DDD1	333317	934132	260	850	182.50	154.06	28.44
Little River County								
333509094025101	13S28W31BCC1	333509	940251	311	260	256.98	259.19	-2.21
333423094091001	14S30W01DAA1	333426	940904	282	375	239.26	238.68	0.58
Miller County								
333419093512901	14S27W02AAB1	333419	935121	255	390	223.88	225.77	-1.89
333200093572501	14S28W13CCB1	333158	935727	266	416	235.93	236.47	-0.54
333234094013301	14S28W17BBC1	333240	940134	270	360	243.88	241.58	2.30
332920093591901	14S28W34CDC1	332919	935920	305	500	293.39	302.91	-9.52
Nevada County								
334622093090401	11S20W15CDC1	334622	930905	175	565	167.32	166.88	0.44
334626093093001	11S20W22AAA1	334624	930926	175	550	177.05	176.76	0.29
334646093141101	11S21W14CAB1	334652	931434	196	550	197.10	197.20	-0.10
334759093231302	11S22W08DAC2	334760	932314	306	232	268.40	264.30	4.10
334756093231804	11S22W08DDB4	334757	932314	306	209	268.32	283.08	-14.76
334832093254001	11S23W12ABB1	334837	932541	381	300	312.37	308.60	3.77
334230093224901	12S22W09CDD1	334230	932250	229	442	225.01	222.63	2.38
334107093213201	12S22W22ACD1	334108	932135	342	600	214.76	215.07	-0.31
334103093210501	12S22W23CBA1	334102	932057	329	630	215.75	215.00	0.75
333742093251201	13S22W07BDC1	333744	932514	343	671	215.16	207.52	7.64

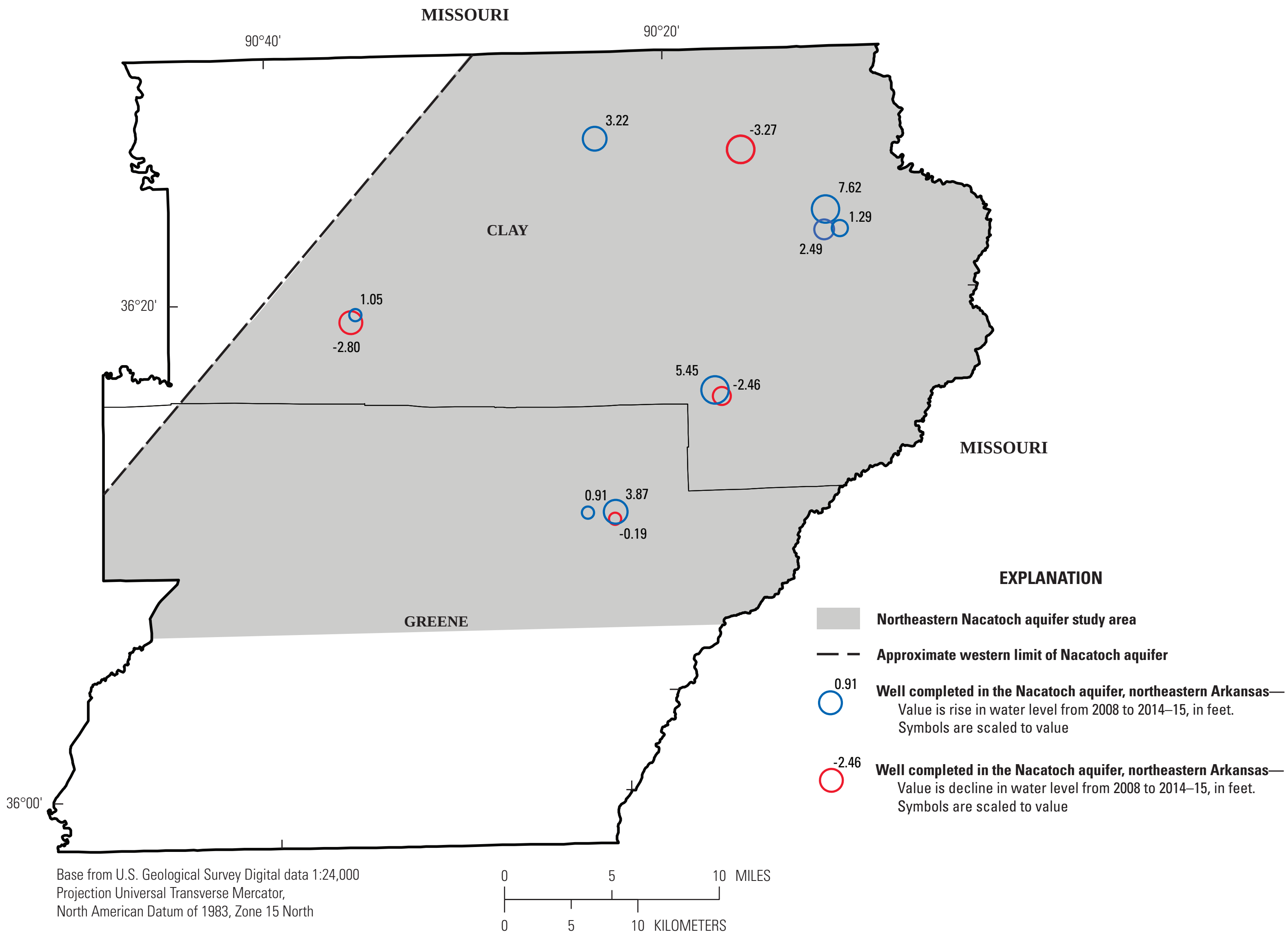


Figure 8. Water-level differences for the Nacatoch aquifer in northeastern Arkansas, 2008 to 2014–15. The circles are scaled in size to represent the relative value of rise or decline.

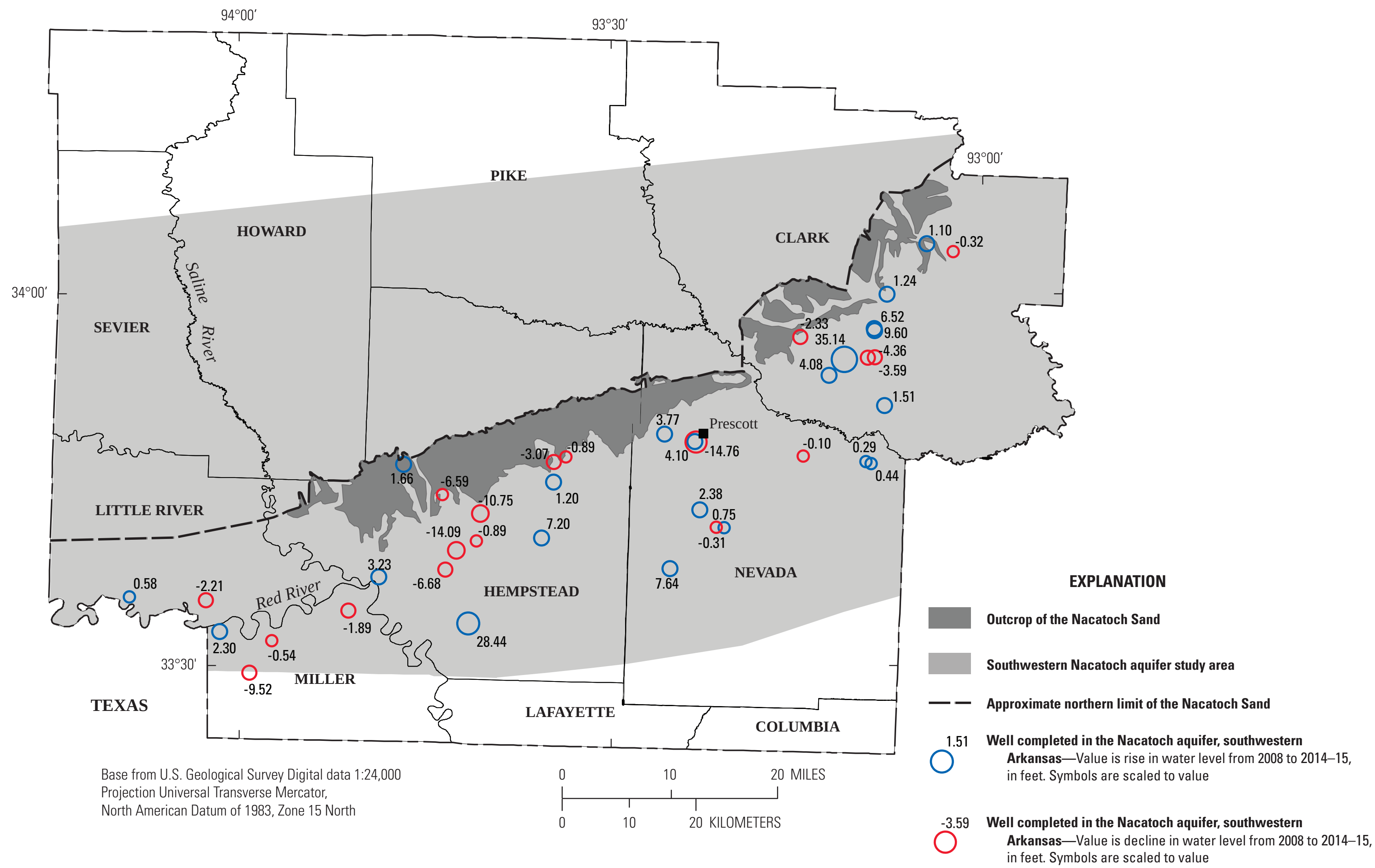


Figure 9. Water-level differences for the Nacatoch aquifer in southwestern Arkansas, 2008 to 2014–15. The circles are scaled in size to represent the relative value of rise or decline.

Long-Term Water-Level Changes

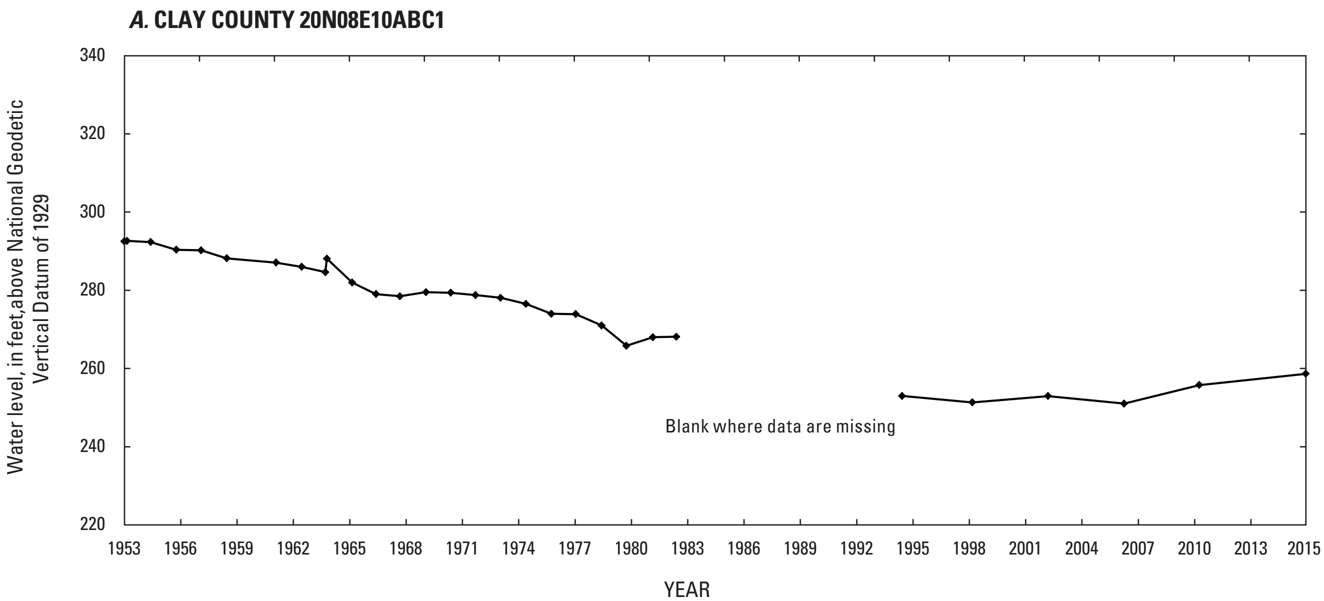
Evaluation of long-term data indicates declining water levels in wells screened in the Nacatoch aquifer in both northeastern and southwestern Arkansas. Water-level trends for Clay County well 20N08E10ABC1 (fig. 10*A*,) indicate a decline of 0.66 foot per year (ft/yr). From 1967 to 2015, water levels declined 33.85 ft likely because water use in Clay County rose by an average of 0.15 million gallons per day per year from 1965 to 2010 (fig. 4) (Halberg and Stephens, 1966; Holland and Ludwig, 1981; Holland, 1987, 1993, 1999, 2004, 2007; Pugh and Holland, 2015). Water-level trends for Greene County well 18N06E14CCD1 (fig. 10*B*) indicate an annual decline of 0.51 ft/yr since 1986. From 1978 to 2015, water levels declined 31.23 ft. Water use in Greene County in 1965 was unreported; however, in 2010, water use for the county was 0.45 Mgal/d (fig. 4) (Halberg and Stephens, 1966; Holland and Ludwig, 1981; Holland, 1987, 1993, 1999, 2004, 2007; Pugh and Holland, 2015).

The water-level hydrograph for Clark County well 08S19W09ACC1 (fig. 11*A*) indicates an annual decline of 0.18 ft/yr since 1986. Between 1963 and 2014, water levels declined 8.25 ft from 185.91 ft to 177.30 ft. Withdrawal rates declined from 0.43 Mgal/d in 2005 to 0.14 Mgal/d in 2010 (fig. 5) (Halberg and Stephens, 1966; Holland and Ludwig, 1981; Holland, 1987, 1993, 1999, 2004, 2007; Pugh and Holland, 2015).

The water-level hydrograph for Clark County well 09S20W16DDC1 (fig. 11*B*) indicates an overall annual decline of 0.33 ft/yr. However, since 1986, water levels have risen approximately 0.44 ft/yr. In 2011, water-level values returned to the 1970 water level when the well was initially measured, which indicates a decline in water use at this well.

The water-level hydrograph for Nevada County well 11S22W08DAC2 (fig. 11*C*) indicates an annual rise of 2.74 ft/yr. Between 1985 and 1990, water use declined from 1.11 Mgal/d to 0.44 Mgal/d (Holland, 1987, 1993, 1999, 2004, 2007; Pugh and Holland, 2015) (fig. 5), which coincided with a rise in water levels. Since 1986, water levels in the well have risen 0.33 ft/yr.

The water-level hydrograph for Miller County well 14S28W13CCB1 (fig. 11*D*) indicates an annual decline of 0.18 ft/yr since 1986. Withdrawals in Miller County have remained relatively stable since 2005 (Holland, 2007; Schrader and Rodgers, 2013).



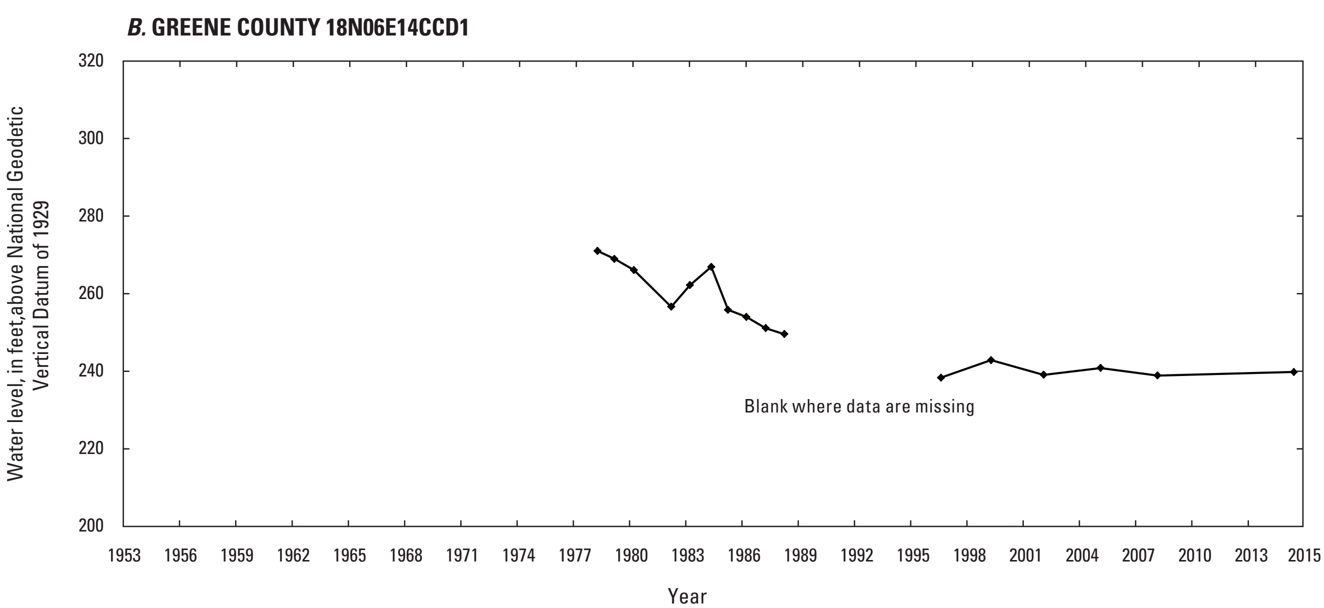


Figure 10. Water-level hydrographs for selected wells completed in the Nacatoch aquifer in northeastern Arkansas.

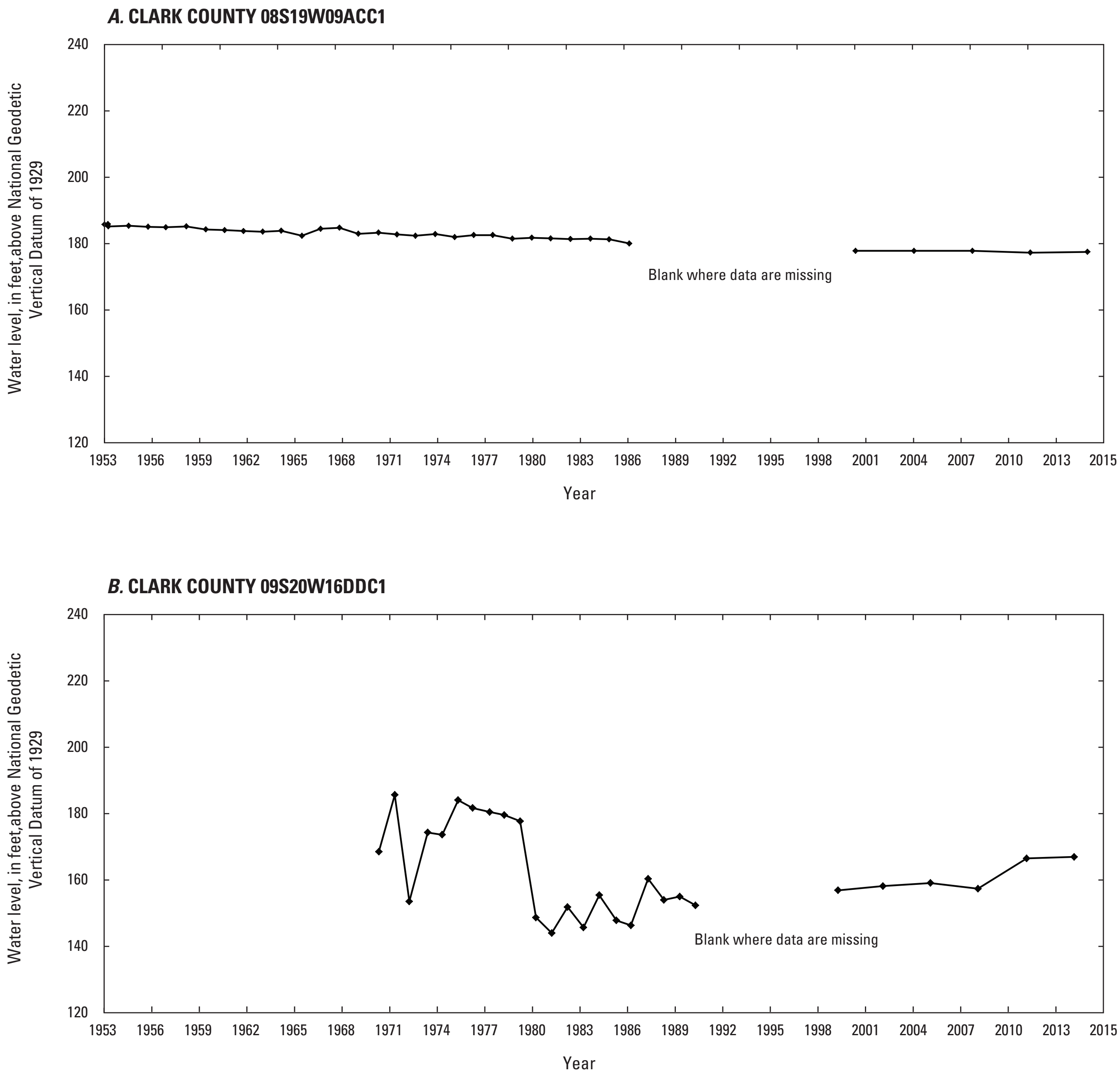
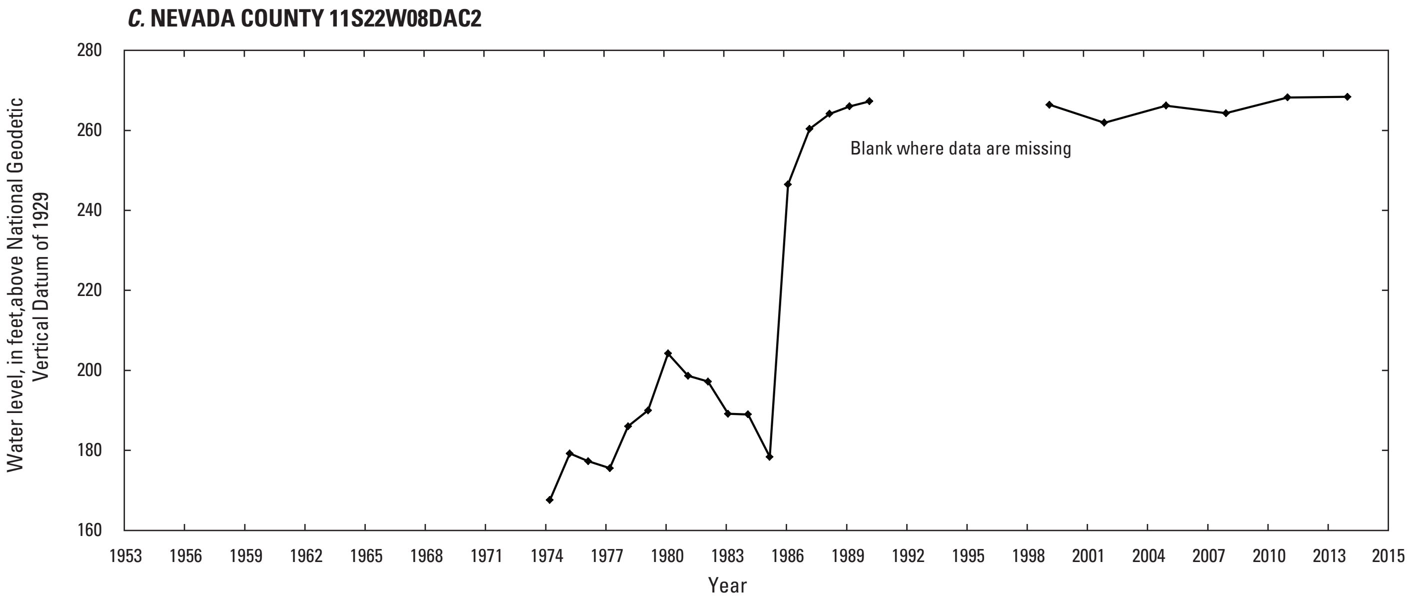


Figure 11. Water-level hydrographs for selected wells completed in the Nacatoch aquifer in southwestern Arkansas.



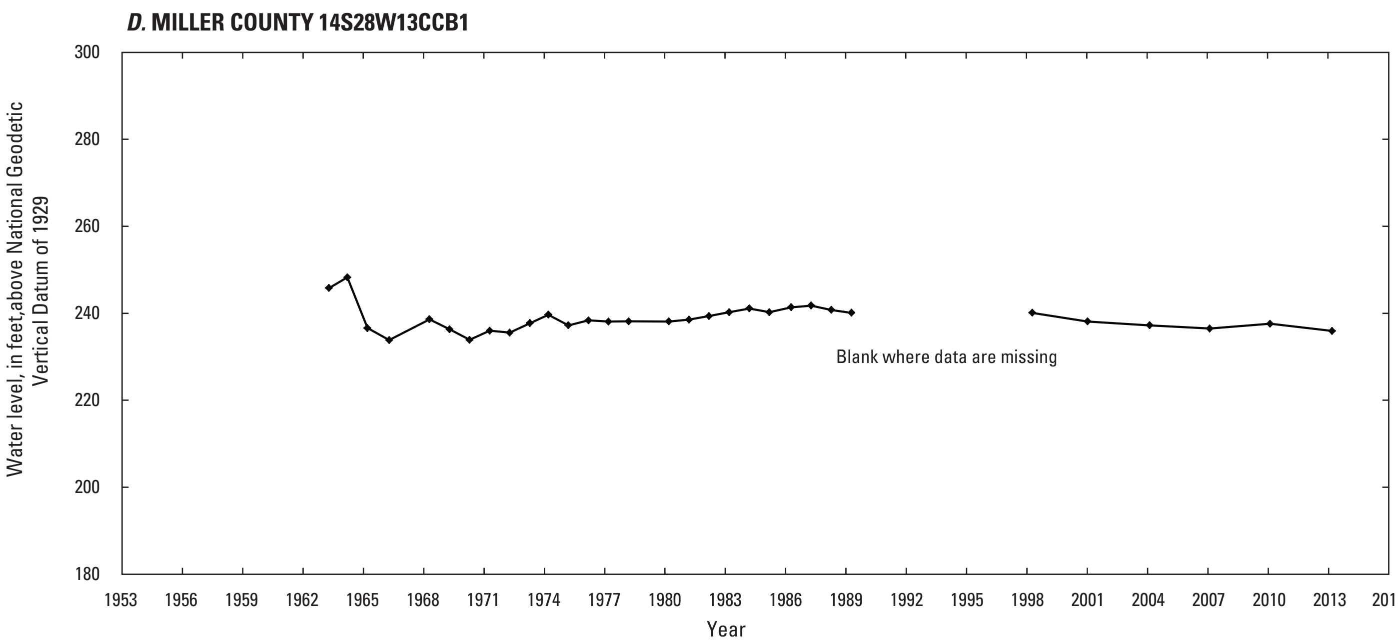


Figure 11. Water-level hydrographs for selected wells completed in the Nacatoch aquifer in southwestern Arkansas.—Continued

Tokio Aquifer

Hydrogeologic Setting

The Tokio aquifer is stratigraphically below the Nacatoch aquifer and is separated by five stratigraphic units, listed here in descending order: Saratoga Chalk, Marlbrook Marl, Annona Chalk, Ozan Formation, and Brownstown Marl (fig. 2). These five units can reach a thickness of as much as 900 ft and are rarely used as water sources (Cushing and others, 1964). The Tokio aquifer is formed by the Tokio Formation in Clark, Pike, Hempstead, Howard, Sevier, and Little River Counties (Miser and Perdue, 1918) and by the Woodbine Formation in Little River, Sevier, Howard, and northwestern Hempstead Counties (Boswell and others, 1965) that are all of Cretaceous age (fig. 3). Rocks forming the Tokio aquifer unconformably overlie consolidated rocks of Mississippian and Pennsylvanian age in Clark and northeastern Nevada Counties (Plebuch and Hines, 1969) and the Trinity Group of Early Cretaceous age in Pike, Nevada, Miller, and most of Hempstead Counties (Petersen and others, 1985). The aquifer is not present in the northeastern part of Arkansas (Kresse and others, 2015) and crops out in a southwest-to-northeast trending band from eastern Sevier County to west-central Clark County. The outcrop attains a maximum width of about 10 mi in Howard County and extends approximately 8 mi to the southwest into Sevier County. In this area, the aquifer is overlain in several places by terrace deposits of Quaternary alluvium. The unit ranges in thickness from about 50 ft to more than 300 ft, dips toward the southeast, and is composed of discontinuous, interbedded gray clay and poorly sorted, cross-bedded quartz sands, lignite, and basal gravel (Counts and others, 1955; Boswell and others, 1965; Plebuch and Hines, 1969; Petersen and others, 1985).

The Tokio aquifer yields potable water to wells in eastern Little River County, southeastern Sevier County, southern Howard and Pike Counties, western Clark County, northern and central Hempstead County, and northwestern Nevada County. Wells penetrating the aquifer range in depth from a few feet in the outcrop area to about 1,200 ft at Hope and Prescott (Ludwig, 1972). Wells in central Hempstead County yield as much as 300 gal/min. Artesian wells, which produce as much as 90 gal/min, are in the bottom-land areas adjacent to streams (Counts and others, 1955). Historical records indicate that water levels in wells screened in the aquifer did not decline appreciably from 1959 to 1968, and that water levels were not greatly affected by withdrawal of water at Hope and Prescott during this period (Ludwig, 1972).

Estimates of water withdrawn from the Tokio aquifer rose by 201 percent from 2.00 Mgal/d in 1965 to 6.02 Mgal/d in 1980 (fig. 12) but had declined to 1.8 Mgal/d in 2000. In 2005, water withdrawn from the aquifer was estimated to be 4.4 Mgal/d, an increase of 144 percent from 2000. Water withdrawn from the aquifer was estimated to be 3.13 Mgal/d in 2010, a decline of 29 percent from 2005 (Halberg and Stephens, 1966; Holland and Ludwig, 1981; Holland, 1999, 2004, 2007; Pugh and Holland, 2015). Between 1985 and 2000, water use in Clark County increased from 0.04 Mgal/d to 0.7 Mgal/day. From 1985 to 1995, water use decreased

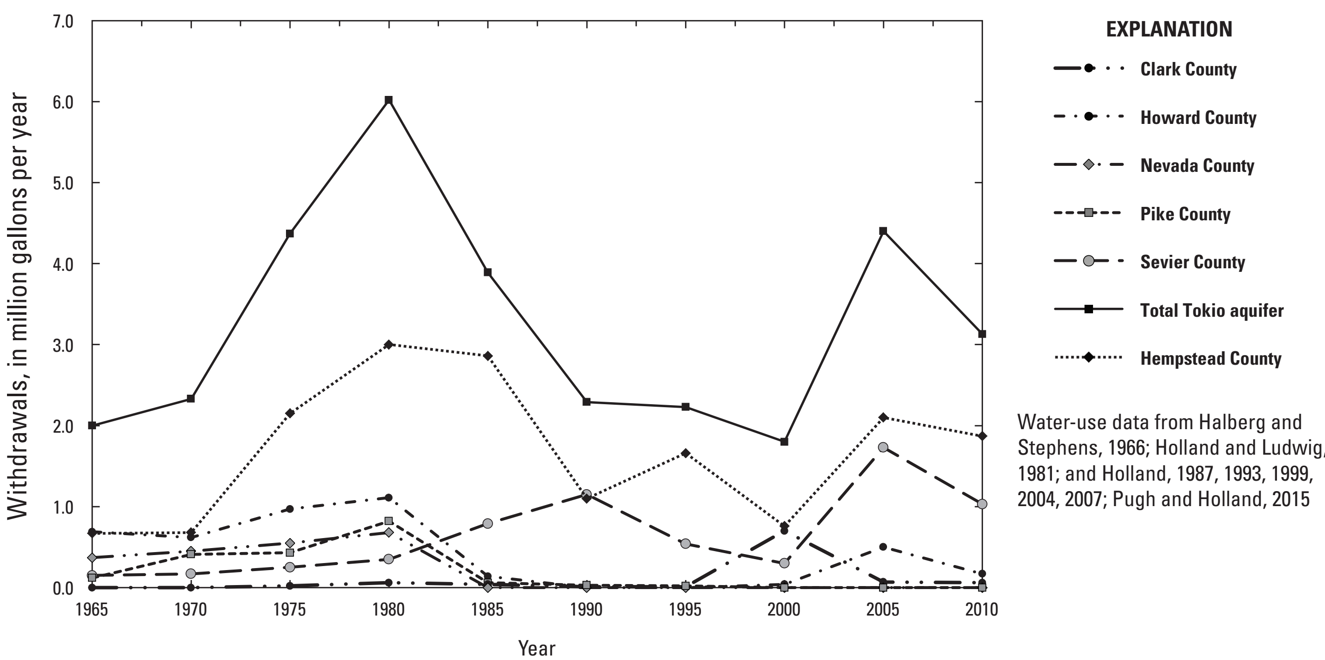


Figure 12. Estimated withdrawals by county from the Tokio aquifer for the southwestern study area.

from 0.06 Mgal/d to 0.02 Mgal/d in Pike County. Water use for Pike County was not reported in 2000. In Howard County, water use was reported in 1985 (0.14 Mgal/d) and in 2000 (0.04 Mgal/d) but was not reported in 1990 and 1995. Water use was not reported for Nevada County between 1985 and 2000.

Recharge to the aquifer is from precipitation where it crops out or is overlain by permeable alluvial and terrace deposits. At the outcrop, the soil is weathered to a sandy consistency that facilitates the percolation of rain and surface water into the sand (Counts and others, 1955). The aquifer yields freshwater to within a few miles north of Ashdown in Little River County then increases in salinity downdip (southeast) from near Prescott to the fault zone trending across Nevada County (Petersen and others, 1985).

Potentiometric Surface

The potentiometric surface indicates that groundwater flow in the Tokio aquifer, in general, is perpendicular to contour lines in the direction of the downward hydraulic gradient, toward the city of Hope. In east-central Howard County, groundwater flows from a water-level altitude of 491 ft above NGVD 29 in the outcrop area to a water-level altitude of 105 ft above NGVD 29 approximately 5 mi northwest of the city of Hope (table 3), in Hempstead County. In southwestern Pike, northwestern Nevada, and southeastern Hempstead Counties, an area of artesian flow exists as evidenced by five flowing artesian wells. Northwest of the city of Hope, an apparent cone of depression exists, which may be a result of groundwater withdrawal in the area (fig. 13). Water-level data were not available for the area south of Hope.

Water-Level Trends

Water-Level Differences from 2008 to 2014

Water-level differences between measurements from 2008 and 2014 in 37 wells show a decline in more than half of the measured wells (fig. 14; table 4). The largest water-level rise was 21.34 ft in Hempstead County, and the largest water-level decline was 39.37 ft in Clark County (table 4). In general, there were declines in Hempstead and Nevada Counties and water-level rises in Sevier County.

In Clark County, no overall trend existed between 2008 and 2014. Of the four water-level difference values calculated, two water levels rose and two water levels declined. The greatest rise (9.64 ft) was measured in well 09S22W05BBB1 located near the Saline River. The greatest decline (39.37 ft) occurred near the outcrop area in well 08S22W15ABB2. Analysis of water-use trends in the area of water-level decline does not provide a reason for the decline. Water levels declined in both wells measured in Nevada County. Water levels declined by 2.43 ft in well 11S22W08DAC8 and 1.57 ft in well 12S21W28ADA1.

Of the 16 wells measured in Hempstead County, water levels declined in 11 wells and rose in 5 wells. Water-level changes ranged from a decline of 27.83 ft in well 12S24W06DAD1 to a rise of 21.34 ft in well 12S27W05AAC1 in west-central Hempstead County. Water levels in three wells in or near the outcrop area indicated a rise in water levels.

Water levels rose in 5 of the 9 wells measured in Howard County. The rise in water levels ranged from 18.78 ft in well 10S27W02ACD1 in southeastern Howard County to 2.14 ft in well 09S27W03DBD1 in the outcrop area of the Tokio aquifer in east-central Howard County. Water-level declines in southern Howard County are in or near the outcrop area with values ranging from 4.86 ft in well 09S27W10BCB1 to 0.10 ft in well 09S27W18ADB1. Water-level rises in three wells in southern Sevier County ranged from 1.06 ft in well 11S29W13CCD1 to 5.40 ft near the Saline River in well 10S28W31DCC1.

Long-Term Water-Level Changes

The water-level hydrograph for Hempstead County well 09S23W33CDA1 (fig. 15*A*) indicates an annual decline of 0.03 ft/yr from 1986 to 2014. The water-level hydrograph of Hempstead County well 09S26W18CBB1 (fig. 15*B*) indicates an annual decline of 0.22 ft/yr since 1986. The water-level hydrograph for Hempstead County well 12S24W06DAD1 (fig. 15*C*) indicates an annual water-level decline of 2.56 ft/yr over the 43-year period of record. Since 1986, the water level has declined 3.10 ft/yr. The decline in water level may be associated with increased withdrawals from the Tokio aquifer in Hempstead County (Schrader and Rodgers, 2013) as evidenced by an apparent cone of depression near Hope where a large decline in water level between 2008 and 2014 (27.83 ft.) is observed. Factors such as climatic change or leakage to and from overlying and underlying rock units may have also contributed to the fluctuation in the measured water levels.

Table 3. Water-level data collected in 2014 from wells completed in the Tokio aquifer in southwestern Arkansas.

[Horizontal datum is North America Datum of 1983; Vertical datum is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); Letters in parentheses correspond to well locations in figure 13 and well hydrographs in figure 15. Values rounded to the nearest whole number]

Site number	Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
			Clark County				
340311093203701	08S22W15ABB2	340313	932018	232	93	325	3/26/2014
335951093225901	09S22W05BBB1	335951	932259	214	98	312	3/24/2014
335943093230001	09S22W05BCA1	335936	932257	206	29	235	3/24/2014
335633093203301	09S22W10DBA1	335832	932022	260	102	362	3/24/2014
335754093212001	09S22W16ACA1	335754	932120	220	13	233	3/24/2014
			Hempstead County				
335710093285801	09S23W20BDA1	335710	932859	250	0	250	3/11/2014
335453093275601	09S23W33CDA1 (A)	335457	932802	271	-1	270	3/11/2014
335634093313201	09S24W25BBB1	335633	933132	268	0	268	3/11/2014
335551093362001	09S24W30DCC1	335556	933607	298	92	390	3/11/2014
335526093343501	09S24W33ADC1	335526	933356	282	47	329	3/11/2014
335920093471701	09S26W08ADA2	335920	934717	436	2	438	3/13/2014
335917093472301	09S26W08ADD1	335918	934717	436	1	437	3/13/2014
335844093465401	09S26W09CDC1	335846	934656	422	3	425	3/13/2014
335819093492501	09S26W18CBB1 (B)	335815	934921	400	25	425	3/13/2014
335048093431001	10S25W30CCD1	335048	934310	299	89	388	3/13/2014
335508093461301	10S26W03BBA1	335507	934612	366	1	367	3/13/2014
334903093490901	11S26W08BBB1	334909	934903	300	72	372	3/13/2014
334716093455801	11S26W23BBB1	334720	934602	249	170	419	3/13/2014
334358093370101	12S24W06DAD1 (C)	334360	933701	105	250	355	3/11/2014
334341093390201	12S25W02DDD1	334341	933902	120	247	367	3/20/2014
334447093335801	12S27W04BBC1	334450	935358	261	174	435	3/18/2014
334439093541601	12S27W05AAC1	334449	935421	280	155	435	3/18/2014
333954093503401	12S27W36DBC1	333958	935024	195	66	261	3/12/2014
			Howard County				
340000093515201	09S27W03DBD1	340000	935153	491	71	562	3/17/2014
335930093523101	09S27W10BCB1	335930	935232	421	113	534	3/13/2014
335840093545201	09S27W18ADB1	335840	935453	413	79	492	3/17/2014
335606093542301	09S27W32BDB1	335606	935424	395	56	451	3/17/2014
335606093542302	09S27W32BDB2	335606	935424	400	50	450	3/17/2014
335454093505501	10S27W02ACD1	335454	935056	301	57	358	3/17/2014
335512093532901	10S27W04BBD1	335512	935330	345	47	392	3/17/2014
335356093502001	10S27W12CAB1	335356	935021	304	79	383	3/18/2014
335336093553401	10S27W18BAC1	335336	935535	323	99	422	3/17/2014
334603093541801	11S27W21CDA1	334603	935418	214	66	280	3/18/2014
			Nevada County				
334757093231208	11S22W08DAC8	334757	932312	211	94	305	3/20/2014
334015093155901	12S21W28ADA1	334015	931559	262	3	265	3/20/2014
			Pike County				
340213093293001	08S23W19ADC1	340213	932931	351	-1	350	2/20/2014
340018092255001	08S23W35DCA1	340004	932530	259	-2	257	2/21/2014
335750093314201	09S24W14AAD1	335810	933139	286	-1	285	2/20/2014
			Sevier County				
335040094015401	10S28W31DCC1	335026	940145	294	36	330	3/18/2014
334949094065201	11S29W05DCA1	334949	940653	324	156	480	3/18/2014
334907094070301	11S29W08DBB1	334907	940704	324	141	465	3/18/2014
334750094031301	11S29W13CCD1	334750	940317	280	80	360	3/18/2014

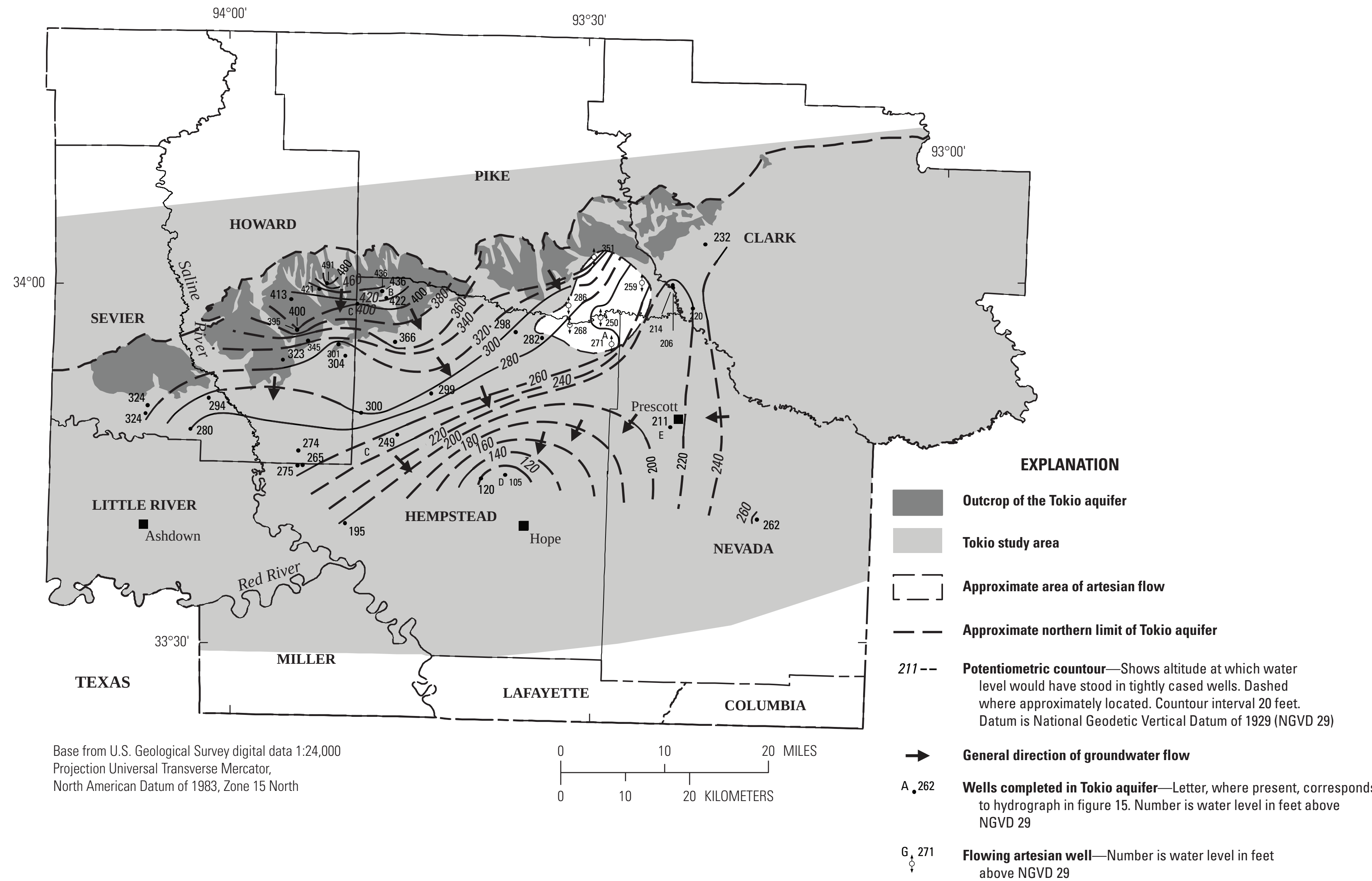


Figure 13. Potentiometric surface of the Tokio aquifer in southwestern Arkansas, 2014.

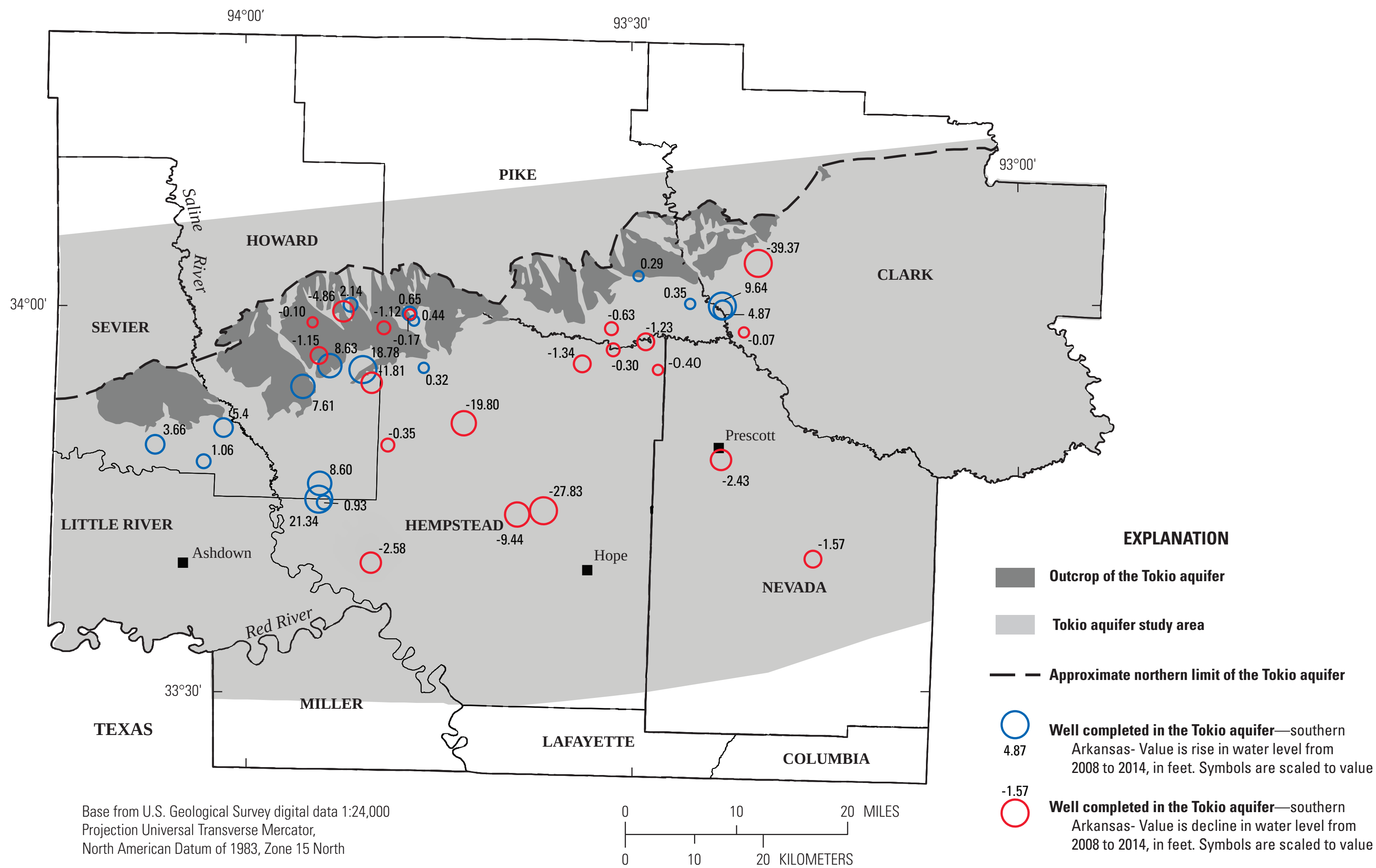


Figure 14. Water-level differences for the Tokio aquifer in southwestern Arkansas, 2008–14. The circles are scaled in size to represent the relative value of rise or decline.

Table 4. Difference in depth to water from 2008 to 2014 in the Tokio aquifer in southwestern Arkansas.

[Horizontal datum is North American Datum of 1983; Vertical datum is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); positive values for water-level difference indicate a rise in water levels from 2008 to 2014 whereas negative values for water-level difference indicate a decline in water levels from 2008 to 2014; --, no data available]

Site number	Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Land-surface datum (feet above NGVD 29)	Depth of well (feet below land surface)	2014 Tokio water-level altitude (feet above NGVD 29)	2008 Tokio water-level altitude (feet above NGVD 29)	Water-level difference (2008–14)
Clark County								
340311093203701	08S22W15ABB2	340313	932018	325	145	232.04	271.41	-39.37
335951093225901	09S22W05BBB1	335951	932259	312	260	214.46	204.82	9.64
335943093230001	09S22W05BCA1	335936	932257	235	202	206.27	201.40	4.87
335754093212001	09S22W16ACA1	335754	932120	233	450	219.70	219.77	-0.07
Hempstead County								
335710093285801	09S23W20BDA1	335710	932859	250	210	250.00	251.23	-1.23
335453093275601	09S23W33CDA1	335457	932802	270	467	270.91	270.95	-0.04
335634093313201	09S24W25BBB1	335633	933132	268	270	268.20	268.50	-0.30
335526093343501	09S24W33ADC1	335526	933356	329	335	281.79	283.13	-1.34
335920093471701	09S26W08ADA2	335920	934717	438	25	436.12	435.47	0.65
335917093472301	09S26W08ADD1	335918	934717	437	25	436.10	436.27	-0.17
335844093465401	09S26W09CDC1	335846	934656	425	16	421.55	421.11	0.44
335819093492501	09S26W18CBB1	335815	934921	425	29.5	400.34	401.46	-1.12
335048093431001	10S25W30CCD1	335048	934310	388	500	298.88	318.68	-19.80
335508093461301	10S26W03BBA1	335507	934612	367	162	366.14	365.82	0.32
334903093490901	11S26W08BBB1	334909	934903	372	550	300.07	300.42	-0.35
334358093370101	12S24W06DAD1	334360	933701	355	1,140	104.61	132.44	-27.83
334341093390201	12S25W02DDD1	334341	933902	367	1,159	119.64	129.08	-9.44
334447093335801	12S27W04BBC1	334450	935358	435	870	261.10	260.17	0.93
334439093541601	12S27W05AAC1	334449	935421	435	906	280.12	258.78	21.34
333954093503401	12S27W36DBC1	333958	935024	261	1,156	194.81	197.39	-2.58
Howard County								
340000093515201	09S27W03DBD1	340000	935153	562	220	490.62	488.48	2.14
335930093523101	09S27W10BCB1	335930	935232	534	195	421.08	425.94	-4.86
335840093545201	09S27W18ADB1	335840	935453	492	200	413.28	413.38	-0.10
335606093542301	09S27W32BDB1	335606	935424	451	150	395.28	396.43	-1.15
335454093505501	10S27W02ACD1	335454	935056	358	260	301.29	282.51	18.78
335512093532901	10S27W04BBD1	335512	935330	392	170	345.15	336.52	8.63
335356093502001	10S27W12CAB1	335356	935021	383	416	304.21	306.02	-1.81
335336093553401	10S27W18BAC1	335336	935535	422	300	322.74	315.13	7.61
334603093541801	11S27W21CDA1	334603	935418	280	800	213.58	204.98	8.60
Nevada County								
334757093231208	11S22W08DAC8	334757	932312	305	1,050	211.10	213.53	-2.43
334015093155901	12S21W28ADA1	334015	931559	265	--	261.51	263.08	-1.57
Pike County								
340213093293001	08S23W19ADC1	340213	932931	350	105	351.30	351.01	0.29
340018092255001	08S23W35DCA1	340004	932530	257	125	258.50	258.15	0.35
335750093314201	09S24W14AAD1	335810	933139	285	140	286.00	286.63	-0.63
Sevier County								
335040094015401	10S28W31DCC1	335026	940145	330	185	293.56	288.16	5.40
334907094070301	11S29W08DBB1	334907	940704	465	395	323.83	320.17	3.66
334750094031301	11S29W13CCD1	334750	940317	360	339	279.64	278.58	1.06

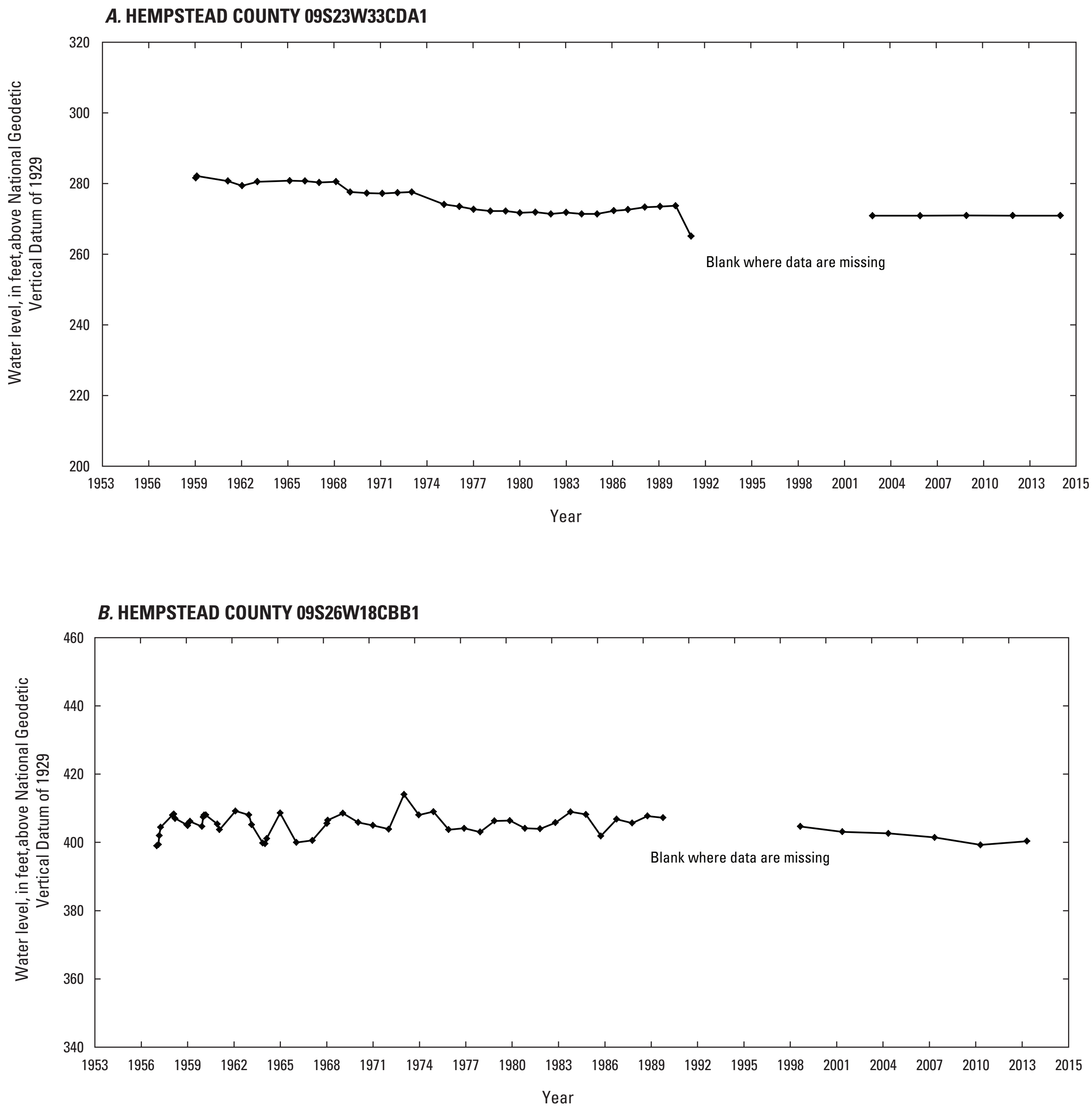


Figure 15. Water-level hydrographs for selected wells completed in the Tokio aquifer in southwestern Arkansas. Blank where data are missing.

C. HEMPSTEAD COUNTY 12S24W06DAD1

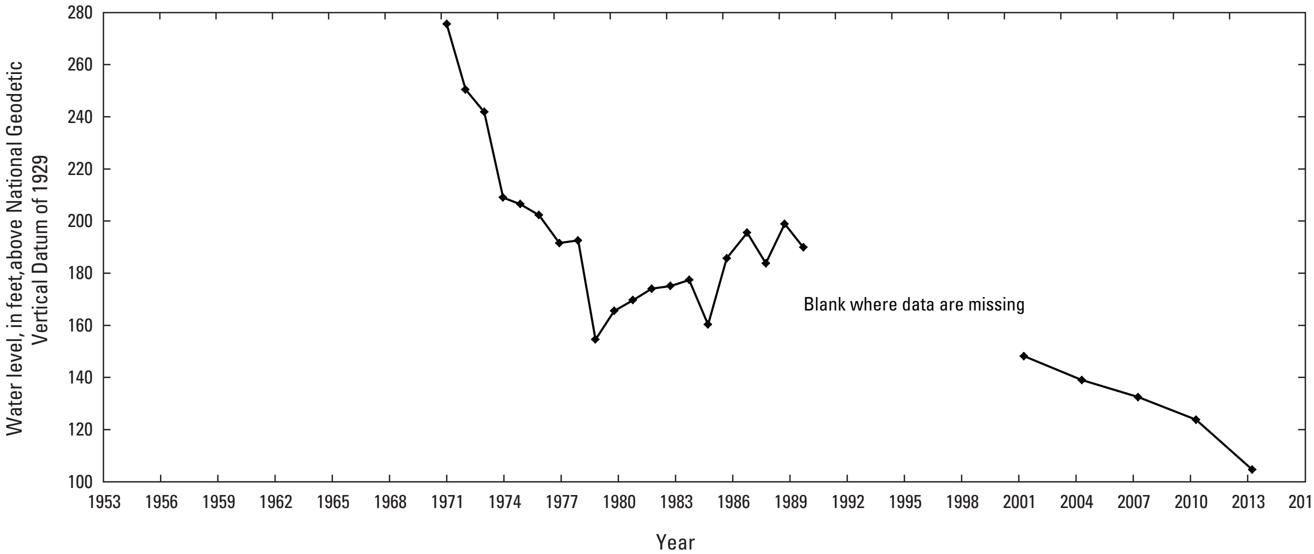


Figure 15. Water-level hydrographs for selected wells completed in the Tokio aquifer in southwestern Arkansas. Blank where data are missing.—Continued

Summary

A water-level survey conducted in 2014–15 in the Nacatoch and Tokio aquifers indicates that water levels in both aquifers have changed over time. Short-term data (2008 compared to 2014–15 data) indicate that water levels increased in over half of the measured wells in the Nacatoch aquifer; however, long-term trends show an overall decrease in water levels. In the Tokio aquifer, short-term data indicate a decline in water levels measured in wells since 2008; however, long-term data from wells showed both decreasing and increasing trends. When compared to previous potentiometric surfaces for both aquifers in 2013, regional groundwater flow direction has not changed. However, both aquifers had cones of depression near the city of Hope that are likely a result of groundwater withdrawals for agricultural, domestic, industrial, and public use, and these cones have altered the local flow direction. Long-term monitoring of groundwater is important to water resource managers because the data can be used to identify sources of water-level fluctuations that result from changes in withdrawal, climate, and interaction with overlying and underlying rock units.

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