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Arkansas Geological Commission

STATUS OF WATER LEVELS IN AQUIFERS IN THE NACATOCH SAND OF SOUTHWESTERN AND NORTHEASTERN ARKANSAS AND THE TOKIO FORMATION OF SOUTHWESTERN ARKANSAS, 1999

Water-Resources Investigations Report 99-4208

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

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By T.P. Schrader

U.S. GEOLOGICAL SURVEY
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Little Rock, Arkansas
1999

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Status of Water Levels in Aquifers in the Nacatoch Sand of Southwestern and Northeastern Arkansas and the Tokio Formation of Southwestern Arkansas, 1999

By T. P. Schrader

ABSTRACT

Nacatoch Sand and Tokio Formation aquifers in southwestern Arkansas and the Nacatoch Sand aquifer in northeastern Arkansas are a source of water for industrial, public supply, domestic, and agricultural uses. Potentiometric-surface maps were constructed from water-level measurements made in 59 wells completed in the Nacatoch Sand and 45 wells completed in the Tokio Formation from April through May 1999.

The direction of ground-water flow in the aquifer in the Nacatoch Sand in northeastern Arkansas generally is towards the southeast. The potentiometric high is located along the north and northwestern boundaries.

The direction of ground-water flow in the aquifer in the Nacatoch Sand in southwestern Arkansas is towards the south-southeast in Little River, Miller, and Hempstead Counties and to the east-southeast in Nevada and Clark Counties. The potentiometric high is located within the outcrop area in north-central Hempstead County. A cone of depression exists in the aquifer in the Nacatoch Sand at Hope in southeastern Hempstead County.

The direction of ground-water flow in the aquifer in the Tokio Formation in southwestern Arkansas generally is towards the southeast. The potentiometric high is within the outcrop area. An area of artesian flow exists in southeastern Pike, northeastern Hempstead, and northwestern Nevada Counties. One apparent cone of depression might exist northwest of Hope in Hempstead County.

In northeastern Arkansas, withdrawals from the Nacatoch Sand increased by 736 percent from 1965 to 1995. In southwestern Arkansas withdrawals from aquifers in the Nacatoch Sand and Tokio Formation increased by 125 percent and 201 percent, respectively, from 1965 to 1980 and decreased by 78 percent and 63 percent, respectively, from 1980 to 1995. Long-term hydrographs were prepared for 13 wells in the study area. Changes in water levels in some wells may be associated with changes in withdrawals from the respective aquifers.

INTRODUCTION

Ground water is a renewable resource important for economic growth and quality of life. Aquifers in the Nacatoch Sand and Tokio Formation in southwestern Arkansas and the Nacatoch Sand in northeastern Arkansas are a source of water for industrial, public supply, domestic, and agricultural uses. Monitoring of ground-water levels and withdrawals provides information needed to effectively plan and manage the resource. A study was conducted in cooperation with the Arkansas Soil and Water Conservation Commission and the Arkansas Geological Commission to provide potentiometric-surface maps and water-level hydrographs associated with aquifers in the Nacatoch Sand and Tokio Formation (hereinafter referred to as the Nacatoch aquifer and Tokio aquifer, respectively) in southwestern Arkansas and the Nacatoch aquifer in northeastern Arkansas.

The study area comprises parts of 10 counties in two subareas of northeastern and southwestern Arkansas. The northeastern subarea includes most of Clay and Greene Counties in the Mississippi Alluvial Plain physiographic province (fig. 1). This subarea is bounded on the north and east by the Missouri State line and on the west by the western extent of the Nacatoch aquifer. The southern boundary of this subarea was defined by the area of water use in the Nacatoch aquifer. The southwestern subarea includes parts of eight counties (Clark, Hempstead, Howard, Little River, Miller, Nevada, Pike, and Sevier) in the West Gulf Coastal Plain physiographic province (fig. 1). This subarea is bounded on the north approximately by the Fall Line separating the Interior Highlands from the West Gulf Coastal Plain, on the west by the Texas State

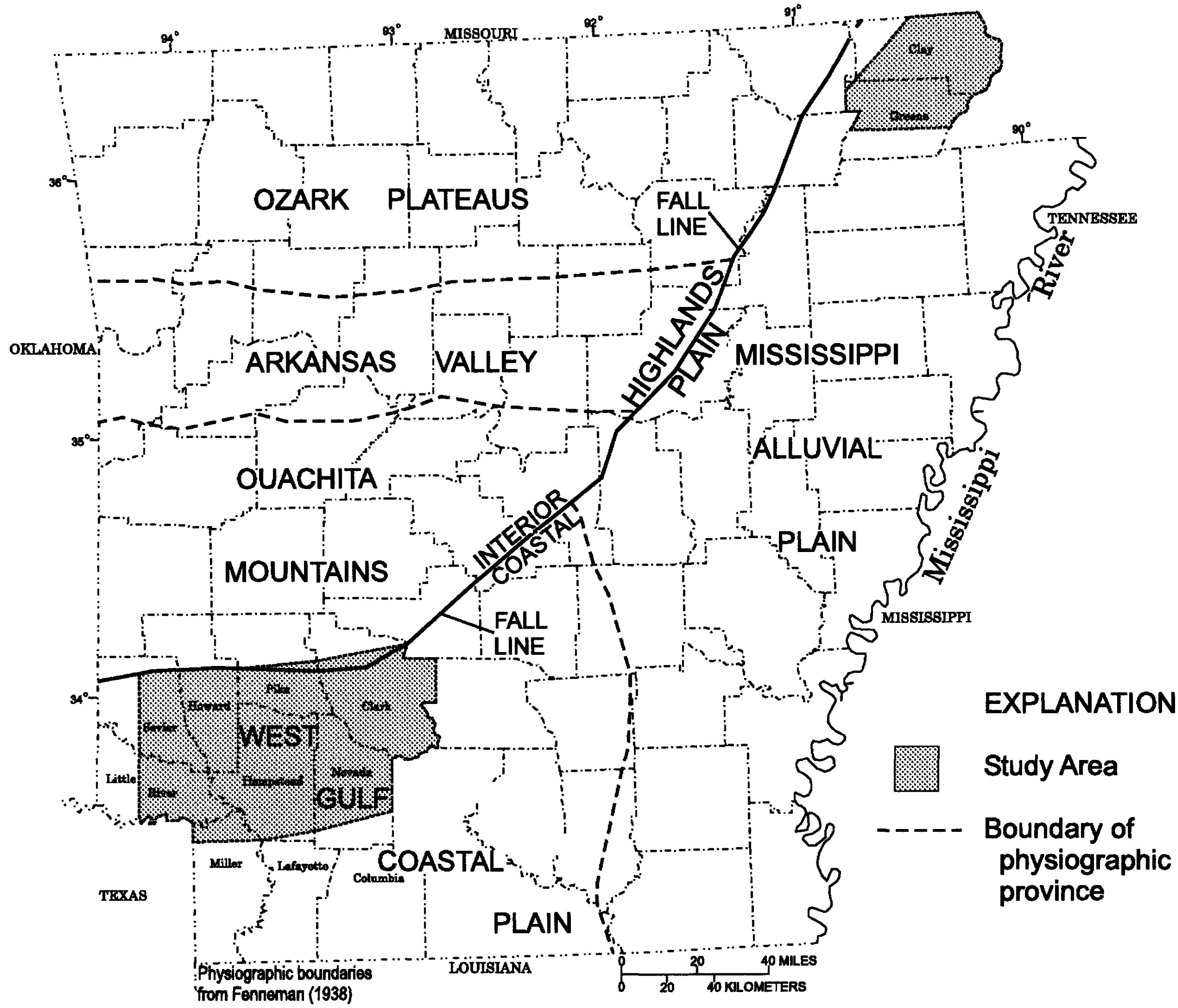


Figure 1. Location of study area.

line, and on the east by the eastern borders of Clark and Nevada Counties. The southwestern subarea was limited to the occurrence of freshwater; the southern boundary of the subarea is defined by a freshwater/saltwater interface. To the south, the ground water 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).

This report presents the results of water-level measurements made in 59 wells completed in the Nacatoch aquifer and in 45 wells completed in the Tokio aquifer during April and May of 1999. These measurements were used to construct potentiometric-surface maps. All water-level data are stored in the U.S. Geological Survey's Ground-Water Site Inventory (GWSI) data storage system. Long-term water-level hydrographs were prepared for selected wells. County withdrawal data collected by the U.S. Geological Survey from 1965 to 1995 were related to these hydrographs.

The Tokio Formation is stratigraphically below the Nacatoch Sand and separated from it by five stratigraphic units, listed here in descending stratigraphic order: Saratoga Chalk, Marlbrook Marl, Annona Chalk, Ozan Formation, and Brownstown Marl. In the study area, these five units are rarely used as water sources and are not discussed in this report.

Cones of depression within a potentiometric surface are indicators of pumping rates that are exceeding the local recharge rates to the aquifer. As a well is pumped, water levels are drawn down, forming a local cone of depression. Water levels will recover in time if pumping rates do not exceed the recharge rates to the aquifer. Pumping rates that exceed recharge rates for an extended period of time will cause cones of depression to enlarge. Local cones of depression can intersect and coalesce, causing a regional decrease in water levels within the aquifer. Variations in climatic conditions and resulting recharge rates can result in the natural rise or decline of water levels and could account for changes shown by long-term hydrographs.

The well-numbering system used in this report is based upon the location of the wells according to the Federal land survey 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 of the well in the quarter-quarter-quarter section. 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 were located using a Global Positioning System (GPS) capable of accuracy to one one-hundreth of a second of latitude and longitude.

NACATOCH SAND

Hydrogeologic Setting

The Nacatoch Sand of Cretaceous age is underlain by the Saratoga Chalk and overlain by the Arkadelphia Marl. In the northeastern subarea, the Nacatoch Sand subcrops beneath Quaternary alluvial and terrace deposits along the western boundary (fig. 3). The top of the Nacatoch Sand has an altitude of about 50 to 100 feet (ft) above sea level[1] along the western boundary, dips toward the southeast, and descends to about 1,200 ft below sea level at the Mississippi River. The unit is about 100 ft thick near the subcrop and attains a maximum thickness of about 600 ft downdip (Petersen and others, 1985).

The Nacatoch Sand in the northeastern subarea consists of interbedded clay, limestone, and fine sand in the lower part, grading upward to loose fine quartz sand in the upper part (Petersen and others, 1985). The Nacatoch aquifer receives recharge from precipitation through the overlying alluvium and terrace deposits in western Clay and Greene Counties.

In the southwestern subarea the Nacatoch Sand outcrops in a belt 3 to 8 miles (mi) wide extending from central Clark County southwestward to western Hempstead County (fig. 4). The belt continues westward as a subcrop below Quaternary alluvial and terrace deposits across Little River County (Boswell and others, 1965). The top of the Nacatoch Sand has an altitude of about 300 ft above sea level in the outcrop, dips towards the southeast, and descends to about 800 ft below sea level at the southern boundary of the subarea. The Nacatoch Sand is about 100 ft thick near the outcrop and attains a maximum thickness of 600 ft (Petersen and others, 1985).

The Nacatoch Sand in the southwestern subarea consists of three distinct units. The upper unit is composed of unconsolidated, gray, fine-grained quartz sand that commonly is cross bedded. Locally the sand is massive and contains a few hard lenses and beds of fossiliferous sandy limestone. This upper sand unit is the main water bearing unit of the Nacatoch Sand. The middle unit consists of a dark-green sand that contains coarse grains of glauconite and weathers to lighter shades of green. This unit generally is fossiliferous where it is glauconitic. The lower unit consists of interbedded gray clay , sandy clay and marl, dark clay-rich fine-grained sand, and hard irregular concretionary beds (Counts and others, 1955; Plebuch and Hines, 1969).

In the southwestern subarea the Nacatoch aquifer receives recharge from precipitation in its outcrop areas in Clark, Nevada, and Hempstead Counties and through the overlying alluvium and terrace deposits in Little River County and in northeastern Texas.

The Nacatoch aquifer is used in northeastern Green County, Clay County, southern Clark County, northwestern Nevada County, central Hempstead County, northern Miller County, and southeastern Little River County. Flowing wells produce yields of 1 or 2 gallons per minute (gal/min) in the lowest stream valleys in Clark and Nevada Counties. Wells in Hempstead County and western Nevada County produce yields of 150 to 300 gal/min. Downdip 2 to 20 mi

[1]In this report, sea level refers to the National Geodetic Vertical Datum of 1992--a geodetic datum derived from a general adjustment of the First-order level nets of the United States and Canada, formerly call Sea Level Datum of 1929

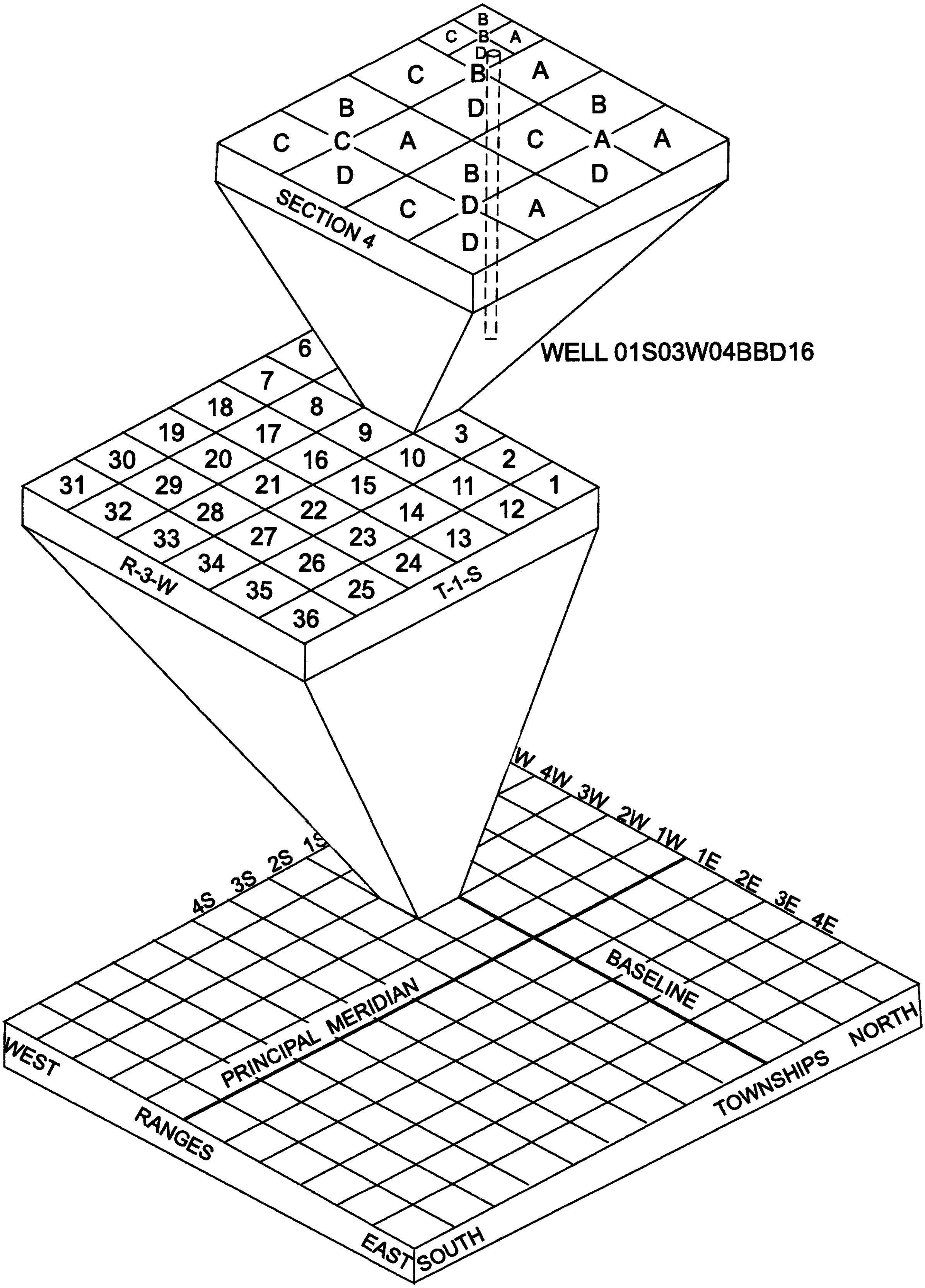
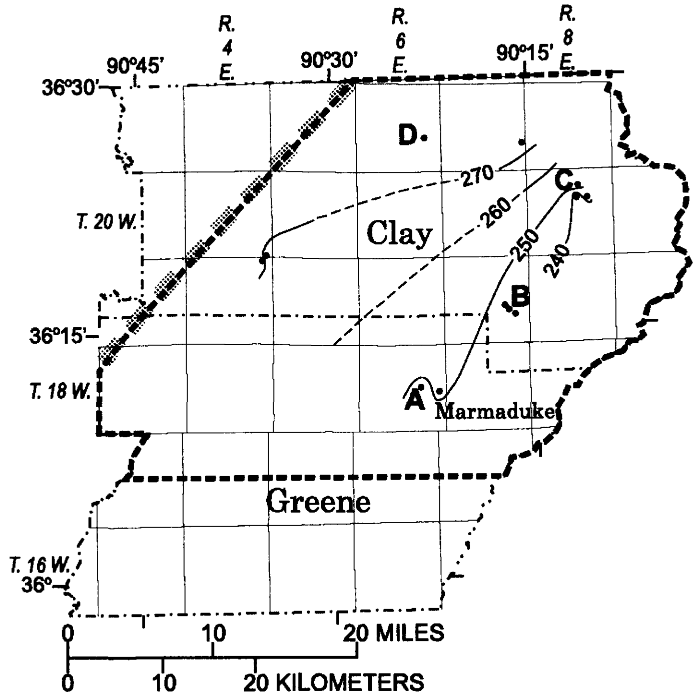


Figure 2. Diagram showing well-numbering system.



EXPLANATION

BOUNDARY OF STUDY AREA

APPROXIMATE WESTERN LIMIT OF NACATOCH SAND

—250– – POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Contour interval 10 feet. Datum is sea level

D• CONTROL POINT--Letter, where present, corresponds to hydrograph in figure 4

Figure 3. Potentiometric surface of the Nacatoch aquifer, northeastern Arkansas, April-May 1999.

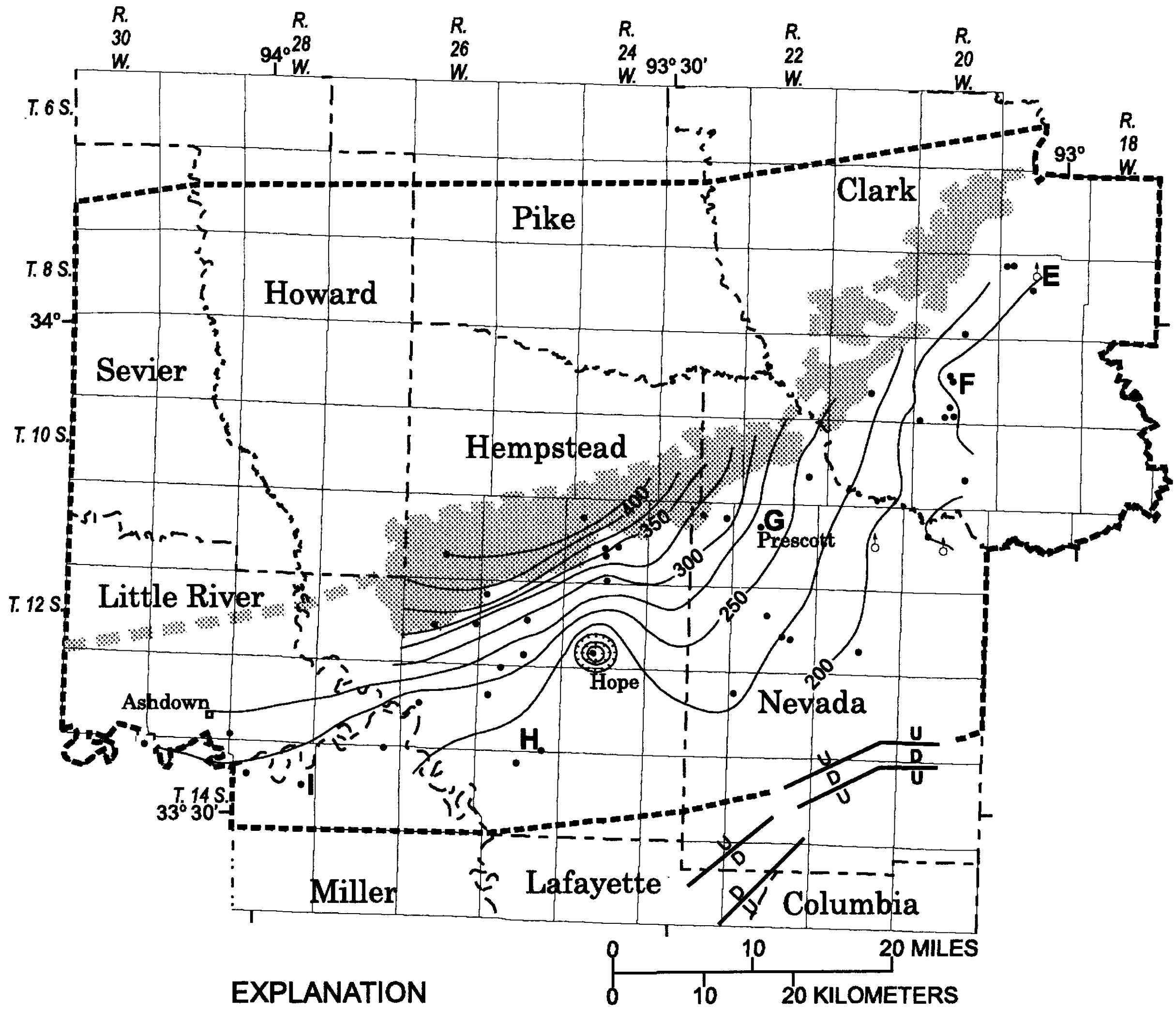
southeast from the outcrop area in the southwestern subarea, the water generally is excessively saline for most uses. In Miller County, eastern Nevada County, and Clark County, yields are generally small and the water may contain considerable chloride (Counts and others, 1955). Aquifer tests made using wells completed in the Nacatoch aquifer at Hope and Prescott show a transmissivity of 3,600 gallons per day per foot (gal/d/ft) (Ludwig,1972).

In the northeastern subarea, water withdrawn from the Nacatoch aquifer was estimated to be 0.25 million gallons per day (Mgal/d) in 1965 and increased to 2.09 Mgal/d in 1995, an increase of 736 percent during a 30-year period.

In the southwestern subarea, water withdrawn from the Nacatoch aquifer was estimated to be 2.11 Mgal/d in 1965 and increased by 125 percent to 4.75 Mgal/d in 1980. Water withdrawn from the Nacatoch aquifer in this subarea was estimated to be 1.02 Mgal/d in 1995, a decrease of 78 percent from 1980 (Halberg and Stephens; 1966, Holland and Ludwig, 1981; Holland, 1999).

Potentiometric Surface

Water-level measurements in 59 wells from April and May 1999 were used to construct potentiometric-surface maps for the Nacatoch aquifer (figs. 3 and 4; table 1). The surface is mapped by calculating the altitude of the water levels (table 1) and is represented on the figures by contours that connect points of equal value. The general direction of ground-water flow is perpendicular to the contours in the direction of downward hydraulic gradient.



EXPLANATION

OUTCROP OF NACATOCH SAND

BOUNDARY OF STUDY AREA

APPROXIMATE NORTHERN LIMIT OF NACATOCH SAND

U/D FAULT--U, Upthrown side; D, Downthrown side

—150— POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells. Contour interval 25 feet. Datum is sea level

H. CONTROL POINT--Letter, where present, corresponds to hydrograph in figure 4

FLOWING WELL

Figure 4. Potentiometric surface of the Nacatoch aquifer, southwestern Arkansas, April-May 1999.

Table 1. Water-level measurements and well information for wells completed in the Nacatoch aquifer

Local well number	Latitude	Longitude	Water level altitude (feet above sea level)	Depth to water level (feet below land-surface datum)	Land-surface altitude (feet above sea level)	Well depth (feet)	Date of measurement
			Clark County				
08S19W06DCA1	340359.21	930432.34	193	76.93	270	148	5/03/99
08S19W06DDA1	340400.87	930413.83	179	5.84	185	109.5	5/03/99
08S19W09ACC1	340323.35	930228.33	178	-0.85	177	195	5/03/99
08S19W16CAB1	340225.62	930247.10	171	1.83	173	--	5/03/99
08S20W34DAB1	335954.15	930744.35	183	16.69	200	100	5/03/99
09S20W16DBD1	335708.15	930847.37	162	78.57	241	228	4/30/99
09S20W16DDC1	335656.77	930844.75	157	76.41	233	241	4/30/99
09S20W28DCB1	335516.13	930900.79	182	20.49	202	245	4/30/99
09S20W31CAD1	335434.79	931111.15	180	79.49	259	276	4/30/99
09S20W33ABD1	335447.13	930852.09	176	33.39	209	245	4/30/99
09S20W33BCD2	335446.06	930926.02	182	24.75	207	236	4/30/99
09S21W21DAD1	335625.47	931453.39	240	105.22	345	110	5/03/99
10S20W22DCB1	335054.14	930757.21	181	79.25	260	500	4/29/99
			Clay County				
19N04E01BDB1	361909.66	903559.97	271	9.25	280	--	4/15/99
19N07E23BAC1	361601.75	901748.02	242	79.69	322	1,100	4/14/99
19N07E23DBC1	361548.58	901730.31	249	34.36	283	1,114	4/14/99
19N07E26AAA1	361531.66	901702.61	244	32.03	276	1,086	4/14/99
20N04E36DCC1	361928.53	903542.09	266	12.61	279	348	4/15/99
20N08E10ABC1	362312.60	901201.74	253	87.02	340	989	4/15/99
20N08E14BAB2	362227.05	901119.62	242	44.33	286	1,000	4/15/99
20N08E15BAA1	362223.50	901207.70	239	142.32	381	1,062	4/15/99
21N06E23DAC1	362618.79	902329.21	277	22.73	300	462	4/15/99
21N07E25AAC1	362549.74	901606.97	274	67.78	342	732	4/15/99
			Greene County				
18N06E14CCD1	361114.55	902419.58	243	44.15	287	1,153	4/15/99
18N06E24BDA1	361058.18	902300.11	251	25.32	276	1,105	4/15/99
			Hempstead County				
11S24W08BDB1	334836.52	933619.25	447	22.58	470	30	4/30/99
11S24W21ADD1	334640.64	933448.80	353	48.31	401	50	4/30/99
11S24W21DDD1	334620.53	933447.12	338	32.64	371	90	4/30/99

Table 1. Water-level measurements and well information for wells completed in the Nacatoch aquifer--Continued

Local well number	Latitude	Longitude	Water level altitude (feet above sea level)	Depth to water level (feet below land-surface datum)	Land-surface altitude (feet above sea level)	Well depth (feet)	Date of measurement
11S24W22ADD1	334647.25	933342.50	338	31.59	370	100	4/30/99
11S24W34CBC1	334443.82	933437.90	298	22.41	320	31	4/30/99
11S26W27BDD1	334610.50	934644.59	425	5.30	430	32	4/28/99
12S24W28CDC1	334012.41	933535.89	133	220.12	353	620	5/05/99
12S25W07ABB1	334345.67	934340.05	398	36.66	435	100	4/28/99
12S25W15DBC1	334213.66	934035.55	292	18.62	311	202	4/28/99
12S25W34BAC1	334001.94	934055.44	254	65.62	320	300	4/28/99
12S26W21AAC1	334158.03	934739.04	368	30.12	398	60	4/28/99
12S26W24ABC1	334159.15	934438.21	312	3.14	315	108	4/28/99
13S25W05ABD1	333915.43	934231.85	262	19.68	282	300	4/28/99
13S25W18AAB1	333739.64	934331.59	232	51.48	283	335	4/30/99
13S25W35DDC1	333406.09	933930.91	220	152.88	373	780	4/30/99
13S26W17DDB1	333705.19	934844.69	235	55.72	291	210	4/30/99
14S25W04DDD1	333317.01	934131.68	212	48.31	260	850	4/30/99
			Little River County				
13S28W31BCC1	333509.35	940250.97	259	51.77	311	260	4/22/99
14S30W01DAA1	333426.16	940904.22	253	29.01	282	375	4/22/99
			Miller County				
14S27W02AAB1	333419.42	935121.43	232	22.64	255	390	4/20/99
14S28W13CCB1	333158.09	935726.62	240	25.91	266	416	4/21/99
14S28W17BBC1	333239.92	940134.07	247	23.39	270	360	4/21/99
			Nevada County				
10S22W23DCB1	335105.16	931934.65	241	1.06	242	45	4/23/99
11S20W08DCD1	334727.45	931037.28	175	5.66	181	525	4/26/99
11S20W22AAA1	334623.76	930925.95	177	-2.05	175	550	4/26/99
11S21W14CAB1	334652.02	931434.14	197	-1.0	196	550	4/26/99
11S22W08DAC2	334759.75	932314.18	266	39.58	306	232	4/26/99
11S23W03DCD1	334840.28	932726.19	306	78.57	385	135	4/23/99
11S23W12ABB1	334837.00	932538.00	311	70.05	381	300	4/23/99
12S21W27BAC1	334016.14	931547.01	194	5.86	200	890	4/27/99
12S22W09CDD1	334229.68	932250.19	228	0.98	229	442	4/27/99
12S22W22ACD1	334107.66	932134.93	225	117.26	342	600	4/27/99
12S22W23CBA1	334102.42	932057.36	222	107.28	329	630	4/27/99
13S22W07BDC1	333744.12	932514.03	227	115.61	343	671	4/27/99

In the northeastern subarea, the direction of ground-water flow in the Nacatoch aquifer generally is towards the southeast (fig. 3). The potentiometric high is located along the north and northwestern boundary of this subarea. The highest water-level altitude measured was about 277 ft in northern Clay County. The lowest water-level altitude measured was about 239 ft in eastern Clay County.

In the southwestern subarea the direction of ground-water flow in the Nacatoch aquifer is generally towards the south-southeast in Little River, Miller, and Hempstead Counties and to the east-southeast in Nevada and Clark Counties (fig. 4). The direction of flow may be affected by the increase in clay content in the downdip direction and by a fault system trending northeastward from northeastern Texas across Miller, Lafayette, and Nevada Counties in Arkansas. The highest water-level altitude measured was about 447 ft in the outcrop area of north-central Hempstead County. The lowest water-level altitude measured was about 133 ft at Hope in southeastern Hempstead County.

A cone of depression exists at Hope in Hempstead County (fig. 4). Historical water levels indicate a decline from 185 ft above sea level in 1942 to 145 ft in 1969 (Ludwig, 1972). The water-level altitude from May 1999 was 133 ft above sea level. This cone of depression alters local ground-water flow directions from the regional direction, with ground water flowing towards Hope from all directions. No other cones of depression were evident in the Nacatoch aquifer. A comparison with the 1996 potentiometric surface maps for the Nacatoch aquifer shows no substantial changes over large areas (Schrader, 1998).

Long-Term Water-Level Changes

Nine hydrographs from wells completed in the Nacatoch aquifer display long-term (minimum of 20 years) water-level altitudes (fig. 5). Four wells (sites A-D) are located in the northeastern subarea (fig. 3). Water levels in each of these wells generally declined over the period of record an average of 0.5 to 1.4 foot per year (ft/yr). Water withdrawal rates from the Nacatoch aquifer for Greene and Clay Counties increased from 0.25 Mgal/d in 1965 to 2.09 Mgal/d in 1995, with a maximum of 2.21 Mgal/d in 1990, an increase of approximately 736 percent from the 1965 withdrawal rates (table 2). The decrease in water levels may be associated with the increased withdrawal from the Nacatoch aquifer in Greene and Clay Counties.

Five wells with historical water-level measurements (sites E-I; fig. 5), are located in the southwestern subarea (fig. 4). Two wells (sites E and F) are located in Clark County and the other three wells are located in Hempstead (site H), Miller (site I), and Nevada (site G) Counties.

Table 2. Estimated withdrawal rates by county from the Nacatoch aquifer

[Units are million gallons per day. Data from Holland, 1999; Holland, 1993; Holland, 1987; Holland and Ludwig, 1981; Halberg, 1977; Halberg, 1972; Halberg and Stephens, 1966]

	Estimated withdrawal rate						
County	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**
Clark	0.44	0.55	0.64	1.73	0.91	0.29	0.34
Clay	0.25	0.51	0.63	1.55	1.13	1.98	1.72
Greene	0.00	0.06	0.08	0.16	0.09	0.23	0.37
Hempstead	1.12	1.72	1.44	1.98	0.15	0.20	0.32
Howard	0.00	0.14	0.22	0.24	0.00	0.00	0.00
Little River	0.20	0.04	0.04	0.06	0.00	0.00	0.00
Miller	0.14	0.03	0.04	0.06	0.00	0.00	0.00
Nevada	0.21	0.45	0.55	0.68	1.11	0.44	0.36
Total	2.36	3.50	3.64	6.46	3.39	3.14	3.11

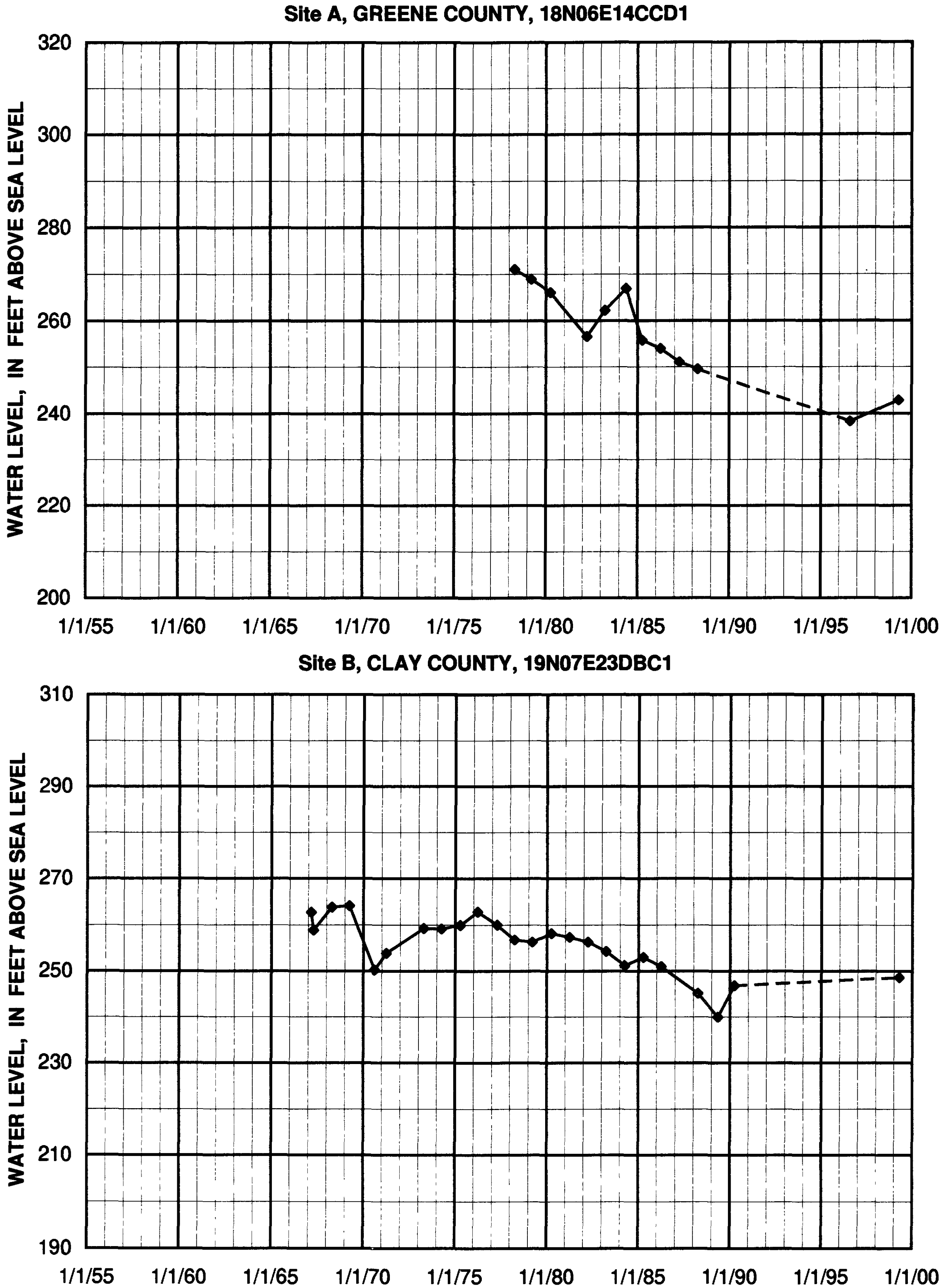
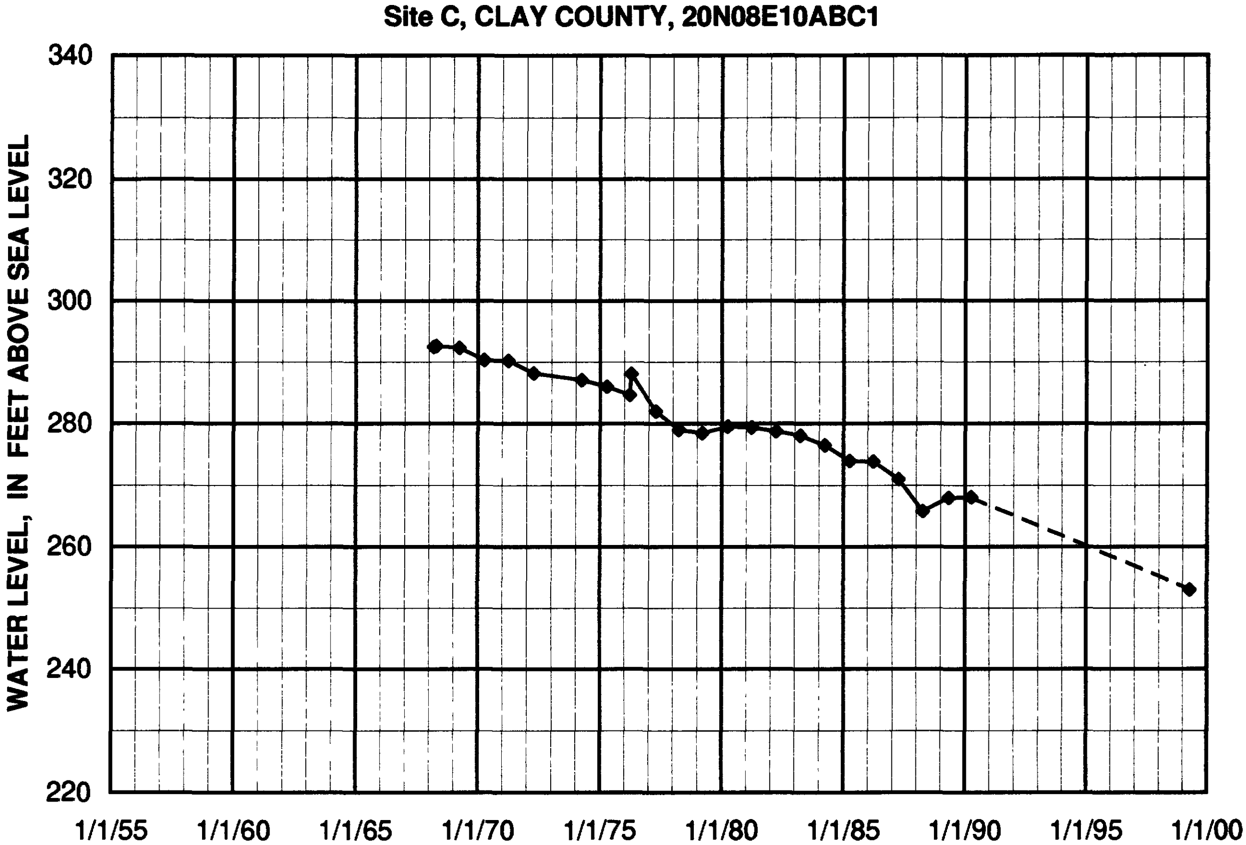


Figure 5. Water-level altitudes for selected wells completed in the Nacatoch aquifer.



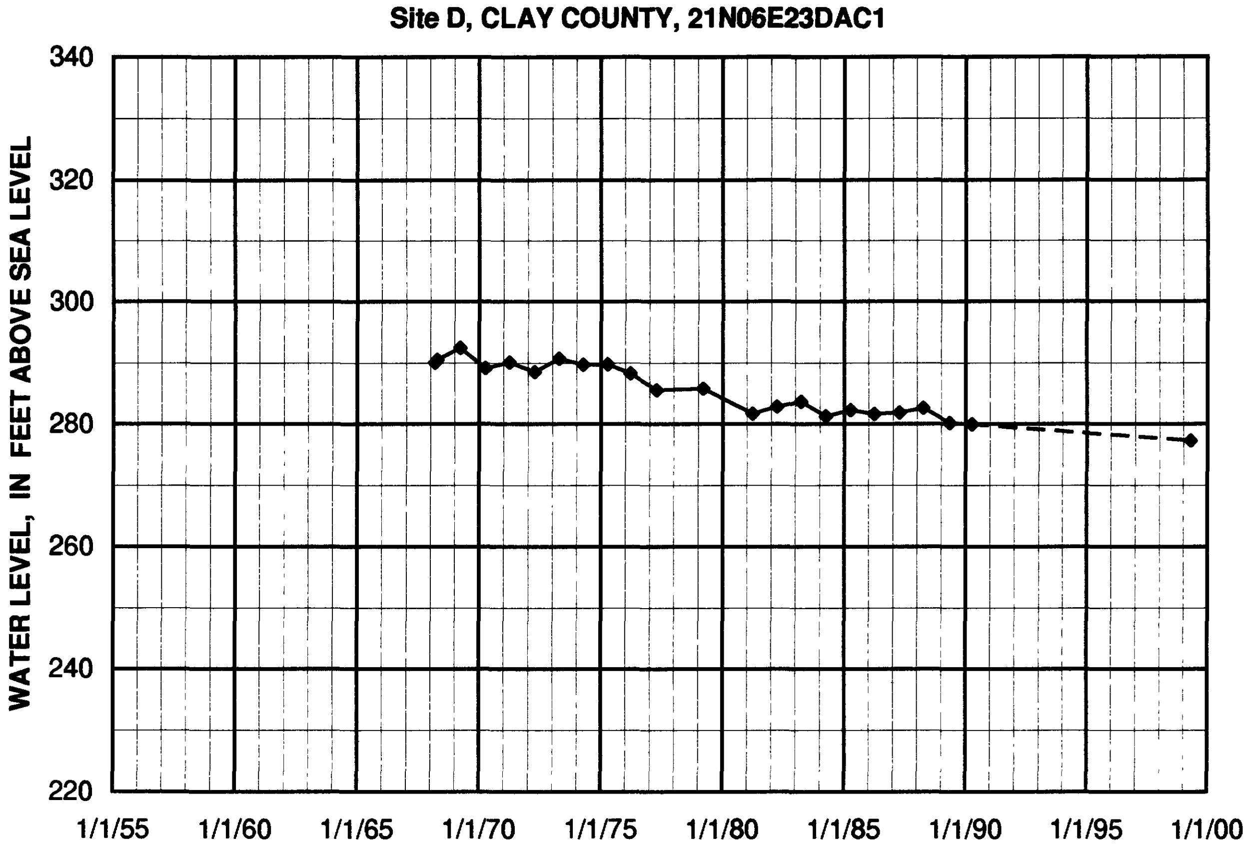
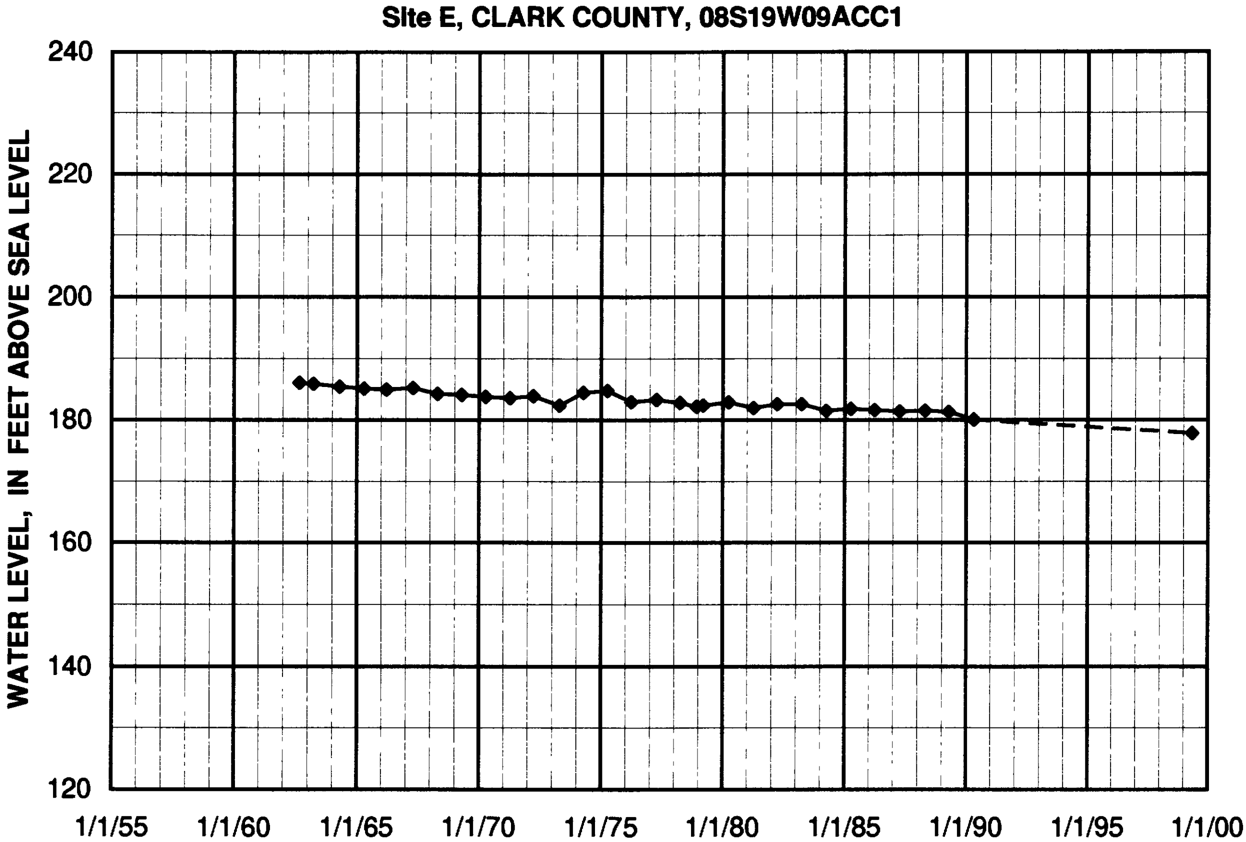


Figure 5. Water-level altitudes for selected wells completed in the Nacatoch aquifer—Continued.



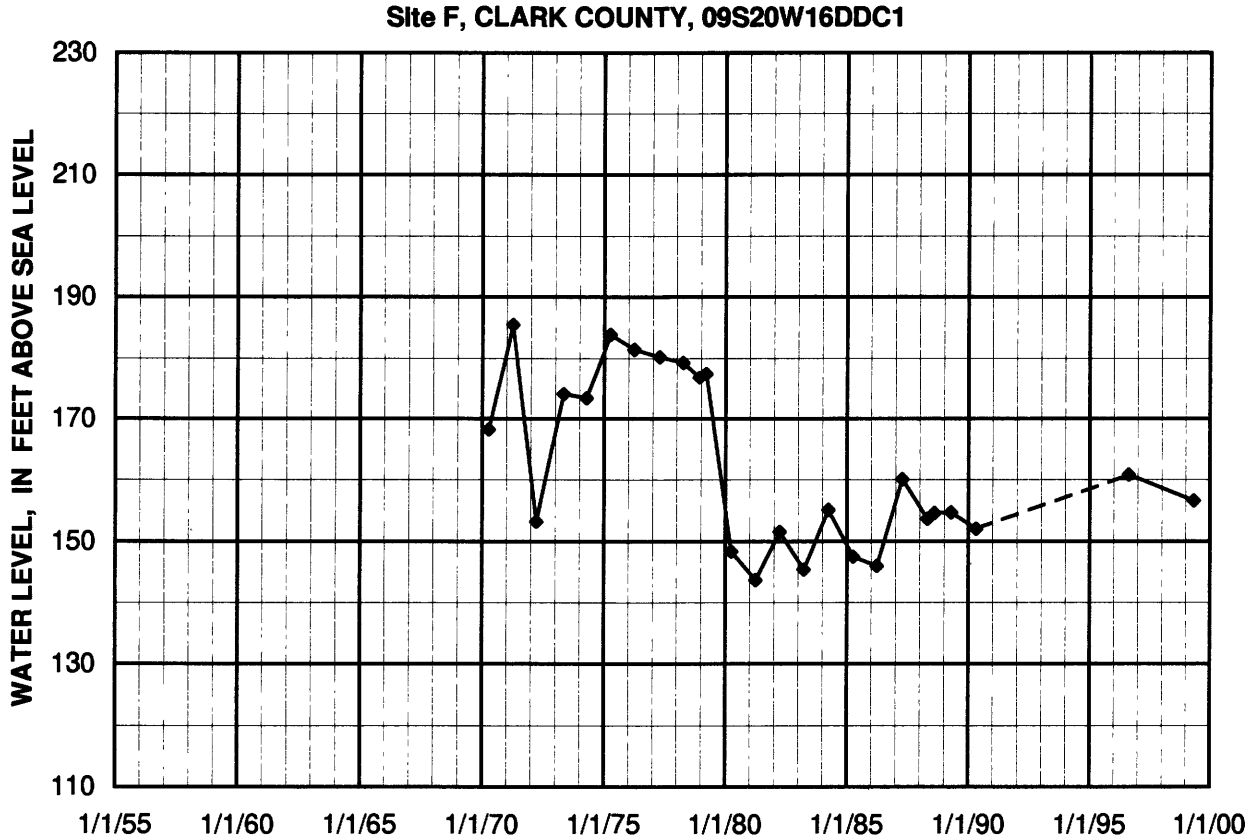
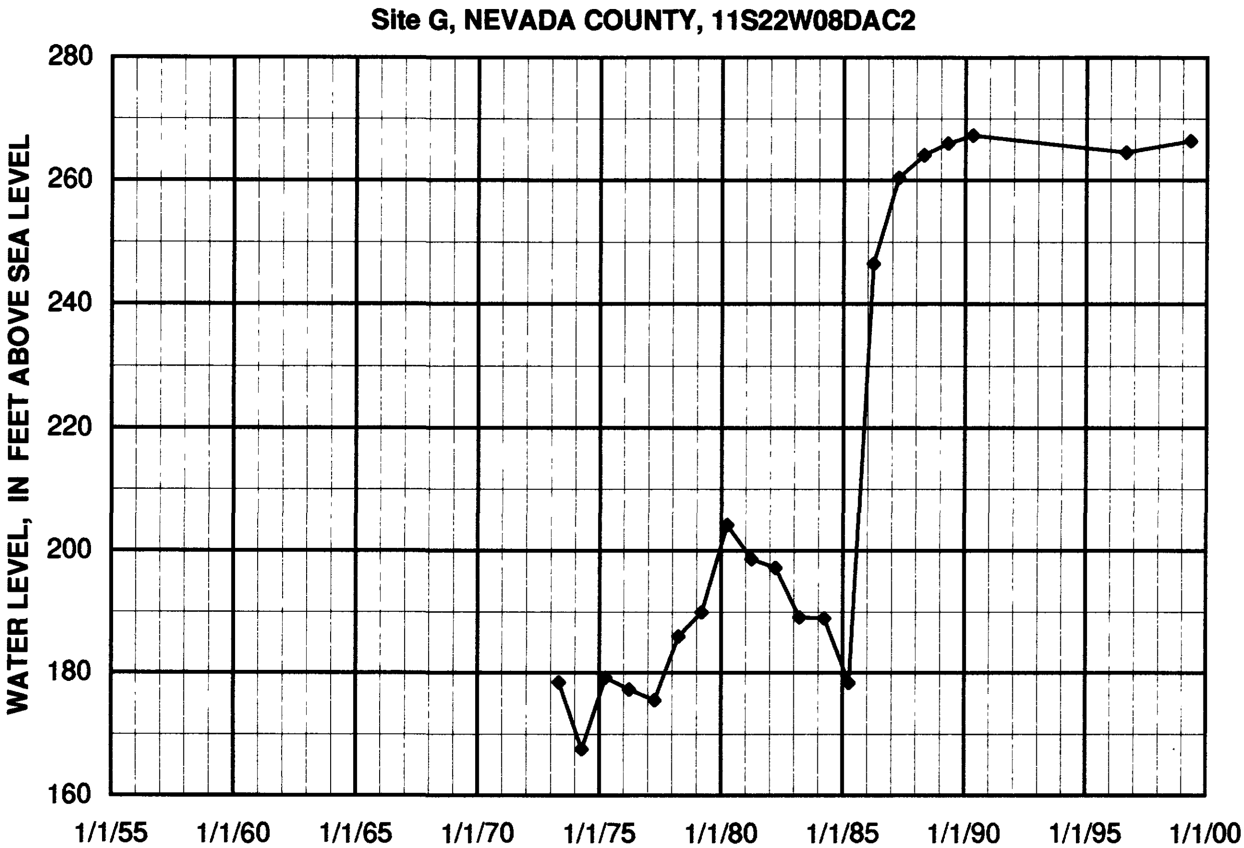


Figure 5. Water-level altitudes for selected wells completed in the Nacatoch aquifer—Continued.



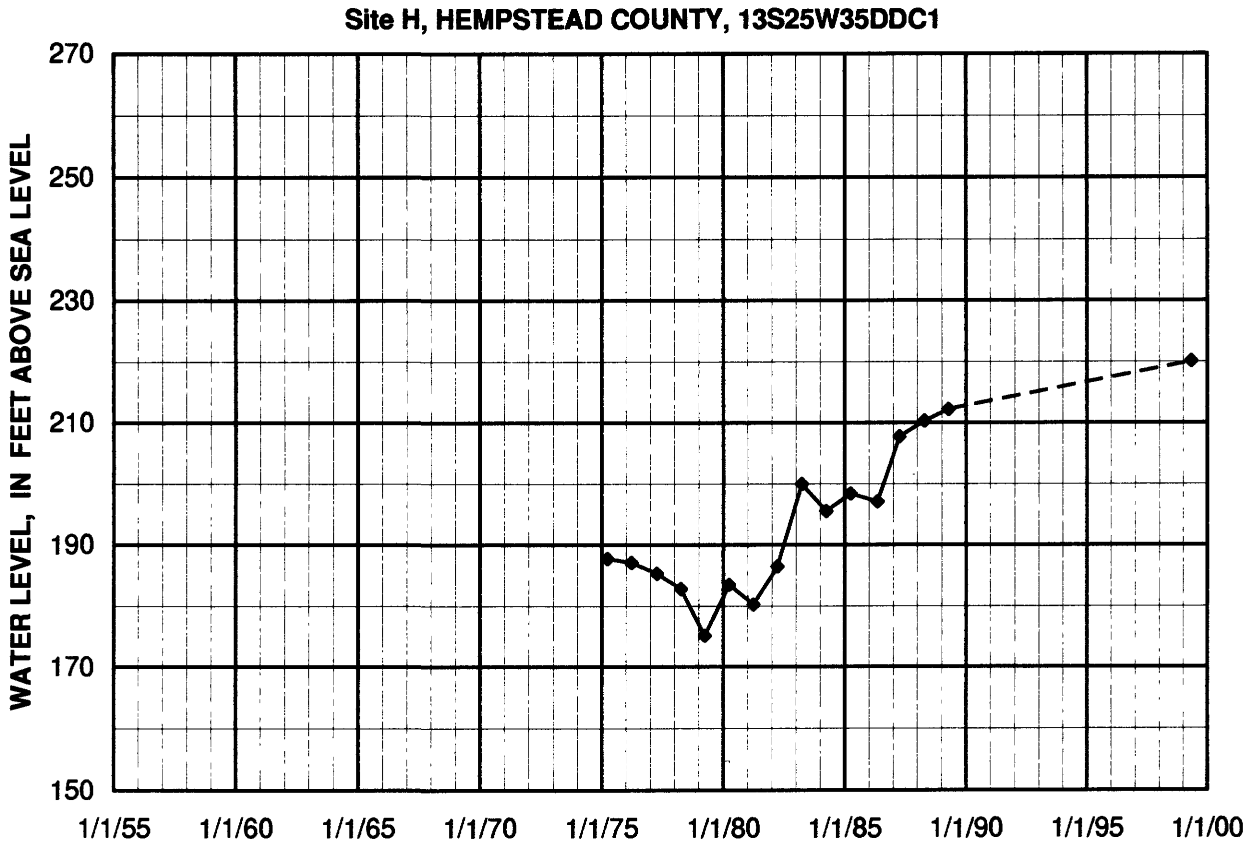


Figure 5. Water-level altitudes for selected wells completed in the Nacatoch aquifer—Continued.

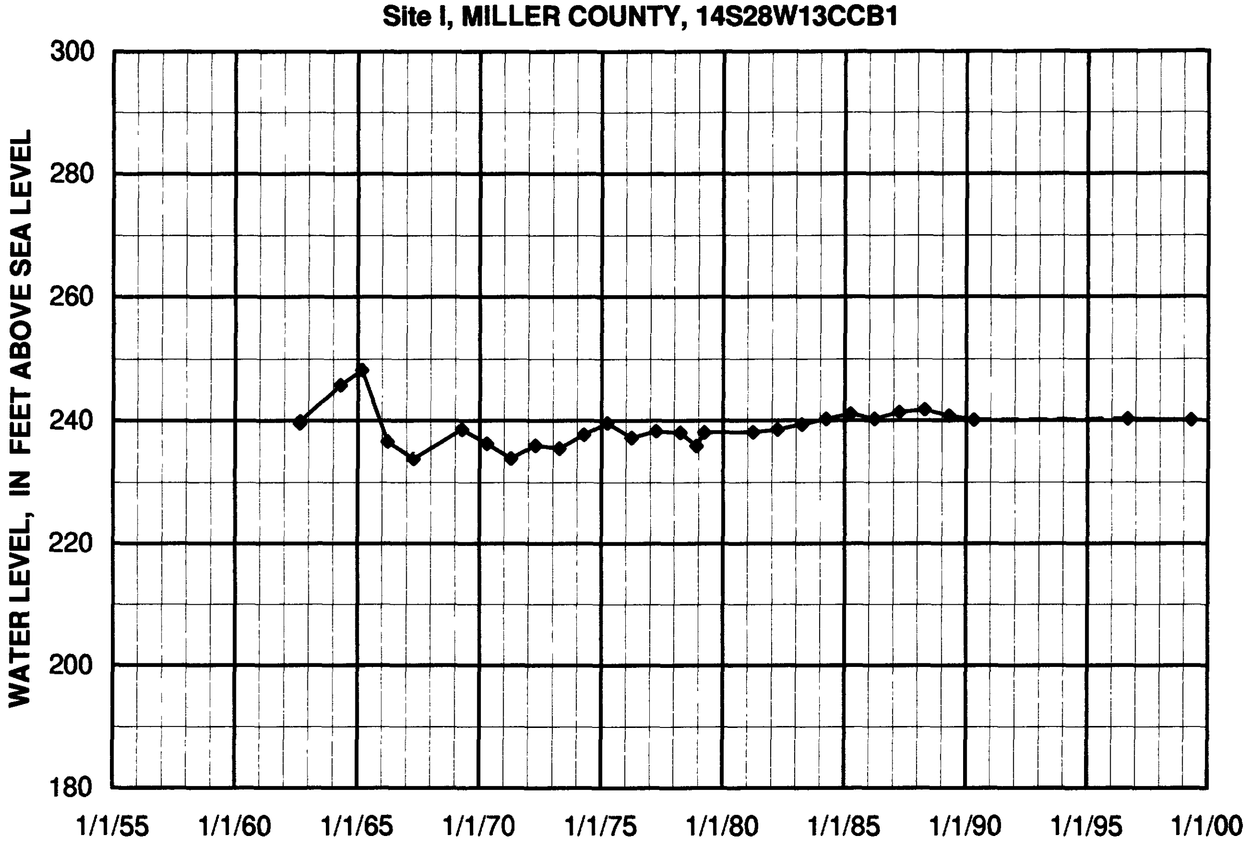


Figure 5. Water-level altitudes for selected wells completed in the Nacatoch aquifer—Continued.

Water levels in well 08S19W09ACC1 (site E, figs. 4 and 5) declined from about 186 ft above sea level in 1962 to about 178 ft in 1999, an average decline of about 0.2 ft/yr.

Water levels in well 09S20W16DDC1 (site F, figs.4 and 5), declined from about 184 ft above sea level in 1975 to about 144 ft in 1981, which is a decline of 6.7 ft/yr. Estimated withdrawal rates from the Nacatoch aquifer in Clark County increased from 0.64 Mgal/d in 1975 to 1.73 Mgal/d in 1980, an increase of 170 percent in withdrawals (table 2). From 1981 to 1996, a general rise in water level was observed during a general decrease in water use in Clark County.

Water levels in well 11S22W08DAC2 (site G, figs. 4 and 5), rose from about 179 ft above sea level in 1985 to about 267 ft in 1990, an average rise of about 17.6 ft/yr. the increase in water levels occurred when the estimated withdrawal rates from the Nacatoch aquifer in Nevada County decreased from 1.11 Mgal/d in 1985 to 0.44 Mgal/d in 1990; a decrease of about 60 percent (table 2).

Water levels in well 13S25W35DDC1 (site H, figs. 4 and 5), declined from 188 ft in 1975 to 175 ft in 1979. Estimated withdrawal rates from the Nacatoch aquifer in Hempstead County increased from 1.44 Mgal/d in 1975 to 1.98 Mgal/d in 1980, an increase of about 38 percent (table 2). From 1979 to 1999, a general rise in water level was observed. Estimated withdrawal rates from the Nacatoch aquifer in Hempstead County after 1980 fluctuated from 0.15 Mgal/d in 1985 to 0.32 Mgal/d in 1995.

Water levels in well 14S28W13CCB1 (site I, fig. 4 and 5) ranged from 248 ft above sea level to 234 ft from 1962 to 1999. The decline and rise in water levels in these wells may be associated with the increased and decreased withdrawals from the Nacatoch aquifer in Clark, Hempstead, and Nevada Counties.

Although water levels in these nine wells may be associated with changes in withdrawals, other factors also may affect water levels. Water levels may be affected by local factors such as pumpage changes, climatic variations, or changes in leakage to and from overlying and underlying rock units.

TOKIO FORMATION

Hydrogeologic Setting

The Tokio Formation of Cretaceous age underlies the Brownstown Marl and overlies consolidated rocks of Mississippian and Pennsylvanian age in Clark and northeastern Nevada Counties (Plebuch and Hines, 1969); the Trinity Group of Early Cretaceous age in Pike, Nevada, Miller, and most of Hempstead Counties (Petersen and others, 1985); and the Woodbine Formation of Late Cretaceous age in Little River, Sevier, Howard, and northwestern Hempstead Counties (Boswell and others, 1965). The Tokio Formation outcrops in a southwest-to-northeast trending mile-wide band in west-central Clark County (fig. 6). The outcrop attains a maximum width of about 10 mi in Howard County and continues southwest into Sevier County approximately 8 mi. In this area, the Tokio Formation is overlain in several places by terrace deposits of Quaternary alluvium. The unit also outcrops in northwestern Little River County, west of the study area. The unit ranges in thickness from about 50 ft to more than 300 ft, dips towards the southeast, and is composed of discontinuous, interbedded gray clay and poorly sorted, cross-bedded quartz sands, lignite, and a prevalent basal gravel (Counts and others, 1955; Boswell and others, 1965; Plebuch and Hines, 1969; Petersen and others; 1985). The Tokio Formation does not occur in the northeastern subarea.

The Tokio aquifer receives recharge from precipitation where it outcrops or is overlain by permeable alluvial and terrace deposits. Salinity increases downdip to the south-southeast. The aquifer yields freshwater to within a few miles north of Ashdown in Little River County (fig. 6). The water in the Tokio aquifer becomes slightly to moderately saline downdip (southeast) from near Prescott to the fault zone trending across Nevada County. Except in its outcrop area, water in the Tokio aquifer is under artesian conditions (Petersen and others, 1985).

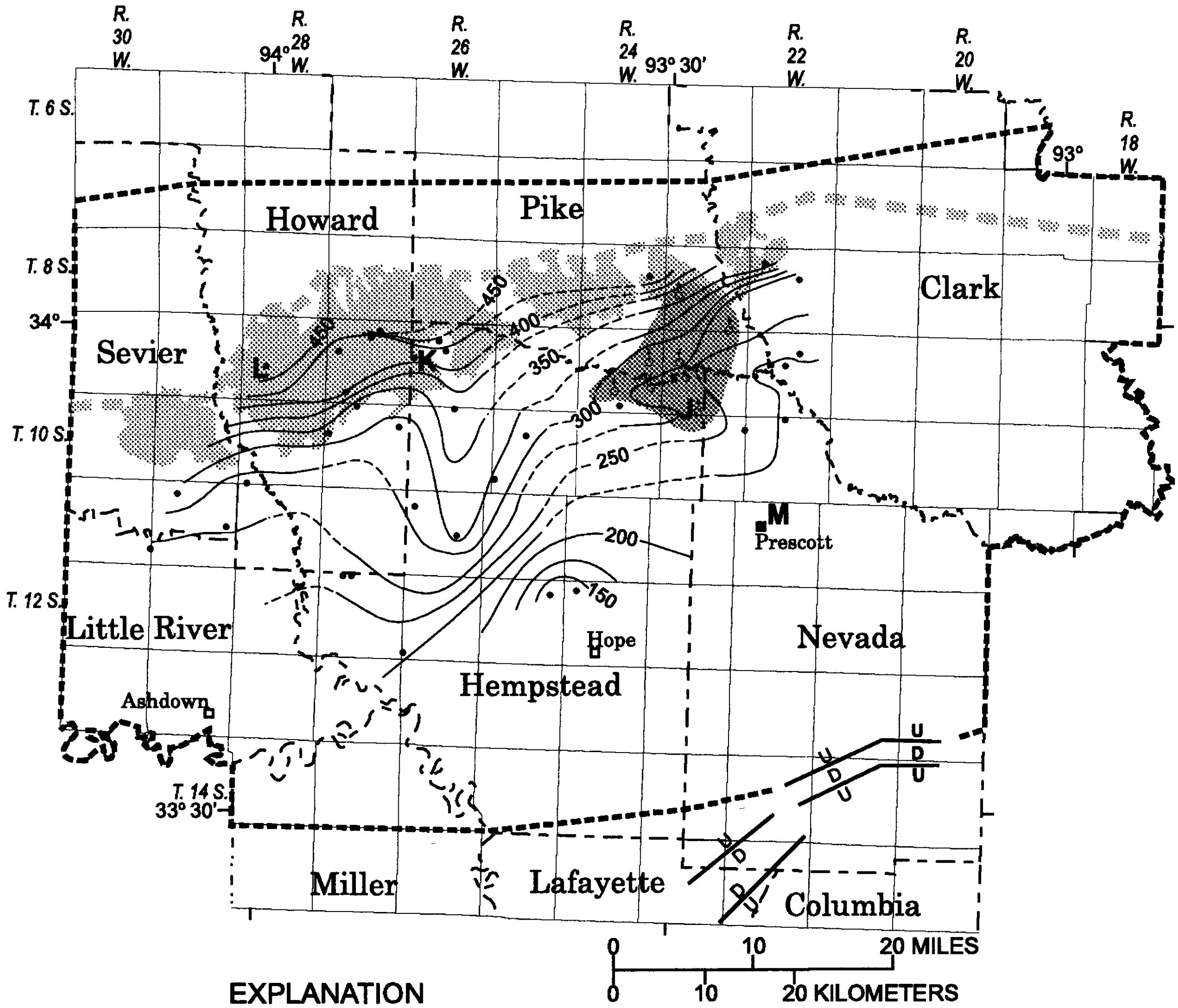
The Tokio aquifer yields potable water to wells in eastern Little River County, southeastern Sevier County, southern Howard and Pike Counties, western Clark County, northern and central Hempstead County, and northwestern Nevada County. Wells penetrating the aquifer range in depth from a few feet in the outcrop area to about 1,200 ft at Hope and Prescott (Ludwig, 1972). Wells in central Hempstead County yield up to 300 gal/min. Wells flowing as much as 90 gal/min occur in the bottom-land areas adjacent to streams (Counts and others, 1955). Historic records indicate that water levels in the aquifer did not decline appreciably from 1950 to 1968, and that water levels have not been greatly affected by withdrawal of water at Hope and Prescott (Ludwig, 1972). Estimates of water withdrawn from the Tokio aquifer increased by 201 percent from 2.0 Mgal/d in 1965 to 6.02 Mgal/d in 1980. Water withdrawn from the Tokio aquifer was estimated to be 2.23 Mgal/d in 1995, a decrease of 63 percent from 1980 (Halberg and Stephens, 1966; Holland and Ludwig, 1981; Holland, 1999).

Potentiometric Surface

The potentiometric surface for the Tokio aquifer shows the altitude that water would have stood in tightly cased wells screened in the aquifer (fig. 6). Water-level measurements in 45 wells from April and May 1999 were used to construct the map (table 3). The surface is mapped by determining the altitude of the water levels and is represented on the map by contours that connect points of equal value. The general direction of ground-water flow is perpendicular to the contours in the direction of downward hydraulic gradient.

In the study area, the direction of ground-water flow in the Tokio aquifer generally is towards the south or southeast. The potentiometric high is within the outcrop area in the northwestern part of the study area. The highest water-level altitude measured was about 493 ft above sea level in Howard County. The lowest water-level altitude measured was about 133 ft above sea level, about 5 mi northwest of Hope in Hempstead County. An area of artesian flow exists in southeastern Pike, northeastern Hempstead, and northwestern Nevada Counties, as evidenced by eight flowing wells.

A cone of depression may exist about 5 miles northwest of Hope. The northern half of an apparent cone of depression northwest of Hope is shown on figure 6. Water level data in the Tokio aquifer were not available south of this area. No other cones of depression were evident in the Tokio aquifer. A comparison with the 1996 potentiometric surface map for the Tokio aquifer shows no substantial changes over large areas (Schrader, 1998).



EXPLANATION

OUTCROP OF TOKIO FORMATION

APPROXIMATE AREA OF ARTESIAN FLOW

BOUNDARY OF STUDY AREA

APPROXIMATE NORTHERN LIMIT OF TOKIO FORMATION

U/D FAULT--U, Upthrown side; D, Downthrown side

—200 – – POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Contour interval 25 feet. Datum is sea level

M. CONTROL POINT--Letter, where present, corresponds to hydrograph in figure 6

FLOWING WELL

Figure 6. Potentiometric surface of the Tokio aquifer, southwestern Arkansas, April-May 1999.

Table 3. Water-level measurements and well information for wells completed in the Tokio aquifer

Local well number	Latitude	Longitude	Water level altitude (feet above sea level)	Depth to water level (feet below land-surface datum)	Land-surface altitude (feet above sea level)	Well depth (feet)	Date of measurement
			Clark County				
08S22W08BBB1	340414.39	932251.93	354	31.04	385	106	4/29/99
08S22W15ABB2	340312.77	932017.91	267	57.54	325	145	4/29/99
09S22W10DBA1	335831.65	932021.45	232	129.81	362	500	4/29/99
09S22W16ACA1	335753.53	932120.02	220	12.84	233	450	4/29/99
			Hempstead County				
09S23W20BDA1	335710	932858	251	-1.2	250	210	4/21/99
09S23W33CDA1	335457.24	932802.43	271	-0.9	270	467	5/03/99
09S24W25BBB1	335633.39	933131.90	269	-0.5	268	270	5/03/99
09S24W28ACC1	335617.26	933414.51	279	-2.1	277	200	5/03/99
09S24W33ADC1	335526.07	933355.97	285	44.04	329	335	5/03/99
09S26W08ADA2	335919.86	934716.71	436	1.89	438	25	4/29/99
09S26W08ADD1	335917.85	934716.84	437	0.49	437	25	4/29/99
09S26W09CDC1	335845.81	934656.00	422	3.38	425	16	4/29/99
09S26W18CBB1	335815.46	934920.92	405	20.32	425	30	4/29/99
10S25W09CDB1	335328.56	934051.57	305	69.62	375	327	4/30/99
10S25W30CCD1	335047.51	934310.18	324	64.19	388	500	4/22/99
10S26W03BBA1	335506.74	934611.68	366	1.11	367	162	4/29/99
11S26W08BBB1	334909.23	934903.22	305	66.92	372	550	4/29/99
11S26W23BBB1	334719.87	934601.93	328	91.28	419	820	4/28/99
12S24W06DAD1	334359.68	933701.28	133	221.8	355	1,140	5/05/99
12S25W02DDD1	334341.13	933901.80	138	228.78	367	1,159	5/05/99
12S27W04BBC1	334449.54	935357.50	265	169.52	435	870	4/28/99
12S27W05AAC1	334448.86	935421.32	264	170.76	435	906	4/28/99
12S27W36DBC1	333959.72	935006.34	233	28.35	261	1,156	4/28/99
			Howard County				
09S27W03DBD1	340000	935152	493	68.89	562	220	4/22/99
09S27W10BCB1	335930	935231	423	110.64	534	195	4/22/99
09S27W18ADB1	335840	935452	416	75.85	492	200	4/22/99
09S27W32BDB1	335606	935423	400	52.2	452	150	4/23/99
09S27W32BDB2	335606	935423	400	49.92	450	61	4/23/99
09S28W20DAC1	335740	940013	468	12.3	480	27	4/22/99

Table 3. Water-level measurements and well information for wells completed in the Tokio aquifer--Continued

Local well number	Latitude	Longitude	Water level altitude (feet above sea level)	Depth to water level (feet below land-surface datum)	Land-surface altitude (feet above sea level)	Well depth (feet)	Date of measurement
10S27W04BBD1	335512	935329	341	50.97	392	170	4/23/99
10S27W12CAB1	335356	935020	311	72.14	383	416	4/23/99
10S27W18BAC1	335336	935534	341	81.29	422	300	4/23/99
			Little River County				
11S30W25DDC1	334618.44	940852.31	266	18.98	285	380	4/29/99
			Nevada County				
09S22W33DCC1	335437.37	932130.47	220	4.57	225	677	4/23/99
10S23W12AAA1	335344.81	932420.89	236	19.78	256	600	4/23/99
11S22W08DAC1	334757.94	932315.14	218	87.49	305	1,052	4/26/99
11S22W08DAC8	334756.76	932311.82	218	86.67	305	1,050	4/26/99
			Pike County				
08S23W19ADC1	340213	932930	351	-1.3	350	105	4/21/99
08S23W35DCA1	340004	932530	259	-1.5	257	125	4/21/99
08S24W14AAC1	340324	933134	439	84.11	523	185	4/21/99
09S23W17BBC2	335804	932924	283	-2.85	280	200	4/21/99
09S24W14AAD1	335810	933138	287	-1.6	285	140	4/21/99
			Sevier County				
10S28W31DCC1	335026.12	940145.37	290	39.55	330	185	4/21/99
11S29W05DCA1	334949.30	940652.64	321	159.07	480	400	4/22/99
11S29W13CCD1	334750.48	940317.44	280	80.27	360	339	4/21/99

Long-Term Water-Level Changes

Four hydrographs from wells completed in the Tokio aquifer display long-term (minimum of 20 years) water-level altitudes (fig. 7). Two wells are located in Hempstead County (sites J and K) and the other two wells are located in Howard (site L) and Nevada (site M) Counties (fig. 6).

The two hydrographs in Hempstead County show differences between water-level trends over long periods. In well 09S23W33CDA1 (site J, figs. 6 and 7), water levels generally declined from 1957 to 1999. Water levels in well 09S26W18CBB1 (site K, figs. 6 and 7), fluctuated through a range of about 399 to about 414 ft above sea level over a 43-year period. There does not appear to be an association between water levels in these two wells and estimated withdrawals from the Tokio aquifer for Hempstead County (table 4).

In Howard County, water levels in well 09S28W20DAC1 (site L, figs. 6 and 7) range from about 476 ft to about 464 ft above sea level over a 43-year period from 1957 to 1999. No significant rises or declines in water levels were observed. There does not appear to be any association between water levels in this well and estimated withdrawals from the Tokio aquifer for Howard County (table 4).

In Nevada County, water levels in well 11S22W08DAC1 (site M, figs. 6 and 7) declined from about 211 feet above sea level in 1972 to about 150 ft in 1985, with a minimum of 135 ft in 1981. This decline averages approximately 4.7 ft/yr. Estimated withdrawal rates from the Tokio aquifer for Nevada County increased from 0.45 Mgal/d in 1970 to 0.68 Mgal/d in 1980, an increase of 51 percent (table 4). From 1985 to 1987, a rise in water level to about 225 ft was observed, which is approximately a 37.5 ft/yr rise. Water withdrawal rates from the Tokio aquifer for Nevada County are estimated to have decreased to zero by 1985. The decline and rise in water levels may be associated with the increased and decreased withdrawals from the Tokio aquifer in Nevada County.

Although water levels in these four wells may be associated with changes in withdrawals, other factors also may affect water levels. Water levels may be affected by local factors such as pumpage changes, climatic variations, or changes in leakage to and from overlying and underlying rock units.

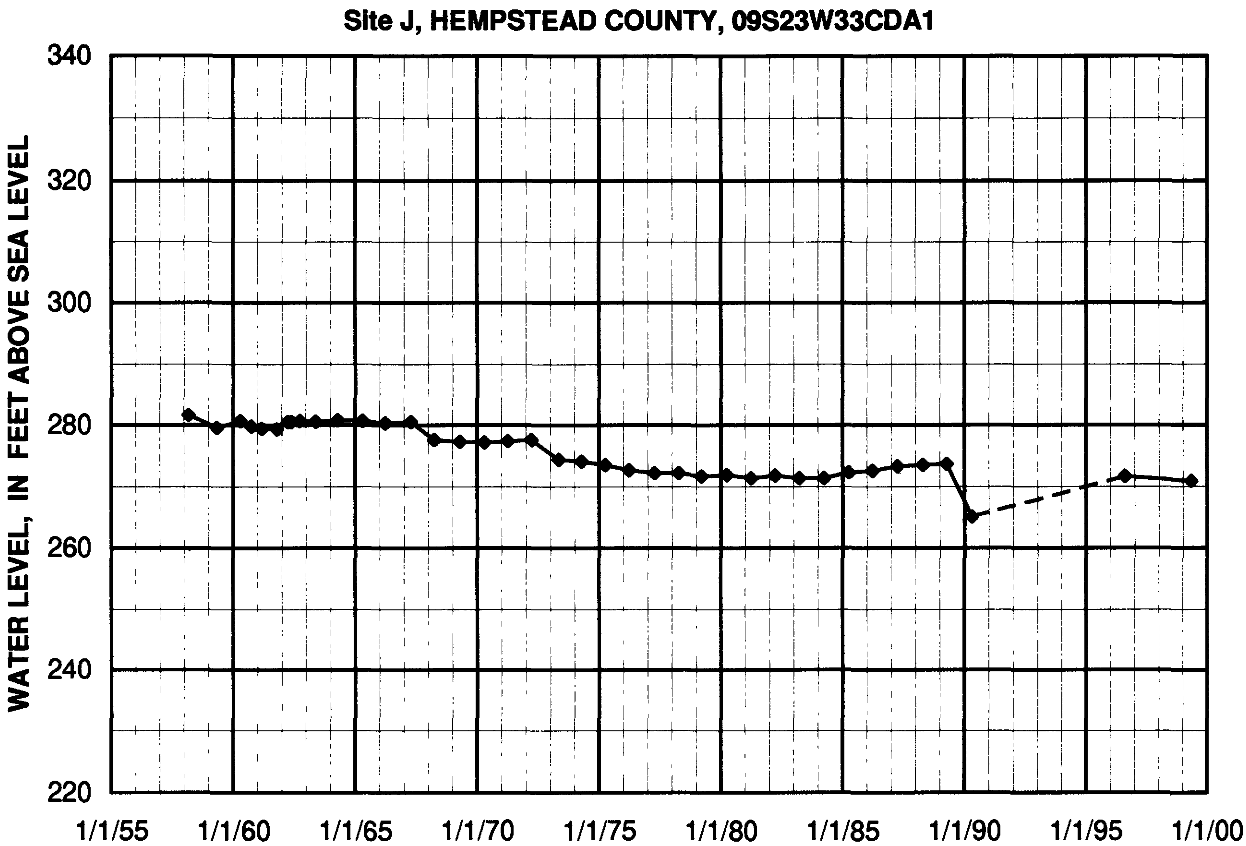
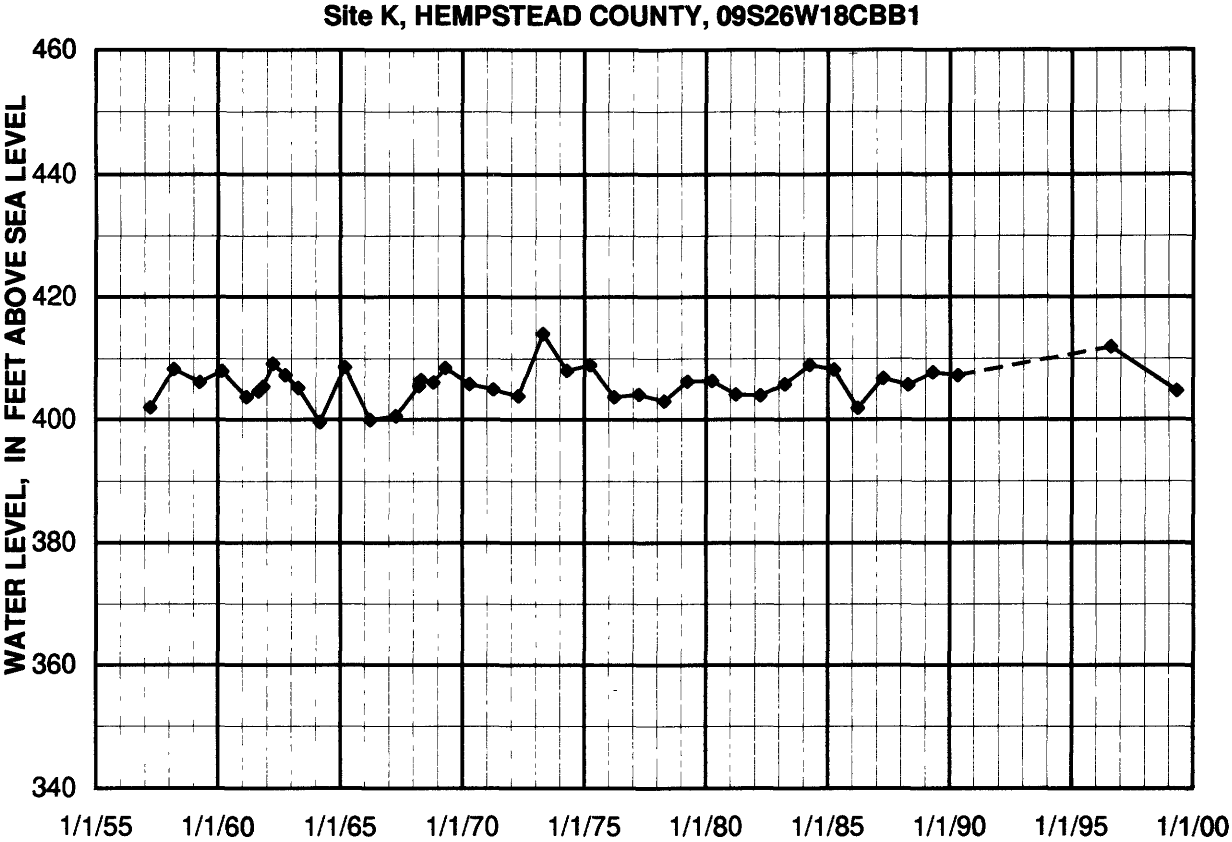


Figure 7. Water-level altitudes for selected wells completed in the Tokio aquifer.



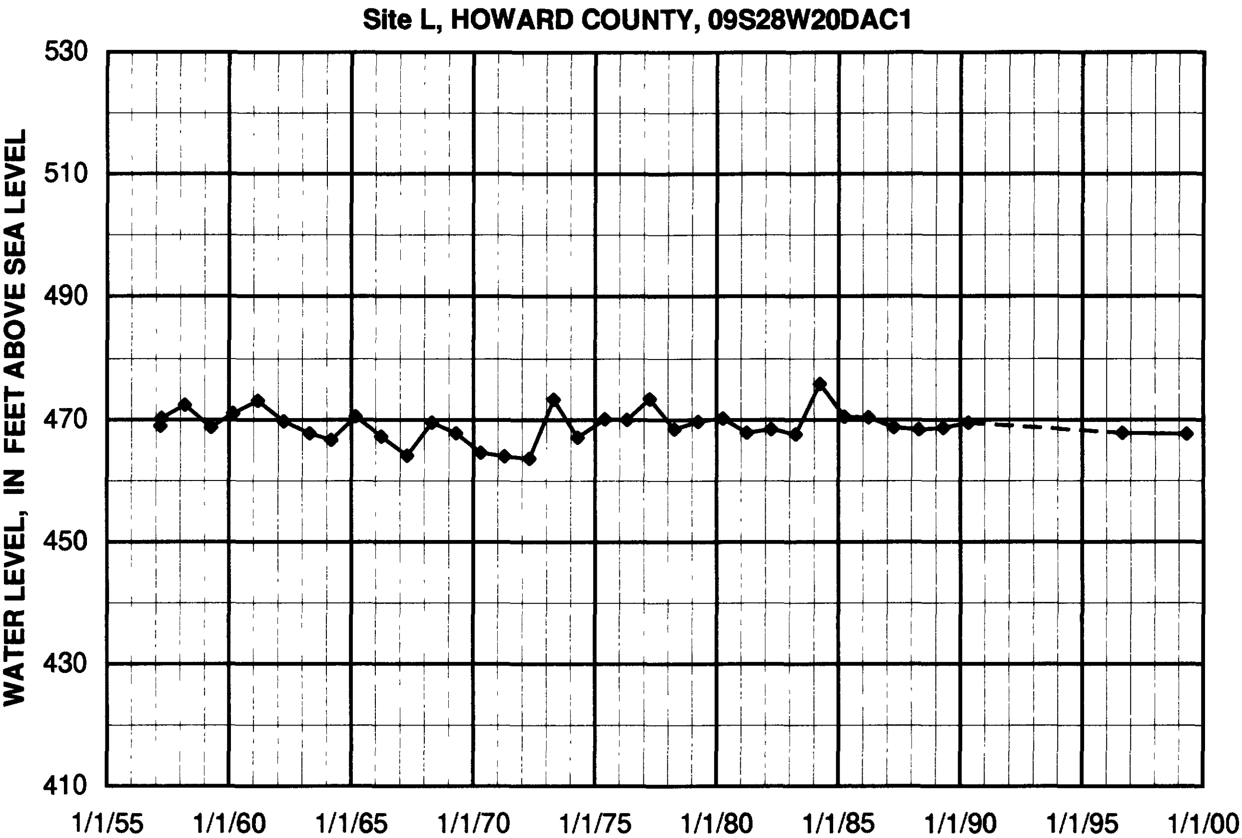


Figure 7. Water-level altitudes for selected wells completed in the Tokio aquifer—Continued.

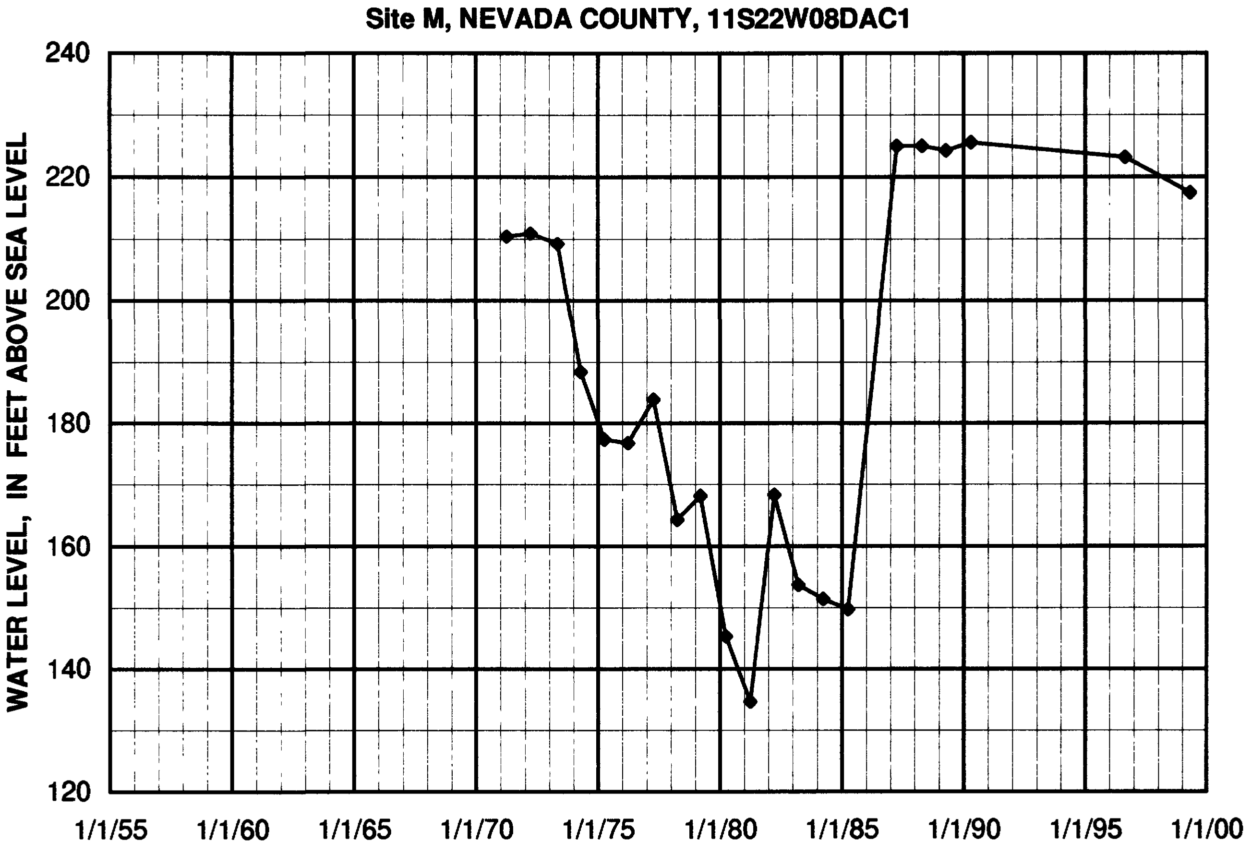


Figure 7. Water-level altitudes for selected wells completed in the Tokio aquifer—Continued.

Table 4. Estimated withdrawal rates by county from the Tokio aquifer

[Units are million gallons per day. Data from Holland, 1999; Holland, 1993; Holland, 1987; Holland and Ludwig, 1981; Halberg, 1977; Halberg, 1972; Halberg and Stephens, 1966]

	Estimated withdrawal rate						
County	1965	1970	1975	1980	1985	1990	1995
Clark	0.00	0.00	0.02	0.06	0.04	0.01	0.01
Hempstead	0.67	0.68	2.15	3.00	2.86	1.10	1.66
Howard	0.69	0.62	0.97	1.11	0.14	0.00	0.00
Little River	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Miller	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nevada	0.37	0.45	0.55	0.68	0.00	0.00	0.00
Pike	0.12	0.41	0.43	0.82	0.06	0.03	0.02
Sevier	0.15	0.17	0.25	0.35	0.79	1.15	0.54
Total	2.00	2.33	4.37	6.02	3.89	2.29	2.23

SUMMARY

Aquifers in the Nacatoch Sand and Tokio Formation in southwestern Arkansas and the Nacatoch Sand in northeastern Arkansas are a source of water for industrial, public supply, domestic, and agricultural uses. Potentiometric-surface maps were constructed from water-level measurements made in 59 wells completed in the Nacatoch Sand and 45 wells completed in the Tokio Formation from April through May 1999. In northeastern Arkansas, withdrawals from the Nacatoch Sand increased by 736 percent from 1965 to 1995. In southwestern Arkansas, withdrawals from aquifers in the Nacatoch Sand and Tokio Formation increased by 125 percent and 201 percent, respectively, from 1965 to 1980 and decreased by 78 percent and 63 percent, respectively, from 1980 to 1995.

The direction of ground-water flow in the northeastern subarea of the Nacatoch aquifer generally is towards the southeast. The potentiometric high is located along the north and northwestern boundary of this subarea. The potentiometric low is located in eastern Clay County.

The direction of ground-water flow in the southwestern subarea of the Nacatoch aquifer is towards the south-southeast in Little River, Miller, and Hempstead Counties and to the east-southeast in Nevada and Clark Counties. The potentiometric high is located in the outcrop area in north-central Hempstead County. A cone of depression exists at Hope in Hempstead County. No other cones of depression were evident in the Nacatoch aquifer.

In the northeastern subarea of the Nacatoch aquifer, water levels in four wells declined during a period of increased withdrawals from the Nacatoch aquifer. Water withdrawn from the Nacatoch aquifer was estimated to be 0.25 Mgal/d in 1965 and increased to 2.09 Mgal/d in 1995, an increase of 736 percent during a 30-year period.

In the southwestern subarea of the Nacatoch aquifer, water levels in four of five wells rose during a period of decreased withdrawal from the Nacatoch aquifer. Water withdrawn from the Nacatoch aquifer was estimated to be 1.02 Mgal/d in 1995, a decrease of 78 percent from 4.75 Mgal/d in 1980. The hydrograph for site E shows no apparent association between water-level changes in a well completed in the Nacatoch aquifer and withdrawals. The variation in water levels in this well could result from differences in localized withdrawals, climatic variations, or leakage of water from overlying and underlying rock units.

The direction of ground-water flow in the Tokio aquifer is towards the southeast. The potentiometric high is located where the aquifer outcrops in the northwestern part of the study area. An area of artesian flow exists in southeastern Pike, northeastern Hempstead, and northwestern Nevada Counties. One apparent cone of depression might exist northwest of Hope in Hempstead County.

The hydrographs of one of four wells completed in the Tokio aquifer showed a decline and a rise in water levels during a period of increased, then decreased withdrawals from the aquifer in Nevada County. Estimates of water withdrawn from the Tokio aquifer increased from 2.0 Mgal/d in 1965 to 6.02 Mgal/d in 1980. Water withdrawn from the Tokio aquifer was estimated to be 2.23 Mgal/d in 1995, a decrease of 63 percent from 1980. Three hydrographs show no apparent association between water-level changes in wells completed in the Tokio aquifer and withdrawals. The variation in water levels in these wells could result from differences in localized withdrawals, climatic variations, or leakage of water from overlying and underlying rock units.

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