USGS
science for a changing world

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

Prepared in cooperation with the
Air Force Civil Engineer Center, San Antonio, Texas

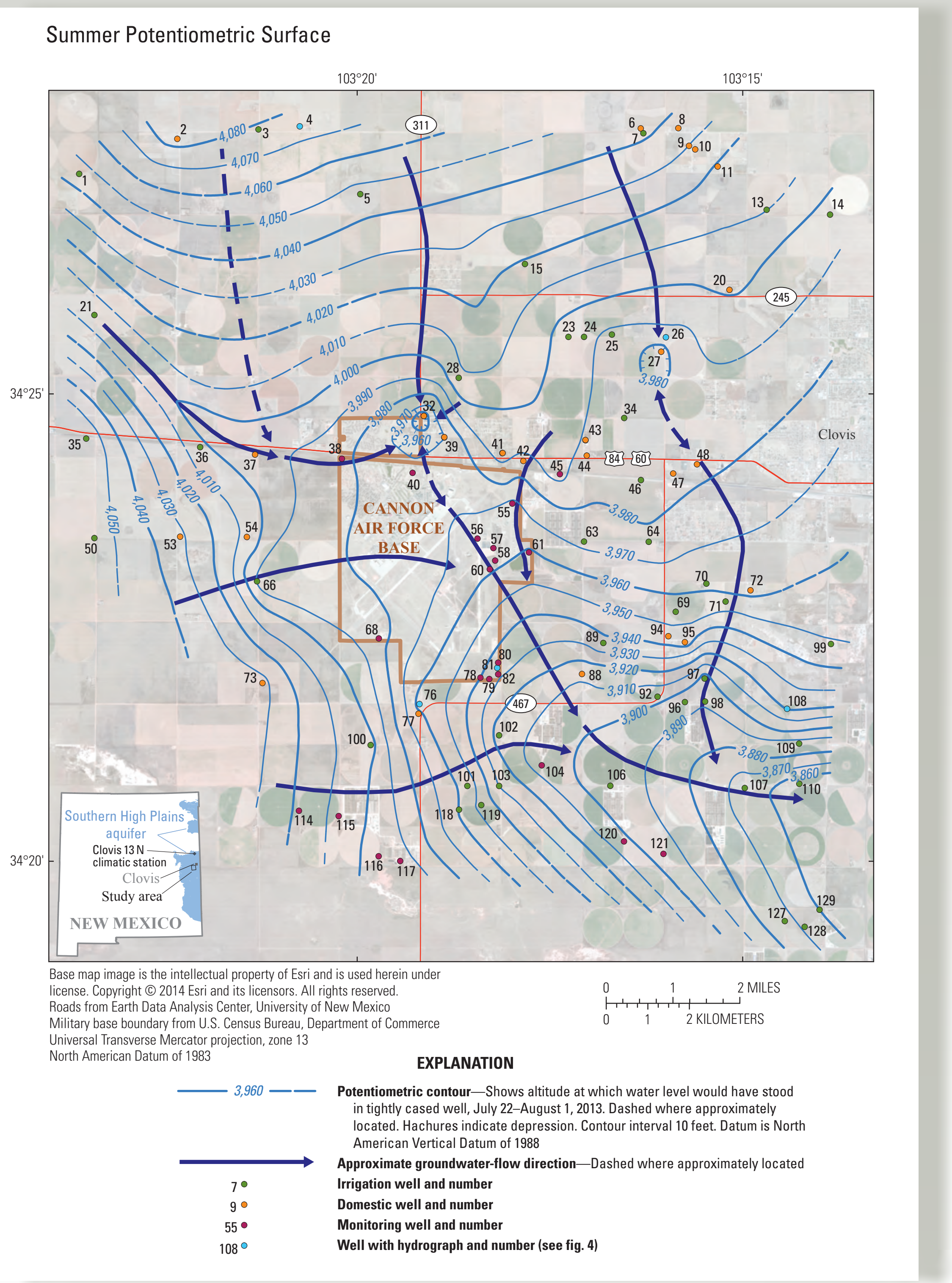
Scientific Investigations Map 3352
Sheet 1

Introduction

Cannon Air Force Base (Cannon AFB) is located in the High Plains physiographic region of east-central New Mexico (Miller, 2000), about 5 miles west of Clovis, N. Mex. Cannon AFB was originally established as a U.S. Army base in 1942 and then reactivated as the current Air Force base in 1951 following the U.S. Army base closure in 1947. The area surrounding Cannon AFB is primarily used for agriculture, including irrigated cropland and dairies. The Southern High Plains aquifer is the principal source of water for Cannon AFB, for the nearby town of Clovis, and for local agriculture and dairies (EPCOR Water, 2014). The Southern High Plains aquifer in the vicinity of Cannon AFB consists of three subsurface geological formations: the Chinle Formation of Triassic age, the Ogallala Formation of Tertiary age, and the Blackwater Draw Formation of Quaternary age (Langman and others, 2006). The Chinle Formation, 0–400 feet (ft) thick and locally known as the “red beds,” consists mostly of clay with some interbedded sand and silt in this area and forms the bottom of the unconfined Southern High Plains aquifer (Langman and others, 2006). The Ogallala Formation, 30–600 ft thick (Gustavson, 1996), is the main water-yielding formation of the Southern High Plains aquifer and consists of eolian sand and silt and fluvial and lacustrine sand, silt, clay, and gravel (McLemore, 2001). The Blackwater Draw Formation, 0–80 ft thick, overlies the Ogallala Formation and consists mainly of eolian sand (McLemore, 2001; Langman and others, 2006). Groundwater-supplied, center-pivot irrigation (the circular features on figs. 1 and 2) dominates pumping from the Southern High Plains aquifer in the area surrounding Cannon AFB, where the irrigation season typically extends from early March through October (Marsalis, 2007; oral commun. with local farmers). The U.S. Geological Survey (USGS) has a long history of groundwater hydrology and water-quality work on and surrounding Cannon AFB, with the most recent publications, Langman and others (2004) and Langman and others (2006), covering a period of study from 1994 to 2005. In addition, the USGS has been monitoring groundwater levels in the vicinity of Cannon AFB since 1954.

Langman and others (2006) reported that groundwater levels have declined in the Cannon AFB and surrounding area and noted that summer water-level declines were followed by partial recovery during the winter. Prior to this study, the most recent potentiometric-surface map in the study area was developed by Langman and others (2006) by using groundwater levels measured during the winter of 1997. The 1997 potentiometric-surface map was developed by using data from approximately 27 wells located on Cannon AFB and in the surrounding area within about 3 miles of the boundary of the base. The 1997 potentiometric-surface map indicated a general northwest to southeast groundwater-flow direction, consistent with potentiometric-surface maps for groundwater conditions observed in 1962, 1967, 1977, and 1987 (Langman and others, 2006). In addition to the general northwest to southeast groundwater-flow direction observed in all these periods, a groundwater trough running diagonally from the northwest to the southeast becomes successively more distinct throughout the 1962–97 series of potentiometric-surface maps as the regional groundwater level declines (see fig. 3 in Langman and others, 2006).

The potentiometric-surface maps developed by Langman and others (2006) are useful in determining the regional direction of groundwater flow; however, the sparse number and distribution of wells used to create these potentiometric-surface maps (approximately one well every 3 square miles) resulted in maps that are too general for determining detailed groundwater-flow directions on a local scale. The USGS in cooperation with the Air Force Civil Engineering Center, San Antonio, Texas, investigated the possible effects of seasonal groundwater-use differences (summer and winter) on groundwater-flow directions in the vicinity of Cannon AFB. To determine more local groundwater-flow directions, data from a dense well network in this study area were needed. In addition, because only groundwater levels measured during winter periods were used in the development of the Langman and others (2006) potentiometric-surface maps, an increased understanding of the effect of summer groundwater levels on the groundwater-flow directions was also needed.



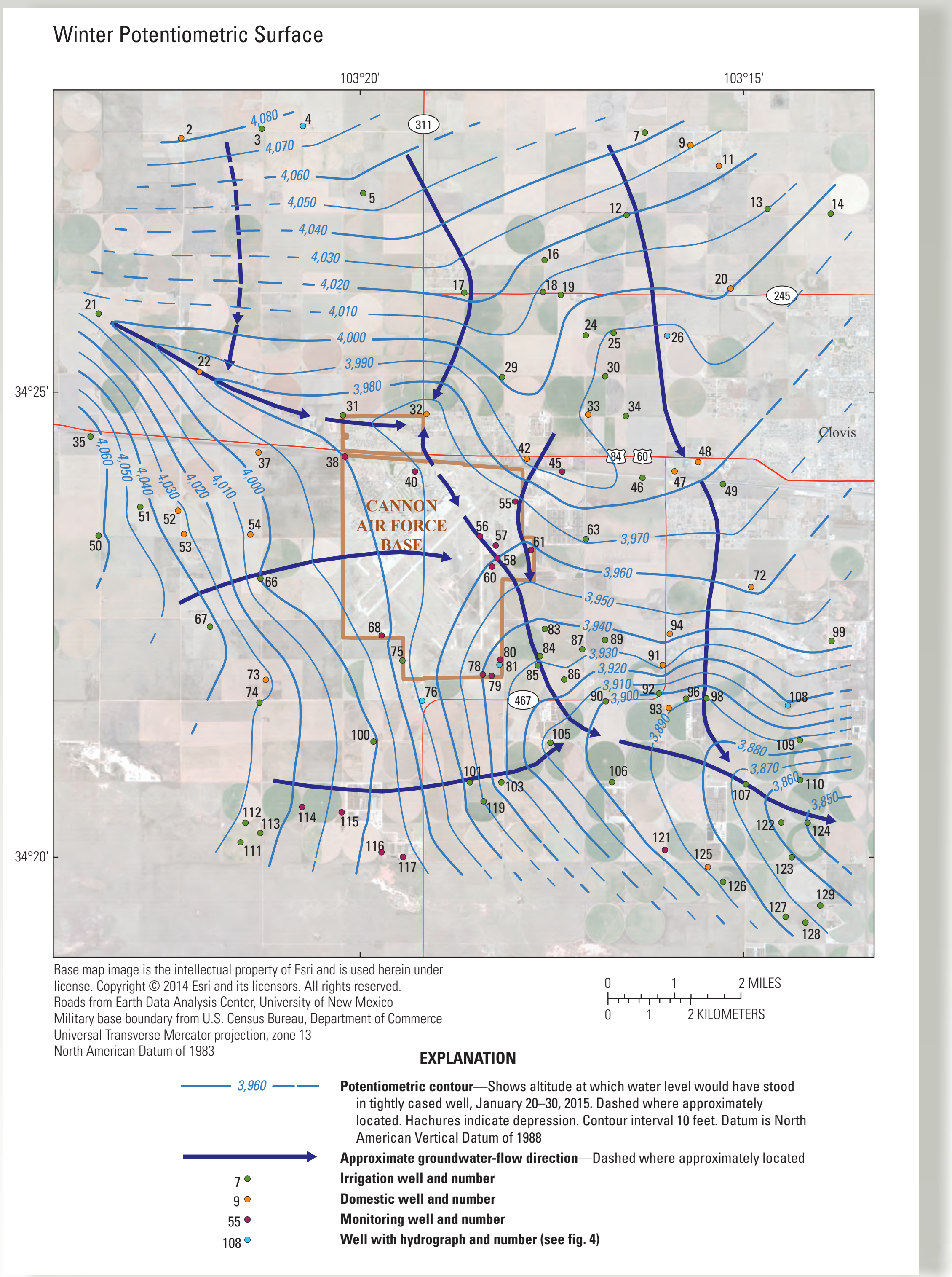
Summer Potentiometric Surface

Base map image is the intellectual property of Esri and is used herein under license. Copyright © 2014 Esri and its licensors. All rights reserved.
Roads from Earth Data Analysis Center, University of New Mexico
Military base boundary from U.S. Census Bureau, Department of Commerce
Universal Transverse Mercator projection, zone 13
North American Datum of 1983

EXPLANATION

3,960	**Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased well, July 22–August 1, 2013. Dashed where approximately located. Hachures indicate depression. Contour interval 10 feet. Datum is North American Vertical Datum of 1988
→	**Approximate groundwater-flow direction**—Dashed where approximately located
7 ●	**Irrigation well and number**
9 ●	**Domestic well and number**
55 ●	**Monitoring well and number**
108 ●	**Well with hydrograph and number (see fig. 4)**

Figure 1. Potentiometric surface of summer groundwater conditions on and around Cannon Air Force Base, July 22–August 1, 2013, Curry County, New Mexico. Data shown in table 1.



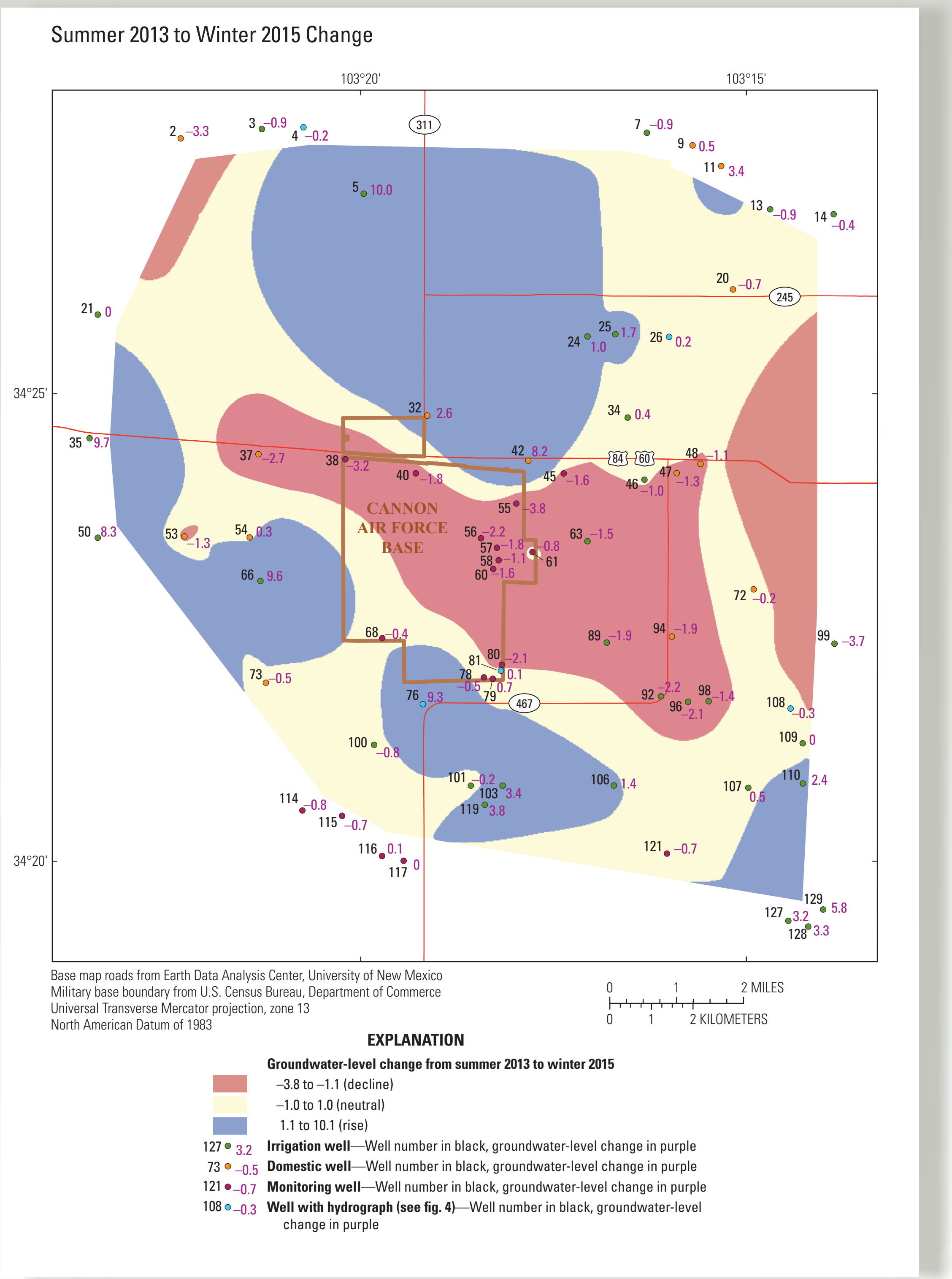
Winter Potentiometric Surface

Base map image is the intellectual property of Esri and is used herein under license. Copyright © 2014 Esri and its licensors. All rights reserved.
Roads from Earth Data Analysis Center, University of New Mexico
Military base boundary from U.S. Census Bureau, Department of Commerce
Universal Transverse Mercator projection, zone 13
North American Datum of 1983

EXPLANATION

3,960	**Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased well, January 20–30, 2015. Dashed where approximately located. Hachures indicate depression. Contour interval 10 feet. Datum is North American Vertical Datum of 1988
→	**Approximate groundwater-flow direction**—Dashed where approximately located
7 ●	**Irrigation well and number**
9 ●	**Domestic well and number**
55 ●	**Monitoring well and number**
108 ●	**Well with hydrograph and number (see fig. 4)**

Figure 2. Potentiometric surface of winter groundwater conditions on and around Cannon Air Force Base, January 20–30, 2015, Curry County, New Mexico. Data shown in table 1.



Summer 2013 to Winter 2015 Change

Base map roads from Earth Data Analysis Center, University of New Mexico
Military base boundary from U.S. Census Bureau, Department of Commerce
Universal Transverse Mercator projection, zone 13
North American Datum of 1983

EXPLANATION

Groundwater-level change from summer 2013 to winter 2015

🟥	–3.8 to –1.1 (decline)
🟨	–1.0 to 1.0 (neutral)
🟦	1.1 to 10.1 (rise)
127 ● 3.2	**Irrigation well**—Well number in black, groundwater-level change in purple
73 ● –0.5	**Domestic well**—Well number in black, groundwater-level change in purple
121 ● –0.7	**Monitoring well**—Well number in black, groundwater-level change in purple
108 ● –0.3	**Well with hydrograph (see fig. 4)**—Well number in black, groundwater-level change in purple

Figure 3. Map of groundwater-level change between summer 2013 (July 22–August 1) and winter 2015 (January 20–30) on and around Cannon Air Force Base, Curry County, New Mexico.

Methods

Groundwater levels were measured synoptically during both an irrigation season (summer of 2013) and a non-irrigation season (winter of 2015). Irrigation, domestic, and monitoring wells within approximately 3 miles of the Cannon AFB boundary were selected for measurement. All selected wells were assumed to be screened in the Ogallala Formation, with the total depth of the wells generally being the top of the Chinle Formation. This assumption is based on the few available drilling logs and discussions by the author with local farmers and drillers. Summer and winter groundwater potentiometric-surface maps were created from 93 and 100 groundwater altitudes, respectively (table 1). Groundwater levels in pumping wells were not measured, and the presence of pumping wells near measured wells was noted on field forms and taken into consideration during the development of figures 1 and 2. Groundwater-level measurement and quality-control procedures set forth by Cunningham and Schalk (2011) were followed; specifically, a minimum of two groundwater-level measurements that were within 0.02 ft of each other were required at each well measured.

Real-time kinetic (RTK) survey-grade Global Positioning System equipment, with an error of plus or minus 2 inches, was used to survey the altitude of the land surface and the height of the measuring point above land surface for each well during March 30–April 7, 2015. An Online Positioning User Service occupation was conducted on four Cannon AFB wells (wells 31, 55, 68, and 81); these four wells served as locations for the base station during the RTK survey. The depth to groundwater below land surface was calculated by subtracting the height of the measuring point from the groundwater-level depth measured below the measuring point. The depth to groundwater below land surface was then subtracted from the surveyed land-surface altitude to calculate the groundwater-level altitude.

The groundwater-level altitudes were used in a geographic information system program to interpolate potentiometric surfaces by using the natural-neighbor method (Childs, 2004), and equipotential contours at 10-ft intervals were added to each seasonal map. Contour results were visually inspected for reasonability and corrected as necessary. Additionally, finer interval, 2-ft, contour lines were used to manually draw flow-direction arrows orthogonal to equipotential lines in the direction of decreasing gradient; these 2-ft interval contour lines were not included on the potentiometric-surface maps for increased readability. Lastly, the starting point for each flow-direction arrow originated at the same location on each potentiometric-surface map to aid in discerning differences in flow paths between seasons.

A groundwater-level change map (fig. 3) was created by using groundwater-level differences (winter 2015 groundwater levels minus summer 2013 groundwater levels) from 67 wells. The groundwater-level changes were divided into three groups by using the natural-neighbor interpolation method (Childs, 2004): (1) greater than a 1.1-ft decrease indicated a decline in groundwater level, (2) from -1.0 through +1.0 ft indicated a neutral change in groundwater level, and (3) more than a 1.0-ft increase indicated a rise in groundwater level. The three groups were visually inspected for reasonability and corrected as necessary. Data collected for this study are in the USGS National Water Information System database (http://nwis.waterdata.usgs.gov/usa/nwis/gwlevels).

Potentiometric Surfaces

The July 22–August 1, 2013, potentiometric surface, representing summer conditions, is presented in figure 1. The summer measurement period was towards the end of the main irrigation season for wheat crops. According to Marsalis (2007), summer irrigation starts each year in March, peaks in June, declines to a low in September, resumes briefly in October in preparation for the next year’s winter-wheat crops, and then declines to annual lows through the winter dormancy period. The January 20–30, 2015, groundwater-measurement period that occurred during the winter dormancy period is presented in figure 2.

Figures 1 and 2 in this report display the presence of what is interpreted to be a groundwater trough, trending from the northwest to the southeast through the study area. This groundwater trough may be the hydraulic expression of a Tertiary-age paleochannel, commonly observed in the Southern High Plains aquifer (Gustavson, 1996), that contains coarser, more hydraulically conductive material than the surrounding subsurface material into which the paleochannel eroded (Fahlquist, 2003). Figures 1 and 2 in this report indicate that groundwater north of the trough flows in a southerly direction into the trough and groundwater south of the trough flows in an easterly direction into the trough.

Although regional groundwater-flow directions are generally the same for the summer and winter potentiometric-surface maps, there are differences between the maps on a localized scale, including cones of depression around wells 27 and 32 as seen in figure 1. The cone of depression around well 32 (figs. 1 and 2) appears to have an influence on the direction of groundwater flow in the groundwater trough. The cone of depression around well 27 may also be present in the winter, but well 27 was not measured in the winter because of active pumping. The groundwater-flow directions around both of these cones of depression were created by using 2-ft interval contour lines, which provided more detail about the effect of the cones of depression on the groundwater-flow direction than can be seen in the 10-ft contours.

The groundwater-level change map (fig. 3) is a visual representation of the change in groundwater level during the 18-month period between the summer 2013 and winter 2015 measurement events. The period between both groundwater-level measurement events contained the remaining months of one irrigation season, one full winter dormancy period, one full irrigation season, and a partial winter dormancy period. In figure 3, wells 5 and 35 showed the largest rise in groundwater levels, a rise of 10.0 and 9.7 ft, respectively. Wells 99 and 55 showed the largest decline in groundwater levels, a decline of 3.7 and 3.8 ft, respectively. The regions to the north and south of the groundwater trough contained the majority of the rises in groundwater levels, whereas the regions within the trough contained the majority of the declines in groundwater levels.

Potentiometric Surfaces, Summer 2013 and Winter 2015, and Select Hydrographs for the Southern High Plains Aquifer, Cannon Air Force Base, Curry County, New Mexico

By
Jake Collison
2016

For sale by U.S. Geological Survey, Information Services, Box 25286, Federal Center,
Denver, CO 80225, 1–888–ASK–USGS

Digital files available at http://dx.doi.org/10.3133/sim3352

Suggested citation: Collison, Jake, 2016, Potentiometric surfaces, summer 2013 and winter 2015, and select hydrographs for the Southern High Plains aquifer, Cannon Air Force Base, Curry County, New Mexico: U.S. Geological Survey Scientific Investigations Map 3352, http://dx.doi.org/10.3133/sim3352.

Printed on recycled paper

ISSN 2329-1311 (print)
ISSN 2329-132X (online)
http://dx.doi.org/10.3133/sim3352

ISBN 978-1-4113-4034-3

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

Prepared in cooperation with the
Air Force Civil Engineer Center, San Antonio, Texas

Table 1. Groundwater-level altitude data used to construct summer (July 22–August 1, 2013) and winter (January 20–30, 2015) potentiometric-surface maps and groundwater-level change data used to construct the change map for the area on and around Cannon Air Force Base, Curry County, New Mexico.

[Well number corresponds to figures 1, 2, and 3 well numbers; groundwater-level change rounded to nearest tenth of a foot; USGS, U.S. Geological Survey; ID, identifier; NAVD 88, North American Vertical Datum of 1988; --, no data]

USGS site ID	Well number	Summer groundwater-level altitude (feet above NAVD 88)	Winter groundwater-level altitude (feet above NAVD 88)	Groundwater-level change from summer 2013 to winter 2015 (feet)
342719103233501	1	4,044.89	--	--
342743103221901	2	4,084.86	4,081.58	-3.3
342747103211301	3	4,078.28	4,077.40	-0.9
342736103203701	4	4,075.12	4,074.97	-0.2
342653103195201	5	4,046.21	4,056.17	10.0
342743103161301	6	4,043.00	--	--
342747103161701	7	4,043.50	4,042.62	-0.9
342750103155101	8	4,034.03	--	--
342739103154201	9	4,030.40	4,030.86	0.5
342737103153701	10	4,028.27	--	--
342725103151901	11	4,018.64	4,022.00	3.4
342654103163101	12	--	4,019.87	--
342658103144101	13	4,010.33	4,009.47	-0.9
342655103135201	14	3,995.38	3,995.03	-0.4
342623103174901	15	4,018.84	--	--
342624103173501	16	--	4,016.45	--
342604103183801	17	--	4,023.18	--
342604103173601	18	--	4,008.09	--
342602103172201	19	--	4,002.45	--
342606103151001	20	4,000.74	4,000.00	-0.7
342551103232201	21	4,003.01	4,002.98	0.0
342512103220501	22	--	3,982.19	--
342536103171501	23	3,994.52	--	--
342520103165601	24	3,991.65	3,992.64	1.0
342537103164101	25	3,987.28	3,989.00	1.7
342633103155301	26	3,986.67	3,986.89	0.2
342526103160401	27	3,973.98	--	--
342455103183301	28	4,009.17	--	--
342509103180801	29	--	4,001.41	--
342506103164701	30	--	3,986.89	--
342445103201301	31	--	3,972.00	--
342445103190801	32	3,958.19	3,960.79	2.6
342444103170301	33	--	3,987.13	--
342444103163201	34	3,985.75	3,986.12	0.4
342419103232301	35	4,058.99	4,068.67	9.7
342425103220201	36	4,003.42	--	--
342421103211801	37	3,996.36	3,993.65	-2.7
342418103201201	38	3,983.53	3,980.31	-3.2
342431103185201	39	3,969.91	--	--
342409103191601	40	3,973.22	3,971.45	-1.8
342418103180601	41	3,994.85	--	--
342417103175001	42	3,984.23	3,992.46	8.2
342429103170201	43	3,988.54	--	--
342419103170101	44	3,981.30	--	--
342408103172201	45	3,992.52	3,990.91	-1.6
342404103161901	46	3,987.67	3,986.66	-1.0
342408103155201	47	3,985.35	3,984.03	-1.3
342415103153501	48	3,983.04	3,981.97	-1.1
342358103151601	49	--	3,977.82	--
342327103232401	50	4,053.98	4,062.24	8.3
342344103224901	51	--	4,043.81	--
342343103222201	52	--	4,032.92	--
342328103221701	53	4,033.33	4,032.03	-1.3
342328103212501	54	4,007.50	4,007.77	0.3
342349103175801	55	3,969.44	3,965.62	-3.8
342328103182401	56	3,966.71	3,964.47	-2.2
342321103181001	57	3,964.07	3,962.24	-1.8
342313103180801	58	3,960.80	3,959.75	-1.1
342307103181601	60	3,960.55	3,958.93	-1.6
342317103174701	61	3,959.15	3,958.31	-0.8
342325103170301	63	3,973.09	3,971.61	-1.5
342310103160901	64	3,977.35	--	--
342259103211701	66	3,990.12	3,999.76	9.6
342228103215701	67	--	4,044.88	--
342222103194301	68	3,983.31	3,982.92	-0.4
342237103155101	69	3,954.39	--	--
342258103152801	70	3,962.17	--	--
342246103151301	71	3,956.36	--	--
342254103145401	72	3,962.74	3,962.56	-0.2
342153103211401	73	4,034.41	4,033.87	-0.5
342139103211801	74	--	4,029.80	--
342206103192501	75	--	3,972.40	--
342140103190501	76	3,959.26	3,968.56	9.3
342134103191201	77	3,961.56	--	--
342157103181701	78	3,939.98	3,939.52	-0.5
342156103180801	79	3,934.88	3,935.55	0.7
342205103181001	80	3,934.12	3,932.01	-2.1
342203103181001	81	3,936.20	3,936.29	0.1
342200103180901	82	3,930.94	--	--
342225103173401	83	--	3,937.16	--
342209103173901	84	--	3,931.42	--
342203103174001	85	--	3,928.39	--
342155103171801	86	--	3,927.92	--
342212103170401	87	--	3,933.40	--
342200103170601	88	3,911.07	--	--
342219103164801	89	3,936.95	3,935.01	-1.9
342126103164501	90	--	3,900.15	--
342204103160401	91	--	3,931.01	--
342145103160501	92	3,902.41	3,900.22	-2.2
342135103155901	93	--	3,890.76	--
342224103155801	94	3,946.65	3,944.80	-1.9
342220103154401	95	3,943.86	--	--
342140103154401	96	3,892.76	3,890.63	-2.1
342157103152901	97	3,895.23	--	--
342142103152901	98	3,891.59	3,890.16	-1.4
342219103135101	99	3,948.69	3,944.95	-3.7
342114103194801	100	4,002.09	4,001.27	-0.8
342048103183401	101	3,957.39	3,957.16	-0.2
342157103181101	102	3,914.08	--	--
342048103180901	103	3,929.58	3,932.97	3.4
342104103173501	104	3,902.90	--	--
342113103173101	105	--	3,905.24	--
342048103164301	106	3,893.73	3,895.13	1.4
342047103145801	107	3,862.90	3,863.44	0.5
342121103142301	108	3,919.53	3,919.24	-0.3
342115103141501	109	3,886.88	3,886.86	0.0
342049103141601	110	3,853.55	3,855.92	2.4
341956103211101	111	--	4,028.04	--
342022103212901	112	--	4,029.15	--
342016103211901	113	--	4,024.25	--
342032103204501	114	4,018.70	4,017.95	-0.8
342029103201401	115	4,006.50	4,005.83	-0.7
342003103194401	116	3,995.36	3,995.42	0.1
342000103192501	117	3,995.16	3,995.14	0.0
342033103184001	118	3,959.65	--	--
342036103182301	119	3,946.57	3,950.33	3.8
342015103163201	120	3,900.78	--	--
342004103160101	121	3,895.46	3,894.78	-0.7
342022103143001	122	--	3,855.82	--
342000103141801	123	--	3,860.78	--
342022103141001	124	--	3,850.14	--
341953103152801	125	--	3,888.84	--
341943103151601	126	--	3,888.48	--
341921103142701	127	3,871.91	3,875.06	3.2
341917103141101	128	3,868.66	3,872.00	3.3
341928103140001	129	3,860.07	3,865.86	5.8

Hydrographs

Five hydrographs created from periodic measurements of groundwater levels in wells on and around Cannon AFB were developed to provide information about historic groundwater-level changes (fig. 4). The five wells with the most complete and longest groundwater-level records were selected to represent areas on and around Cannon AFB. The five hydrograph wells are measured up to twice a year by the USGS in cooperation with the New Mexico Office of the State Engineer. Data from Bhate and Trinity (2013) were used to fill in data gaps for the monitoring well on Cannon AFB (well 81). In figure 4, the axes of the hydrographs are standardized to include the same time period (1954–2015) on the horizontal axis and the same amount of groundwater-level change (120 ft) on the vertical axis, allowing for comparison of groundwater levels and trends across the five hydrographs.

The period of record for the five hydrographs ranges from 20 years (well 81) to 60 years (wells 4 and 76; fig. 4). The long-term trend since the mid-1950s is a steady decline in groundwater levels, with some areas declining faster than others. There appear to be some decadal differences in rates of decline; specifically, some of the hydrographs (wells 4, 26, 76, and 108) show less groundwater-level decline or static groundwater-level conditions during the mid- to late 1980s. The cause of less decline or static conditions in the mid- to late 1980s may be related to an above-average period of precipitation from 1984 to 1988 (fig. 5). The more abundant moisture from 1984 to 1988 may have resulted in less groundwater pumping during this period. Except for this period in the mid- to late 1980s, there is a common trend of steady groundwater-level decline for this region. Well 4, north-northwest of Cannon AFB, had the smallest average annual groundwater-level decline of 0.41 feet per year (ft/yr). Well 26, northeast of Cannon AFB, had an average annual groundwater-level decline of 0.86 ft/yr for the period of record. Well 26 is also located near the local cone of depression formed by well 27. Well 76, directly south of Cannon AFB, had an average annual groundwater-level decline of 1.36 ft/yr for the period of record. Lastly, the two wells with the greatest average annual groundwater-level decline for the period of record were well 81, near the southeastern corner of Cannon AFB, and well 108, east-southeast of Cannon AFB, with declines of 2.81 and 1.99 ft/yr, respectively (fig. 4). Overall, the southeastern part of the study area exhibits the greatest average annual groundwater-level decline, and the northwestern part of the study area exhibits the smallest average annual decline. Additionally, the hydrographs of wells in proximity to the groundwater trough (76, 81, and 108) show the most rapid declines in groundwater levels (fig. 4). Langman and others (2006) also showed that the most rapid groundwater-level declines occurred in three wells within or near the trough, while wells farther away from the trough had a less rapid decline.

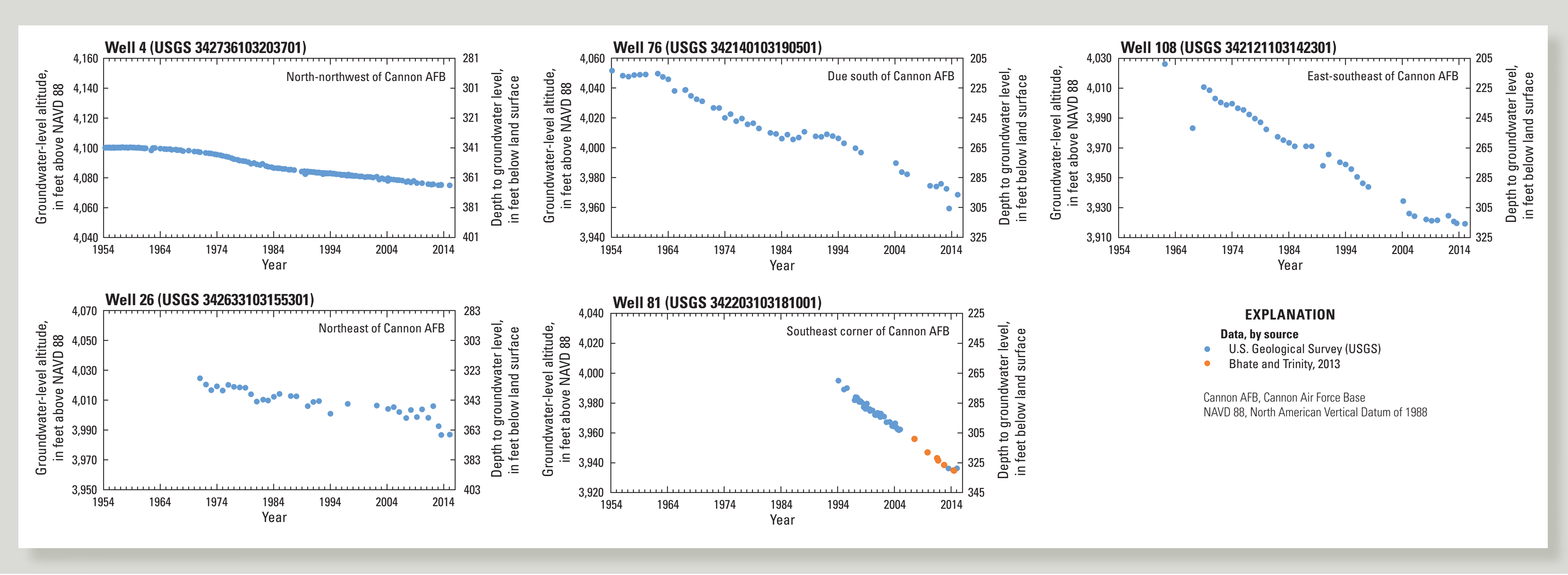


Figure 4. Groundwater-level altitude hydrographs from selected wells on and around Cannon Air Force Base, Curry County, New Mexico, 1954–2015.

Acknowledgments

The author would especially like to thank Laura Peters, Environmental Restoration Manager with Cannon Air Force Base (AFB) Environmental Restoration Program, for her help in securing access to monitoring wells on Cannon AFB. The author would also like to thank the many private well owners who allowed the U.S. Geological Survey (USGS) access to their wells. Their cooperation was greatly appreciated and made this report possible.

The author would like to thank Darwin Ockerman, hydrologist with the USGS and liaison to the Air Force Civil Engineering Center, San Antonio, Texas, for his help in developing this project and measuring groundwater levels. The author also would like to thank the following USGS New Mexico Water Science Center employees: Nathan Myers, groundwater specialist, for his expertise and advice during the course of this project; Alyse Briody, hydrologist, for organizing and participating in the winter groundwater-level measurement event and the measuring-point survey; and Scott Christenson, scientist emeritus, for volunteering his time and expertise during the winter groundwater-level measurements event and measuring-point survey.

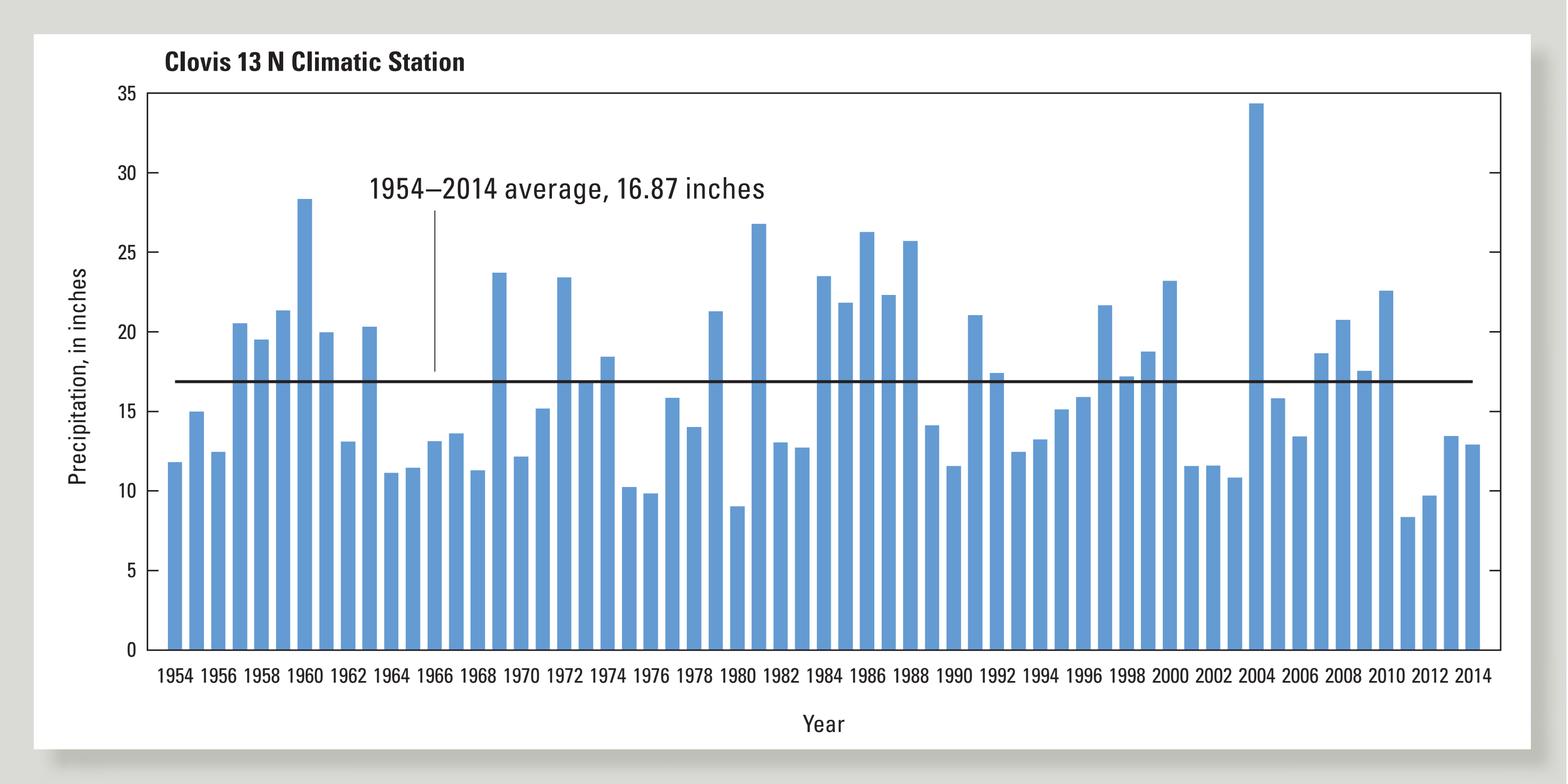


Figure 5. Annual precipitation at the Clovis 13 N climatic station and 1954–2014 average (16.87 inches). Data from National Climatic Data Center (2016).

References

Bhate and Trinity, 2013, Biennial groundwater monitoring and annual landfill inspection report, landfills LF-03, LF-04, LF-05, LF-25, and former sewage lagoons, Cannon Air Force Base, New Mexico: Trinity Analysis & Development Corp.

Childs, Colin, 2004, Interpolating surfaces in ArcGIS spatial analyst: ArcUser, July–September, p. 32–35, accessed May 2015 at http://www.esri.com/news/arcuser/0704/files/interpolating.pdf.

Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater technical procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 p., accessed May 2015 at http://pubs.usgs.gov/tm/1a1/.

EPCOR Water, 2014, Your 2014 water quality report, Clovis district: EPCOR Water, accessed May 2015 at http://www.epcor.com/water/wq/wq-clovis-2014.pdf.

Fahlquist, L.S., 2003, Ground-water quality of the Southern High Plains aquifer, Texas and New Mexico, 2001: U.S. Geological Survey Open-File Report 2003–345, 59 p., accessed May 2015 at http://pubs.er.usgs.gov/publication/ofr03345.

Gustavson, T.C., 1996, Fluvial and eolian depositional systems, paleosols, and paleoclimate of the upper Cenozoic Ogallala and Blackwater Draw Formations, Southern High Plains, Texas and New Mexico: Report of Investigations no. 239, Bureau of Economic Geology, University of Texas at Austin, 62 p.

Langman, J.B., Falk, S.E., Gebhardt, F.E., and Blanchard, P.J., 2006, Ground-water hydrology and water quality of the Southern High Plains aquifer: U.S. Geological Survey Scientific Investigations Report 2006–5280, 61 p.

Langman, J.B., Gebhardt, F.E., and Falk, S.E., 2004, Ground-water hydrology and water quality of the Southern High Plains aquifer, Melrose Air Force Range, Cannon Air Force Base, Curry and Roosevelt Counties, New Mexico, 2002–03: U.S. Geological Survey Scientific Investigations Report 2004–5158, 42 p., accessed May 2015 at http://pubs.usgs.gov/sir/2006/5280/.

Marsalis, M.A., 2007, Small grain silages for New Mexico: New Mexico State University, Cooperative Extension Service—College of Agriculture and Home Economics, circular 630, accessed May 2015 at http://aces.nmsu.edu/pubs/_circulars/CR630.pdf.

McLemore, V.T., 2001, Oasis State Park, *in* Lucas, S.G., and Ulmer-Scholle, D.S., eds., Geology of Llano Estacado: Socorro, New Mexico Geological Society, p. 34–37.

Miller, J.A., ed., 2000, Ground water atlas of the United States: U.S. Geological Survey Hydrologic Atlas 730, 13 chapters, accessed May 2015 at http://water.usgs.gov/ogw/aquifer/atlas.html.

National Climatic Data Center, 2016, Climate data online, monthly summaries station details, Clovis 13 N: Accessed February 27, 2016, at http://www.ncdc.noaa.gov/cdo-web/datasets/GHCNDMS/stations/GHCND:USC00291963/detail/.

Potentiometric Surfaces, Summer 2013 and Winter 2015, and Select Hydrographs for the Southern High Plains Aquifer, Cannon Air Force Base, Curry County, New Mexico

By

Jake Collison

2016

For sale by U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225, 1–888–ASK–USGS

Digital files available at http://dx.doi.org/10.3133/sim3352

Suggested citation: Collison, Jake, 2016, Potentiometric surfaces, summer 2013 and winter 2015, and select hydrographs for the Southern High Plains aquifer, Cannon Air Force Base, Curry County, New Mexico: U.S. Geological Survey Scientific Investigations Map 3352, http://dx.doi.org/10.3133/sim3352.

Printed on recycled paper

ISSN 2329-1311 (print)
ISSN 2329-132X (online)
http://dx.doi.org/10.3133/sim3352

ISBN 978-1-4113-4034-3